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OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

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

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TABLE OF CONTENTS.

PROCEEDINGS.

LIST OF THE FOSSILS FIGURED AND DESCRIBED IN THIS VOLUME.

[In this list, those fossils the names of which are printed in Roman type have been previously described.]

Name of Species.	Formation.	Locality.	Page.
	Plantæ.		
Chara, seeds of	Tertiary	Brazil	82
Pachytheca sphærica	Silurian	South Wales	499
	Spongiæ.		
Stromatopora, sp. Pls. iii.–v.	Devonian	Canada	48
Caunopora hudsonica. Pl. iv. f. 9 & Pl. v. f. 10	Silurian	Canada	52
Cœnostroma galtense	Devonian	Canada	52
—— nodulata. Pl. v. f. 11, 12	Devonian	Canada	52
	Foraminifera.		
Loftusia columbiana. Pl. vi.	Carboniferous	British Columbia	74
	Cœlenterata.		
	(*Actinozoa.*)		
Actinacis insignis. Pl. viii. f. 8	Greensand	Haldon	93
—— *stellulata.* Pl. viii. f. 7	Greensand	Haldon	93
Baryhelia reticulata. Pl. viii. f. 1	Greensand	Haldon	92
Haldonia Vicaryi. Pl. viii. f. 2, 3	Greensand	Haldon	91
Heliopora cærulea. Pl. viii. f. 16–18	Greensand	Haldon	94
Oroseris haldonensis. Pl. viii. f. 9, 10	Greensand	Haldon	92
Stelloria incrustans. Pl. viii. f. 4, 5	Greensand	Haldon	91
Thamnastræa belgica	Greensand	Haldon	92
—— *Ramsayi.* Pl. viii. f. 6	Greensand	Haldon	92
Trochoseris constricta. Pl. viii. f. 11, 12	Greensand	Haldon	93
—— *Morrisi.* Pl. viii. f. 13–15	Greensand	Haldon	94
Trochosmilia varians	Greensand	Haldon	90

ANNELIDA (*continued*).

CRUSTACEA.

Vertebrata.

(*Pisces.*)

Name of Species.	Formation.	Locality.	Page.
Ctenacanthus æquistriatus. Pl. x. f. 15	Coal-measures	Yorkshire	185
Distacodus incurvus. Pl. xv. f. 9	Cincinnati	Canada	357
Drepanodus arcuatus. Pl. xv. f. 7, 8	Cincinnati	Canada	357
Hoplonchus elegans. Pl. x. f. 12–14	Coal-measures	Yorkshire	183
Phricacanthus biserialis. Pl. x. f. 16, 17	Coal-measures	Yorkshire	186
Pleurodus affinis. Pl. x. f. 1–11	Coal-measures	Yorkshire	181
Polygnathus coronatus. Pl. xvii. f. 1	Devonian	Canada	365
—— *crassus.* Pl. xvii. f. 3	Devonian	North America	365
—— *cristatus.* Pl. xvii. f. 11	Devonian	North America	366
—— ? *curvatus.* Pl. xvii. f. 7	Devonian	Canada	366
—— *dubius.* Pl. xvi. f. 6–18	Devonian	North America	362
—— *duplicatus.* Pl. xvi. f. 19	Devonian	Canada	364
—— ? *eriensis.* Pl. xvii. f. 6	Devonian	Canada	366
—— *immersus.* Pl. xvi. f. 21	Devonian	Canada	364
—— *linguiformis.* Pl. xvii. f. 15	Devonian	North America	367
—— *nasutus.* Pl. xvi. f. 22	Devonian	North America	364
—— *palmatus.* Pl. xvii. f. 16, 17	Devonian	North America	367
—— *pennatus.* Pl. xvii. f. 8	Devonian	North America	366
—— *princeps.* Pl. xvi. f. 23	Devonian	North America	365
—— *punctatus.* Pl. xvii. f. 14	Devonian	North America	367
—— *radiatus.* Pl. xvi. f. 20	Devonian	Canada	364
—— ? *serratus.* Pl. xvii. f. 4, 5	Devonian	Canada	365
—— ? *simplex.* Pl. xvii. f. 18	Devonian	North America	367
—— *solidus.* Pl. xvii. f. 2	Devonian	North America	365
—— *truncatus.* Pl. xvii. f. 12, 13	Devonian	North America	366
—— *tuberculatus.* Pl. xvii. f. 9, 10	Devonian	North America	366
Prioniodus abbreviatus. Pl. xv. f. 15	Devonian	North America	359
—— *acicularis.* Pl. xv. f. 18, 19	Devonian	North America	360
—— ? *alatus.* Pl. xvi. f. 5	Devonian	North America	361
—— *angulatus.* Pl. xv. f. 17	Devonian	North America	360
—— *armatus.* Pl. xv. f. 20, 21	Devonian	North America	360
—— *clavatus.* Pl. xv. f. 16	Devonian	North America	360
—— elegans. Pl. xv. f. 10	Cincinnati	Canada	358
—— *erraticus.* Pl. xv. f. 14	Devonian	North America	359
—— *furcatus.* Pl. xv. f. 13	Cincinnati	Canada	358
—— *Panderi.* Pl. xvi. f. 4	Devonian	North America	361
—— ? *politus.* Pl. xv. f. 11, 12	Cincinnati	Canada	358
—— *radicans.* Pl. xv. f. 1–6	Chazy	Canada	356
—— *spicatus.* Pl. xvi. f. 1–3	Devonian	North America	361
Myliobatis or *Zygobatis*, sp. Pl. vii. f. 13	Tertiary	Brazil	88

EXPLANATION OF THE PLATES.

THE

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OF

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Vol. XXXV.

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1. Notes *on the* Physical Geography *and* Geology *of* North Gippsland, Victoria. By Alfred William Howitt, Esq., F.G.S., a Warden of the Gold-fields of Victoria, &c. (Read June 21, 1876.)

Introduction.

I have felt some hesitation in placing this paper before the Society, but I have been determined to do so by the reflection that it is clearly the duty of every working geologist to carry his contribution of knowledge to the common stock, however small it may be. I have also considered that these notes on North Gippsland may be of interest to geologists, not only because the district is little known, but also (and more especially) because, as it seems to me, the study of its geological structure furnishes the key to that of Victoria as well as to a great portion of South-eastern Australia.

In no part of this colony, nor possibly even of Australia, is there any locality where the igneous rocks generally (the crystalline metamorphic schists and their relations to the sedimentary strata, as well as to each other) can be studied more advantageously than in the district under consideration.

I may refer briefly to the manner in which the observations have been made, the results of which I have recorded. The nature of my official duties rendered it impossible that I could carry out any detailed survey in the usual manner, excepting perhaps in the immediate neighbourhood of my headquarters at Bairnsdale; but I found that it might be possible to carry on investigations on a different system which promised to be not entirely barren of results. Being required to visit constantly the gold-fields in all parts of North Gippsland east of the Mitchell River, I believed that by varying the route from place to place as much as possible, and by making use of those routes as lines of investigation, I might in course of time cover the whole district with, as it were, a network of traverses on which illustrative sections might be constructed.

This I have done so far as was possible to me; and wherever I found points of interest requiring further illustration, I have worked out those special localities with more detail. A long-continued series of aneroid readings has furnished me with the means of working out the sections with some degree of certainty. Finally, on the data thus obtained, I have constructed three main sections approximately across the general strike of the older sedimentary strata, and three other sections approximately at right angles to the former.

Where feature-surveys were available I have used them; but where, as unfortunately was too often the case, there were none, I have made such traverses with the compass, estimating the distance by the watch or by pacing, as would furnish me with fairly reliable data.

The knowledge which I have gained of the geology of the district has therefore resulted from actual inspection in the field; and it will be for geologists to say whether my interpretation of facts and the inferences which I have drawn therefrom are well grounded or not.

In these notes I propose to summarize the general results at which I have arrived. The details are partly contained in the 'Reports of Progress of the Geological Survey of Victoria,' and partly in papers which are now in process of completion*.

The sketch sections given in this paper do not pretend to represent the exact features of any one locality; but I have endeavoured to portray in them, in a condensed form, that which I have observed in the field, and at the same time to do so in accordance with the results shown by the sections I have referred to.

The encouraging assistance of friends has not been wanting. I am under great obligations to Professor M'Coy, of Melbourne University, for examining the collections of fossils which I have made and for indicating their geological age; to Mr. C. H. F. Ulrich, F.G.S., of the Industrial and Technological Museum, Melbourne, who has most kindly aided me by examining collections of rocks in comparison with those of the Technological Museum in Melbourne; and to Mr. R. Brough Smyth, F.G.S., the Secretary for Mines, &c., under whose direction the Geological Survey of this Colony has been resumed, for every assistance which a long-standing friendship and a warm interest in the geological examination of the Colony could suggest. It was in consequence of a suggestion made by my friend Mr. R. Brough Smyth some years ago that I determined to attempt systematically the geological examination of North Gippsland.

* The papers now in hand are "On the Devonian Rocks of North Gippsland" and "Section 1 of the Geological Structure of North Gippsland."

If these notes are thought worthy of any consideration by geologists, I shall feel that I am amply rewarded for any labour I may have undergone, and that the many days of wanderings and solitary encampment by night among the rugged mountains and precipitous defiles of the Australian Alps have not been in vain.

General Consideration of the District.

The district to be considered may be described as being all that part of North Gippsland lying eastward of the Macallister River, and also that part of the Omeo country between the Great Dividing Range and a line drawn from Mount Gibbs to Mount Hotham.

It is approximately 130 miles in length by 80 miles in width, or about 10,400 square miles in area.

It is divided into two unequal portions by the Great Dividing Range. This mountain-chain has a general trend to N. 60° E. and S. 60° W., and conforms to the outline of the coast. It is not, however, continuous in this course throughout; from Forest Hill to Mount Phipps it follows this direction, as also from Mount Hotham to Mount Howitt; but the intermediate portion lies at right angles. From Mount Phipps the general direction of the Dividing Range is continued by a line of mountains, such as Mount Birregun, Castle Hill, and Mount Wellington, through which the rivers have cut their course southward. From Mount Hotham the line of direction is similarly continued north-easterly by the Bogong Mountains and Mount Gibbs to Mount Kosciusko, which is on the Dividing Range, and the highest known mountain in Australia *. On this line also the Mitta Mitta and the Limestone Rivers have cut a passage through the highlands and flow to the north †.

The Great Dividing Range, with the two extensions just noted, may be said to define the north and south limits of an extensive plateau, averaging a hundred miles in length with a width of twenty-five miles. The drainage of the north-eastern moiety falls into the river Murray, and that of the south-western moiety into the rivers flowing into the Gippsland lakes.

The transverse part of the Great Dividing Range, which thus separates the two halves of what may be called the Omeo plateau, extends from Mount Phipps to Mount Hotham. It is comparatively low in elevation; it falls suddenly into the Dargo River to the west, but has a gentle slope on the east towards Omeo.

The average elevation of the Omeo plateau is probably not less than 3000 feet above the sea-level; the highest point rises to 6508 feet in Mount Bogong; and the lowest level is found in the Omeo

* The heights of these mountains above the sea-level, as determined by the Geodetic Survey of Victoria, are as follows:— Mount Hotham 6100 feet, Mount Howitt 5715 feet, Castle Hill 4860 feet, Mount Wellington 5363 feet, Mount Kosciusko 7256 feet, and Mount Bogong (the highest mountain in Victoria) 6508 feet.

† The Limestone River, also called the Indi, is one of the sources of the river Murray.

basin at 2374 feet, which is the height of Lake Omeo above the sea. I have excluded in this estimation the deep river-valleys draining this plateau which, as at Eagle Vale or Tom Groggin, are under 1000 feet.

From the Great Dividing Range and approximately at right angles to its course successive spurs extend towards the coast; these spurs separate the rivers which drain the mountains. Some of these rivers empty themselves into the Gippsland lakes, and the remainder directly into the sea*. The most easterly of these somewhat parallel ranges forms the western watershed of the Snowy River; this river rises in New South Wales on an extensive plateau, known as the Maneroo district, similar in character to that of Omeo, but of greater extent. The southern boundary of these highlands is well defined as the Coast Range, and, as is the case with the Great Dividing Range, conforms to the coast-line. The slope northward, forming the Maneroo tableland, is very gentle, while it is sudden and abrupt towards the sea.

Commencing at Mount Phipps, the most southerly extension of the Great Dividing Range, near Omeo, a line of high land can be traced connecting it with the Coast Range. On this view the Omeo and Maneroo plateaux form one great tableland; these heights, commencing at Mount Phipps, are the Nunnyong Mountain, the Gelantipy tableland, Turnback Mountain, and the Bowen Mountain, where the Coast Range may be said to commence.

From this Coast Range spurs run towards the seas, separating the waters of the Goungrah, Bem, Tamboon, Wingan, and Genoa rivers; these spurs either end as promontory-like hills, or die away gradually in the marine Tertiaries.

All the rivers which I have enumerated present certain marked features in common. The character of the valleys varies with the geological formation in which they have been excavated, and the course of the rivers is sharply divided into a torrent portion and a river portion; the latter commences so soon as the streams leave the hills and enter the fringing Tertiary area. Here the valleys have been excavated in almost horizontal beds of sand, clay, and coarse shelly limestone, and are wide and flat.

The bottom of such a valley is usually occupied by a more or less wide stretch of alluvial soil, through which the river winds a slow and tortuous course. In other cases, such as the streams flowing into lake Tyers, the bottom of the valley is an estuary.

Where the rivers debouche into the Gippsland lakes, they do so usually between two banks, or natural levels, which have been formed in the manner of a delta. That at the mouth of the Mitchell River extends on each side from the termination of the higher ground into Lake King. The one on the north side of the river is about twelve miles, and the one on the south side of the river about six miles in length. The two levels end at the same point in Lake King. Each

* Into the Gippsland lakes, the rivers Macallister, Avon, Mitchell, Nicholson, and Tambo; into the sea, the Snowy River, the rivers Buchan, Murindel, and Toonginbooka.

bank is composed of alluvial deposit, and is timbered almost to where the end finishes off in a clump of reeds; the width of these natural embankments, which separate the waters of the Mitchell River from Jones's Bay on the north and Eagle Bay on the south, does not, on the average, exceed ten chains.

I believe these banks have been formed partly by the ploughing action of the floods in the soft deposits at the mouth of the river, and partly by the deposition of sediment carried down where the current is checked by the reed-beds, and also by similar causes whenever the floods rise over the bank itself.

I have reason to believe from personal observation, as well as from information derived from boatmen, fishermen, and others navigating the lakes, that these great expanses of scarcely more than brackish water are extremely shallow, and are only navigable in the deep channels which traverse them. These, it seems to me, foreshadow future river-channels so soon as the lakes shall have been silted up by the river-deposits or laid dry by further gradual elevation of the coast-line.

It seems to me that we see in these lakes and in the channels through them the former condition of the river-valleys, and that the present courses of the rivers are probably not due so much to the erosion by them of channels in the alluvial bottoms of the valleys as to their still flowing in channels which were formed under estuarine or lacustrine conditions*.

The rivers of Gippsland are liable to frequent floods, which are due either to heavy rains, generally from the eastward, or to the melting of snow accumulated during the winter months on the mountains, or to both causes combined.

During the past five or six years these floods have been exceptionally frequent and severe. Neither the oldest white settlers nor the oldest aboriginal natives remember floods of like frequency or magnitude.

I have observed during the time mentioned that the beds of the torrent portions of the rivers appear to have been deepened, as in the upper waters of the Mitchell, Nicholson, Tambo, or Buchan rivers. The course of the rivers in the flat country has been completely changed within certain limits, as at Stratford and Bruthen. In steep mountain country the hillsides have been stripped of soil to the level of high-flood mark, as at the Turnback crossing of the Snowy River. Large trees which stood on islands have either been torn down and swept away, or stripped of their bark by drifting timber. All these various effects I have specially noticed in the Deddick River.

The amount of deposit carried down by these rivers is, of course,

* Mr. R. Brough Smyth informs me that he has detected in Western-Port Bay that a divide of mud separates the head of the east and west channels, and that this is obscured when the tide is up. We may have probably here the commencement of such channels as are a marked feature in the Gippsland lakes.

commensurate with the force and volume of these floods, and must tend materially to raise the alluvial flats in the low country and, eventually, to fill in the Gippsland lakes themselves. A deposit of an inch or more of silt and slime on the river-flats after one of these floods is not unfrequent; and I have seen instances where it amounted, in places, to feet.

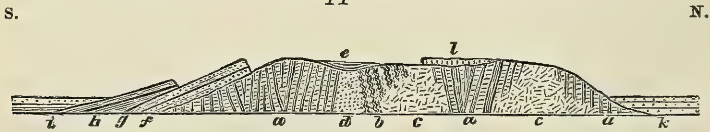
The progress of settlement, by the formation of tracks and roads, the clearing of land, and even the paths made by cattle and horses, tends to drain the land more rapidly, to concentrate the flood-waters, and to increase the amount of sediment carried down from the higher grounds.

Within the last few years and, indeed, contemporaneously with the wet seasons I have mentioned, the wide flat gullies commonly seen in parts of the mountains, and especially near Omeo, have, almost without exception, been cut back into deep channels by the rain. The black soil has been cut into so as to form narrow deep ravines, locally known as "washouts," and which extend occasionally miles back into the hills *.

Classification of the Subject.

I have endeavoured to classify the various formations in the subjoined tabular form in accordance with my present knowledge. The first list exhibits them stratigraphically; in the second list I have shown the Igneous and Metamorphic rocks as I conceive their geological age to be.

Fig. 1.—*Diagrammatic Section across the Australian Alps in North Gippsland.*



a. Silurian.
b. Metamorphic crystalline schist.
c. Granite.
d. Quartz-porphyries.
e. Middle Devonian.
f. Upper Devonian.
g. Carboniferous.
h. Mesozoic Coal-measures.
i. Marine Tertiaries of Gippsland.
k. Tertiaries of the Murray River.
l. Volcanic.

* There are at present very few data available relating to the annual volume of water poured into the Gippsland lakes, or the amount of sedimentary matter deposited in them. Some idea may, however, be formed from the following statement, which is extracted from the "Report on the Physical Character and Resources of Gippsland," by the Surveyor-General and the Secretary for Mines (Melbourne, 1874, p. 29):—"The quantity of water which the rivers, their feeders, would pour into the lakes during ordinary weather, in the months of November, December, January, and February, is, according to estimates formed by us from data obtained by the late Mr. Dawson, 16,132,500,000 cubic feet, representing a depth of four feet and half an inch over the superficial area of the lakes."

The relations of these various formations to each other and their general relations to the mountain-chain, the Australian Alps, will be seen from the diagram-section, fig. 1. The Carbonaceous (Mesozoic) strata of South Gippsland have been added to complete the comparison, but will not be further considered, as they lie outside the district described.

Table of the Geological Formations of North Gippsland.

I. Lower Palæozoic.	1. *Silurian*	(*a*) Auriferous slates and sandstones of rivers Crooked, Dargo, Wentworth, Nicholson, Bonang, Bendoc, and Delegete. (*b*) Metamorphic crystalline schists of the Omeo district. (*c*) Granites connected with (*a*) and (*b*).
II. Upper Palæozoic.	2. *Devonian*	(*d*) Snowy-River porphyries; felstones and agglomerates of Wombargo. (*e*) Middle Devonian limestones of Buchan and Bindi; Tabberabbera shales. (*f*) Upper Devonian shales and limestones of Cowombut and Native-Dog Creek, Iguana-Creek and Maximilian-Creek beds, Snowy-Bluff and Mount-Tambo beds (?).
	3. *Carboniferous*	(*g*) Sandstones of Avon river.
III. Tertiary.	4. *Miocene*	(*h*) Bairnsdale limestones.
	5. *Pliocene*	(*i*) Moitun-Creek beds; sandstones and marls of Jemmy's Point and Lake Tyers. (*k*) Dolerites and basalts of Dargo High Plains, Cobungra, Nunnyong, Gelantipy.
	6. *Pleistocene and Recent*	(*l*) Sand- and gravel-beds up to about 800 feet above sea-level; clay terraces along the rivers and lakes; sand dunes, swamps, flooded lands, and river-gravels now forming.

Table of the Igneous Rocks of North Gippsland.

I. Plutonic.	1. *Older Plutonic* ...	(*a*) Granites which have invaded and metamorphosed Silurian strata, as at Dargo, Neoyang, Deddick, Delegete, Omeo, &c.
	2. *Newer Plutonic* ...	(*b*) Quartz-porphyries of the Snowy River, Mount Wombargo, Mount Tambo, Mount Taylor, &c.
		(*c*) Dykes of compact, porphyritic, and quartziferous felstones of Omeo, Neoyang, Tabberabbera, &c.
		(*d*) Amorphous masses and dykes of porphyrite of Mount Leinster (?), Bulgurback, &c.
		(*e*) Amorphous masses and dykes of greenstone and other basic igneous rocks of Omeo, Limestone River, Maximilian Creek, Tabberabbera, &c.
II. Volcanic.	3. *Palæozoic*	(*f*) Felstones (lavas), ash, and agglomerates of Mount Wombargo and the Black-Mountain tableland, Snowy Bluff, Tabberabbera, Maximilian Creek, &c.
		(*g*) Dolerites and basalts of the Snowy Bluff.
	4. *Tertiary*............	(*h*) Dolerites and basalts of the Dargo High Plains, Cobungra, Nunnyong, Gelantipy, Tubbut, &c.
III. Metamorphic.	....	(*i*) Metamorphic crystalline schists of the Omeo district.
		(*k*) Indurated rocks, spotted schists, Hornfels, &c.

Note.—I have used the term "Plutonic" as being the most convenient I can at present use for purposes of classification. It is probable that the term "Hydro-plutonic" might be better.

I. Lower Palæozoic.

1. *Silurian.*

(*a*) Rocks referable to this age are exposed over a large part of the district; but the areas are not continuous, and the boundaries somewhat difficult to define shortly in words. Broadly viewed, a description may thus be given:—The largest area will be found between the Mitchell and Tambo rivers, north of the road from Bairnsdale to Bruthen. It includes almost all the drainage-areas of the Mitchell and Nicholson rivers and that of the west side of the Tambo River, south of a line drawn from Mount Balahead to the Fainting Range. The next area in size is found between the Snowy River, the boundary-line of the Colony, and the sea-coast. Outcrops are met with of various sizes, as at Bendoc, at Mount

Nowa Nowa, near Bindi, at the Reedy River (which is one of the feeders of the Buchan), and in other minor localities which need not be further specified. In the country between the upper waters of the Mitchell and Macallister rivers Silurian strata probably underlie the Upper Palæozoic groups.

The strata which I regard as Silurian consist of alternating slates and sandstones, with rare bands of crystalline limestone in the upper part of the series. These have been tilted, folded, compressed, and subjected to influences which have produced alterations lying between a schistose and a flinty structure. They have subsequently been extensively denuded before the deposition upon them of later formations. The strike of these strata naturally varies, owing to the many disturbing causes which have affected them. I have found some difficulty in determining the average direction of strike; but, from the consideration of all the observations which I have been able to make throughout the district, I believe that the average strike will be found to lie between 35° to the west and 20° to the east of north. The dip appears usually to be between 60° and vertical, and varies rapidly; but I am inclined to believe that it is more generally to the eastward than the westward, and would therefore indicate not only a general acute folding, but also a subsequent tilting over to the west.

I have observed in two localities, near Dargo Flat and Neoyang, where the contact with the granite has been laid bare by denudation, that the strike has turned nearly east and west, the dip being both against and from the granite.

The largest Silurian area is situated, as I have said, between the Mitchell and Tambo rivers, and extends from the Great Dividing Range to near the sea-coast. Broadly viewed, it is a country of deep valleys and corresponding high and steep ridges, among which occasional outcrops of granite are to be found. These are usually in valleys, but also in some cases as mountains, such as Mount Baldhead. The Silurian mountains are in places capped with outliers of Upper Palæozoic strata, or with Tertiary volcanic outflows. Here are situated the alluvial gold-workings of the Crooked, Dargo, Wentworth, Tambo, and Nicholson rivers, of Merrijig and Boggy Creeks, of Shady Creek and the Haunted Stream, and other places, and the quartz-mines of Grant, the Upper Dargo, Boggy Creek, and Deptford.

The second area, as to size, is, as I have said, east of the Snowy River. The country is one of steep and high mountains, gradually culminating in the chain known as the Coast Range. Their structure is perhaps best seen at the Deddick River, and I shall refer to that as an illustration*. The general features are that the summits of the mountains are of highly inclined strata, usually much indurated, so that the slates are flinty and the sandstones quartzites. In many places the original structure of the rocks is almost oblite-

* The Deddick River is also called, in parts of its course, the Tubbut, Jinigallalla, and Bonang, these being the native terms for the various localities through which it flows.

rated, and the planes of deposit can only be distinguished by alternating and undulating narrow lines of different colour. An examination of the whole district shows, however, plainly that these inclined and vertical strata dip downwards, becoming more and more altered, and generally end abruptly against the granite which occupies all the low ground and valleys.

Thus in the Deddick River a contour-line which would separate the high ground from the valleys would also approximately indicate the position of the granite as below this line. Were the whole of the granite stripped of the superior strata without being itself denuded, it would present an extremely uneven and irregular surface; for we find, on examining the streams, that in places the Silurian strata descend below the general surface of the granite, and are much contorted and folded back on themselves, while in other places we find bosses of granite appearing through high ridges of the Silurian slates*.

The hard quartzites appear often to have marked out the ridges, as in Mount Bowen and Delegete Hill.

Among the much indurated and altered strata occasional patches are found which have been less affected, as, for instance, the black Graptolite-slates of Deddick, in close proximity to the granite boundary and the larger area of Bendoc and Delegete, where are situated mines both in auriferous alluvium and quartz veins. So far as I am aware, neither alluvial gold nor auriferous quartz veins have been met with at the Deddick River.

This Silurian formation extends beyond the coast-range down the Goungrah, Bem, and Cann rivers; and gold-workings have been there opened. Little is as yet known concerning the geology or the resources of that part of the district; it is mountainous and covered with dense scrubs, but it presents indications of being generally more or less gold-bearing. I have traversed it in three different directions, and can speak to the difficult nature of the country.

In respect to the other minor Silurian areas I need say but little. The general features are such as I have already noted. We find the same general direction of strike and high angle of dip, the same alternation of slates and sandstones with quartz veins, the same paucity of fossils, and the same intimate relation to the crystalline schists, the granites, and the older plutonic rocks generally, which I have yet to indicate more particularly.

This formation has been regarded as probably Lower Silurian. It has so far proved almost entirely barren of fossil remains throughout the district; and it is only to the east of the Snowy River, as I have before said, that Graptolites have been met with †. These, the apparent connexion of the whole series, its relation to rock formations of later age, the high angle of dip, amd the universally indurated and slaty condition of the strata as compared with others

* Accommodation Creek at Deddick as to the former, and Marriott's Mountain at Bonang, and especially Mount Goungrah, as to the latter statements.

† 'Prodromus of the Palæontology of Victoria' &c., decade i. p. 12, by Frederick M'Coy, F.G.S., Government Palæontologist, &c. &c.

yielding Upper Silurian fossils, have led to this belief. But too much weight may have been perhaps attached to this negative evidence. In a group of strata at Tabberabbera, many of which are as indurated and slaty as any in the district, Middle Devonian fossils are met with*.

I point out these doubts as to the propriety of considering all this area as Lower Silurian, or even Silurian; but provisionally I use these terms for description.

The apparent paucity of fossils is probably due to the slight examination which has yet been possible of an immense area of mountainous country, all of which is clothed with forest, and very much with dense and sometimes almost impenetrable scrubs.

(*b*) *Metamorphic Crystalline Schists.*—We find, occupying the central part of the Omeo plateau, and intimately connected with the last-mentioned strata, a great extent of crystalline schists. They may be defined as extending from the Dargo River to the Limestone River, in a direction east and west, and from the Fainting Range northward far beyond the limits of the district I am considering.

They do not, however, occupy exclusively the whole of this tract of country. Slaty and indurated rock masses, which I regard as Silurian, appear in places, as at Bindi, while other extensive areas are of granite, not belonging to the crystalline-schist series, and elsewhere are varieties of quartz-porphyries. At the Omeo Plains there is a wide extent of nodular argillaceous schists, which are connected with, but do not, as it seems to me, belong to the Omeo crystalline schists.

These latter form a complete series of varieties of mica-schist and gneiss, with subordinate varieties of quartz-schist, the extreme end of the series being, on the one hand, a fine-textured, glistening mica-schist, as at Swift's Creek, and, on the other, granitic gneiss or schistose granites, as, for instance, in the Dry-Hill Creek at Omeo. Many of these latter are, in hand specimens, undistinguishable from an ordinary ternary granite.

The connexion of these crystalline schists with the Silurian is clearly shown in many places. I subjoin a sketch section (fig. 2), which, I believe, exhibits tolerably clearly the position of the Omeo schists in the geological series. The section has been sketched from one constructed to scale from notes which I have prepared to illustrate a series of papers on the geological structure of North Gippsland.

In looking at the details of this section we see that the tilted and denuded Silurian strata appear from under the scarped edge of the Upper Palæozoic "Iguana-Creek beds." They extend, as the section shows, across to the Dargo River, forming a mountainous country excavated into deep valleys and high steep ridges by the Wonan-

* Professor M'Coy, who kindly examined a collection from Tabberabbera, identifies the fossils as *Spirifera lævicostata* of the Buchan Limestone and a *Grammysia*. See also the 'Report of Progress of the Geological Survey of Victoria,' No. II. Appendix to "Notes on the Geology of part of the Mitchell-River Division" &c., p. 72.

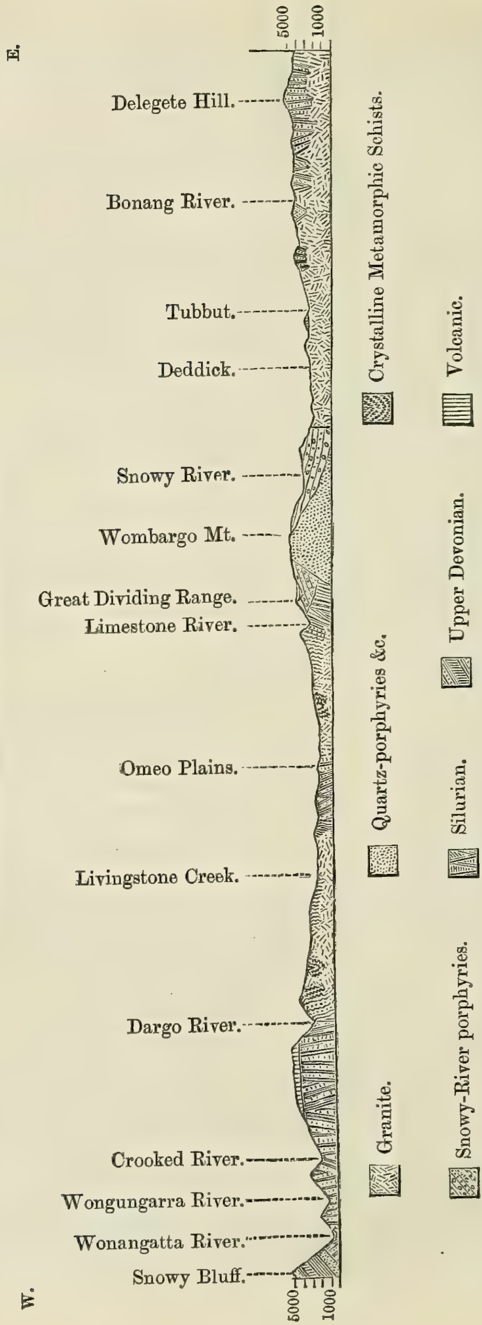


Fig. 2.—*Sketch Section from the Snowy Bluff to Delegete Hill.*

(Horizontal scale about $16\frac{1}{2}$ miles to 1 inch.)

gatta, the Wongungarra, and the Crooked rivers and their subsidiary streams. On the western side of the Dargo-River valley, on the line of section, the Silurian strata are exhibited as greenish and bluish clay-slates, alternating with quartzose or micaceous sandstones, and having a strike to the north-west and a dip of from 70° to 80° to the north-east. On crossing the Dargo River at Mayford, the hillside shows bluish clay-slates of the same direction of strike and dip, but having a somewhat crumpled silky appearance. On ascending the steep eastern side of the valley a gradual change is met with from these last-named rocks, through finely micaceous schists to gneiss.

Although these schists are in places much crumpled and contorted, it is still possible to see that the foliations of the various beds, and the beds themselves, conform to the direction of the strike and dip of the Silurian clay-slates; and it is important to bear in mind that the dip of the clay-slates, and of the mica-schists into which they seem to pass, is to the north-east, and therefore underneath the more highly altered schists at the summit of the hill. The slope of the ascent is great, and in so far is favourable to observation as resembling a cliff-section. The vertical height from the clay-slates of the river to the gneiss at the summit is 1350 feet, and the horizontal distance about from 80 to 100 chains.

This summit is the Great Dividing Range, and from this point there is gently undulating country to within about two miles of the Omeo township. Throughout this distance the following rocks alternate:—Gneiss and gneissoid mica-schist, schistose granite, granites of binary, ternary, and quaternary composition, consisting of orthoclase and quartz, orthoclase, quartz, and mica (principally black), or the three together with black and greenish-black hornblende.

It is to be remarked that so soon as the schists, in ascending from the Dargo River, become more siliceous, irregular patches or veins of slightly translucent and somewhat greasy-looking quartz appear, forming part and parcel of the foliations. More rarely, veins are met with of coarsely aggregated orthoclase, quartz, silvery mica, and often black schorl, and these are usually associated with the granite schists or the granites (metamorphic).

Other veins are also to be met with of orthoclase, quartz, and fibrolite, all confusedly aggregated together. The fibrolite in places shows certain resemblances in colour and in imperfect prismatic forms to andalusite and even to kyanite. It is found of pale tints of lilac, blue, pink, as well as white, and is exceedingly tough in texture.

The granites are usually met with in the low grounds, in the valleys, but also as small plains at higher elevations. In fact, granites belonging to this division are met with in this locality at all heights, but more generally, as I have said, where streams have cut deep into the schist surface.

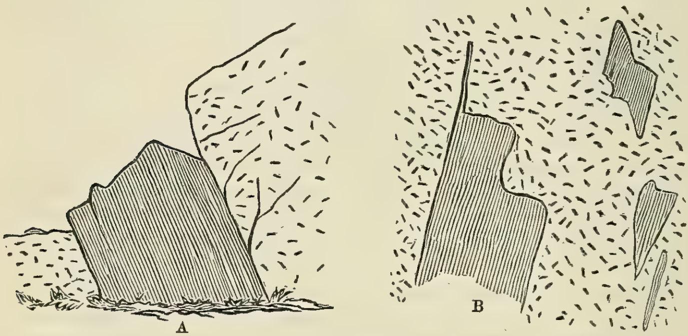
In the schists and granites, speaking generally of the whole series, we meet with numerous intrusive dykes, from a few inches to over twenty feet in width. A preliminary microscopic examination of a number of these in thin sections has shown me that they are varieties of compact felstones, diorites, and basalts; but many have evidently undergone great mineral changes, partly due to metamorphism, which has, I believe, also generally affected the already metamorphosed schists, and partly due to alterations which have affected the dykes alone. I am, at present, unable to assign a classificatory position to these.

Some of these intrusive dykes or masses are no doubt Palæozoic, but others are undoubtedly connected with the outflows of the Tertiary dolerites, which will be mentioned later *.

Epidote is of frequent occurrence, both in the intrusive dykes and in the schists themselves, and forms a marked feature in the Omeo rocks.

The subjoined sketches (fig. 3) will show the relations of such intrusive dykes to the schists and granites of Omeo.

Fig. 3.—*Aphanitic Dyke at Sandy Creek, Tambo River.*



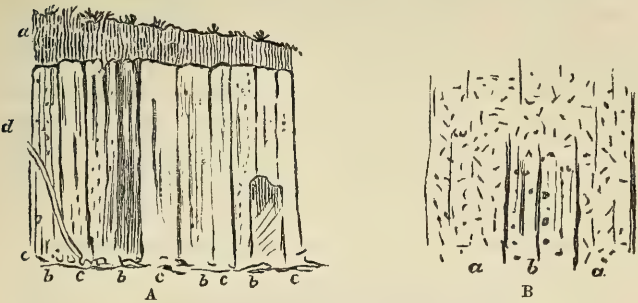
A. Section. Dip N. 10° W. at 80°. B. Ground-plan. Strike N. 80° W.

The rock through which the dyke cuts is a metamorphic granite.

These crystalline schists extend across the valley of Livingstone Creek towards the Omeo Plains, where they appear to pass into the argillaceous schists. These latter still distinctly show the former condition of the beds, being alternations of altered slates and sandstones. The former have become spotted or nodular argillaceous schists; the latter quartzites. The connexion of these with the crystalline schists is seen in a gully near the Livingstone Swamp, from which I have taken the subjoined sketch (fig. 4).

* I have in this paper followed the suggestion made by Mr. Allport in his most valuable paper "On the Microscopic Structure and Composition of British Carboniferous Dolerites," read before the Geological Society of London, June 24, 1874 (p. 529 of the Quarterly Journal of the Society, vol. xxx. 1874), and have used the term "dolerite" as including all those Tertiary volcanic rocks of which basalt is the compact form. I have, however, still used the restricted term melaphyre in one instance.

Fig. 4.—*Argillaceous and Crystalline Schists near Omeo.*



A. Section near the Livingstone Swamp.
a. Surface-soil and rubble. *b.* Glistening nodular argillaceous schists.
c. Quartzite. *d.* Quartz vein.
Dip about N. 60° E. at 75° to 80°.

B. Ground-plan of contact of the argillaceous and crystalline schists from a gully near Livingstone Swamp.
a. Granitic schist. *b.* Nodular argillaceous schist. No well-marked contact can be seen at this place between *a* and *b*, excepting at the sides of *b*, as shown. The nodules are unusually large, being oval and up to a quarter of an inch in length.

In crossing to the eastward, these argillaceous schists are seen to extend beyond the Omeo Plains; but it is only occasionally that the rocks are visible. They appear to have been much disturbed by the quartz-porphyries which form the mountains of the Great Dividing Range on the south side of the plains, and are considerably indurated and altered in texture along that line.

In proceeding southward from the plains, a gradual series of changes in the rocks may be traced connecting the argillaceous schists with the indurated slates and sandstones, which end in the granite of Bindi, and which have so completely the appearance and position of the Silurian rocks elsewhere seen to have been invaded by granites, that I have felt little doubt in regarding them as such. I think we may infer that the complete metamorphism which produced the crystalline schists of Omeo has been subsequent to the first alteration of the sedimentary strata into the argillaceous schists.

These latter rocks continue to the eastward for some distance beyond the plains; but the structure of the country then becomes marked by extensive flats of clay derived from the hills connected with Mount Leinster. In one place a coarse black mica-schist is met with, having a dip to the west of 43°.

Passing still further to the eastward over a tract of country occupied by the porphyritic rocks of Mount Leinster and by hornblendic granite, the crystalline schists are again found*. This is at

* I am at present unable to assign an exact place to the interesting rock masses of Mount Leinster; but, from a few microscopic sections which I have prepared, I conclude that they probably all belong to the class of "porphyrites."

the extreme edge of the Omeo basin, where the country rises to form the watershed of the Limestone River. At this place I have noted what seems to be a gradual passage from coarse granite to gneiss, mica-schist, then to a wrinkled and glistening clay-slate, with a high dip to the eastward.

At the Limestone River the rocks are seen to be dark-blue and yellowish clay-slates with narrow quartz veins, and bedded with them greyish crystalline limestone. This group of strata has a general dip to N. 85° W. at 60° to 70°. The crystalline limestones and marbles occasionally show indistinct traces of corals; but so far none have been identified.

(*c*) *Granites.*—The granites of North Gippsland may be separated into two classes:—

(*a*) Those which are the result of the perfect metamorphism of sedimentary strata; and,

(*b*) Those which appear to have invaded, and partly absorbed and altered, sedimentary strata.

I can feel no doubt as to the origin of many of the granites which are seen alternating with the mica-schist and gneiss of Omeo. A series of rock-specimens can be collected there showing the finest shades of gradation from a true mica-schist to a true ternary granite, or to a quaternary granite, where the fourth constituent appears to be an amorphous green mineral. It is, however, quite possible that in some instances denudation of the schists may have laid bare granites belonging to the second division; but on this point data are at present wanting.

The second class of granites is met with in numerous localities.

In examining generally the whole district where the Lower Palæozoic sedimentary rocks are visible, it will be seen that granites occur in various places, usually in the river-valleys or as basins of low hills surrounded by Silurian or younger strata (as at Bulgurback, Dargo Flat, Neoyang, the Lower Tambo river, the Snowy River in its upper course, Deddick, the Genoa River, &c.), but are also sometimes seen as hills or mountains protruding from among the stratified rocks, as at Mount Baldhead, the Forlorn Hope, at the sources of the Tambo and Buchan rivers, and many other places. In all these instances and, indeed, wherever I have met with granites in North Gippsland of this class, their present position, either in the valleys of rivers or as mountain masses, appears certainly to be due to denudation and erosion, subsequent to their invasion of Lower Palæozoic formations.

Some of the broad features to be noted in respect to this class of granite I have already referred to. I may add further that the highly tilted Silurian strata are seen to dip down onto the granite, and to be there cut off either across the direction of dip or of strike; but in following the general direction of strike of the Silurian strata across the granite, we find that the former recur with the same general direction of strike and dip as before.

The passage from the sedimentary rocks to the granite varies both in rapidity of change and in the nature of the change itself. In examining any of the isolated granite areas, the Silurian strata are found in the neighbourhood to maintain their general direction of strike and dip until in near proximity to the granite, where they exhibit signs of pressure and of alteration. The beds are thrust in all directions, and extensively broken up by irregular joints. Granite veins are found to traverse these contact-margins, showing in different localities the same general features, and especially the distinct contact of the sedimentary rock and the granite vein, as clearly as elsewhere the contact of the granite with the mass of intrusive dykes is shown. The stratified rocks themselves are greatly altered, either resembling fine-textured gneissose or micaceous schists, or forming dense crystalline rocks in which the planes of deposit can barely be distinguished by wavy lines of various shades of colour. The extreme form of this series is Hornfels. The changes resulting in the former series of alterations seem to be heralded by a micatization of the rocks; in the latter by the appearance of chiastolite-like markings, which can often be still distinctly recognized in an enlarged form in the Hornfels.

A microscopic examination of thin sections of the Hornfels series has led me to believe that, in some cases, the markings I have referred to are probably due rather to the somewhat different aggregation of materials than to the introduction of fresh elements into the rock masses.

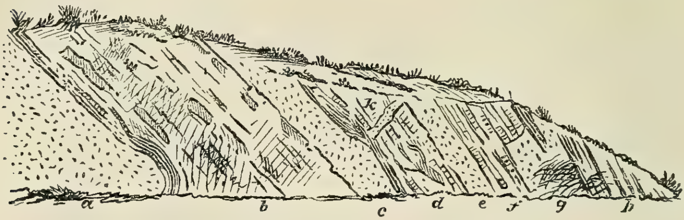
Sometimes both forms of alteration are seen in the same area, and occasionally in near proximity, as at Dargo Flat, where the micaceous alterations are seen, especially on the northern margin (Dargo River), and the indurated rock series on the south side (Orr's Creek).

These alterations of adjacent rocks extend for uncertain distances from the visible granite surfaces; and I think that this may be accounted for on the belief that the granite continues nearer to the present surface in some directions than in others—in other words, that it is due to the granite surface being as highly uneven underground as we see it to be where denudation has laid it bare.

In some parts of North Gippsland the rock masses which have apparently been invaded by granites do not present so much the alterations I have described as a general silicification of the strata, by which great portions have assumed the character of quartzites, as, for instance, Delegete Hill and the Bowen Mountain. But it seems to me significant of some connexion between the changes seen and the appearances of invasion by the granites, that the intensity of those alterations in the sedimentary strata varies in an inverse proportion to the distance of the former. But in these tracts there are also places where the rock masses present just such alteration as I have before mentioned; for instance, Marriott's Mountain, where the Silurian slates and sandstones have, near the granite, assumed a finely gneissose appearance.

The annexed section (fig. 5), sketched from a cutting in Orr's Creek, Dargo Flat, will illustrate the contact appearances generally seen.

Fig. 5.—*Contact of Granite and Silurian, Orr's Creek, Dargo Flat.*



(*a*) Ternary felspathic granite, very much decomposed.
(*b*) Altered Silurian. Under the lens appears granular felspathic, with minute black specks (mica ?).
(*c*) Fine-grained granite vein, about 3 feet wide, consisting of felspar, quartz, black mica. This is sharply defined as regards the bounding rock, which is similar to (*f*).
(*d*) Altered Silurian. In places micaceous, like (*f*); elsewhere indurated, finely crystalline, bluish black in colour. Traces of planes of deposit recognizable by lighter or darker undulating lines.
(*e*) Decomposed felspathic vein or dyke, like (*g*), but more granitic. About 12 feet wide.
(*f*) Metamorphic rock, schistose, and the joints lined with silvery mica. This seems to embrace and overlie (*g*).
(*g*) Felstone vein or dyke, with minute patches of a foliated black mineral.
(*h*) Indurated slates and sandstones (Silurian), as seen down the course of Orr's Creek (auriferous).
(*k*) Granitic vein crossing (*d*), a few inches in width; at the sides rather coarsely crystalline-granular, of yellowish orthoclase and translucent quartz. In the centre the same, but coarser, and with aggregations of silvery mica and black schorl.

Note.—In the above sketch the lateral extension of the rocks has been condensed in order to bring the whole section into view; but the features have been preserved as faithfully as possible. The apparent dip is due to the section lying at an angle with beds which are in reality vertical, or nearly so.

As the granites of the series (*b*) have invaded, cut off, absorbed, or altered the Silurian strata, so also have extensive extravasations of quartz-porphyries and of rocks connecting them with the true granites taken place among the sedimentary strata. The effects produced are, however, far less marked than in the granites.

The quartz-porphyries all agree in having a felsitic or somewhat crystalline-granular base, in which are usually porphyritic crystals or patches of orthoclase, and in all cases crystals or crystalline grains of quartz. The colour varies from almost white in restricted localities to shades of yellow, red, and purple. Some varieties are earthy, while others are highly silicified. The extreme forms are, on the one hand, a rock which might be classed as a somewhat crystalline form of binary granite (Mitchell River); and, on the other hand, a highly porphyritic rock, in which the orthoclase crystals are over an inch in length and often distinctly formed, and the quartz-crystals large and often in very regular double pyramids without any apparent intervening prism (Mount Taylor). The total area occupied by quartz-porphyries falls, no doubt, somewhat short of that of the granites; but the localities are, generally speaking, between the Tambo and Snowy Rivers, and extending between similar limits north of the Great Dividing Range. The granite, on the contrary, is found in all places where denudation has been sufficiently deep. Where I have been able to examine the contact of the quartz-porphyries and the Silurian strata, as at the Omeo Plains, I have found the latter broken up and penetrated by dykes of felstone—which is in places granular (apparently owing to decomposition), in other instances, however, compact, and in such cases, almost without exception, more or less distinctly quartziferous. The forms of Silurian rocks which I have observed to have been invaded by the quartz-porphyries are the argillaceous schists and quartzites of the Omeo Plains, and the indurated slates and sandstones of Bindi; and we thus see that the irruption of the quartz-porphyries has been subsequent to the invasion and alteration of the Silurian strata by the granites. Near Bairnsdale the Silurian has been broken through by enormous masses of quartz-porphyry and allied rocks, which now are seen as the triad group of hills, Mount Taylor, Mount Lookout, and Mount Alfred; and here the sedimentary rocks have either apparently undergone no change, as at Bulumwaal, or, as at Clifton, have been altered to very nearly the true Hornfels condition. In the river-gravels derived from the neighbourhood of those hills fragments of perfect Hornfels are frequent, showing that the change has been a common one there.

Where I have been able to observe the relations of the quartz-porphyries and the granites, as at the Snowy River near Turnback, and not far from where the latter rocks have invaded the black graptolite slates of Deddick, I have found that the quartz-porphyries have come up through the granite in mountain masses and with a well-defined line of contact. The boundary of the two rocks at Turnback seems to be along a north and south line, and may indicate a great fault; if so, it is almost the only fault which I have been, so far, able to recognize.

At Turnback we again see the same general relations of the Silurian, the granite, and the quartz-porphyries that I have already pointed out as being indicated at Omeo Plains.

All these divisions—the Silurian, the granites, the quartz-porphyries—may from one point of view be regarded as forming a group in the geological series. In this aspect they constitute the great "rock-foundation" of North Gippsland on which the younger formations rest.

I find all over the district that this group has been subject to enormous denudation during Palæozoic time, and that, broadly viewed, the first great stratigraphical break may be placed here. The Sections figs. 1 and 2 (pp. 6 & 12) will further illustrate my views on this subject. This first "Horizon" may be also regarded as marking the division between the Lower and Upper Palæozoic times. Below it we have, as at Deddick, Lower Silurian slates with *Diplograpsus rectangularis*, M'Coy *, as the oldest; and at Gibbo River, and pro-

* 'Prodromus of the Palæontology of Victoria,' decade i. p. 11. Frederick

bably also at the Limestone River, Upper Silurian Limestones with corals (at the former containing "*Palæopora*") as the youngest known strata.

Above this "Horizon" the first sedimentary deposits known to exist, and in places immediately resting on the "rock-foundation," are Middle Devonian marine limestones, with *Spirifera lævicostata*, Placodermatous fish, and corals perfectly identical with specimens from the European Devonian limestones of the Eifel*.

I shall in the next division of this paper refer to these; but before doing so I must discuss an extensive formation which lies between those two Palæozoic fixed points.

II. Upper Palæozoic.

2. *Devonian.*

(*d*) *Snowy-River Porphyries.*—The immense extent of rock masses, both horizontally and vertically, which have been known by the above designation have, so far, included nearly all the rocks occurring over the tract coloured by Mr. Selwyn, in his geological sketch map of Victoria, as "Trap or Hypogene," and also under the same classification in the more recent sketch map of Mr. R. Brough Smyth, the present Director of the Survey. The greater part of this area is occupied by porphyritic rocks of the acid series and by granites. Of the former, some are the quartz-porphyries which I have already considered. The remainder are, so far as I have yet been able to work them out, immense accumulations of ancient volcanic materials, consisting principally of ash and agglomerates and of felstone lavas.

One tract only I have as yet been able to examine in any but a cursory manner. The country is rugged in the extreme. The Snowy River on the east and the Buchan River on the west have cut down into the granites and the associated sedimentary strata, and left these "Snowy-River Porphyries" standing up as a high rugged tableland, some 2000 to 3000 feet in altitude above these rivers.

From this tableland streams falling into the Snowy River and the Buchan (or Native-Dog Creek) have cut deep clefts, among whose rugged defiles the geologist can only make his examinations with great difficulty and not altogether without danger.

The subjoined diagram section (fig. 6) across this tableland will illustrate my views of its structure, and is also generally applicable to other places where I have crossed it, as, for instance, from Fanwick to Mountain Creek, or from Buchan to the Rodgers River. The natural features have been condensed, and the horizontal distance much shortened, in order to bring the whole under view. The dip of the country generally seems to be towards the sea-coast from the Great Dividing Range, so that at Buchan the "Lower Palæozoic

M'Coy, F.G.S., Professor of Natural Science in the Melbourne University, Government Palæontologist, &c. &c.

* Intercolonial-Exhibition Essays, 1866. Professor M'Coy "On the Recent Zoology and Palæontology of Victoria," Essay No. 7, p. 327.

foundation" which is seen at the Black Mountain or Fanwick is no longer visible, having sunk below the level of the rivers.

In constructing this diagram section, I admit that much of the subterranean representation must necessarily be hypothetical, and its possible truth must depend, in a great measure, upon the accuracy of my observations and also upon the soundness of the inductive reasoning based upon them.

In the observations made as to the surface appearances, I can feel the confidence which has been created by repeated examinations during the last five or six years; of those features I have inferred to exist, such as the subterranean extension of the Silurian strata of the Limestone River and the position of the central mass of quartz-porphyries, I may say the following words:—

At the north-west end of the section the limestones and slates suddenly end at the foot of the porphyry hills forming the east side of the Limestone River; they present no more than the normal degree of disturbance or alteration, nor any such appearances as would lead me to suspect that the igneous rocks had come up through them. On the contrary, where last seen, they appear merely to pass under the great mountain of porphyritic rock which there forms part of the Great Dividing Range. These rocks themselves are found on examination to be principally quartziferous felstones, which I regard as merely altered ash; for almost everywhere the weathered surfaces show more or less of the fragmentary nature of the composition. I am informed by persons who have prospected for gold in the streams falling into the Limestone River from the Great Dividing Range at

Fig. 6.—Diagram Section from Marengo Creek to the Snowy River across the Wombargo Mountain.

a. Tertiary volcanic. *b.* Upper Devonian. *c.* Silurian. *d.* Felstone lavas, ash, agglomerates. *e.* Quartz-porphyries. *f.* Granite.

the place I speak of, that, in shafts sunk through the detritus in the beds of those streams among the porphyritic hills, slates and limestones similar to those in the Limestone River are found as the bedrock.

In the valley of the Native-Dog Creek where that stream has cut through the thin remains of Upper Devonian fossiliferous limestones and shales into the underlying porphyries, several masses of metamorphosed sedimentary rocks of a most remarkable character are revealed protruding from the peaty soil and snow-grass. These have apparently been calcareous shales, but are now calcareous schists of a pale yellowish or nearly white colour, and are not only extremely altered, but are bent into the most abrupt angular contortions. I may roughly represent the appearance of these schists thus :—

Fig. 7.—*Contorted Schists, Native-Dog Creek.*

They present no similarity to any of the metamorphic schists of North Gippsland which I have ever seen. But I have observed that among the limestones and slates of the Limestone River there are thin calcareous bands which may represent the comparatively unaltered condition of the schists of the Native-Dog Creek. Further to the southward down the same stream, but above Fanwick, is another patch of shales and crystalline limestones, here also altered in an unusual manner, but somewhat similar to those I have just described. They appear in a deep valley from under the great porphyritic tableland. From these appearances I believe that the indicated extension of the Limestone-River strata is not inconsistent with the probable truth.

In mentally looking over the whole district, I perceive that here and there mountains or ridges of quartz-porphyries stand out from the "Snowy-River Porphyries" or in their neighbourhood, in the latter cases being often in the Marine Tertiary areas, from which they rise as isolated hills. Taking the Wombargo Mountain as an example, I notice that grouped round the central mass of quartz-porphyries there are immense thicknesses of successive accumulations of ash, agglomerates, and felstones, which, where the deeply cut ravines show the vertical structure, are often clearly seen to be not only bedded, but also seamed with dykes of compact pale-coloured felstone. These appearances are seen in descending from Wombargo to the Native-Dog Creek, to the Tooginbooka River, or to the Little River.

Many of the agglomerates are extremely interesting. They are formed entirely of angular or slightly rounded fragments, varieties of felstone, or of quartz-porphyries, and with, in some instances, fragments of granite; these fragments are of all sizes from almost dust up to several feet in diameter. When the base is light in hue, or dark red, the contrast to the variously coloured and textured fragments is striking. Generally, however, the weathered surfaces are dull, and only show the fragments standing out in relief.

The whole of these rock masses have evidently been subject to great changes; they are almost universally quartziferous, the quartz being more or less perfectly crystallized in double pyramids; and I suspect that a great part of the apparent felstones is merely altered silicified ash.

The general series of this formation, as seen in the deep gorge of the Little River, may be about 2000 feet; the stream has cut a constant succession of falls in its rock-bound chasm. The lowest rocks visible are allied to the quartz-porphyries with occasional agglomerates; in the upper parts there are agglomerates, ash, and felstones, all much consolidated and siliceous, and penetrated by irregular branching veins and dykes of hard white felstone. In this gorge I found some of the beds of coarse ash beautifully distinguished from each other, not only by marked planes of deposit, but by the different texture of the beds themselves. The whole of the series appears to be of subaerial origin.

All these considerations have led me to believe that in the Wombargo Mountain we may recognize the site of a Palæozoic volcano, the central mountain being the denuded core round which some small portions of the vast masses of ejectamenta still remain grouped.

The Cobboras, St. Pancras Peak, Mt. Statham, may be indicated as presenting quite similar appearances to those of Wombargo, and taken together may possibly represent a somewhat north and south line of volcanic orifices extending southward through the Buchan country. The isolated mountains which I have mentioned as standing in the Marine Tertiary area convey to my mind a strong suggestion of similar origin and similar age. Such are Mount Taylor and Mount Nowa Nowa, in the neighbourhood of each of which the Tertiary gravels are largely composed of felstones and other igneous rocks belonging to the "Snowy-River Porphyries."

The relative proportions, as given in the sketch section, of the central quartz-porphyry and the surrounding felstones, are no doubt quite conjectural, and the former I believe to be far in excess of the truth. I merely wished to indicate as nearly as possible the general genetic relations, as I believe them to be, of these most interesting rock masses.

(*e*) *Middle Devonian.*—I have already pointed out that the ancient volcanic materials of the Snowy-River country rest upon the Silurian, and are overlain by Middle-Devonian marine beds. On taking a general view of North Gippsland it is seen that there are isolated patches of limestones which present perfectly similar characters as to position and lithological character, and, what is of more importance, an identity of fossil remains. Mr. R. Brough Smyth's geological sketch map of Victoria well shows this. These limestone patches are usually found, as at Buchan, in the hollows of basins formed in and surrounded by the Snowy-River porphyries; at the "Basin" and on the Snowy River at the junction of the Rodgers River, not far from Buchan, similarly situated; or, as at Bindi, where the basin is formed by granites, quartz-porphyries, indurated Silurian and crystalline schists, in fact the "Lower Palæozoic rock-foundation." At New Gellingall, on the Buchan River, the basin resembles that of Buchan. At Gelantipy, however, we find three small outliers of the Buchan Limestone on the summit of the tableland, resting on the Snowy-River porphyries, and covered by late Tertiary (Pliocene?) doleritic rocks.

These limestones are generally somewhat thick-bedded and compact, usually of a dark blue or blackish colour, and undulate at a somewhat low angle, but are in places seen to have been much folded at high angles. They produce a country of rolling hills or steep grassy ridges, with an excellent red soil, and lightly timbered with *Eucalyptus* and Acacias. "Sinkholes" are of common occurrence, as in other limestone districts, and the scenery is strikingly soft and pleasing in contrast to the harsh and rugged mountains which frame these basins.

The age of these Buchan Limestones has been determined by Professor M'Coy as being Middle Devonian*.

At Buchan argentiferous galena and copper-ore, principally pyrites, has been found and worked.

At Tabberabbera, at the junction of the Mitchell and Wentworth Rivers, I have found a group of strata which present features differing in many respects from those just described, but which, from the fossils gathered from them by me, have been referred by Professor M'Coy to the same age as the Buchan Limestones †.

The group of strata at Tabberabbera consists mainly of more or less indurated or slaty shales, which alternate with quartzites, coarse sandstones with pebble bands, and has a subordinate belt of compact dark blue limestone. The fossils are found abundantly in a black shale adjoining this; but the limestones have not as yet yielded any thing.

The inclination of these strata is nearly as great as, and their general direction of strike and of dip approximate to, that usually found in the great series of slates and sandstones with auriferous quartz veins which are regarded as Silurian, and together with which the Tabberabbera shales have been also folded. The extension either on the strike or laterally, I have as yet been quite unable to determine; but I believe it to be great. I have identified this group down the course of the Mitchell River nearly to Cobbannah Creek; to the

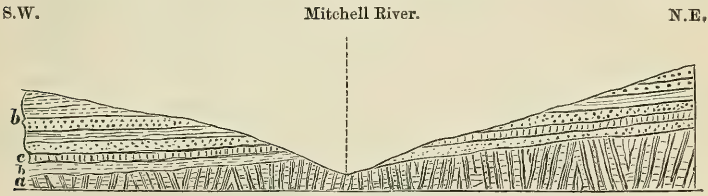
* Intercolonial-Exhibition Essays, 1866, No. 7, p. 327.

† Report of Progress, Geological Survey of Victoria, No. 2, p. 72.

westward, wherever the nearly vertical strata have been laid bare by denudation and erosion, these strata, shales, and quartzites resemble those of Tabberabbera more than any others in the district, and of these they are apparently an extension. Such rocks are to be seen at Cobbannah Creek, at Davy's Nob, and thence through to Maximilian Creek, where they constitute the "bed rock" of the gold-workings.

The subjoined section (fig. 8) will convey an idea of the position of the Tabberabbera shales, and is also applicable in its general features throughout the localities which I have just named.

Fig. 8.—*Diagram Section across the Mitchell River near Tabberabbera.*



a. Tabberabbera Shales (Middle Devonian).
b. Iguana-Creek beds (Upper Devonian).
c. Felstone sheet.

The Tabberabbera shales have been greatly disturbed and pierced by dykes and masses both of basic and acidic igneous rocks. The former are probably doleritic or basaltic, and the latter porphyritic and quartziferous felstones.

One peculiarity in regard to the position of the Tabberabbera shales deserves mention. The Lower Palæozoic rocks in most places constitute the "foundation" on which the Upper Palæozoic strata have been laid down; but here we find that the Tabberabbera shales have, together with all older formations, been folded, compressed, and denuded; and on the surface thus formed the nearly horizontal Upper Devonian beds are found to rest. We have therefore the second great stratigraphical break, or horizon, between the Middle and Upper Devonian formations. Although the distinction between the amount of disturbance by which the strata above and below this plane have been affected is more marked than the analogous difference of disturbance above and below the First Stratigraphical Horizon, yet I think that this is due merely to the fact that in descending in time we find that each successive group of rock-formations has been subjected to a cumulative series of disturbing forces.

(*f*) *Upper Devonian.*—The various isolated groups of strata which have been referred to the Middle Devonian period appear to be merely the remains of a once widespread formation which probably extended over the whole of North Gippsland. The sketch section which I have given (fig. 8) will, to a certain extent, show the facts observable at Bindi, Tabberabbera, and other places, from which it is evident that the denudation to which that formation was exposed removed the greater portion of it before the succeeding groups of strata were laid down. Denudation had also probably removed much of the volcanic materials of Wombargo and other localities of the Snowy-River porphyries. I have now to consider those groups of strata, which I believe may be classified as above.

Mr. Selwyn described several groups of strata in North-east Gippsland, in the localities of the Avon, Freestone Creek, Iguana Creek, and Mount Tambo, as provisionally classified as Upper Palæozoic, and he regarded the plant-bearing sandstones and conglomerates of Mount Tambo as being below the fossiliferous limestones of Bindi, and therefore as "older than the true European Palæozoic coal-measures"*.

I believe that I shall be able to show that this view of the probable age of the Mount-Tambo beds is untenable, being based on a misconception of the true stratigraphical relations of the Mount-Tambo and Bindi formations. At first sight, however, their positions appear to be such as are indicated by Mr. Selwyn.

The groups of strata which until now have collectively been spoken of as the Avon Sandstones have recently been separated into two divisions—the Avon Sandstones proper, containing *Lepidodendron australe*, M'Coy, and referred to the base of the Carboniferous †, and the Iguana-Creek beds, with *Archæopteris Howitti*, M'Coy, *Aneimites iguanensis*, M'Coy, and *Cordaites australis*, M'Coy ‡, and referred to the Upper Devonian.

Still further inquiries have enabled me to extend the Iguana-Creek beds northward as far as Tabberabbera, and westward as far as Maximilian Creek, thus confining the Avon Sandstone proper within much narrower limits than formerly. The exact stratigraphical relations of the two groups have not yet been worked out. At present I incline to believe that the passage may be gradual from one to the other, that is, from the Upper Devonian to the Lower Carboniferous, which is not unusual elsewhere.

I now proceed to describe the Upper Devonian strata from the typical locality Iguana Creek, and from which I have named the whole group.

Iguana Creek joins the Mitchell River just within the line where the fringing marine Tertiaries thin out on the older rocks. It is here that the Iguana-Creek beds are seen to dip at a low angle underneath the Tertiary sands and clays. The base of the series is not here visible, the "Lower Palæozoic formation" having dipped together with the overlying strata, so that at the place mentioned, and also generally, though not at all places along the same line, it is below the water-level of the rivers.

* "Notes on the Physical Geography, Geology, and Mineralogy of Victoria," by A. R. C. Selwyn, &c., Intercolonial-Exhibition Essays, 1866, p. 17.

† A. R. C. Selwyn, "Notes on the Physical Geography, Geology, and Mineralogy of Victoria," &c., Intercolonial-Exhibition Essays, 1866, p. 15; and 'Prodromus of the Palæontology of Victoria,' decade i. p. 37, by Frederick M'Coy, F.G.S., Government Palæontologist, &c.

‡ 'Report of Progress, Geological Survey of Victoria,' No. 2, p. 72.

The section as seen at Iguana Creek, commencing at the river-level, consists of alternating shales, sandstones, quartz-grits, and conglomerates. The shales are either without apparent stratification and of a brick-red or purple colour, or thinly laminated and bluish or greenish grey, and it is in these latter that I have found the plant-remains before mentioned.

Plant-impressions are, however, common, but indistinct in character, though frequently indicating the ribbon-like character of *Cordaites*. The conglomerates are of quartz and other hard and siliceous rocks, and together with the sandstones and quartz-grits intermingle and exhibit interesting examples of false bedding and changing condition of deposits. The upper parts of the series are mainly quartzose sandstones; and some of the lower rubbly shales become locally nodular and calcareous.

The thickness of the series visible at Iguana Creek is probably under 800 feet. The continuity of the beds is unbroken to Tabberabbera, as I ascertained last summer by descending the Mitchell River in a canoe, accompanied by two black fellows, and by that means was able to examine the constant succession of grand natural sections which the rocky gorges of that untraversed river-valley present, which would not be accessible, except in isolated places, by any other means.

Having premised that the Iguana-Creek beds continue in an unbroken manner to Tabberabbera, about 20 miles, I must now, in order shortly to point out the interesting features of this Upper Devonian group, refer to a locality where the natural sections will be found to disclose the underlying older Palæozoic rocks, which no doubt elsewhere also underly the Iguana-Creek beds at no great depth.

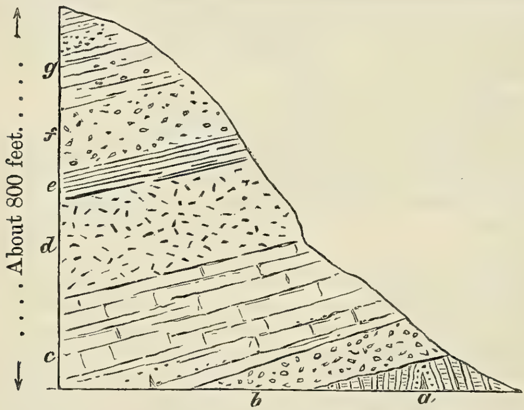
The valley of the Mitchell River shows at Tabberabbera sections, two of which I have condensed in the sketch, fig. 8. The lower nearly vertical shales, sandstones, and limestones contain Middle Devonian marine fossils, and have evidently, together with the still older Palæozoic sedimentary rocks, been tilted, compressed, and denuded, so that at present their extension to the north is undetermined beyond a distance of 2 miles from Tabberabbera, and is quite undetermined to the east and west. To the south they extend down the Mitchell River to near Cobbannah Creek. Lying nearly horizontally on these, the slight dip being southward, we find about from 800 to 1000 feet of sandy shales, conglomerates, and sandstones, principally of a reddish or yellowish colour. We have here the north-eastern escarped edge of the Iguana-Creek beds. Resting on the lowest bed, a red sandy shale, is a sheet of porphyritic and nodular felstone, in which irregular cavities have been filled by agate or quartz, either completely or as geodes. Above this is the remainder of the series of conglomerates and sandstones.

The same sequence of beds is seen in following down the Mitchell River to Cobbannah Creek, where the felstones sink out of sight, and where the overlying sedimentary strata are about 500 feet in thickness. The felstones show as a rugged cliff where last visible, about 80 feet above the river, and they present almost the same triplicate appearance of compact beds with either porphyritic orthoclase and quartz crystals, or quartz crystals alone, in a compact base, and one well-marked bed of nodular and geodic felstone. The remarkable persistence of these well-marked divisions over so large an area leads me to regard this as a contemporaneous sheet.

Dykes and masses of diorite and of other basic igneous rocks, which I have not as yet been able satisfactorily to determine, of porphyritic and quartziferous felstones, have penetrated, cut off, and generally disturbed the nearly vertical Tabberabbera shales, but do not seem to have risen up through the Iguana-Creek beds.

In Maximilian Creek, about 16 miles to the westward of Iguana Creek, which I lately visited in company with Mr. Reginald Murray, of the Geological Survey of Victoria, I found the series of strata shown in the subjoined sketch (fig. 9), which has been condensed from several natural sections.

Fig. 9.—*Diagram Section of Group of Beds at Maximilian Creek.*



a. Quartzite.
b. Coarse quartz and slate conglomerate.
c. Coarse reddish sandstones with pebble bands.
d. Porphyritic, quartziferous, and concretionary felstones.
e. Shales.
f. Quartz conglomerates.
g. Sandstones with pebbles.

I need only point out that, making due allowance for slight lithological differences, we have here identically the same series of rocks, both sedimentary and igneous, as that seen at Tabberabbera and the Mitchell River near Cobbannah Creek.

In following the northern edge of the Iguana-Creek beds no break is found to the westward, and they appear continuous with those at Maximilian Creek.

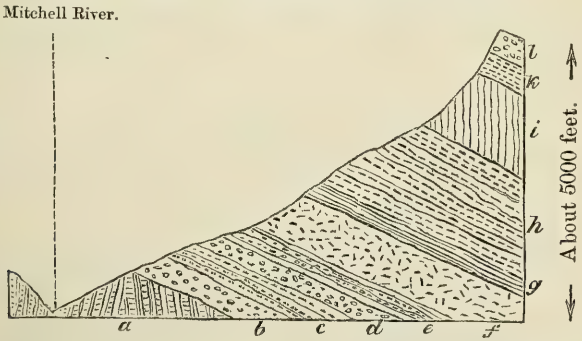
In the absence of any palæontological evidence the indications afforded by the groups of strata themselves are stratigraphically so strong that I have no hesitation in regarding the Maximilian-Creek beds as a continuation of those of Iguana Creek, and therefore Upper Devonian, rather than as belonging to the Avon Sandstones, which are comparatively near at hand to the west.

The nearly vertical quartzites and thin slaty shales which, at Maximilian Creek, seem to represent the indurated shales and sandstones of Tabberabbera, have been cut across by a very strong dyke of compact and, in some places, vesicular diorite. Possibly only as a coincidence this dyke shows prominently at the two localities where the most remunerative alluvial gold-workings have been met with.

Proceeding up the Mitchell River to where it is joined by the Moroka River, which rises among the almost unknown defiles of the great mountain mass north of Castle Hill and Mount Wellington, we find the picturesque mountain known as the Snowy Bluff, standing at the junction of those rivers. It rises immediately from the valley, first buttressed by rugged forest-covered ridges, then up to the summit with a series of encircling precipices and steep grassy slopes. The height of the Snowy Bluff is about 4500 feet above the sea.

This, perhaps the grandest natural section in the Gippsland mountains, gave me the following section (fig. 10), which I have condensed in order that the features may be brought somewhat into more prominence and less space.

Fig. 10.—*Diagram Section of the Snowy Bluff.*



a. Slates and Sandstones (Silurian ?).
b. Coarse conglomerate.
c. Red Sandstone.
d. Finer conglomerate.
e. Red sandstone and red sandy shale.
f. Porphyritic and quartziferous felstones.
g. Yellow and red slaty shales.
h. Alternating red sandstone and slaty shales, with two felstone beds.
i. Melaphyre.
k. Coarse reddish sandstone.
l. Quartz conglomerate.

We see here on an enlarged scale the same group of strata which is met with at Tabberabbera, the Mitchell River, and Maximilian Creek. Of the nearly vertical slates and sandstones forming the basis of the section I can say no more than that they are evidently part of the "Palæozoic rock foundation," and are not unlikely of the same age as the auriferous rocks, near at hand, of the Wonangatta, Wongungarra, and Crooked Rivers. The overlying sedimentary beds are more or less coarse conglomerates, sandstones, sandy or slaty shales, all of a reddish or yellowish colour, and narrowly resembling similar beds in the Iguana-Creek series. We have also here a great thickness of felstones, in which occur not only the wavy undulating lines of various colour, but also the angular fragments of different colour and texture such as are seen so frequently in the ash and fine agglomerates of the Wombargo Mountain and other localities of the Snowy-River porphyries.

Near the summit the Snowy Bluff is encircled by a high precipice. The rugged face is worn into cavernous hollows as the component rock varies in hardness, and is seamed in all directions by a multitude of joints. It is only to be ascended in a few places, where rain-gullies have cut through from the upper grassy slopes of the mountain; but elsewhere is the inaccessible haunt of the Rock Wallaby.

This series, some thousand or more feet in apparent thickness, consists of various beds of a basic igneous rock, either porphyritic with plagioclase prisms, as in the lowest bed visible, or dense in texture, or vesicular and amygdaloidal, as in the upper parts. But everywhere the joints are lined or filled by quartz, chalcedony, or yellowish-green epidote; and the cavities are either geodes of quartz and epidote, or filled by those minerals severally or by chalcedony. An examination of this precipice and of its various component portions, as well as of the underlying and overlying strata, has led me to conclude that these basic igneous rocks are interbedded, and not intrusive.

A preliminary examination of some thin sections of these rocks which I have prepared for the microscope at once disclosed to me the familiar appearance of close-grained dolerite or basalt, in which either the plagioclase or the magnetite were predominant, and in which quartz, chalcedony, and epidote have been very largely introduced as secondary minerals. The plagioclase has in many cases been altered from the centre outwards by (apparently) chloritic minerals, and the magnetite has become still further oxidized, so as to show the translucent blood-red colour of hæmatite.

In accordance with the views which appear now to meet with general acceptance*, these rocks, as being probably dolerites or basalts of pretertiary age, would be classed under the restricted term of Melaphyre, or perhaps they may with still greater propriety be called Upper Devonian Dolerites.

In a paper which I am preparing for the next Progress Report of the Geological Survey of Victoria I hope to be able to describe more fully the microscopic as well as the macroscopic peculiarities of these most interesting rock masses.

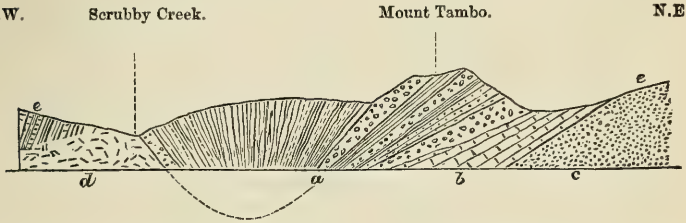
In proceeding to the eastward of the Mitchell River no traces of

* Zirkel, 'Untersuchungen, &c., der Basaltgesteine,' p. 198: Tschermak, 'Die Porphyrgesteine Oesterreichs,' p. 136; Allport, "Microscopic Structure and Composition of British Carboniferous Dolerites," Quarterly Journal of the Geological Society of London, 1874, vol. xxx. pp. 529, 530. Other references might be given, but these may suffice.

formations similar to those I have now endeavoured to describe are met with until Mount Tambo is reached beyond Omeo.

The subjoined diagram section of the Mount-Tambo beds (fig. 11) is condensed from the sections which I have worked out to illustrate the paper I have already mentioned.

Fig. 11.—*Diagram Section across the Mount-Tambo beds.*



a. Tambo beds.
b. Bindi Limestone.
c. Quartz-porphyries.
d. Granites.
e. Silurian.

We have here the lowest part of a synclinal fold resting unconformably on the Bindi Limestone, and in a basin of the "Lower Palæozoic rock-foundation." The series commences with a thick coarse conglomerate of pebbles of quartz, indurated slates, and other siliceous rocks, and extends upwards, through sandstones, grits, and red rubbly shales, to another thick bed of somewhat similar but less coarse conglomerate. From this point the mountain slopes rapidly into lower country. All these beds to the second conglomerate thin out to the southward, and are entirely wanting in Bindi.

The remainder of the series gradually becomes finer in character until the uppermost beds are all rather fine sandstones and slaty shales.

Conglomerates show again at the next margin of the basin, and I regard these as being the probable equivalents of the second conglomerate. Shortly following that conglomerate I have found a thick band of compact yellowish or whitish felstone, which is in places quartziferous. But I am quite unable at present to say whether it may represent the felstones of Tabberabbera, Maximilian Creek, and the Snowy Bluff, or whether it is a very large intrusive mass.

A great irregular dyke-like mass of diorite (?) is also visible in one section, but does not seem to show either to the north or south along the strike of the Tambo beds, and is doubtless intrusive.

I was unfortunately unable to find the plant-bearing shales mentioned by Mr. A. R. C. Selwyn *; but bearing the fact stated by him in mind, and considering the marked resemblance in the lithological character, the sequence, and stratigraphical position of the Tambo beds, their resemblance to those of Iguana Creek becomes strongly

* Intercolonial-Exhibition Essays, 1866, "Notes on the Physical Geography, Geology, and Mineralogy of Victoria," p. 15.

apparent; and I incline to the belief that they belong to the age of the latter, that is, that they are Upper Devonian. Their position as regards the Middle Devonian limestone of Bindi favours this view.

Further again to the eastward numerous traces of ancient conglomerate beds are met with resting on the summits of the mountains, as, for instance, near Carrabungla, at the sources of the Limestone, Tambo, and Reedy Rivers, on the flanks of the Cobboras near Cowombut, and again further to the south and east at Combyingbar, near the boundary-line of this colony. These are similar to those with which the groups at Mount Tambo and the Snowy Bluff commence, and may, with much probability of truth, be regarded as parts of the Great Upper Palæozoic arch, of which the Iguana-Creek beds seem to be the lowest.

According to an opinion expressed to me by Professor M'Coy he regards the marine limestones and shales of the Native-Dog Creek and Cowombut as somewhat older than the Iguana-Creek beds, and this would accord very well with the facts I have observed in the field; for at the former places the last traces of these marine beds are found to be resting on the Snowy-River porphyries in the bottoms of basins, while high up on the intervening mountains (the Cobboras) are the old conglomerates of which I have spoken.

It will have been remarked that almost invariably the Buchan and Bindi Limestones, wherever met with, are seen to lie in basins of the older rocks. The same peculiar feature is to be remarked in the Upper Devonian limestones and calcareous shales of the Native-Dog Creek and of Cowombut, and in the Mount-Tambo and Snowy-Bluff beds. The explanation is afforded by the section at Mount Tambo and by a view of the north side of the Snowy Bluff.

We there see that the preservation of these beds is due to the circumstance that in the folding of the earth's crust, after the laying down of the Devonian strata, certain portions formed what may be termed "pockets" in the lower "palæozoic formation." Subsequent denudation left these "pockets" below the general surface, and erosion by the rivers has worn them out into basins by the removal of the limestones and shales more rapidly than the refractory and silicified rock masses in which they generally rest. In Mount Tambo and the Snowy Bluff we may see the converse of the process which I have indicated as having taken place in regard to the Devonian limestones. In those instances the synclinal "pockets" consisted of siliceous rocks which have proved harder to remove than the older formations in which they were enfolded.

3. *Carboniferous.*

(*g*) *Avon Sandstones.*—Of this group of strata I am at present able to say but little. Mr. A. R. C. Selwyn, in the "Notes on the Physical Geography, Geology, and Mineralogy of Victoria," Exhibition Essays, 1866, speaks of them as being "yellow and brownish red coarse-grained sandstones and micaceous freestones with numerous impressions of plants. Very good specimens of *Lepidodendron* are found here, also other vegetable impressions not sufficiently distinct to be determined." He adds that these plant-beds are underlain by a great thickness of purple-red rubbly and nodular shales, interstratified with purple-red and claret-coloured sandstones.

Professor M'Coy, in his essay on the Palæontology of Victoria (Exhibition Essays, 1866), says that the sandstones of the Avon were the only trace of the Carboniferous formation which he could recognize in Victoria, and the only fossil from them, the *Lepidodendron*, identical with that recognized by him many years before from New South Wales and Queensland; and further, in the 'Prodromus of the Palæontology of Victoria,' Decade I., he figures and describes this among the Palæozoic coal-plants (Carboniferous series) as *Lepidodendron australe*, M'Coy.

Up to the present time opportunity has been wanting to enable me to visit the Avon country and make a personal examination. As I have already pointed out, the Avon Sandstones do not extend at any rate to the eastward of Maximilian Creek, and thus the bounds have been narrowed down within which the correlation of the *Lepidodendron*-beds of the Avon with the *Archæopteris*-beds of Iguana Creek is to be sought. Present information leads me to suspect that the passage may be gradual and undefined.

III. Tertiary.

Passing upwards from the rocks of the last-described period, there is an immense break in the geological series; the missing part of the record seems so completely lost that there are no means, so far as my present knowledge goes, to enable us even to suspect where any portions of it ever existed in the district I describe.

In looking at the sketch section, fig. 1 (p. 6), it will be seen at once that the Palæozoic rocks form a great mass of mountainous country fringed on the north and south by Tertiary deposits; the former those of the "Murray basin," the latter marine. Whether the Mesozoic Coal-measures of South Gippsland extended over the northern part of the district, in the same way that we see the Upper Palæozoic groups did, is not known. There are at present no data; but, so far as I can judge, it seems to me very doubtful.

4. *Miocene.*

(*h*) *Bairnsdale Limestone.*—The oldest of the Tertiary formations in North Gippsland is the Bairnsdale Limestone, collections of fossils from which have been referred by Professor M'Coy to the Middle Miocene period *; it is of the age of similar marine limestones of Corio Bay and other localities in Victoria. It is a coarse shelly limestone, which varies locally in texture, being in some places without apparent stratification for considerable thicknesses. Numerous remains of species of *Cypræa*, *Ostrea*, *Pecten*, and Brachiopoda are frequent, together with a large echinoid, probably a *Clypeaster*. It shows itself in the river-valleys of the Mitchell, the Nicholson, and the

* Geological Survey of Victoria, No. 2. p. 72.

Tambo rivers, and on the banks of the arms of Lake Tyers; but it does not seem anywhere to extend to the hills of older formation on the north or to the sea-coast on the south. Its surface has evidently been much affected by denudation and is irregular. The rivers have cut deeply into it, leaving high yellow cliffs, which are rugged or crumbling as the texture of the great limestone bed varies. It probably does not anywhere rise more than 250 to 300 feet above the sea-level.

5. *Pliocene.*

(*i*) *Moitun-Creek beds &c.*—Overlying the Bairnsdale Limestone, filling in its hollows and extending from the hills to the sea-coast, are the Upper Tertiary or Pliocene beds. These are mainly sandy, clayey, or gravelly deposits, with sometimes, as at Sandy Creek, coarse sandy flags or ferruginous conglomerates, with occasional concretionary ferruginous bands containing casts of marine shells. Collections of these have been submitted to Professor M'Coy, who considers them to be Lower Pliocene and, in some cases, possibly Upper Miocene *.

On the sea-coast at Jemmy's Point there are calcareous sandstones and marls with Upper Pliocene shells similar to those of Wanganui in New Zealand, and characterized among others by a new *Trigonia* (*T. Howitti*, M'Coy) and by a *Struthiolaria* †.

These marine Tertiary formations, speaking of the whole, rise gently from the sea-coast, and thin out, as I have before indicated, in the hill-country at heights which vary somewhat in places, but which probably may be taken at an average of from 600 to 700 feet above sea-level; and I think that no traces of any marine formation of Tertiary age are to be found at more than 800 feet above the sea. At any rate, though well acquainted with the whole line of contact, I know of none.

The Upper Pliocene fossils of Jemmy's Point and Lake Tyers are the youngest yet found. Regarding these formations in their stratigraphical relations, there does not appear to be any well-marked break or unconformity to the present time. The indications of changing conditions are those seen in the slightly varying composition of the various beds and in the evidence of long-continued but intermitting elevation of the land, continuing probably to the present time.

6. *Pleistocene and Recent.*

We may assume that the upper margin of the sandy and clayey beds represents a period somewhat later than the Upper Pliocene sandstones of Jemmy's Point, on which similar sandy clays and ferruginous conglomerate beds rest in places. We see that subsequently the rivers have excavated wide valleys in the Tertiary fringe of the land. There are also to be seen a series of two or more terraces, extending often from near the coast-line, almost invariably

* Report of Progress, Geological Survey of Victoria, No. 2, p. 72.
† Ibid.

from the margins of the Gippsland lakes far up the river-valleys, extending round the margins of the lakes from river to river and up the rivers to the foot of the hills. The lowest terraces are in some places not more than a few feet above the river-level; the highest terraces may merge into the sandy ridges, and are edged in places by the high-level river-gravels. It seems to me not unreasonable to refer this Terrace Epoch of Gippsland to the Pleistocene period.

Succeeding these terraces, and but little elevated above sea-level, we find the alluvial flats of the rivers and the swamps and morasses bordering the lakes, and, as at Ewing's Marsh, lying in the hollows between an older coast-line and the sand dunes forming the present shore-line.

Nowhere in Gippsland have I been able to detect any appearances which I could in any way refer to a Glacial period analogous to that of the northern hemisphere. I have nowhere met with grooved or scratched rocks, erratic boulders, moraines, or any traces of ice-action; and I think that had such existed they would have been met with ere this. Mr. Selwyn has, I believe, already noted this.

The only features of the country which I think could in any way suggest glacial conditions are the apparently ancient lake-basins near Omeo. Most of these have now been drained and their beds deeply cut into by the streams. The sequence of the various gold-drifts has suggested to me that some of the workings were the beds of lakes during the Deep-Lead epoch. At Omeo one lake-basin still retains some water during and after wet seasons (Lake Omeo), and one other is a swamp. The bed of a third is now worked for gold, at the Dry Hill, Omeo. A slight alteration in the general level of the country would have sufficed to drain these lakes; and I think that the succession of several old stream-beds, the traces of which as auriferous leads are seen at increasing heights above Livingstone Creek, suggest an equal succession of periods of elevation of the land and of repose.

(*k*) *Volcanic.*—I believe that all the rocks to be classed under this head belong to the "Newer Volcanic." They consist of extensive flows of vesicular or compact dolerites and basalts. Three of the large outflows, known as the Wonangatta, the Dargo, and the Cobungra High Plains, are situated at about 5000 feet above the sea-level and immediately adjoining the Great Dividing Range. That of Nunnyong is only separated from it by the valley of the Tambo River; that of the Gelantipy and Black-Mountain tableland extends within fifteen miles of the Central Chain, and is situated on the line of high land connecting it with the Coast Range.

Smaller patches are found on the Buchan River to the west and on the Snowy River and near Tubbut to the east of Gelantipy.

Independently of the great outflows of the Bogong Mountains which I have spoken of (Cobungra High Plains &c.), there are some minor tracts on the Morass Creek, the Gibbo River, and Wambat Creek, all on the northern side of the watershed.

The larger areas named above are found capping the summits of the mountains, and also, in places, as flows, partially filling the valleys.

They are not only scarped at the sides, but occasionally completely isolated by the sources of streams feeding the adjoining rivers. There is, for instance, evidence pointing to the conclusion that the Dargo and Cobungra High Plains were once continuous across the present valleys of those rivers. This is shown by the Tabletop Mountain, which stands in the valley of the Upper Dargo River.

Underneath these flows is found in places auriferous quartz-gravel, which is now worked by miners. The deposits have not yet been sufficiently opened up to admit of any opinion being formed as to their precise nature or value; but there is little doubt that they will prove to be the ancient beds of those streams which now flow in the valleys a thousand feet or more below.

At Cobungra layers of black clay have been met with in the auriferous quartz-gravel, and contain lignite and leaf-impressions; but these have not yet been determined.

I have nowhere observed the traces of volcanic orifices. It is possible that craters may have been situated in those tracts now eroded into valleys; but, on the other hand, it is somewhat improbable that all volcanic orifices connected with the various lava-flows spread over such a wide district should have been obliterated, or that, if such existed in the areas now seen as valleys, some traces of them should not have remained. During ten years that I have been constantly looking for such evidence I have never met with it. Mount Battery on the Cobungra River certainly appears at first sight to resemble a volcanic cone; but on inspection it will be found that it is merely a projecting spur from the doleritic sheet of the Cobungra River. In places a well-marked columnar structure is seen, vertical to the horizontal flow; and I have no doubt that it is merely a much thicker portion of the sheet which has filled the former valley, and has been subsequently isolated by the river.

Throughout the whole of the district in which these volcanic rocks occur, and which extends only about thirty miles south of the central chain, immense numbers of intrusive dykes and masses of basic igneous rocks are met with. An inspection of thin slices from a great number of these, from all parts of this district, has shown me that a large proportion exhibit the familiar appearance of doleritic and basaltic rocks, and, moreover, of exactly the same general mineral character as the Tertiary dolerites and basalts of the district. These are characterized by a predominance of plagioclase and magnetite.

It seems therefore not impossible that these great doleritic and basaltic flows have been emitted from fissures rather than from true volcanic orifices.

It seems worthy of remark that we should find these traces of Tertiary volcanic activity following the direction of the Great Dividing Range. So far as I am aware, they extend in the same way far into New South Wales.

Gold-Workings.

I have not touched upon the gold-workings of the district: the subject is hardly within the scope or the limits which I had proposed for this paper; but I may remark that my inquiries into the source from which the alluvial gold has been derived have, so far, shown that the auriferous character of the formations will have to be extended from the Silurian to the very highest Palæozoic groups with which we are here acquainted.

At Tabberabbera alluvial gold is worked where the "bed-rock" is Middle Devonian and the overlying strata Upper Devonian. At the Lower Mitchell River the whole of the strata are of the latter age. At lower Boggy Creek the bed-rock is quartz-porphyry overlain by Upper Devonian; but in this instance, as I have indicated elsewhere*, the gold may have been derived from the detritus of the Silurian hills higher up the stream. At Maximilian Creek the lowest strata of the upper part of its course are probably Middle Devonian overlain by Upper Devonian, and in the lower part entirely the latter. My inquiries are at present not sufficiently advanced to enable me to speak decidedly; but, so far as they go, the conclusion seems very probable that the gold has been derived from the narrow quartz veins of the Middle Devonian shales, slates, and quartzites, or from the quartz-conglomerates of the Upper Devonian, which have certainly been derived from older and probably auriferous strata, or from the narrow quartz veins which here also intersect the conglomerate and sandstone. A fragment of quartz containing gold has been given to me which is said to have been taken from such a quartz vein in the Iguana-Creek beds of Maximilian Creek. If this can be satisfactorily substantiated great light will be thrown on the subject. I hope before long to be able to seriously attack this important question.

General Summary and Conclusion.

In the preceding pages I have attempted to give, as shortly and as clearly as I could, an account of the physical geography and geology of North Gippsland, so far as my inquiries have made me acquainted with the subject. I may briefly sum up the conclusions which it seems to me may be arrived at, and which I believe to be warranted by the facts stated.

In glancing backwards through the dim geologic ages the earliest record of the past which we can discern is the great Silurian series. Whatever formations of prior date there may have been, on which the "35,000 feet" of Silurian † slates and sandstones reposed, no trace whatever, it would seem, now remains of them. The natural forces (dynamical, hydro-plutonic, whatever they may be termed) which compressed and folded the strata, which caused them to be metamorphosed, partially absorbed, or even invaded by the granites, no doubt also completely obliterated all those older rock masses on which the Silurian reposed, and from the wearing of which those Silurian strata were formed.

* Report of Progress, Geological Survey of Victoria, No. 2, p. 70.

† "Making due allowance for this repetition of the same beds at the surface, the total vertical thickness of the series can scarcely be estimated at less than 35,000 feet."—A. R. C. Selwyn in "Notes on the Physical Geography and Geology &c. of Victoria," Intercolonial-Exhibition Essays, 1866, p. 11.

We find that the Upper Silurian Limestones of the Gibbo River, and also those of the Limestone River, which I regard as probably of the same age, are part of the great general group of Lower Palæozoic formations which I have described by the term "the Lower Palæozoic foundation" of North Gippsland. We may therefore not unreasonably infer that those great changes in the earth's crust continued to the close of the Silurian period. The surface of all these Silurian strata shows the long ages of denudation which must have elapsed before the succeeding Devonian groups, as we see them, were laid down.

This long period seems to have been one of volcanic activity. The "Snowy-River porphyries" show the extension, and the Wombargo Mountain reveals to us the structure, of these ancient volcanos. Isolated hills of quartz-porphyries and allied rocks which have penetrated the Silurian and the granite suggest strongly the idea of cases of similar volcanos from which the ejected materials have been denuded, but which are still to be recognized in the large percentage of felstone and porphyry pebbles in the accumulations of Tertiary marine gravels surrounding them.

That these Palæozoic volcanos were subaerial, and probably terrestrial, may be inferred from the fact that the great piles of felstones, ash, and agglomerates now remaining contain no beds which I can recognize as aqueous; and this inference would accord with the fact that, so far as our present palæontological evidence extends, no Lower Devonian marine strata exist; for the Buchan and Bindi Middle Devonian limestones rest on the Snowy-River porphyries, and these latter upon the Lower Palæozoic rock masses.

But if the Lower Devonian period was thus one of terrestrial conditions, it follows that the succeeding period was one of subsidence of the land. Denudation must have been very great over the Snowy-River porphyries, over the Silurian and the metamorphic schists, the granites and quartz-porphyries, before the marine limestones of Buchan, Bindi, Gelantipy, and elsewhere were deposited.

To the westward, somewhat similar marine conditions accompanied the formation of the Tabberabbera shales and limestones.

During this Middle Devonian period I am unable as yet to recognize any traces of volcanic action.

Succeeding this period, we have equally clear evidence of great and long-continued movements of the earth's crust. The Bindi limestones were denuded; the Tabberabbera shales and sandstones were tilted at a high angle, folded, and apparently denuded even more than the Bindi limestones. We no longer have strata containing a well-marked marine fauna; but the beds of Iguana Creek and of Mount Tambo only yield us somewhat scanty traces of a terrestrial flora; while the shales and limestones of Cowombat and the Native-Dog Creek appear to me to indicate a shallower sea or a nearer proximity to land than the Buchan and Bindi beds.

The Upper Devonian conglomerates, sandstones, and shales suggest the proximity of land; and volcanic activity is again apparent in the felstones and felstone ash, somewhat resembling the older accumulations at Wombayo and the Snowy River. But these volcanic products seem to be interstratified with aqueous beds. The remains of land-plants, the lithological characters and peculiarities of structure of the beds, perhaps even the prevailing red colour of all the groups of this age (Upper Devonian), suggest to me the possibility that we may have here lacustrine rather than marine conditions, following the gradual emergence of land from the deep-sea areas of Middle Devonian periods, and, if so, yielding another singular parallel to observations made in Europe and remarked upon by Professor Ramsay*.

The evidence, so far as it goes, suggests that volcanic activity may have become dormant in the east while it became active in the west, and also, as seen at the Snowy Bluff, that the volcanic materials changed from an acid to a basic character.

A consideration of all the localities where I know strata to occur, which may not unreasonably be referred to the Upper Devonian group, of which the Iguana-Creek beds are the type, has led me to believe that, at the commencement of the deposition of those strata, denudation had almost proceeded to the extent which it has again gained. This may be seen at Mount Taylor, Tabberabbera, the Snowy Bluff, Cowombat, the Native-Dog Creek, and the Gibbo River.

I have at present no evidence to advance as to the condition or the position of the Upper Devonian land.

Future inquiries may possibly throw light on this obscure question; and I look forward with some slight hope to an examination of the great and almost unknown mass of mountains between the sources of the Mitchell and Macallister Rivers, whose dark gorges may possibly yield as grand and instructive natural sections as the deep defiles of the Snowy River have done.

Neither is there any light as to the conditions of what is now North Gippsland during all the long ages succeeding the Devonian until Tertiary times. The Avon Sandstones only show us that they were similar to those under which the Iguana-Creek beds were laid down.

The denuding agencies which have removed the enormous thickness of the Avon and Iguana-Creek groups may certainly have at the same time stripped off superior and younger formations; but, on the other hand, it is worthy of consideration that nowhere, so far as I know, have even traces of any strata of marine origin younger than Carboniferous been met with in the mountains of Eastern Victoria above the height of 2000 feet, or, excluding the Mesozoic Coal-measures, above the height of 1000 feet from the sea-level.

Passing over the question whether the Mesozoic Carbonaceous rocks of South Gippsland ever extended over the whole, or even over the greater part, of North Gippsland, as it is evident the Upper Devonian and, perhaps, the Carboniferous formations once did, I may point out that all the groups of marine strata of Tertiary age

* The only reference which I can at present make to Professor Ramsay's paper is in a short summary in Professor Geikie's edition of Jukes's 'Manual of Geology,' p. 567.

are horizontal, or merely lie at very low angles; that the highest beds thin out on the flanks of the mountains at elevations nowhere exceeding 1000 feet, and probably not averaging more than 600–700 feet above sea-level; and, further, that similar statements also apply to the Murray-River Tertiaries to the north of the Great Dividing Range.

A careful consideration of the interesting features presented by the deep leads of the Ovens District on the north side of the mountains, and of the Gippsland Marine Tertiaries on the south side, has led me to the belief that at the close of the Miocene or the commencement of the Pliocene period, the land-surface of Eastern Victoria probably did not differ essentially in its physical features from what is seen now, but that it stood at least some 300–400 feet lower, relatively to the sea-level, than it now does.

I perceive, further, that the upper margin of the Tertiary marine beds is now some 600–700 feet above the sea; and we have thus represented to us continuously, from the Miocene period inclusive, a high mountainous country falling in elevation to the westward, and having the sea on the south, and varying conditions of land and water to the west and north*.

The fact that different genera of fish are found in the waters flowing from the north and south sides of the Australian Alps points to a high antiquity of the land-surface, and to a long continuance of the watershed.

Whatever may be the conclusions arrived at in respect to the continuity, duration, and elevation above the sea of the land-surface during Mesozoic times, it cannot, I think, be doubted that the Gippsland mountains have existed as dry land continuously since the earlier part of the Tertiary age.

A difficulty may be felt to arise from the fact that we have at Bacchus Marsh Miocene beds with plant-remains of "a totally different facies to the recent flora of the country, . . . an entirely extinct series of species, having generic and general resemblance to the foliage of Asiatic plants of tropical types of Dicotyledonous plants"†. It seems to me that such a difficulty may possibly be more apparent than real. In Eastern Gippsland we find at present, in the coast-lands and the river-valleys, a flora which has been described by Baron v. Müller as being of an Indian type, before which the *Eucalyptus*-vegetation recedes‡.

The inland mountains and plateaux show essentially the ordinary flora of Victoria. If a subsidence of the land were to cause the present flora of the littoral country to become fossilized, and a re-elevation of the land were subsequently to take place, it might be that

* So far as I now remember, the Oligocene beds of Mount Martha at Port-Philip Bay, which are the oldest Tertiary deposits with which I am acquainted, also conform to the generally horizontal position of all the Tertiary groups.

† Professor M'Coy, Intercolonial-Exhibition Essays, 1866–67, "Recent Zoology and Palæontology of Victoria," p. 16; also Geological Survey of Victoria, Quarter-sheet, No. 12, N.E., notes 5 and 12.

‡ Catalogue of the Victorian Exhibition, 1861. Essay by Ferd. Müller, M.D., Ph.D., F.R.S., &c.

the changed conditions of the land would no longer permit the spread of East-Australian forms of vegetation into the newly-emerged tract, but that it would be occupied by Victorian forms. The geologist of that time would then meet with a somewhat parallel case to that now seen in the difference between the Miocene fossil flora of Bacchus Marsh and the recent flora of Victoria.

2. *On* Foyaite, *an* Elæolitic Syenite *occurring in* Portugal. By Charles P. Sheibner, Esq., Ph.D., F.G.S., Assoc. Inst. C.E. (Read May 22, 1878.)

[Plates I. & II.]

The name of this rock is derived from the locality where it occurs, viz. from Mount Foya, in the south of Portugal. It is cursorily referred to as granite in Charles Bonnet's description of the Province of Algarve; and as early as 1861 specimens of it were submitted to Professor Blum, of Heidelberg, who was the first to examine its composition *. This distinguished petrologist at once recognized it as a true nepheline-bearing syenite; and so struck was he with the close resemblance it bears, not only to certain Norwegian syenites (often erroneously termed zirconia-bearing syenites), but also to a syenite occurring in one of the Cape-Verd islands, that he united them all into a separate group called Foyaites. Of these, however, the Foyaite proper is so rarely met with that, to the large majority of petrologists, it is almost *terra incognita*; nor is the locality itself easily accessible to geological research. I have been enabled to examine under the microscope more than 40 sections of this rock representing different parts of the locality; and so interesting and varied is its composition, that it may not be inopportune to give a description of it, which I shall preface by a rapid sketch of the leading features of the Foya district, as illustrated by the annexed plan and section (Plate I.).

The range of hills which forms the northern boundary of the ancient province of Algarve, in the south of Portugal, may be regarded as a continuation of the Sierra Morena in Spain, intercepted by the river Guadiana. It consists chiefly of Devonian greywacke, slates, and sandstones, and, striking west, reaches nearly to the Atlantic, whilst its numerous southerly spurs come in contact with Jurassic limestones and Cretaceous strata as they approach the coast-line. It is in the north-western part of Algarve, viz. in the Sierra de Monchique, that from the greatly disturbed and contorted greywacke strata there rises an extensive outcrop of crystalline rock in the shape of two flat, elongated domes—the Foya and the Picota. They are the highest points south of Lisbon, their altitudes being 905 and 735 metres, or 2968 and 2410 feet respectively †. The point of contact with the greywacke strata lies at contour 182: hence the vertical outcrop of the crystalline mass is equal to 726 metres, or about 2400 feet, whilst the superficial area it covers amounts to about 84 square miles. It is a noticeable feature that the Picota does not follow the general direction of strike, and that its longitudinal axis deviates from that of the Foya by an acute

* Jahrbuch für Mineralogie, 1861, p. 426. The specimens were collected by Dr. Reiss.

† The altitudes are taken from General Folque's Ordnance Map of Portugal, scale $\frac{1}{500,000}$.

angle of about 34°. The two mountains are united at their base, thus forming a valley which is called the "Barrocal," and which, owing alike to its beautiful climate and exuberant vegetation, is looked upon as an El Dorado by the inhabitants.

The local nature and position of the crystalline mass both seem to differ greatly at different points. The rock often changes abruptly from coarse to fine-grained; and all varieties, from the coarse crystalline to a porphyritic, from the unaltered to a metamorphic variety, are represented. A very fine-grained, almost compact variety intersects the coarse crystalline mass in narrow veins, and occurs likewise interbedded as dykes. The surface of both mountains is strewed with large blocks which often form conically-shaped mounds and are frequently weathered. On the whole, it would appear, from the specimens I have examined, that the main portions of the Foya and the Picota, as well as the eastern slopes, consist chiefly of the fine-grained variety; whilst on the southern slopes the rock is more coarse-grained. Again, the greywacke strata at the eastern extremity, near Marmeleta, are altered and decomposed at the point of contact; whereas to the south, as near Coldas, no alteration is perceptible. Not the least interesting feature in this district is the large number of veins of Tertiary eruptive phonolitic and basaltic rock which occur throughout the crystalline mass, and coincide with similar veins in the Jurassic and Tertiary strata near Cape St. Vincent. These veins intersect the surface in all directions, and warrant the conclusion that the whole district has lost much of its former height, an enormous mass of rock having probably been removed by denudation.

An examination of Foyaite with the naked eye shows its essential constituents to be monoclinic felspar (orthoclase), elæolite (the coarse variety of nepheline), and hornblende.

Orthoclase is largely predominant, generally of a greyish-white colour, showing strong greasy lustre on the planes of cleavage. Elæolite shows hexagonal or rectangular contours, and is of a reddish-grey or flesh colour with strong greasy lustre. Hornblende occurs chiefly in long, slender, prismatic crystals of a greenish-black colour, with strong lustre on the planes of cleavage. The porphyritic variety shows large crystals of orthoclase, and in places also crystals of elæolite imbedded. The accessory constituents, determinable with the lens, are brownish-yellow titanite, dark lamellar biotite, grains of magnetite, and traces of pyrite.

But under the microscope Foyaite exhibits a far more varied and interesting appearance. Not only do all the constituents I have mentioned present themselves with all their peculiarities of structure, of intergrowth, of juxtaposition, but noscan and sodalite are found to be present as characteristic accessories under altogether novel conditions, whilst triclinic felspar, muscovite, hæmatite, and apatite are also met with.

Orthoclase is predominant in large crystals, not always with regular outlines, of a greyish-white colour, dull, generally translucent, showing numerous Carlsbad twins in polarized light. It is nearly always intergrown with some *plagioclase*, which, from numerous measurements of the angle*, I found to be oligoclase, as determined by M. Des Cloizeaux. This triclinic felspar forms in one case a zonal frame round the orthoclase, and in polarized light the twin-striation can be easily recognized. Numerous interpositions of hæmatite, as well as microcrystals of biotite, apatite, and magnetite are discernible whenever the orthoclase is tolerably pellucid. Orthoclase predominates largely in the coarse-grained variety of Foyaite.

Elæolite does not occur in well-defined crystals, but shows irregular outlines, is colourless, transparent, and full of transversal cracks and fissures. In one or two cases it shows, however, distinct zonal structure, and is frequently associated with nosean and sodalite, these being imbedded in it. Though on the whole fresh and unaltered, there are traces of decomposition, owing to the influence of magnetite. It is frequently studded with microlites and interpositions of hæmatite forming rows and bands across the length and breadth of the mineral; grains of magnetite, hexagonal needles of apatite, microcrystals of titanite, and distinctly dichroitic hornblende, in extremely small but clearly-defined crystals, constitute the remaining interpositions; nor are there wanting rows and chains of fluid-cavities, such as are generally observed in this mineral. I may add that I found more elæolite in the fine-grained than in the coarse-grained Foyaite.

Hornblende and *Augite* occur in Foyaite in almost equal quantity, and so intergrown and associated are they with each other, that it would often be difficult to distinguish them were it not for their different deportment in polarized light, the larger prismatic angle of hornblende in sections vertical to the main axis, and the characteristic crystallographic combination of augite, viz. the prism with ortho- and clinopinakoid. Moreover, I found that, when measurable, the angle between the main axis and the plane of vibration in sections parallel to the orthopinakoid is always below 20° in the hornblende, and varies between 40° and 50° in augite—a result which agrees with the measurements of Dr. Tschermak, and constitutes an important criterion when both minerals occur in juxtaposition. The colour of both is a rich green, with occasionally a brownish tinge in hornblende. The crystals, which vary considerably as to size, are generally long, columnar, six-sided in hornblende, eight-sided in augite, and show, on the whole, distinct outlines, though these are frequently blurred by the characteristic black frame traceable to decomposition. Both minerals are almost invariably associated with biotite, magnetite, and not unfrequently with titanite, and contain not only innumerable microlites and interpositions of the accessory constituents of Foyaite, but also microcrystals of their own kind; nor are there wanting twins whose seam comes out with admirable clearness in polarized light. But the most remarkable feature in connexion with hornblende and augite in Foyaite is their peculiar intergrowth and their tendency to molecular alteration or paramorphosis, not unfrequently exhibited in

* The angle by which the plane of vibration deviates from the twin line.

beautifully developed crystals in which an eight-sided augite forms the nucleus of hornblende (Pl. II. fig. 2). The tendency in augite to intergrowth has been pointed out by Dr. Tschermak, who found augite as nucleus not only of hornblende, but also of diallage crystals; and, similarly, the mineral known as uralite has been recognized as augite whose nucleus has remained intact whilst the outer portion of the crystal has been altered into hornblende, frequently bearing traces of its augitic origin. The larger crystals of hornblende and augite in Foyaite are often fractured: in the fine-grained variety, which contains considerably more of both than the coarse-grained, they are diffused throughout the rock, partly in fragments, now and then in fresh clearly-defined microcrystals, or, again, in large aggregations with magnetite and biotite.

Nosean and *Sodalite* occur in Foyaite almost invariably associated and intergrown, a fact which, so far as I know, has not hitherto been observed in other rocks. Four- and six-sided sections of nosean, often showing zonal structure with a dark nucleus, are imbedded in and surrounded by an irregular broad belt of sodalite (Pl. II. fig. 1). The outlines of nosean are often indistinct, owing to the rapid decomposition of the mineral, whose sections are generally filled with the characteristic muddy yellowish dust, grains of magnetite, and innumerable bluish-green microcrystals; nor are needles of apatite less numerous. Sodalite has similar interpositions, but is generally clear and transparent, with vitreous lustre and occasional zeolitic veins, conspicuous by their vivid polarization. Both nosean and sodalite are met with imbedded in elæolite; and the frequent intergrowth of those two isomorphous minerals exhibits in many sections a very characteristic appearance. One section, in which both minerals are thus associated and have suffered comparatively little from decomposition, gave rise to a micro-chemical test for sulphuric acid in nosean and for chlorine in sodalite. Treated with hydrochloric acid and chloride of barium, nosean gave a distinct white precipitate; and an unmistakable chlorine reaction resulted from treating sodalite with nitric acid and nitrate of silver; so that no doubt could be entertained as to the true nature of these two minerals. The crystals of nosean vary greatly in size, but measure sometimes as much as 1·75 millim. across the section.

Biotite is met with in numerous brown, lamellar, transparent plates and flakes, showing marked dichroism and strong absorption in polarized light. It is invariably associated with hornblende, augite, and magnetite, and contains a great variety of interpositions of apatite, titanite, and other accessories occurring in the rock. The prismatic plates are frequently distorted, torn, and fractured, and vary greatly in size. In the fine-grained variety of Foyaite, biotite forms large aggregations with hornblende, augite, and magnetite. Muscovite occurs also in Foyaite, though very rarely, and only in very small, transparent, colourless, irregular, polygonal plates, which are distinctly lamellar, and on that account cannot be mistaken for quartz, though their vivid chromatic polarization is liable to mislead. It should be noticed that in Foyaite this white mica is not found intergrown with biotite, but with felspar and elæolite.

One of the most noteworthy features in Foyaite is the very frequent occurrence of *titanite.* This mineral is distinguished by the freshness of its crystals and the distinctness of its outlines. It occurs with great regularity in all the varieties of Foyaite, and is at once recognized by its delicate yellow colour, its transparency, its strong lustre, and the singular purity of its substance. It is met with chiefly in elongated rhombic and six-sided prisms, which are traceable to the favourite combination of this mineral, viz. the hemipyramid with positive hemidome, clinodome, and basal plane. Though frequently intergrown with hornblende and augite, it occurs more particularly in isolated crystals which are found imbedded in elæolite and biotite. Some of the crystals abound in interpositions of hornblende, augite, biotite, apatite, and magnetite; and in some rare cases the edges show some slight traces of decomposition. Pleochroism is generally so faint that it is hardly perceptible; on the other hand, twins are by no means so rare in this titanite as might be supposed, and it is notably in crystals of small size that a delicate seam attests twin-structure.

The occurrence of *magnetite* in opaque black grains or polygonal outlines is so uniform in rocks that it does not call for special reference here; nor need I dwell on *hæmatite*, *pyrite*, and *apatite*, which occur in Foyaite, as in other kinds of rock, purely as adventitious minerals—hæmatite in pink microscopic six-sided plates, or in rows and bands as interpositions; pyrite in isolated opaque grains showing yellowish reflected light; and apatite, whose microscopic, colourless, transparent, columnar, hexagonal prisms, wedges, and needles are truly ubiquitous.

As regards the chemical composition of Foyaite and its constituents, it is notably elæolite which deserves special investigation, with a view to ascertain the presence and percentage of sulphuric acid; and an analysis I made of this mineral gave the following result:—

Silica	43·46	per cent.
Sesquioxide of iron	1·67	„
Alumina	32·77	„
Lime	0·40	„
Magnesia	0·09	„
Soda	15·26	„
Potassa	4·34	„
Sulphuric acid	0·13	„
Water	1·56	„
	99·68	„

This result coincides with the analyses made by Prof. Scheerer, Rammelsberg, and others of elæolite occurring in other rocks, though the presence of sulphuric acid has been established only in a few cases. An analysis of Foyaite made by Mr. T. S. Humpidge gave the following composition of the rock:—

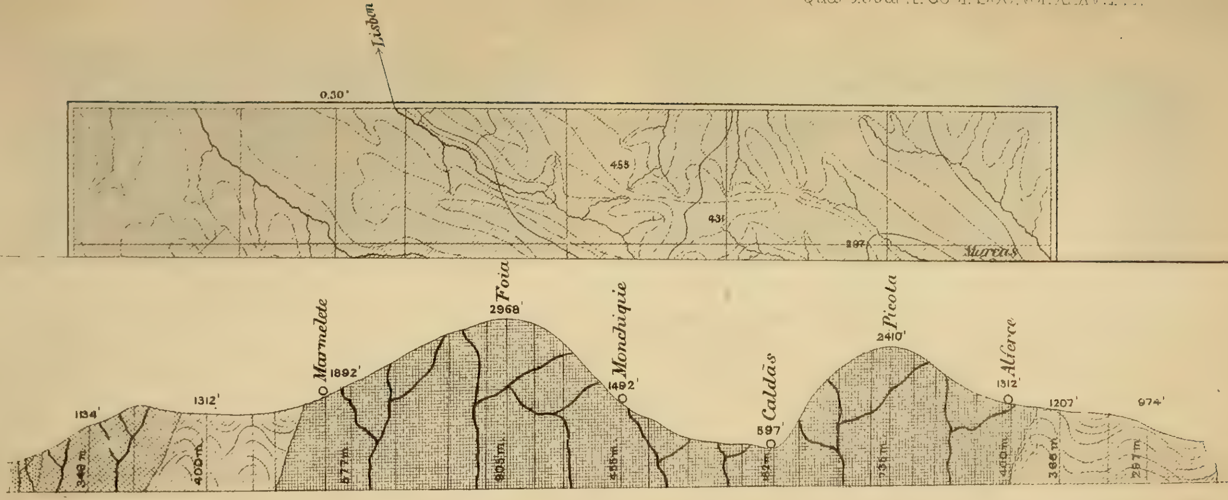


Fig. 2.

Greywacke, slates, sandstones &c. (Devonian)
Jurassic limestones
Cretaceous Strata
Foyaite
Phonolite &c.

Des. and Const. C.P.S.

Dangerfield Lith. 22 Bedford St. Covent Garden.

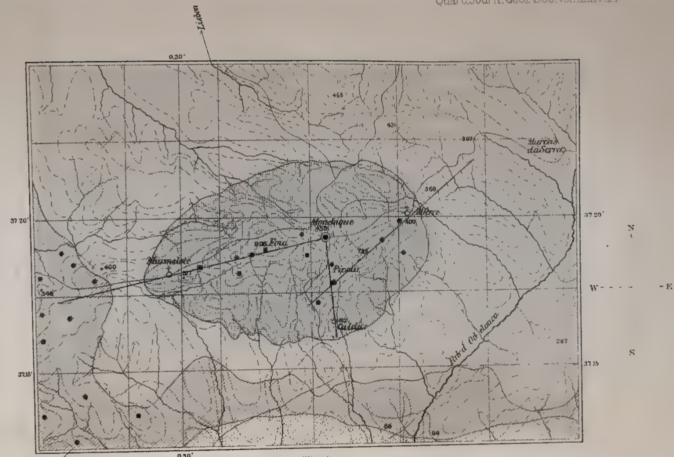
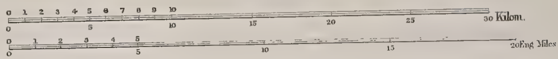


Fig. 1.

Scale, $\frac{1}{250,000}$.



PLAN AND SECTION

OF THE FOYA DISTRICT, SOUTH OF PORTUGAL.

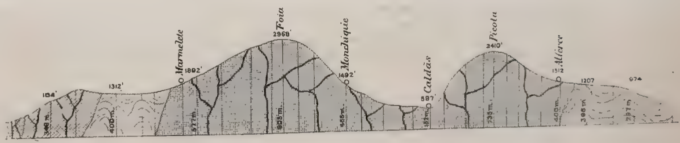


Fig. 2.

Greywacke, slates, sandstones &c. (Devonian)

Jurassic limestones

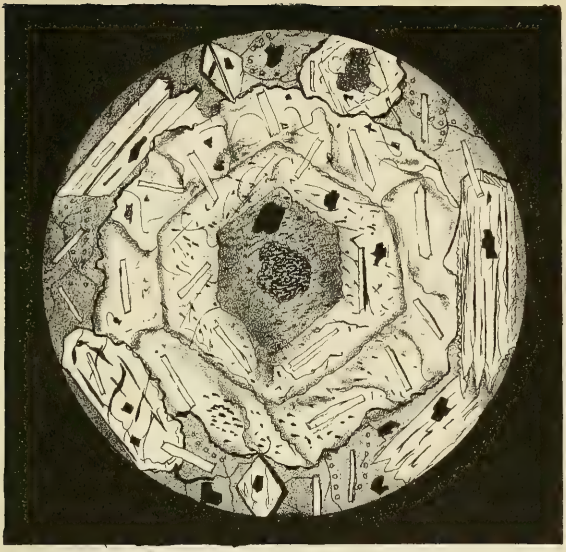
Cretaceous Strata

Foyaite

Phonolite &c.

Des. and Const. C.P.S.

Dangerfield Lith. 22 Bedford St. Covent Garden.



1.

2.

FOYAITE.

Silica	56·23	per cent.
Sequioxide of iron	0·17	„
Protoxide of iron	6·21	„
Alumina	23·15	„
Lime	2·39	„
Magnesia	0·40	„
Soda	3·84	„
Potassa	5·33	„
Titanic acid	0·27	„
Phosphoric acid	0·13	„
Sulphuric acid	0·09	„
Chlorine	0·07	„
Water	1·06	„
	99·34	„

Such is the mineralogical and chemical composition of Foyaite. It shows that in virtue of its essential constituents, coupled with the absence of quartz, this rock is a true elæolitic syenite belonging to the more ancient eruptive series, accompanied by porphyritic varieties of the same, and by corresponding phonolitic varieties of Tertiary origin. By its wealth of rare but purely adventitious minerals it bears a close resemblance to ditroite (Transylvania), miascite (Siberia), and certain syenites of Brevig and Cape Verd, most of which are fully described in the luminous works of Prof. Zirkel, Vom Rath, Rosenbusch, and others. Hence there is no apparent reason why the nomenclature of petrology should be further encumbered by a special group of Foyaites, more especially as microscopic investigation of rocks is constantly producing fresh evidence not only of the infinite variety, but of the beautiful simplicity of Nature.

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1. Plan of Foya District, Portugal. Altitudes in metres.
2. Section of ditto.

Plate II.

Fig. 1. Section of Foyaite, showing nosean crystal surrounded by belt of sodalite, with interpositions of magnetite and apatite, and associated with elæolite, augite, hornblende, biotite, titanite, &c. Magnified 20 diameters.
2. Section of Foyaite, showing hornblende crystal with augite nucleus, with associated minerals. Magnified 20 diameters.

3. *On the* MICROSCOPIC STRUCTURE *of* STROMATOPORIDÆ, *and on* PALÆOZOIC FOSSILS *mineralized with* SILICATES, *in illustration of* EOZOON. By J. W. DAWSON, LL.D., F.R.S., F.G.S., &c. (Read June 5, 1878*.)

[PLATES III.–V.]

AMONG the collateral subjects which have arisen in the discussions with respect to *Eozoon canadense*, two of the most important are:—1st, the question of its structural relations with the Palæozoic fossils of the genus *Stromatopora* and allied genera; 2nd, the occurrence in Palæozoic rocks of fossils mineralized with hydrous silicates akin to the serpentine and loganite found in some of the best-preserved specimens of the Laurentian fossil. For several years I have taken advantage of every opportunity to make collections illustrative of these questions, and to subject the specimens obtained to microscopic examination. In this I have been greatly aided by friends who will be mentioned in the sequel, and by the large number of excellent sections prepared by Mr. Weston, of the Geological Survey of Canada, for the late Sir W. E. Logan and for myself. In the following paper I purpose to state the conclusions arrived at as the result of these observations, with such portions as may be necessary of the large accumulations of facts on which they are based.

I. STROMATOPORIDÆ.

1st. *Microscopic Structure.*—The Stromatoporidæ have long been a zoological stumbling-block, and have been referred to Corals, Sponges, Foraminifera, and even to Hydractiniæ. I do not purpose to review these diverse opinions, most of which are undoubtedly based on imperfect acquaintance with the microscopic structure of these curious fossils, but to give an intelligible account of the structure of some typical species, preparatory to the consideration of their relation with *Eozoon*.

The genus *Stromatopora*, properly so called, is founded on the species *Stromatopora concentrica*, Goldfuss, and its allies, which range from the Upper Cambrian to the Devonian inclusive. Avoiding, for the present, complexities arising from the various states of preservation and of weathering, I may refer in the first instance to remarkably well-preserved specimens from the Corniferous Limestone of Ohio, and from the island of Marblehead in its vicinity, which have been placed in my hands by Mr. A. E. Walker of Hamilton, and Dr. Newberry of New York. In these the concentric laminæ and pillars of the fossil are in the condition of opaque calcite, apparently retaining its minute structure and not affected by crystallization; and the interspaces or chambers are occupied by transparent calcite,

* For the Discussion on this paper see p. 68.

permitting all the structures to be very well seen, either on polished surfaces or in transparent slices *.

In these specimens about three interspaces and two laminæ occur in the space of a millimetre; and though neither the laminæ nor the interspaces are uniform in thickness, the latter are about twice the width of the former. In some places the laminæ rise into conical or rounded eminences with corresponding depressions; in others they are nearly flat and concentric, this difference being apparently accidental. The laminæ are connected with each other by pillars, which are either round or somewhat flattened (Pl. III. fig. 1). The texture of the laminæ is not spicular, but perfectly continuous and finely granular, as if made up of minute fragments of calcite. When the mass is broken parallel to the laminæ, the pillars appear as minute tubercles (Pl. IV. fig. 5), *but a true exterior surface is smooth.* The laminæ are pierced with numerous round pores about one tenth of a millimetre in diameter. Some of these pass through hollow pillars across one interspace into another; but the greater part pass through the laminæ from one interspace into the next. The laminæ themselves are here and there pierced with horizontal tubes which thicken the laminæ where they pass (Pl. III. fig. 3, *b*); they appear to traverse the laminæ obliquely from one space into another, or from the hollow pillars laterally. They may be called canals. In addition to the ordinary laminæ, some of the chambers or interspaces are subdivided by very thin secondary laminæ. In a few cases these are attached to ordinary laminæ as a sort of inner wall. The ordinary laminæ in the more regular specimens are often of great continuity, extending without interruptions for several square inches.

In some specimens there are a few rounded perforations, less than a millimetre in diameter, which extend vertically through several interspaces. Their walls are densely calcareous. They are often covered up with the growth of the laminæ, and seem to have no connexion with the other parts of the structure. I do not regard them as oscula, but as perforations of some parasitic animal; and I attribute to the same origin certain rounded cavities, similarly walled, in other parts of the mass.

The above is an accurate description of the most common type of *Stromatopora* when, as nearly as possible, in its natural condition. Other species of the genus, as now usually limited, differ principally in the thicknesses and distances of the laminæ, in the number and size of their perforations, and in their more or less tuberculated surfaces. In some species the pores are so numerous that the laminæ appear reticulated; in others the laminæ are so much thickened that the pores appear as tubuli. The pillars also differ somewhat in size and form. In the very numerous specimens which I have examined, I have convinced myself that while the laminæ are always porous they are never spicular, and that the so-called oscula are accidental. They are due either to the causes above referred to or to

* These specimens are associated with a beautiful *Saccammina*, having a calcareous test, which I have described as *Saccammina eriana*.

branches of *Syringopora* and similar corals included in the mass of *Stromatopora*.

It is evident from the above description that the animal matter of *Stromatopora* must have occupied the chambers or interspaces, and must have extended from chamber to chamber through the pores and hollow pillars. Such a structure is obviously that of a rhizopod rather than of a sponge. Further, the arrangement of the laminæ and pillars is very nearly allied to that of *Parkeria* and *Loftusia* as described by Carpenter and Brady, which I have myself studied in specimens kindly given to me by Professor T. R. Jones *. In so far as the hollow pillars and perforated plates are concerned, it has some points of correspondence, though more remote, with *Receptaculites*. The supposed oscula on which has been based a reference of these forms to sponges are certainly not constant. I have seen large masses of the form above described, presenting more than 30 square inches of surface, without a trace of an osculum; and in those specimens where tubular orifices appeared, I have found that they cut like perforations made by a boring instrument through the mass, irrespective of its structure, and that they were lined with continuous calcareous walls different from the laminæ of the fossil. It is scarcely necessary to say, after the above descriptions, that I attach no scientific value to the ingenious and elaborate attempt of Mr. H. J. Carter ('Annals and Magazine of Natural History,' ser. 4, vol. xix. p. 44) to prove that *Stromatoporæ* are skeletons of hydroids allied to *Hydractinia*. The resemblances of *Stromatoporæ* to these hydroids are altogether superficial, and depend on both having a parasitic and concentric habit of growth. In every essential character they differ entirely, and can have no close zoological affinity. In comparison with *Eozoon*, the general appearance and habit of growth are so similar that specimens cannot easily be distinguished by the naked eye, or where the minute structures are not preserved. In microscopic structure the thin laminæ of *Stromatoporæ* correspond to the proper wall of *Eozoon*. The thickening of the walls corresponds to the supplemental skeleton, and the horizontal tubes to the canals, while the interspaces and the pillars correspond to the chambers and connecting walls of the older fossil. The main structural difference is, that while *Eozoon* has a delicately tubulated proper wall of Nummuline type, that of *Stromatopora* has coarser perforations and pores. *Stromatopora* and *Eozoon* may both be regarded as large sessile laminated calcareous Rhizopods; but the former presents a less generalized type than the latter, which combines structures that were usually separated even in the Palæozoic period.

Stromatoporæ of the type above described are abundant in the Corniferous Limestone. They occur throughout the Upper Silurian and are especially abundant and of large size in the Niagara Limestone, where they abound even in those Dolomitic beds that contain

* More recently I have also studied the remarkably beautiful species of *Loftusia* from British Columbia described by Mr. G. M. Dawson, which confirm the resemblance of these specimens to *Stromatoporæ* (see his paper read before this Society, *infrà*, p. 69).

few other fossils. They are also abundant in the Dolomite of the Guelph Limestone; and it is perhaps not accidental that both here and in the Laurentian, fossils of this structure are associated with magnesian rocks. They occur also in the Lower Silurian, though less abundantly; and the oldest specimen I have seen is in the Potsdam Sandstone; and this, its structure not being preserved, may have belonged to *Eozoon* rather than to *Stromatopora*. The Lower Silurian species have usually very thin and continuous walls. In the great Niagara Limestone, as seen at Niagara Falls, the masses of *Stromatopora* occur precisely as *Eozoon* occurs in the Laurentian limestones, and are mineralized with quartz and dolomite, and often almost entirely converted into crystalline masses, though occasionally showing their structure in great perfection.

Certain beds of the Niagara formation, near Hamilton, contain not only *Stromatoporæ*, but multitudes of sponges; and through the kindness of Lieutenant-Colonel Grant, of that place, I have been enabled to examine a number of specimens of these, and to compare them with *Stromatoporæ*. These sponges are all siliceous and spiculate, and belong chiefly to two or three species of *Astylospongia* of Römer, and to *Aulocopina* of Billings, of which his *A. Grantii* is the type. The species of *Astylospongia* present a most regular and beautiful hexactinellid structure, as perfect as that in the sponges of the Cretaceous, showing even the hollow nodes, which have been supposed to be absent in the Palæozoic Hexactinellidæ. *Aulocopina* has a different structure, presenting series of hexagonal tubes built up with interlaced spicules, and giving off bundles of spicules in a radiating manner. These sponges are thus entirely distinct, both in material and structure, from the contemporary *Stromatoporæ*, and there is no link of connexion whatever.

The species included in the genera *Caunopora* of Phillips and *Cœnostroma* of Winchell, and in part in *Syringostroma* of Nicholson, and which may be represented by the *Stromatopora polymorpha* of Goldfuss, have the horizontal canals largely developed in laminæ thickened by supplemental deposit, and traversed by an infinity of minute canaliculi or ramifications of the canals opening at their surfaces. The horizontal canals radiate from central points where they are connected with vertical tubes or groups of tubes penetrating the whole thickness of the mass (Pl. IV. fig. 9, and Pl. V. fig. 10). The whole organism thus becomes divided into a series of vertical systems, which often very much obscure the concentric lamination, and in different states of preservation give very perplexing appearances. They may all be explained by bearing in mind that the horizontal canals, like those of *Stromatopora* proper, pass in the substance of the laminæ, now much thickened, and that at the centres of the systems they descend through the chambers by vertical tubes or groups of tubes which correspond to the hollow pillars of *Stromatopora*.

A great number of specimens of *Caunopora*, *Cœnostroma*, and allied forms, both European and American, have passed through my hands; but I was unable to decide, except inferentially, as to their minute structure, till I was so fortunate as to obtain, through the kindness of Mr. Selwyn, Director of the Geological Survey of Canada, a specimen collected by Professor R. Bell on the Albany River, Hudson's Bay, in rocks of Upper Silurian age. In this specimen the skeleton remains as carbonate of lime, while the canals and tubes are in great part empty, so that their minute ramifications are in the condition of a recent specimen, and can be injected with colouring-matter. The actual structures thus presented are as follows :—

Laminæ thin and obscure. Chambers almost entirely filled with supplemental deposit, traversed by innumerable microscopic horizontal canaliculi, which are tortuous and anastomose frequently. They are connected with systems of radiating canals which terminate centrally in vertical tubes traversing the whole thickness of the specimen, and opening at the surface in round pores visible to the naked eye and placed on the summits of slight eminences. The pores are about 4 millimetres apart horizontally. The upper surface is smooth and does not show the radiating canals, but these are disclosed by erosion or by horizontal fracture. This species closely resembles Hall's *Caunopora incrustans*, from the Devonian of New York; but the pores are more regular and less than half as far apart, and the radiating tubes are more numerous. For the above species I have proposed the name *Caunopora hudsonica* (Pl. IV. fig. 9 and Pl. V. fig. 10).

I have described in a former publication* a fossil preserved in a similar way, but less perfectly, and which has vertical tubes in groups instead of singly; it is from the Galt Limestone of Ontario, and belongs to the genus *Cœnostroma*, as limited in the sequel. I would propose for it the name *C. galtense*.

The structures in *Caunopora* and *Cœnostroma* are unquestionably, at first view, more akin to those of sponges than are those of the typical *Stromatoporæ*, as the vertical tubes may be taken for oscula, and the extremities of the fine tubes for the incurrent pores. On the other hand, the solidity of the calcareous walls and supplemental thickenings is at variance with such a view; and in many respects they more nearly resemble *Eozoon* than any of the Palæozoic fossils with which I am acquainted. The canal-system in both is, indeed, so much alike that it would not be easy to distinguish it, except that *Eozoon* wants the continuous vertical tubes and possesses a true nummuline wall.

The minute structures of such species as the *Stromatopora nodulata* of Nicholson (*S. sanduskyana* of Röminger, Pl. V. fig. 11), connect the true *Stromatoporæ* with the species of the genus *Cœnostroma*; and these, by confluence of the separate tubes, pass into those of the genus *Caunopora*.

Of the species separated by Nicholson in the genus *Syringostroma*, that which he has named *S. columnaris* is a very peculiar type. It is penetrated vertically by what seem to be solid columns, and which, on microscopical examination, prove to result from upward bending and fusion of the laminæ along certain vertical lines. The effect is obviously to give much additional strength to the skeleton. Between

* 'Life's Dawn on the Earth,' p. 160.

the columns the laminæ are supported by pillars as in *Stromatopora.* They are also penetrated by horizontal canals which ramify radially, and are connected with vertical tubes as in *Cœnostroma*, to which this form is very closely allied; I have seen only one species from the Corniferous Limestone, specimens of which have been kindly given to me by Dr. Newberry and Mr. Hinde of Toronto.

Dictyostroma of Nicholson includes species in which the connecting pillars are formed by upward bending of the laminæ themselves in conical points. The only species described by Nicholson (*D. undulatum*) is from the Niagara formation of Louisville, Kentucky. I have, however, seen an imperfectly preserved specimen with this structure from the Black-River Limestone of Port Claire. Mr. Hinde has sent me another from the Corniferous of Port Colborne. These seem to be different from Professor Nicholson's species in the distance between the laminæ, which is much less than in the coarsely constructed species which he has described. The laminæ are porous in these specimens; but I have seen no vertical tubes or oscula.

The species *Stromatopora compacta*, from the Trenton Limestone, described by Billings, and which is not uncommon, does not appear to belong to this group of organisms. It consists of very minute hexagonal tubes with extremely thin walls and well-developed tabulæ, which, from their strong development and continuity, give in some specimens an appearance of concentric lamination. The species seems to belong to the genus *Stenopora*, but its cells are excessively minute. Corals of the genus *Fistulipora*, with small tubes imbedded in a cellular cœnenchyma, may readily, in certain states of preservation, be mistaken for *Stromatopora.*

Stromatoporæ seem not unfrequently to have overgrown corals of different species; and, in the case of *Syringopora*, the tubes of these projecting through the mass often simulate oscula. Mr. Hinde informs me that, in the case of one species, this association is so common that it suggests the idea of a case of "commensalism."

As connected with *Stromatopora,* it may be well to remark that some misapprehension still appears to exist respecting *Archæocyathus*, a fossil of the Cambrian rocks of Mingan, Labrador, and of which several species have been described by Billings. Of these the only one I have studied is *A. profundus.* This is certainly a calcareous, chambered organism, with pores connecting the chambers, and must have been the skeleton of a Rhizopod. The other species have similar structures. It is true, however, that on treating them with acids, Billings obtained siliceous spicules in the matrix, which I have myself examined. I regard them as having belonged to lithistid sponges of the genus *Trichospongia* of Billings, accidentally associated with the *Archæocyathus.*

Some specimens of *Stromatopora* present remarkable lines of growth, caused by the appearance of two or three layers of smaller cells at intervals of seven or eight interspaces (Pl. IV. fig. 4). The preservation of these without the intervening portions may, in some cases, account for the abnormally wide interspaces sometimes seen in imperfectly preserved specimens. I have not been able to satisfy myself whether these lines of growth are of specific value. In one specimen from the Devonian of Iowa, a *Stromatopora* of this type presents large vertical tubes which extend from one growth-line to the next, but are sparsely distributed through the mass, and not connected with radiating tubes as in *Caunopora*.

Another interesting structure, seen in a species from the Corniferous Limestone, usually, though perhaps incorrectly, identified with *S. concentrica*, is the division of the pillars at their summits into branches (Pl. III. fig. 2), so as to support at many points the layer above, which in this case is thin and not much strengthened with supplemental deposit.

2nd. *State of Preservation.*—*Stromatoporæ* have apparently always been calcareous when recent. They are sometimes preserved in the state of calcite with the chambers either filled with the same material or with silica. Sometimes they are entirely silicified, or the laminæ and pillars are silicified and the chambers filled with calcite. Occasionally the chambers are filled with dolomite or the whole structure is dolomitized.

A specimen of the type of *S. concentrica* from the Devonian or Upper Silurian of James's Bay is now before me, and affords a good illustration of modes of preservation in silica. In some places the laminæ and pillars have been silicified, while the chambers are filled with limestone. When weathered or treated with acid, these portions show the whole structure very clearly, including the perforations of the laminæ and the hollow pillars (Pl. IV. fig. 7). Other portions have the chambers also filled with silica, the laminæ being distinguishable by their less transparent and porous character. In these portions the laminæ and pillars have usually been first coated over with minute crystals of quartz. A layer has then been deposited of chalcedony with botryoidal surfaces, and finally the remaining cavities have been filled with crystalline vitreous quartz. In the greater part of the specimen, however, the chambers have been filled with silica, while the laminæ have remained as calcite, and these portions, when weathered, present the appearance of thick structureless laminæ separated by thin spaces and penetrated by numerous round holes representing the pillars. Portions in this state might be mistaken for a coral of the type of *Fistulipora*, but in certain aspects they present that lobated amœboid form which is so characteristic of similarly preserved specimens of *Eozoon*.

In specimens of *Stromatopora* from the Niagara Limestone, it not unfrequently happens that certain layers or groups of layers are silicified, while others alternating with them remain as calcite. In this case, when the specimens are weathered, they present distant concentric layers very different in appearance from the actual structure.

As with other fossils, crystallization plays strange freaks with *Stromatoporæ*, reducing them to such a condition that, but for the partial preservation of portions here and there, they might be mistaken for inorganic bodies. This is well seen in the abundant *Stro-*

matoporæ of the great dolomite-beds of the Niagara Limestone. Of these many are entirely reduced to crystalline masses of quartz or dolomite, except small portions at the surface, while others have become hollow and resemble cavities lined or filled with crystals. In the Upper Silurian dolomite of Guelph, in like manner, there are specimens which have been converted into a granular dolomite, in which, however, the laminæ and, in some cases, the canals are more or less apparent.

The study of *Stomatoporæ* in these different conditions throws great light on the appearances presented by *Eozoon* in various states of preservation, and forms a guide to the interpretation of these, which should be before the mind of every one who desires to form correct opinions on the subject.

Since writing the above, I have seen the remarks of Dr. Nicholson on the calcareous nature of *Stromatopora*, and Zittel's observation of the occasional calcification of the spicules of siliceous sponges, as reported in the 'Geological Magazine' for January 1878. It had not occurred to me that any one acquainted with *Stromatoporæ* would doubt their calcareous nature; but Nicholson has sufficiently disposed of such doubts by the consideration that the *Stromatoporæ* are found silicified only in beds in which corals and shells have suffered the same change. Nor had it seemed necessary to refer in this connexion to the replacement of siliceous spicules with calcite. It is, or should be, well known from the behaviour of siliceous spicules with alkalies, and when heated, that many of them are not purely siliceous, but contain animal matter. This, with the more soluble character of their silica, enables them to be changed or removed without affecting the siliceous matrix. Hence in the siliceous sponges from the Niagara Limestone the spicules are sometimes opaque and granular in appearance, or have disappeared altogether, or have been replaced with calcite or with iron pyrite. These changes are, however, rare, and have no bearing on the calcareous nature of *Stromatopora*.

3rd. *Classification of Stromatoporidæ.*—It is not my purpose to enter into any revision of the numerous species of this family, or to attempt to summarize the work which has been done with reference to the American species by Hall, Winchell, Nicholson, Billings, Röminger, and others. It may, however, be useful to state the results at which I have arrived with reference to the leading generic forms.

1. *Stromatopora* (Goldfuss, 1827).—In the original definition by Goldfuss the genus is characterized as exhibiting "alternating strata of a solid and porous character." The porous strata in this definition are the real laminæ, the solid strata are the filled-up chambers; and according as one or the other is preserved, we have in this type thin laminæ connected by pillars, or thick laminæ perforated with round holes and separated by vacant spaces. The typical species is *S. concentrica* of Goldfuss, and the genus may be held to include all the species with thin or moderately thick laminæ connected with solid and hollow pillars and perforated with minute pores, or having

a reticulated texture. *Stromatocerium* of Hall is a synonym. The genus ranges from the Upper Cambrian to the Devonian inclusive, and it is not easy to separate the species which have been described.

2. *Caunopora* (Phillips, 1841).—The typical species, *C. placenta,* is defined by Phillips as "amorphous," composed of concentric or nearly plane masses perforated by flexuous or vermiform small tubuli and by larger straight subparallel or radiating open tubes, persistent through the mass. This definition includes those species with simple tubes giving origin to radiating tubuli passing through the thickened laminæ. *Cœnostroma* (*Caunopora*) *incrustans* of Hall is a typical American species, as is also *Caunopora hudsonica* above referred to.

3. *Cœnostroma* (Winchell, 1867).—This genus, as defined by its author, includes those species in which the radiating tubes diverge from the surfaces of little eminences raised in the concentric lamellæ; but, as Hall has well remarked, the presence or absence of eminences is a trivial character. The real distinction should be based upon the absence of the central simple radiating tubes, which in these species are represented by a group of more or less divergent ascending tubuli, so that the surface of the last layer presents eminences not with a single large pore at the summit, but with several small pores diverging from their sides. My *Cœnostroma galtense* above referred to and Hall's *Caunopora* (*Cœnostroma*) *planulata* are typical forms. I have been obliged to reverse the generic names as used by Hall, in the twenty-third Report of the Regents of New York, in the manner above stated, as Phillips's name certainly applies to the species with *single* vertical tubes.

Stromatopora nodulata of Nicholson (Ohio Report, vol. ii.) probably belongs to this genus.

4. *Syringostroma* (Nicholson, 1875).—This genus is defined by the author as composed of concentric laminæ and vertical pillars which are so thickened and so amalgamated with one another as to leave nothing but the most minute rounded cells. Laminated tissue traversed by numerous large irregularly disposed horizontal canals. The species *S. densa* included under this genus in the Ohio Report is undoubtedly to be referred to *Cœnostroma* as above defined, being a species with the vertical tubes small and the radiating tubes very large. The species *S. columnaris* has, however, a very special character in the apparent want of vertical tubes, and in the coalescence of the laminæ along certain vertical lines, giving solid columns terminating in imperforate or microscopically perforate tubercles at the surfaces.

5. *Dictyostroma* (Nicholson, 1875).—In this genus the upper surface of each lamina is developed into conical points which support the lamina above instead of pillars. The laminæ have horizontal canals, and the upper surface is apparently solid, though, no doubt, minutely perforate; the irregular oscula referred to by Nicholson are probably accidental. *D. undulata,* Nicholson, is the typical species; but I think we may add to these several others in which

the thin laminæ extend upwards in conical forms instead of pillars, and in some of which the laminæ are thin and apparently destitute of the horizontal tubes.

It is not impossible, though the specimens in my possession are not sufficiently perfect to render this certain, that *Labechia conferta* of Edwards and Haime, from the English Wenlock, may be allied to this or the last genus.

[The above descriptions of Stromatoporidæ were written before the publication of Nicholson and Murie's excellent memoir in the Journal of the Linnean Society, which reached me only a few days before the proof of the above pages. Their descriptions of the structures, and views as to the classification and affinities, agree in the main with those above given, and where they differ deserve careful consideration. They do not seem to have met with so good examples of the hollow pillars and perforated laminæ as those I have described, nor to have so distinctly observed the relation of the horizontal canals to a supplemental deposit of calcareous matter. In their comparison with *Parkeria* too much importance is, I think, attached to the arenaceous character of that fossil—a character which we find in living Rhizopods associated with forms not dissimilar to those which are calcareous. It is also not improbable that some Stromatoporidæ are built up of microscopic calcareous grains. *Loftusia* likewise presents points of comparison of some importance; and the Carboniferous species of that genus described and figured by Dr. G. M. Dawson (see p. 69) is especially instructive. In the memoir in question the genus *Syringostroma* of Nicholson is divided into *Stylodictyon* and *Pachystroma, Stromatocerium* of Hall is retained as a separate genus for some peculiar Stromatoporidæ of the Lower Silurian, and a new genus (*Clathrodictyon*) is formed for vesicular species without pillars. The separation of forms contained in *Syringostroma* I have myself suggested above; and I think the grounds for retaining *Stromatocerium* and adding *Clathrodictyon* may be sustained. The authors should, however, I think, have retained *Cœnostroma* of Winchell, and placed in it some forms which they have distributed in other genera. The new facts stated respecting *Labechia* are important with reference to that somewhat problematical fossil.]

The geological distribution of the American Stromatoporidæ known to me may be stated as follows, though the species, no doubt, require some revision :—

Potsdam formation	Stromatopora, sp.
Trenton formation	Stromatopora rugosa, *Hall.*
	Dictyostroma ? sp.
Niagara formation	Stromatopora concentrica, *Goldfuss.*
	Cœnostroma constellatum, *Hall.*
	Caunopora hudsonica, n. sp.
	Dictyostroma undulatum, *Nicholson.*
Guelph formation	Stromatopora ostiolata, *N.*
	Cœnostroma galtense, n. sp.

Corniferous formation	Stromatopora granulata, *Nicholson.*
	S. mammillata, *N.*
	S. Hindei, *N.*
	S. perforata, *N.*
	S. ponderosa, *N.*
	S. substriatella, *N.*
	S. tuberculata, *N.*
	Syringostroma columnare, *N.*
	Cœnostroma densum, *N.*
Hamilton formation	Stromatopora nux, *Winchell.*
	S. cæspitosa, *W.*
	Cœnostroma monticulifera, *W.*
	C. pustulifera, *W.*
Chemung formation	Stromatopora expansa, *Hall.*
	S. erratica, *H.*
	S. alternata, *H.*
	Caunopora incrustans, *H.*
	Cœnostroma solidulum, *H.*
	C. planulatum, *H.*

II. Palæozoic Fossils associated with Serpentine and other Hydrous Silicates.

Fossils having their cavities and pores infiltrated with hydrous silicates are much more abundant in Palæozoic limestones than is usually imagined. In some instances serpentine itself is found to have been concerned in such infiltration; while in other cases the infiltrating hydrous silicates are found to approach to pollyte, fahlunite, and other minerals which have usually been regarded as products of decomposition or metamorphism, but which, as Dr. Sterry Hunt has justly remarked, cannot reasonably be referred to such an origin when they are found filling the pores of Crinoids and other fossils in strictly aqueous deposits. In this case they must surely be the results of original deposition in the manner of glauconite; and, as we shall find, they sometimes appear to be strictly the representatives of that mineral, which occurs under similar conditions in other parts of the same formations.

1. *Serpentine of Lake Chebogamong.*—Mr. Richardson, of the Geological Survey, has observed, north of the Laurentian axis, on the Saguenay River, certain rocks which appear to be similar in mineral character to the Quebec group of Sir William Logan, and occupy a geological position intermediate between the Laurentian and the Trenton formation. Among these he describes a band of serpentine associated with limestone at Lake Chebogamong, which lies about 200 miles to the N.E. of Lake St. John, in a little-explored region. Among the few specimens which Mr. Richardson was able to bring back with him was one of extreme interest—a specimen apparently from the junction of the limestone and serpentine, and containing a portion of a tabulate coral, of which some of the cells are filled with a mixture of serpentine and calcite, and some with calcite. The serpentine seems to have been weathered; it has a granular, uneven appearance, and under the microscope shows patches with fibrous structure like chrysotile. There are also whitish serpentine veins, fringed with chrysotile or a mineral re-

sembling it under the microscope. The cell-walls of the coral are perfectly black and opaque, and probably carbonaceous. The coral found thus mineralized was examined by Mr. Billings, who had no doubt of its nature, though uncertain as to its generic affinities. After careful study of it, I am disposed to refer it to the genus *Astrocerium* of Hall, and it is not distinguishable in structure from *A. pyriforme* of that author, a species very common in the Upper Silurian limestones of the region in which the specimen occurs. The genus *Astrocerium* is specially characteristic of the Niagara formation; and though Edwards doubts its distinctness from *Favosites*, I think there are constant points of difference, especially in the microscopic characters of the cell-walls, which entitle it to be separated from that genus. In such specimens of *Astrocerium* as are well preserved, the walls of the hexagonal cells seem to have been of corneous texture, with minute corneous spicules instead of radiating septa. They have pores of communication, and there are also occasional larger pores or tubes in the angles of the cells. The tabulæ are very thin and apparently purely calcareous. This accounts for the singular fact, mentioned by Hall, that the cell-walls are sometimes entirely removed, leaving the tabulæ in concentric floors like those of *Stromatopora*. I think it likely that the typical species of *Astrocerium* may have been inhabited by Hydroids, and may have been quite remote from *Favosites* in their affinities.

The formation in which the serpentine and limestone of Lake Chebogamong occur is described as consisting of chloritic slates, in some places with hornblende crystals, dolomites, and hard jaspery argillaceous rocks. Upon these rest conglomerates and breccias with Laurentian fragments, and also fragments of the rocks before mentioned, and on these lie the limestone and serpentine. The serpentine has been analysed by Dr. Hunt, who finds it to contain chromium and nickel, and in this respect to be similar to that of the Quebec group, and not to that of the Laurentian*. The fossil would give evidence of a much later date than that usually attributed to rocks of the character above stated; but it is quite possible that there may be two series of different ages in the region, the lower being Lower Silurian or perhaps older, and the upper of Upper Silurian age. If the serpentine belongs to the newer formation, its association with a coral of the genus *Astrocerium* would of course be quite natural. If it belongs to the older formation, and the overlying limestone to the newer, the serpentine in the latter may be a *remanié* silicate derived from the older rocks and mixed with the limestone at their junction.

2. *Serpentine of Melbourne.*—The serpentines of this place belong to a great series of more or less altered rocks extending through the province of Quebec, and referred by Sir William Logan, on stratigraphical grounds, to his Quebec group, equivalent to the Arenig or Skiddaw series of England †. In ascending order these rocks at Melbourne present first a thick series of highly plumbaginous schists

* Report of Geological Survey of Canada, 1870–71.

† Hunt, however, holds that these rocks are in part Huronian.

or shales, with thin bands of limestone holding fragments of Lower Silurian corals and crinoids. These pass upwards into a thick series of slaty rocks characterized by the prevalence of a shining crystalline hydro-mica, and known as nacreous or hydro-mica slates. They are associated with quartzose bands, and also with lenticular layers of crinoidal limestone. Parallel with these beds and, according to Logan's observations, overlying them, is the series containing the serpentine, which is associated with layers of limestone and nacreous slate, and also with brecciated and arenaceous beds, probably originally tufaceous, with beds of anorthite, steatite, and dolomite, and also with red slates, the whole forming a miscellaneous and irregular group, evidently resulting from the contemporaneous action of igneous and aqueous agencies, and affording few traces of fossils. The serpentines, which occur in thick and irregular beds, are different in colour and microscopic texture from those of the Laurentian system, and also present some chemical differences, more especially in the presence of oxides of nickel, chromium, and cobalt, and of a larger percentage of iron and a smaller proportion of water*.

These serpentines are undoubtedly bedded rocks and not eruptive; but they may have originated from the alteration of volcanic materials†. They appear, shortly after their original deposition, to have been broken up, so as in many places to present a brecciated appearance, the interstices of the fragments being filled with limestone and dolomite, which themselves are largely mixed with the flocculent serpentinous matter, and traversed by serpentinous veins sometimes compact and sometimes fibrous. Besides the very impure limestone thus occurring in the serpentinous breccia, there are also true layers or beds of limestone and dolomite included in or near to the great serpentine band. No well-preserved fossils have been found either in these beds or in the brecciated serpentine; but on treating the surfaces of slabs with an acid or making thin slices, fragments of organic bodies are developed which well illustrate the manner in which serpentine, whatever its origin, may be connected with the mineralization of such fragments.

It is to be observed here that the irregular bedding of the serpentine, and the apparent passage on the line of strike into dolomite and red slate, might accord either with a purely aqueous and oceanic mode of deposition like that of glauconite, or with deposition as beds of volcanic sediments, afterwards altered and partly redeposited by water. The association with ash rocks and agglomerates would, how-

* Under the microscope the Laurentian serpentines are usually homogeneous and uncrystalline, but with the structure of netting veinlets which I have elsewhere called septariform. The Melbourne serpentines usually present a confused mass of acicular crystals or a fibrous structure, and, where structureless, polarize more vividly than those of the Laurentian.

† Sandberger (Essay on Metallic Veins) quotes many German chemists to the effect that "olivine rock and the serpentine formed from it always contain copper, nickel, and cobalt." This origin might thus apply to the serpentines in the Quebec group in Canada, but not to those of the Laurentian, as I have already urged on other grounds in my reply to Hahn, in the 'Annals and Magazine of Natural History,' 1876, vol. xviii. pp. 32, 33.

ever, tend rather to the latter view, as would also the chemical characters of the serpentine already referred to; but the association with fossils mentioned below tends to show that at least a part of the mineral is an ordinary aqueous deposit. It is also to be observed, with reference to the superposition of serpentine on fossiliferous Lower Silurian rocks, that a similar relation is affirmed by Murray to occur in Newfoundland, where massive serpentines overlie unaltered fossiliferous rocks of the Quebec group*.

No fossils have been found in the compact serpentine, but only in the limestone paste of the brecciated masses and in the limestone bands interstratified. The limestone of the breccia contains not only angular fragments of serpentine but disseminated serpentine and small veins of the same mineral. Its fossils are limited to small tubular bodies, crinoidal joints, and fragments, apparently of *Stenopora*, very imperfectly preserved. The tubular bodies may be portions of *Hyolithes* or *Theca*. Their interior is usually filled with dolomite; their walls are in the state of calcite; and they are incrusted with an outer ring of serpentine. In some instances the calcareous organic fragments are seen to be filled in the interior with serpentine. The crinoidal fragments are in a similar condition, the serpentine having apparently surrounded them in a concretionary manner after the cavities had been filled with dolomite. Fragments of calcite, dolomite, or older serpentine included in the limestone, and of no determinate form, are enclosed in the new or *remanié* serpentine in like manner, and in some cases this newer or coating serpentine was observed to have a fibrous structure. The serpentine thus coating and filling fossils and fragments is of a lighter colour than the serpentine of the fragments themselves, and in this respect resembles that of the small veins traversing the limestone. Such traces of fossils as exist in the layers of limestone are similar to those in the breccia, but not, so far as observed, coated with serpentine.

It would thus appear that, contemporaneously with the original deposition of the serpentine, thin bands of limestone were laid down, with a few fragments of crinoids, corals, and shells; that subsequently, but perhaps within the same geological period, and while the deposition of serpentine was still proceeding, portions of the surface of the serpentine were broken up and imbedded in limestone; that the fissures of this limestone were penetrated with serpentine veins, and its few fossils coated with that mineral, which also forms flocculent laminæ in the limestone.

The mode of deposition of this Palæozoic serpentine is thus considerably different from that of the Laurentian, which forms layers intimately interstratified with great limestones, and also nodules, concretionary grains, and fillings of fossils in these limestones. This difference in mode of occurrence is, no doubt, connected with the difference in composition of the two varieties of the mineral already noticed. In both cases, however, the serpentine has been so depo-

* Bedded serpentines also occur in unaltered Silurian dolomites at Syracuse in New York (Hunt, Chem. and Geol. Essays, p. 310).

sited that it could take part in the mineralization of marine organic remains.

The condition of the fragments of Silurian fossils in the limestones associated with the nacreous or hydro-mica slates is of interest in connexion with this subject. The shining laminated mineral associated with these fossils has been regarded from its chemical composition as a hydro-mica. Under the microscope, however, it shows a want of homogeneity which suggests the presence of two or more silicates, or the association of crystals of hydrous mica with minute grains of siliceous matter of some other kind. Though now highly crystalline, it must originally have been a fine sediment, since it fills the finest cells of *Stenopora* and *Ptilodictya.* Nor can its present state have been produced by any extreme metamorphism, as the undistorted state of these fossils amply testifies. Further it is interesting to observe that though the hydrous silicate is little magnesian, the fossils themselves are not infrequently converted into dolomite. In these fossiliferous beds there are also tabular crystals, apparently of anhydrous mica, little groups of crystals of tremolite, cavities filled with quartz, and crystalline grains of a mineral having the microscopical characters of olivine ; and these have been developed or included in the mass without injury to the structures of the most delicate corals.

Similar appearances are presented by limestones from other parts of the Quebec group, of which a great series of slices has been prepared by Mr. Weston under the direction of the late Sir W. E. Logan, who, in his later researches in this group of rocks, gave much attention to the microscopic fossils in the more altered beds, as a means of determining their ages. Besides large series from Melbourne and its neighbourhood, I have examined slices from Stanford, Farnham, Cleveland, Bedford, Orford, Arthabaska, Point Levi, Rivière du Loup, and other places, in most of which Lower Silurian fossils occur associated with hydrous silicates.

The fossils above referred to occur in rocks undoubtedly of Lower Silurian age, and regarded as altered or metamorphosed members of the Quebec group. In the unaltered representatives of these rocks at Point Levi and the island of Orleans there occur considerable quantities of a true glauconite, which has been analyzed by Dr. Hunt, and which is without doubt an original deposit in the sandy and argillaceous beds in which it occurs, which in many cases are precisely similar to Cretaceous greensands. Dr. Hunt's analysis shows that this glauconite contains alumina, iron, potash, and magnesia, and thus approaches to the Laurentian loganite. In the forms of its little concretions it resembles the serpentine grains in the Laurentian limestones; and like modern glauconite it has moulded itself in organic forms. Some of these are spiral or multilobate, as if casts of minute univalve shells or of spiral and textularine Foraminifera*. Others are annular or are arcs of circles, and some pre-

* Ehrenberg has found casts of rotaline and textularine Foraminifera in Lower Silurian beds in Russia; and such forms occur in Upper Silurian limestones in Nova Scotia.

sent a delicate fibrous or tubulated appearance, as if they had moulded themselves on porous shells or very minutely-celled corals, spicules of sponges, &c. Shreds of corneous Polyparies, perhaps of Graptolites, abound in the matrix, but are not connected with the glauconite grains. Unfortunately there are no *Stromatoporæ* in these beds, otherwise we might have an almost precise recurrence of the relations of serpentine with *Eozoon* in the Laurentian*.

Another appearance which may be mentioned in this connexion occurs in certain beds of Utica Slate in the vicinity of the trappean mass of Montarville, and converted into a hard sonorous rock. In one of these are stems of crinoids which have retained their external form, while the calcareous material has been entirely removed and replaced by a soft green crystalline mineral whose physical and microscopical characters are those of chlorite, and which in any case may be regarded as one of those hydrous silicates sometimes termed "viridite."

3. *Limestone of Pole Hill, New Brunswick, and of Llangwyllog in Anglesey.*—In a paper in the Transactions of the Royal Irish Academy, and subsequently in 'Life's Dawn on the Earth,' I noticed a remarkable limestone discovered by Mr. C. Robb, of the Geological Survey, at Pole Hill in New Brunswick, and believed to be of Upper Silurian age. It is composed of fragments of crinoids and shells, the cavities of which are finely injected with a hydrous silicate of alumina, iron, and magnesia, the composition of which, according to Dr. Hunt, approaches to that of the pollyte of Von Kobell, and also to that of a hydrous silicate described by Hoffmann as filling the cavities of specimens of *Eozoon* found in Bohemia. It has also some resemblance to the loganite which mineralizes the *Eozoon* of Burgess, in Canada. At the same time I mentioned a specimen of limestone of similar character which I had found in the McGill-College collection, and which I supposed to be from Wales. It is labelled "Llangolloc," and belonged to the collection of the late Dr. Holmes, of Montreal. Professor Ramsay, to whom I have applied for information as to the locality, kindly informs me that the name is probably "Llangwyllog," that the place so named is in Anglesey, and that limestone of Lower Silurian or Cambrian age occurs in its vicinity.

A portion of this specimen was submitted to Dr. Sterry Hunt, from whose analysis it appears to be of similar character with that of Pole Hill, and like it injects in the most beautiful manner the pores and cavities of crinoids, shells, and corals†. The limestone containing this silicate is of subcrystalline texture, with occasional bright cleavage-faces which belong to crinoidal fragments. Its colour, owing to the included silicate, is dull olive, and it shows occasional small deep green and reddish specks. Its aspect is so waxy, that at a little distance it might be mistaken for an impure serpentine.

When examined with the microscope, the flocculent olive-green silicate is seen to penetrate the mass exactly in the manner of the

* Report of Geological Survey of Canada, 1866.

† As the analyses of these specimens by Dr. Hunt have not been published

serpentine in ophiolite, and it has a polariscope appearance approaching to that of serpentine; while greenish by reflected light, it appears reddish when seen in thin slices with transmitted light. It penetrates the finest pores of crinoids, and at the same time fills the cavities of shells and the cells of corals. The larger fillings of this kind give the deep green spots above mentioned, while the red spots are apparently caused by the partial oxidation of the iron of the mineral. In one shell, apparently a small *Orthoceras* or *Theca*, the dark green filling has cracked in the manner of *Septaria*, and the fissures have been filled with carbonate of lime. In some places the mineral has penetrated the pores of shells of Brachiopods or crusts of Trilobites, producing a tubulated appearance not unlike the proper wall of *Eozoon*.

From the characters of the fragments, I should imagine that this limestone is Lower Silurian rather than Cambrian. It affords an excellent instance of the occurrence of hydrous silicates infiltrating organic fragments, and it deserves the attention of collectors having access to the locality. A curious point of coincidence of this limestone with some of those in the Lower Silurian of Canada is the occurrence of a few bright green specks, probably of apatite or vivianite, giving on a small scale that association of phosphates with hydrous silicates which we find on the great scale in the Laurentian.

The above facts I intend to be supplementary to my papers on *Eozoon* and on the graphite and phosphates of the Laurentian already

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in England, or in such a manner as to be readily compared with each other, I reproduce them here:—

	Pole Hill, New Brunswick.	Llangwyllog, Wales.
Silica	38·93	35·32
Alumina	28·88	22·66
Protoxide of iron	18·86	21·42
Magnesia	4·25	6·98
Potash	1·69	1·49
Soda	0·48	0·67
Water	6·91	11·46
	100·00	100·00

In the Llangwyllog specimen the silicate amounted to three per cent. of the whole, the remainder being carbonate of lime with a very little siliceous sand and fine clay. In the Pole-Hill specimen the silicate amounted to about five per cent., the remainder being limestone with a few quartz grains.

It will be seen that these two silicates, evidently deposited from solution in such a manner as to fill the finest organic pores, are remarkably similar in composition; and the fact that they closely resemble Hoffmann's mineral found in Bohemian *Eozoon*, and also the loganite filling the Burgess *Eozoon* (Quart. Journ. Geol. Soc. vol. xxi. 1865), gives them additional interest.

published in the Journal of this Society, and as illustrative more especially of the affinity of *Eozoon* with its successors in function, the Silurian *Stromatoporæ*, and of the abundant occurrence of serpentine and other hydrous silicates in association with fossils in the Lower Silurian as well as in the older Laurentian.

III. Imitative Forms resembling Eozoon.

It is easy for inexperienced observers to mistake laminated concretions and laminated rocks either for *Stromatopora* or for *Eozoon*, and such misapprehensions are not of unfrequent occurrence. As to concretions, it is only necessary to say that these, when they show concentric layers, are deficient altogether in the primary requirements of laminæ and interspaces; and under the microscope their structures are either merely fragmental, as in ordinary argillaceous and calcareous concretions, or they have radiating crystalline fibres like oolitic grains. Laminated rocks, on the other hand, present alternate layers of different mineral substances, but are destitute of minute structures, and are either parallel to the bedding or to the planes of dykes and igneous masses. In the Montreal mountain there are beautiful examples of a banded dolerite in alternate layers of black pyroxene and white felspar. These occur at the junction of the dolerite with the Silurian limestone through which it has been erupted. Laminated gneissose beds also abound in the Laurentian. Still more remarkable examples are afforded by altered rocks having thin calcite bands, whether arising from deposition or from vein-segregation. One of these now before me is a specimen from the collection of Dr. Newberry, and obtained at Gouverneur, St. Lawrence County, New York. It presents thick bands of a peculiar granitoid rock containing highly crystalline felspar and mica with grains of serpentine; these bands are almost a quarter of an inch in thickness, and are separated by interrupted parallel bands of calcite much thinner than the others. The whole resembles a magnified specimen of *Eozoon*, except in the absence of the connecting chamber-walls and of the characteristic structures. A similar rock has been obtained by Mr. Vennor on the Gatineau; but it is less coarse in texture though equally crystalline, and appears to contain hornblende and pyroxene. These are both Laurentian, and I consider it not impossible that they may have been organic; but they lack the evidence of minute structure, and differ in important details from *Eozoon*. Another specimen from the Horseshoe Mountain in the Western States (I regret that I have mislaid the name of the gentleman to whom I am indebted for this specimen) is a limestone with perfectly regular and uniform layers of minute rhombohedral crystals of dolomite. The layers vary in distance regularly in the thickness of the specimen from two millimetres to one, and must have resulted from the alternate deposition in a very regular manner of dolomite and limestone. These are but a few of the examples of imitative structures which might readily be confounded with *Eozoon*, or which, if resulting from organic growth, have lost all decisive evidence of the fact.

Perhaps still more puzzling imitative forms are those referred to by Hahn, which occur in some felspars, and which I have found in great beauty in certain crystals of orthoclase from Vermont. They are ramifying tubes resembling the canal-system of *Eozoon*, and are evidently a peculiar form of gas-cavities or inclusions. Similar appearances are, however, often presented by the more minute and microscopic varieties of graphic granite, in which the little plates might readily be mistaken, in certain sections, for organic tubulation.

In the present state of knowledge, it is perhaps more excusable to mistake such things for organic structures than to deny the existence of true organic structures because they resemble such forms. Those who have examined moss-agates are familiar with the fact that while some show merely crystals of peroxide of iron or oxide of manganese, others present the forms of *Vaucheriæ* or *Confervæ*. So if one were to place side by side some fibres of asbestos, spicules of *Tethea*, and coniferous wood, preserved, like some from Colorado, as separate white siliceous fibres, they might appear alike ; but, even if thoroughly mixed together, the microscope should be able easily to distinguish them. I have specimens of fossil wood, collected by Hartt in Brazil, which have been mineralized by limonite in such a manner that no one, without microscopic examination, could believe them to be other than fibrous brown hæmatite. Such difficulties the micro-geologist must expect to find, and by patient observation to overcome.

EXPLANATION OF THE PLATES.

Plate III.

Fig. 1. Vertical section of *Stromatopora* from the Niagara formation, showing the laminæ and pillars, without supplemental matter, × 20.

2. Vertical section of *Stromatopora* from the Corniferous Limestone, showing pillars ramifying and thickened at the ends, and laminæ without supplemental matter, × 20.

3. Vertical section of *Stromatopora* from the Corniferous Limestone, with much supplemental matter, but showing unthickened laminæ at *a a*, also horizontal canals at *b b*, × 20.

Plate IV.

Fig. 4. Vertical section of *Stromatopora* from the Corniferous Limestone, × 2, showing lines of growth, *a a*; *c*, vertical section of part of the same, × 20; *d*, surface of lamina, × 20, showing solid and hollow pillars.

5. Portion of lamina of another specimen, × 20, showing large pores and bases of two pillars.

6. Portion of another specimen, × 20, showing hollow and solid pillars and a pore at *a*.

7. Portion of silicified *Stromatopora*, weathered, and showing laminæ and pillars in relief, × 20.

8. Portion of *Stromatopora* resting on a tabulate coral and showing acervuline cells at base, × 2.

9. Vertical section of *Caunopora hudsonica*, showing vertical tube and horizontal canals, × 20; *a*, horizontal section of part of the same, showing canals and canaliculi ; *b*, vertical section, more magnified.

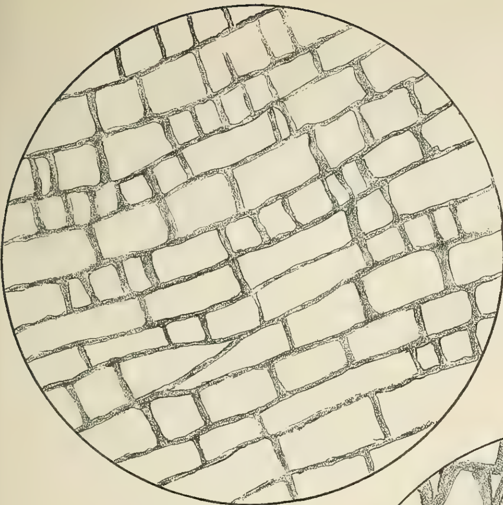
Plate V.

Fig. 10. Horizontal section of *Caunopora hudsonica*, showing canals radiating from a central tube, × 20.

11. Vertical section of *Cœnostroma nodulata*, Corniferous Limestone, showing canals and concentric laminæ, with much supplemental matter, × 20.

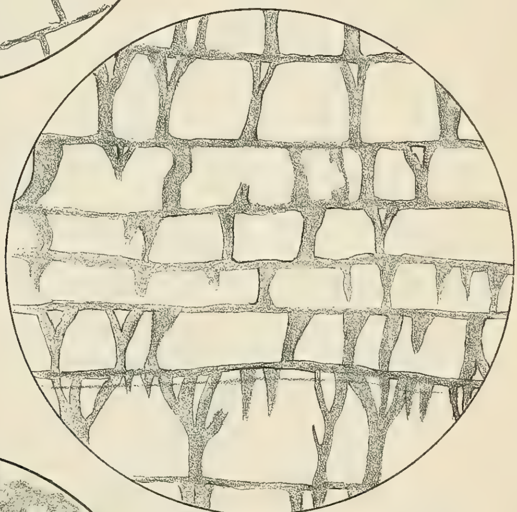
12. Horizontal section of the same, showing large radiating canals, × 20.

1.



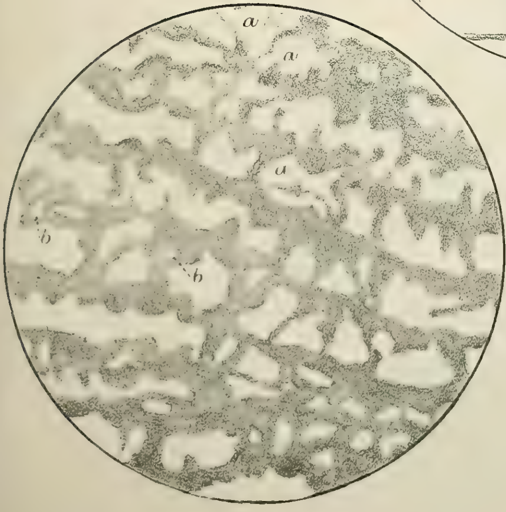
x 20

2.



x 20

3.



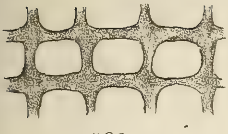
x 20

H. Olson lith.

Mintern Bros. imp.

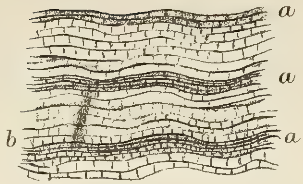
STROMATOPORIDÆ.

4 c.



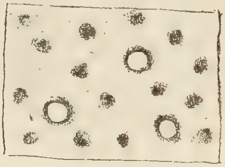
× 20

4.



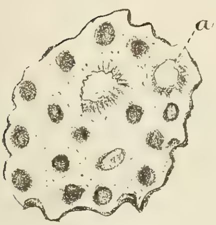
× 2

4 d.



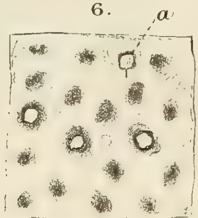
× 20

5.



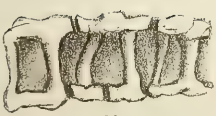
× 20

6.



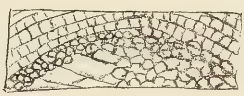
× 20

7.



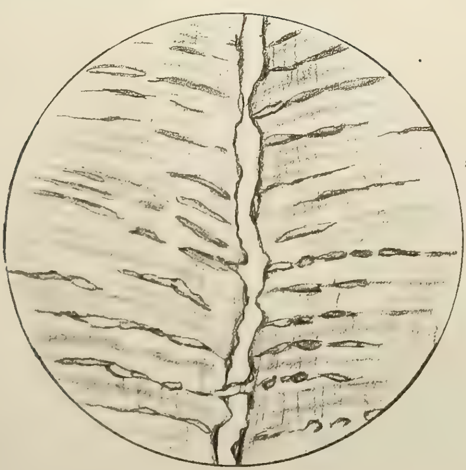
× 20

8.



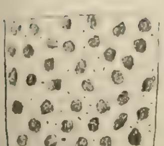
× 2

9.



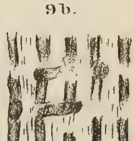
× 20

9a



× 50

9 b.



× 50

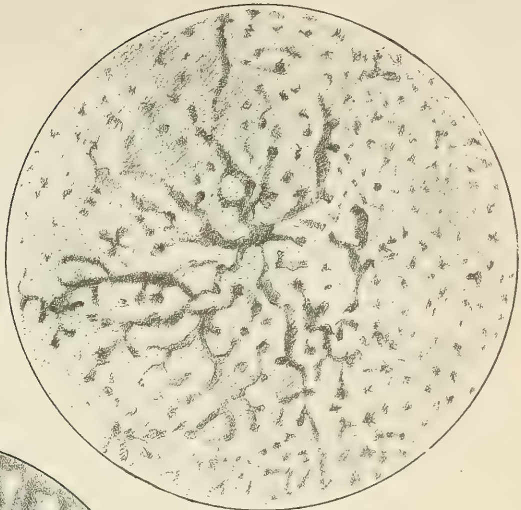
H Olson lith.

STROMATOPORIDÆ.

Mintern Bros. imp.

10.

× 20

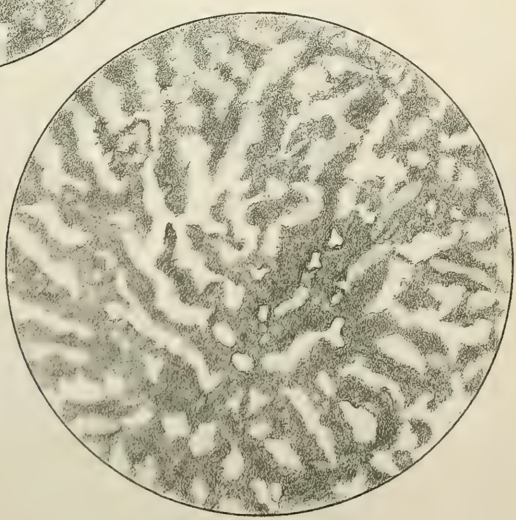


11.

× 20

12.

× 20



H Olson lith.

Mintern Bros. imp.

STROMATOPORIDÆ.

4. NOTE *on some* DEVONIAN STROMATOPORIDÆ *from* DARTINGTON *near* TOTNES. By A. CHAMPERNOWNE, Esq., F.G.S. (Read June 5, 1878.)

I DESIRE to present to the Society some specimens chiefly representing what some observers look upon as the natural group, and others as the heterogeneous mixture named *Stromatoporidæ.*

I have for some time been finding these fossils in large numbers; and as the subject has of late aroused considerable interest, it occurred to me that the Geological Society might be glad to possess a few from this locality.

I will not pretend to offer a decided opinion myself as to which set of observers are right, and yet, as far as the important question of the original constitution of the skeleton is concerned, I think it is very hard to believe in the uniform replacement of siliceous by calcareous matter in all or nearly all of these forms, and from so many different localities. On the other hand it is difficult to regard them as forming a compact group of Calcispongiæ, since whatever may be held as to their embracing true Hexactinellid (and, if so, siliceous structures), or, again, Foraminiferal structures, they clearly seem to embrace structures similar to that of the Milleporidæ. Among these some varieties of *Caunopora* (*Stromatopora*) *placenta* (Lonsd.) are remarkable.

I may perhaps be pardoned for referring to some words of Prof. Phillips in describing this organism (Pal. Foss. Cornwall, Devon, &c., p. 18), where he mentions the "larger . . . open (?), non-lamelliferous (?) tubes, persistent through the whole mass." I have, in several beautiful sections from the neighbourhood of Teignmouth, observed most distinctly that the axis of the tube is not open, but is lamelliferous, giving some appearance of a columella, and is quite unlike any true sponge-structure with which I am acquainted, and equally unlike a true *Stromatopora* (such as *S. concentrica* or *polymorpha*).

With regard to their mode of occurrence at Dartington, the specimens sent are all from dolomitic beds ("Pit-Park" quarry); but some of the group are always found wherever the limestone is fossiliferous. The rock is light-coloured, highly crystalline at the above-named quarry, is worked for road-metal, and at one spot, which has been left for some time unworked on account of the friable, almost sandy, condition of a small piece, these fossils occur. They are associated with *Alveolites*, *Favosites cervicornis* (v. *reticulata*), *Heliolites porosus*, *Cystiphyllum vesiculosum*, *Heliophyllum*, *Cyathophylla* (simple), Crinoidal joints, pelvic plates of *Hexacrinus* (rare), and occasional Brachiopoda (among which Mr. Davidson recognized *Spiriferina cristata* (v. *octoplicata*); and from a quarry in an adjoining field the specimens of *Uncites gryphus* now in the Museum of the Geological Survey were derived.

There is every sign of the Stromatoporoids having grown in the position in which they are now found, and nothing to suggest their having travelled.

They can be followed a few yards from where they come out whole, but rapidly become merged in the crystalline rock, and then their internal structure becomes obliterated.

I mentioned above that the fossils sent were chiefly Stromatoporidæ. They include also an example of *Smithia Hennahi* and *Heliolites porosus*. They are all from the Great Devon Limestone, Dartington.

I will only add that specimens found later than those sent are decidedly finer (for they take some weeks to get washed from the clay and sandy dolomitic rock in which they are imbedded); and I am hoping to get them largely cut and polished, and shall have great pleasure in sending some more.

Discussion.

Prof. Duncan expressed his belief that many different forms were united under the one head of *Stromatopora*, and that the confusion was often due to the mode of mineralization. He called attention to a *Smithia* on the table, which, by destructive mineralization, had assumed a deceptive resemblance to *Stromatopora*. He thought this had been the case in some of Mr. Lonsdale's specimens. The tubules in the laminæ of *Stromatopora* certainly had much resemblance to the tubules of *Millepora*. Some of the specimens on the table seemed to have openings like calices; as they opened into the cœnenchyma they could not be corals. The cross tubules excluded them from Polyzoa. They showed no true supplemental skeleton or nummuline layer like *Eozoon*, and so he doubted their Foraminiferal character. With regard to the mineralization, he had some years before received specimens of fossils from Canada, which Dr. Dawson's description had recalled to his mind.

Mr. Champernowne described the tubular structure which he had observed in some of the Stromatoporidæ from Devonshire, both in the horizontal and vertical sections, and felt certain that the group contained many different forms. He had never seen Eozoonal structure in the Devonshire fossils.

Dr. Murie stated that some specimens which he had seen resembled the Hexactinellidæ, and he thought they represented sponges, not precisely Hexactinellids.

5. *On a* NEW SPECIES *of* LOFTUSIA *from* BRITISH COLUMBIA. By GEORGE M. DAWSON, D.S., Assoc.R.S.M., F.G.S., of the Geological Survey of Canada. (Read June 5, 1878.)

[PLATE VI.]

IN 1869, Dr. W. B. Carpenter and Mr. H. B. Brady described, in the 'Transactions' of the Royal Society, two remarkable types of gigantic arenaceous Foraminifera, under the generic names of *Parkeria* and *Loftusia*. For the description of the latter form Mr. Brady is more particularly responsible, and to the genus then created by him I have now to add another species, for which the name of *Loftusia columbiana* is proposed.

The original specimens of *Loftusia* were obtained many years ago by Mr. W. K. Loftus in Persia. They were referred to in his paper on the geology of the Turco-Persian frontier and districts adjoining, published in the Quarterly Journal of the Geological Society in 1855, but remained undescribed till they came into Mr. Brady's hands. From the geological descriptions by Mr. Loftus, and other forms of Foraminifera found in the same stones, Mr. Brady believes the geological position of *Loftusia persica* to be in the oldest Tertiary rocks.

The specimens now to be described are from the interior of British Columbia, and their age is, I believe, Carboniferous. Examples of the form were first collected by Mr. J. Richardson, of the Geological Survey of Canada, in 1871, and are mentioned in the Report of Progress for 1871–72. About a year ago, I examined Mr. Richardson's specimens with some care; but during the past summer, having opportunity to visit the locality from which they were procured, the occasion was taken to collect a large number of additional specimens, representing all varieties of appearance and preservation. Mr. Thomas C. Weston has prepared from these and Mr. Richardson's specimens a number of transparent sections, from which the accompanying descriptions and drawings have been made.

Most of the specimens are from Marble Cañon, a remarkable valley which runs through from the banks of the Fraser River to the bend of Hat Creek, with a direction nearly transverse to that of the main features of the country. For a distance over ten miles, the sides of the valley are formed almost continuously of mountains of limestone or marble. The first impression is that an immense thickness of limestone is represented in the exposures; but, although the dips are too obscure to allow the attitude of the beds to be worked out throughout the length of the Cañon, some small sections show that part at least of the beds have been sharply folded and the whole series of folds overturned. This being the case, it may be that a comparatively thin limestone or series of limestones forming a succession of folds superimposed on a broad anticlinal flexure account for the appearance presented. That the limestones have a very considerable thickness, however, would appear from the fact that about seventeen miles to the north-west they are seen forming a range of mountains, which rise to altitudes of over 1500 feet above the level of the neighbouring valleys, and run from near Kelly's Lake to Canoe Creek. The physical relations of the beds will, however, be described at greater length in the next Report of the Geological Survey.

Though inclined to correlate these limestone beds, on stratigraphical and lithological evidence, with others from which Carboniferous forms have been obtained, no fossils more characteristic than the joints of Crinoidal columns were for some time found in association with the Foraminifer now described. After some search, however, specimens of *Fusulina* were discovered, thus bringing these into relation with the *Fusulina*-bearing limestones found elsewhere in the province, and also very widely over the western part of the North-American continent.

Many loose fragments and boulders of *Loftusia*-limestone were also found at "The Fountain," on the surface of a high terrace, there overlooking the Fraser. This place is about nine miles southwestward from the nearest of the Marble-Cañon exposures; and the specimens here may have been derived from a distinct outcrop not yet discovered.

In certain beds of the limestones of Marble Cañon, the *Loftusia* occurs almost to the exclusion of other forms, characterizing the rock, and having been the agent in its production, just as *Fusulinæ* occur in the best examples of *Fusulina*-limestone or *Globigerinæ* in the Atlantic ooze. Other beds of a nearly white colour and almost porcellanous aspect on fracture—though purely calcareous—are found on microscopic examination to consist of the comminuted remains of smaller Foraminifera, the mass resembling a thoroughly hardened chalk. Through these a few more or less perfect *Loftusiæ* may be scattered. *Fusulinæ* appear to be very scarce in the Marble-Cañon limestones; they are much more abundant in those of other parts of the country, composed principally of Crinoidal fragments. They seem to have preferred a bottom composed of the débris of the larger calcareous organisms to the fine oozy bed most congenial to the *Loftusia*.

The typical and most abundant form of *Loftusia*-limestone is a pale or dark grey cryptocrystalline rock, in which the more perfect specimens of *Loftusia* appear thickly crowded together as paler spots, generally pretty sharply defined. The limestone breaks freely in any direction, the fracture passing equally through the matrix and included organisms, which it is impossible to separate from the stone. The matrix generally seems to be composed in great part of granular calcareous matter similar to that employed in building up the test of the *Loftusia*, but more irregular in size of grain, and with an occasional fragment of a Crinoid or example of some smaller Foraminifer. When a *Fusulina* is found, even on the same thin section with a *Loftusia*, it differs totally from the latter in appearance. The fine tubulation of the walls has not been preserved; but the calcite is homogeneous and almost milky in appearance, while the fragmental character of the test of *Loftusia* is apparent even under a low power, and it has a peculiar sparkling aspect.

In form, the species bears a close resemblance to *L. persica*, especially to the stouter variety represented in plate lxxvii. fig. 3 of Messrs. Carpenter and Brady's memoir. I have not observed any specimens to assume a form quite so much elongated in proportion to the breadth as that given in figure 3 of the same plate. It is a regular oval, with circular cross section, the ends varying from obtusely rounded to bluntly spindle-shaped. The Marble-Cañon form, however, is very much smaller than *L. persica*, both in its external dimensions and proportionally in all its structures. By measurement of a number of specimens, the average length of the shorter axis appears to be from 19 to 20 hundredths of an inch, that of the longer axis about 30 hundredths; one specimen measuring as much as $\frac{27}{100}$ in its lesser diameter has been found. Some may attain a length of $\frac{35}{100}$ or even $\frac{40}{100}$ of an inch; a remarkably long and narrow example measured $\frac{16}{100}$ of an inch by $\frac{33}{100}$ of an inch. I have not been able to observe any regular furrowing of the outer surface of the test, though from the appearance in cross sections, it is probable that a tendency to such marking exists in some specimens. Others must have become more or less rough and irregular in form, from the acervuline mode of growth frequently assumed in the larger examples. Many specimens are, like those of the Persian form, more or less oval or elliptical in the outline of the cross section. As, however, in some specimens many examples may be found in different stages of degradation towards absolute shapelessness, I believe, as Mr. Brady does of the Persian form*, that this is abnormal, and the result of changes after the death of the animal. In some cases, specimens of irregular form are scattered among others of normal appearance, and seem to have decayed or collapsed more or less completely before the consolidation of the sediment. In other layers, the whole rock has very evidently been compressed during metamorphism, all the Foraminifera being flattened parallel to one plane.

The structure of this form is in most respects strikingly similar to that of *Loftusia persica*, and, like it, extremely complicated. Without Mr. Brady's elaborate and lucid description of the former, it would have been a matter of no small difficulty to make out the plan of growth of this smaller species, which it is possible to examine in thin sections only.

In describing the structure, the same terms made use of in the memoir already several times referred to will be employed. I would also call attention to the diagrammatic representation of the plan of the test of *Loftusia* on page 743 of the memoir.

No central primordial chamber, or series of chambers, like that of *Parkeria* has been found. The nucleus of the test appears to be, as in *L. persica*, a loose-textured granulated mass, nearly circular in cross section. It has not been observed, however, to become so distinctly cancellated as appears to be the case in *L. persica*.

In theory, this test may be said to consist, like that of the original

* *Op. cit.* p. 742.

species, "primarily of a continuous lamina coiled upon itself, like a scroll constricted at the ends. The space enclosed by this 'primary lamina' is divided into chambers by longitudinal septa. The septa are of 'secondary' growth; that is to say, they are not continuous with the principal wall or 'spiral lamina,' but are rather offshoots from it"*. As seen in a transverse section of the test, these septa are not perpendicular to the spiral lamina, but very oblique to it; and on further examination they are found to lie nearly parallel to the surfaces of a supposed second scroll, concentric with the first, but not, like it, constricted at the ends. The lines of intersection of the "secondary" septa and "primary" lamina make, therefore, curved or oblique outlines on the surfaces of the latter. The septa show, however, as straight or nearly straight lines in longitudinal and tangential sections.

A series of "tertiary" ingrowths further pass between the opposed surfaces of the "primary" lamina and these and the "secondary" septa. These processes are in the form of pillars, and are arranged in rows, longitudinally and transversely, appearing most regular in a longitudinal section. They are at right angles, or nearly so, to the "primary" lamina. The structure is further complicated by the fact that the "tertiary" columns, where they attach themselves to the spiral laminæ at their distal extremities, expand into a more or less regular cross-shaped form, the arms of which, uniting with those from the neighbouring pillars, form a reticulated framework. This, owing to the regularity of position of the columns, may almost be considered as forming a system of crossed rafters supporting the "roof" of the space contained between each two consecutive folds of the "primary" lamina, while the columns do not show any such expansion on the "floor." The spaces between the expansions or rafters, constituting a series of imperfect chambers, are further filled with a loose cancellated growth, which sometimes depends more than halfway to the "floor." This represents the system of "irregular anastomosing tubes" and "parallel columnar or tubular processes" occupying a like position in *L. persica*; but in the form now under consideration, probably owing to the greater size of the calcareous particles in proportion to that of the test, and its consequent rougher construction, no distinct tubulation is recognizable.

The greatest number of convolutions of the "primary" lamina actually observed is seventeen. Ten is a very common number in average-sized specimens. The average breadth of the space enclosed between two successive convolutions of the lamina is one hundredth of an inch; and this is maintained with considerable regularity, though in young specimens the first two or three whorls are much less. The "tertiary" processes or pillars, and the bars of the reticulated framework connected with them, are generally in diameter from one four-hundredth to one three-hundredth of an inch, very rarely as much as one hundredth.

The "primary" lamina, as in *L. persica*, is a thin and definite wall, generally appearing in microscopic sections as a well-defined,

* *Op. cit.* p. 743.

though often somewhat flexuous dark line. The "tertiary" ingrowths, or pillars, are composed of comparatively large particles, though these scarcely ever attain a size of one thousandth of an inch. Though rough in outline when examined under a high power, they are well defined and compact-looking at their proximal extremities; where they are involved in the spongy growth from the roof, they become less definite and occasionally appear almost to vanish before uniting with the lamina.

The expansions of the pillars against the roof, or rafters as they have been called, are much deeper than wide, and though definite and clearly seen in tangential sections of the lamina, are generally not distinguishable from the spongy ingrowth in transverse or longitudinal sections. Both the rafters and cancellated ingrowth appear to differ much in texture from, and to be much more transparent than, the columns. The secondary ingrowths, or septa, are of similar material, and in many cases are scarcely to be distinguished but for the expansion of the pillars upon them.

The separation of the primary lamina from the subsidiary cancellated growth, said to be common in *L. persica*, and represented in plate lxxix. fig. 2 (*op. cit.*), has not been observed in any of these specimens, a circumstance probably in connexion with their smaller size and less complex structure. Many specimens show externally a layer of variable thickness of acervuline or irregular growth. This appears to occur chiefly in those examples which may be supposed to have attained maturity, and to have formed a stronger protecting crust round the delicate fabric of the test. Fig. 2 (Pl. VI.) represents this feature, which does not appear to be found in *L. persica*. A layer of chambers without any definite external lamina appears to be formed, and these chambers communicate outward, with still less regular openings, and degenerate eventually into a cancellated or spongy mass of calcareous particles, which is generally limited by a firmer and darker outer layer. Smaller Foraminifera are occasionally included in the substance of the test of the *Loftusia*, though much larger than any of the granular fragments usually composing it.

In the matrix of some of the specimens are a few examples of a form which, though seen only in transparent section, from its precise resemblance in size and shape to that figured by Mr. Brady as *Climacammeria antiqua** in his memoir on Carboniferous and Permian Foraminifera, I have no hesitation in referring to this species.

Mr. Brady says of the genus *Loftusia* that it would "seem to find a natural place at the head of the Arenaceous series of Foraminifera, a position corresponding to *Alveolina* in the Porcellanous group, and *Fusulina* among the Vitreous forms." It is indeed remarkable to find the Palæozoic forerunner of the more gigantic Tertiary *Loftusia* agreeing with it so precisely, even in many of the more minute points of structure. The case is analogous to that of the discovery by Mr. Brady in Carboniferous rocks of *Nummulina pristina*, which in the

* Monogr. Palæontographical Society, vol. xxx. p. 68, plate ii. fig. 8.

same way corresponds very closely with the Tertiary and modern Nummulites.

In the arrangement of the pillars uniting the folds of the lamina, the spongy ingrowth filling the chambers, and in other points, this *Loftusia* bears a striking resemblance to some forms of *Stromatopora*. It differs, however, in its regularly spiral character, and in the fact that no pores have been observed to traverse the "primary" lamina. It is scarcely probable, however, that the organic connexion between the different parts of the *Loftusia* was maintained only in directions parallel to the circuitous course of the lamina.

Genus Loftusia, Brady.

Loftusia columbiana, sp. nov.

Test oval; circular in transverse section; the ends rounded or very obtusely spindle-shaped; chambers many, narrow; septa very oblique, more nearly parallel to the sides of a cylinder than is the primary lamina; primary lamina and septa, or "secondary" ingrowths, supported by pillars or "tertiary" ingrowths; pillars numerous, arranged in parallel lines transversely and longitudinally, expanding laterally at their distal extremities to form imperfect chambers, which are filled with a loose, granular, cancellated growth. Exterior of test frequently becoming irregular and acervuline. Length of test about $\frac{30}{100}$ of an inch, width of test about $\frac{19}{100}$ of an inch; intervals between successive folds of the adult primary lamina about $\frac{1}{100}$ of an inch.

Carboniferous Limestone, Marble Cañon, British Columbia.

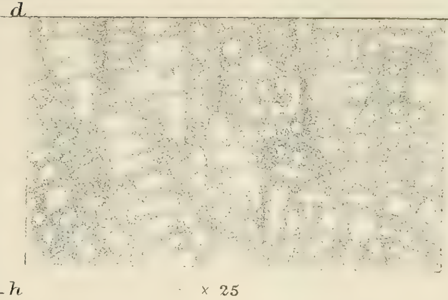
DESCRIPTION OF PLATE VI.

Fig. 1 represents portion of a transparent section, nearly at right angles to the longer axis of the Foraminifer. The test is represented by the darker shading, while more transparent calcite fills the chambers. The primary lamina is designated by *a*, and is seen to be thickened by the spongy ingrowth. *b* designates one of the more perfect secondary growths or septa. Many of the tertiary ingrowths end proximally before reaching the inner lamina; this may arise in some cases from the slight obliquity of the plane of section to the direction of their axes. That the section is not truly through the centre of the form is seen at *d*, where it becomes tangential to the inner layer, and exhibits a portion of the primary lamina in plan. (× 25.)

Fig. 2 is a portion of a longitudinal section of the outer part of the test. *a* designates the primary lamina; *c* the tertiary processes or pillars. *e*, *f*, & *g* refer to the acervuline or irregular exterior portion, well developed in this specimen. At *e* an irregular tier of chambers has been formed, which pass outwards in some places almost imperceptibly into *d*, a spongy or cancellated mass, which is generally limited externally by a more or less definite wall, *g*. The secondary growths, or septa, are not seen in this section, and this is very frequently the case in longitudinal sections. It arises partly from the greater transparency of these as compared with the thickened floors and the pillars, and apparently partly also from the circumstance that they are in reality more fragile. (× 25.)

Fig. 3 represents a portion of a longitudinal tangential section, which is very instructive, as showing nearly all parts of the test. This may profi-

1.



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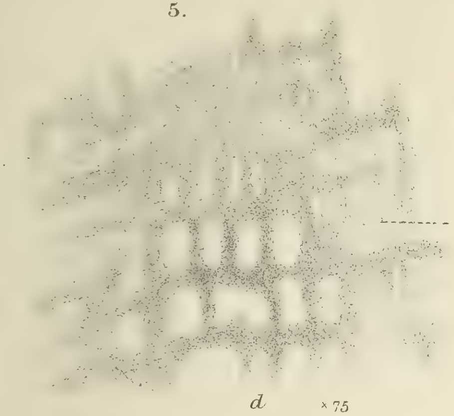
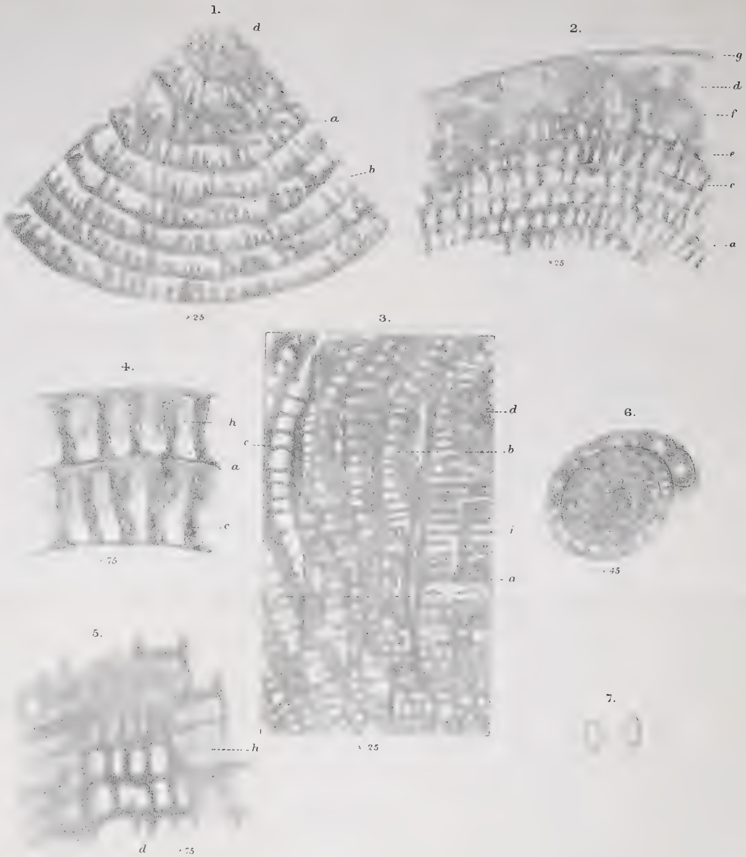


7.

A. S Foord lith.

Mintern Bros. imp.

LOFTUSIA COLUMBIANA.



A. S Foord lith. Mintern Bros imp

LOFTUSIA COLUMBIANA.

tably be compared with that given on plate lxxix. fig. 1 of Messrs. Carpenter and Brady's memoir. *a* indicates a part of the primary lamina, which is thickened, as before described, and may consequently be seen as a series of rather broad dark zones, indefinite on their inner edges, and running parallel to each other. *b* points out one of the secondary growths or septa; these may be seen running parallel to the longitudinal axis of the form. They appear wide, from being cut obliquely, but also, in many cases, from the identification with them of the longitudinal rods or rafters formed by the expansion of the pillars. At right angles to these, at *i*, are seen rods formed by the union, transverse to the axis, of the distal ends of the pillars. At *c* the section becomes nearly radial, and the pillars are seen as in figure 2. At *d* part of the thickened primary lamina is shown in plan. (× 25.)

Fig. 4 is nearly longitudinal and radial, representing part of three folds of the primary lamina (*a*) and the pillars uniting them (*c*). The irregularities of these are shown, and the cancellated growth from the inner side of the lamina is indicated by *h*. (× 75.)

Fig. 5. Portion of the thickened primary lamina shown in plan. At *d* the greater part of the spongy thickening has been removed in grinding down the section. The rafter-like thickenings from the intersections of which the columns spring are here clearly seen. The darker zone surrounding this part represents the primary lamina and its thickening (*h*) obliquely cut. Where, at the edges, the section becomes more nearly at right angles to the curved lamina, the pillars may be seen running out. (× 75.)

Fig. 6. Transverse section through the nucleus of a very young specimen, showing the first convolutions. (× 45.)

Fig. 7 represents the external form of the organism of actual size. The figure on the right is of an unusually long variety.

6. *On the* Tertiary Deposits *on the* Solimões *and* Javary Rivers, *in* Brazil. By C. Barrington Brown, Esq., F.G.S., Assoc. R.S.M. *With an* Appendix, *by* R. Etheridge, Esq., F.R.S., V.P.G.S. (Read June 19, 1878.)

[Plate VII.]

Whilst engaged on the Geological Commission of the Amazon Steam Navigation Company of London, in the year 1874, I had an opportunity of examining some beds on the banks of the Solimões, or Upper Amazon, and one of its tributaries, the Javary, which contained similar species of fresh- and brackish-water shells to those found in the Tertiary beds at Pebas, still further up the Amazon. These, I naturally concluded, were part of a southerly extension of the same deposit; and my conclusion is, I think, borne out by the facts.

Thinking that any additional records of this highly interesting Tertiary deposit might prove acceptable to geologists, I have embodied the scanty results of my investigations in the present paper. Amongst the fossils I collected were some hitherto undescribed genera and species, which have now been examined by Mr. Etheridge, who has described them in an Appendix which he has done me the honour to attach to this paper.

The late Professor Orton was the first to mention the occurrence of fossiliferous beds on the Amazon; and Mr. Gabb, to whom he submitted the fossils for examination, pronounced them to be of Tertiary age. As Professor Hartt, in a paper "On the Tertiary Basin of the Marañon," published in the 'American Journal of Science and Arts,' vol. iv. July 1872, has already pointed out, Professor Orton erred in stating that these shells occurred in "the coloured plastic clays which stretch unbroken from the foot of the Andes to the Atlantic;" while Mr. Woodward, in his paper* on the Pebas fossils collected by Mr. Hauxwell, arrives at the mistaken conclusion that the Pebas beds are "evidently bed II. of the late Professor Agassiz's ideal" and erroneous "section."

Professor Hartt having very thoroughly examined the Éreré district, across which Professor Agassiz's section was run, is better able than I am to speak upon the subject; and I therefore refer any one interested in the matter to the first paragraph of page 58 of his paper above mentioned.

Regarding the error first referred to above, it is easy to see that Professor Orton has confounded together two distinct deposits—one being an old river-formation composed of coloured clays beneath, and white, red, and yellow sands above, capped by red clayey loam which passes into the sands; and the other, part of a set of blue fossiliferous clays containing seams of impure lignite.

This old river-deposit, spreading over a great portion of the

* 'Annals and Magazine of Natural History' for January and February 1871.

Amazon valley, similar to the loess of the Rhine, is of exceeding interest, cliff-sections of it, ranging from 10 to 300 feet in height, being exposed in many places on the banks of the great river and its tributaries, where, in their windings through their present alluvial plains, they pass at intervals by its edges. It lies unconformably upon the Tertiary clays; for, on the Javary, the white and red sands are seen forming the upper portions of some of the cliff-sections, resting on what are undoubtedly denuded surfaces of the fossiliferous beds. Unfortunately, in every instance, the actual junction of the two is obscured by talus and landslips. As every geologist who has worked in the tropics must be aware, cliff-sections are invariably unsatisfactory in their greater portions, owing to landslips caused by atmospheric agencies, and to the dense masses of vegetation which cover them with an impenetrable mask when their faces incline in a slight degree from the perpendicular. Again, another difficulty presents itself—the sections along a river bordered by recent alluvium are never continuous, long intervals of low mud shores intervening between each exposure, and forming puzzling breaks in their continuity, very trying to one who is endeavouring to trace out the sequence of a set of beds.

Professor Hartt, in the paper before referred to, speaking of some sections examined and described for him by a Mr. Steere, remarks as follows:—"In examining the above sections we find the surface-bed always composed of variegated clays, with more or less sand, which, according to Mr. Steere, were deposited on the much denuded surface of the lower fossiliferous beds, the last being clearly Tertiary." Here, then, we have further evidence that there is no relation between the two deposits, the upper being, as I before stated, a river-deposit, and the lower a brackish-water formation.

Previous to the time of my visiting the country, the Tertiary deposit had been traced from Loreto, in Peru, down the Amazon to a short distance below Tabatinga, in Brazil. The most easterly spot at which I met with it on the Solimões, or Upper Amazon, was in a cliff-section two miles below St. Paulo, a town situated on the southern bank of the river, at a distance of 1350 miles from its mouth, measured in a straight line, and 150 miles below Tabatinga. Following the bends of the river, the distance is 1922 miles. Although there were no fossils to be seen, yet, from its similarity to the fossiliferous beds on the Javary, I feel confident that it is part of the same formation.

A detailed section of it gives the following horizontal layers:—

Soil	Yellowish loam.	
Tertiary	10 feet.	Greyish-blue clay.
	5 „	Dull purplish clay.
	3 „	Dark clay, impregnated with vegetable matter.
	1 foot.	Impure lignite.
	10 feet.	Greenish-blue clay.
	1 foot.	Impure lignite.
	20 feet.	Greenish-blue clay.
	10 „	Bluish arenaceous clay, containing calcareous nodules.
River.		

Another section, nearer the town, gives the following:—

River-deposit.	29 feet.	Reddish arenaceous loam. White sand, with pebbles.
Tertiary	58 ,,	Bluish-grey clays. Greenish arenaceous clay.

It is difficult to determine whether the Tertiary beds ever extended eastward down the Amazon beyond St. Paulo ; for, with the exception of a blue shaly clay weathering of a brownish-green colour, lying at the base of the river-deposits, and only exposed when the waters are low, no beds are seen in any way resembling them. This shaly clay, which is seen in most sections on the Solimões as far down as the mouth of the Purus, is unconformable to the base of the overlying beds, and contains well-preserved leaves, which are of very doubtful value in determining its age. Beds of friable sandstone occupy its place below the river-deposit at Obidos and Montealegre; but not sufficient data have, as yet, been collected to show whether they are of Tertiary age or otherwise.

In ascending the river from St. Paulo, the next cliff-sections are at St. Cruz, and again at Caldeirão, on the north side of the Solimões some 84 miles on; but they do not expose any Tertiary beds.

Some 20 miles below the mouth of the Javary, on the south bank, the low cliffs there seen are composed of Tertiary beds, which, further on, at a place called Rebeirós, are fossiliferous. The section there exposed is as follows:—

River-deposit.	17 feet.	Red clay. Mottled grey and red clay.
Tertiary	1 foot.	White sand and gravel.
	5 feet.	Light greenish clay.
	12 ,,	Greenish-blue clay, with layers of shells, and having a layer in it of hard reddish clay full of shells.
River.		

The fossils in the greenish-blue clay are of the same kinds as those found in the sections on the Javary, described below, while the hard reddish clay contains a great abundance of small univalves.

The Tertiary beds first met with on the Javary are at the Barreiras (cliffs) of Santa Anna, where, at the foot of their sloping front of reddish and grey clays (a short distance below the landing-place), greenish clays containing brown concretionary nodules are seen. At the time of my visit the level of the Javary stood at 38 feet below its high-water mark of floods, and consequently was some 20 feet above its lowest level in the dry season. Thus it will be seen that a considerable portion of each cliff-section was hidden from view.

At Barreiras Braga the first bed of lignite, which is 2 feet 6 inches in thickness, is seen with its base at the water-level, dipping south at an angle of 3°. Lying upon it is a thick layer of greenish-grey arenaceous clay, containing shells like those at Canama, a section to be described further on. There is this difference, however, that the bivalves predominate in number over the univalves in this section, whilst at Canama they are more evenly balanced.

Again, amongst them was one large freshwater bivalve, which, owing to its friable condition, was so broken in its removal that it is impossible to say to what genus it belongs, though at the time I took it to be a *Hyria*. Upon the greenish clay comes grey clay, while all above that is rendered obscure by a landslip.

There are numbers of poor sections from which nothing can be clearly made out until some cliffs on the Peruvian side, a few miles below Canama, are reached, where the following section occurs:—

Tertiary	3 feet.	Reddish loam.
	13 "	Greyish clay.
	2 "	Impure lignite.
	13 "	Blue clay containing fossils.
	6 "	Greenish-grey clay.
	2 " 6 in.	Impure lignite.
	20 "	Soft light greenish-blue clay. Blue clay, with fossils.
River.		

Here I found some large freshwater shells (*Unio* and *Anodon*) in the blue clay below the upper lignite, and one small species of univalve different from those of the other sections; also a portion of the body-whorl of a large Gasteropod. At the lower end of the same cliffs the river-deposit, consisting of red loam and white sands, forms the greater portion of their height, and rests upon a dark grey clay, below which is the light greenish-blue clay usually found beneath the lower layer of lignite—thus showing evident unconformability, the upper beds and lignites having been denuded before the deposition of the sands and loam.

Undoubtedly the clearest section that I had an opportunity of examining was that at Canama, at a distance of 200 yards above the little settlement of that name, and some 50 miles up, in a straight line, from the mouth of the Javary. The arrangement there was as follows:—

River-deposit.	3 feet.	Reddish loam.
	5 " 6 in.	Grey clay, mottled with iron-oxide stains.
Tertiary	1 foot	Dull purplish clay, containing numerous casts of bivalves, chiefly of *Anisothyris*.
	14 feet	Slightly arenaceous bluish clay, containing great quantities of shells arranged in horizontal lines, chiefly *Anisothyris* and *Neritina*.
	1 foot	Nodular concretionary clay-rock, the concretional centres of which were composed of blue limestone, containing shells of same species as those in the clay.
	14 feet	Greenish-blue slightly arenaceous clay, containing shells sparingly scattered through it, of similar genera to those in the beds above, and two thin layers of concretionary calcareous nodules.
	1 foot 8 in.	Lignite.
	6 feet	Light blue clay.

This layer of lignite is composed of a hard brownish vegetable substance intimately mixed with earthy materials, and contains pieces of wood, the original appearances and texture of which are very slightly altered. It contains a thin layer, hardly an inch in thickness, of pure lignite, while all the rest is impure and uninflammable. Amongst the decidedly woody parts are surfaces covered with minute crystals of iron pyrites. The lignite exposed in the section at Canama-Settlement landing, though evidently a continuation of the same layer, differs exceedingly from the above in its upper half being composed of peaty matter containing vast quantities of entire and comminuted shells, most of which are minute univalves. Seeds or nuculæ of a species of *Chara* are also very common in it. The lower portion is composed of impure lignite, and does not contain any shells.

Although the cliff-front at the landing-place of Canama appears to have slipped, rendering the section doubtful, still I think the following is the true sequence of the beds :—

ft.	in.	
10	0	Yellowish clay containing layer of lignite.
4	0	Dull greenish-blue clay with fossils.
6	0	Light bluish clay.
2	10	Impure lignite with fossils in its upper portion.
3	0	Bluish clay with shells.
5	0	Sloping clay talus.
		River.

These beds dip east at an angle of 6°. The yellowish clay is slightly arenaceous in parts, and, where it reaches a level of about 6 feet above the water-line, contains numbers of fossil shells, chiefly of *Melania*, *Cerithium*, and *Anisothyris*, together with a very curious little *Neritina* marked with black dots. The shells found in the two clay beds of the above section are chiefly *Neritina* and *Anisothyris*.

From a perusal of the descriptions of the above sections it will be seen that though there is a great similarity in the composition of these beds in the various spots on the Javary where they occur, yet their thickness and relative positions vary greatly within short distances. While most of the sections show horizontal bedding, two of them, viz. that at Canama landing and that at Barreiras Braga, disclose clear dips at gentle angles. It is therefore next to impossible to construct a general section representing the true continuity of the whole along the river's edge with any degree of accuracy. It would appear that in being raised to their present position they have become in some degree disturbed. Again, on the other hand, if we compare the section that is described as occurring above Canama, on the Javary, with a section taken by Mr. Steere at Pebas some fifty miles to the northward, we find a remarkable similarity between the two, suggesting, in fact, that they are both on the same horizon. Mr Steere's section is as follows :—

	ft.	in.	
"Surface deposit ...	10	0	Red and white clay.
	5	0	Blue clay, full of fossils.
	13	0	Blue clay, with an occasional shell too badly preserved to be removed.
	0	6	Lignite. For a few inches above and below this the clay is filled with vegetable remains.
	15	0	Blue clay. In the middle is a band 3 feet in thickness containing shells.
			Talus disguising rest of section."

The chief differences in the two are, that in the place of the nodular calcareous bed of the upper Canama section, the Pebas section has a layer of lignite; while the arrangement of the fossils appears to be somewhat different. From my lower Canama section it would appear as if the upper bed of lignite corresponded in position with the nodular calcareous bed—in fact, that one passed horizontally into the other. It appears to me that the Pebas 13- and 15-feet beds of blue clay correspond exactly to, or are the same as, the two Canama 14-feet beds of blue clay. Thus it will be seen that though the sections vary on the Javary in short distances, still there is a remarkable similarity between one section there and one at Pebas.

One cannot fail to be struck with the great extent of these beds, occupying a tract of country, as far as at present known, of 300 miles in length by 50 miles in breadth, and containing, curiously enough, associated fresh- and brackish-water shells, as well as with their position at so great a distance from the Atlantic ocean. At the time of their deposition the physical features of the north-eastern portion of South America must have been vastly different from what they are at the present day. The sea then reached far inland, probably to 1500 miles west of its present shore-line, and covered the country which is now the valley of the Amazon. Instances of false-bedding, showing the action of the strong currents, being nowhere observable in the beds of this deposit which have been examined, it is probable that they were formed in comparatively still water, into which flowed numerous streams bearing much vegetable matter. I think we may infer that they are almost the highest beds of a series which has been deposited under similar conditions to delta-beds of the present day. No speculation of this sort can as yet take a definite form, but all must remain visionary until further data have been gathered bearing upon the extent, nature, and thickness of this deposit where it occurs in other portions of the same region. Then we may arrive at the true explanation of its deposition, and find out whether it is an old delta as supposed, or otherwise, as well as whence came the rivers which contributed to its formation.

It is with a view to assist in the elucidation of these problems that I have here recorded my observations on the structure and extent of these interesting Tertiary beds, where I have met with them.

APPENDIX.

Notes *on the* Mollusca *collected by* C. Barrington Brown, Esq., A.R.S.M., *from the* Tertiary Deposits *of* Solimões *and* Javary Rivers, Brazil. By R. Etheridge, Esq., F.R.S., V.P.G.S.

The collection of Tertiary Mollusca made by C. B. Brown, Esq., to illustrate a portion of his investigation of the geological features of certain portions of the Upper Amazon, although few in species, is nevertheless of value on account of its showing a considerable extension of these later Tertiaries on the Solimões or Upper Amazon and Javary rivers in Brazil, ranging over an area 300 miles in length by 50 miles in breadth; again, the great extension westwards of the Atlantic, probably, as Mr. Brown believes, some 1500 miles west of the present shore-line and covering the area now the valley of the Amazon, is of sufficient interest to demand some notice of the Mollusca once occupying the now elevated sea-, estuarine, and freshwater deposits.

Mr. T. A. Conrad* and Dr. H. Woodward† have both described certain species of Mollusca from these Tertiary deposits, many of them being the same as those collected by Mr. Brown, thus precluding other notice than reference to them in the volumes cited below. I am enabled to add and describe about fourteen new species or forms, or such as I cannot determine from the works of others.

Plantæ.

Chara (seeds of).

The only remains of this freshwater plant are some eight or ten seeds, smaller than those of our British Charas; nothing whatever can be determined as to the specific characters of the plant through the seeds. It is a widely distributed genus, occurring in stagnant, fresh, and brackish water. The Upper Eocene beds (Hempstead series) of Britain contain three species, and three occur in the Post-Pliocene series; we should expect to find the remains of this plant in extensive marsh and shallow-lake districts. The habit of the plant tends to its preservation, owing to the amount of carbonate of lime secreted in the stems and nuculæ. About forty species are known, and about fourteen are British.

Loc. Canama, in the lignite bed.

Mollusca.

Lamellibranchiata.

Dreissena acuta, Ether. (Pl. VII. fig. 1.)

I give this a provisional name, *first*, because it is the only specimen, and *secondly*, the *Dreissenæ* are so much alike that, without a

* Amer. Journ. of Conch. vol. vi. p. 192, t. 10, 11 (1871).

† Ann. & Mag. Nat. Hist. ser. 4, vol. vii. pp. 59, 101, t. 5 (1871).

proper series for comparison, it would be wrong to do more than give it a name for the purpose of recognition; the strong ridge, acute umbo, and longitudinal lines clearly determine it to be a *Dreissena*.

Dr. C. L. F. Sandberger, in his exhaustive work 'Die Land- und Süsswasser-Conchylien,' names many species of *Dreissena*; but none appear to agree with our form; the extremely acute and curved umbo and strong keel in our species distinctly separate it from the forms figured by Sandberger; his *D. claviformis* mostly resembles our specimen, but the ventral ridge is much more strongly marked than in his species.

Loc. Canama.

Anisothyris carinata, Conrad, *loc. cit.* p. 196, t. 10. f. 7; H. Woodward, *loc. cit.* p. 106, t. 5. f. 6.

This singular shell is without question the same as Conrad's *Pachydon carinatus*, which is so well described by Conrad and Woodward, *op. cit.*, that it needs no notice from myself. It evidently is an abundant shell in these Amazonian beds.

Loc. Canama.

Anisothyris tenuis, Gabb (*Pachydon*), American Journal of Conchology, vol. vi. p. 196, t. 10. fig. 1.
Pachydon tenua, Gabb, ib. vol. iv. p. 199, t. 16. fig. 6.

This shell is described and figured in the American Journal above quoted under the name *Pachydon*. Conrad suggested the name *Anisothyris* for this genus, the name "*Pachydon*" being preoccupied. Dr. Woodward adopts *Anisothyris* in his paper on the Tertiary shells of the Amazon valley, where the affinities and differences are also ably discussed.

Loc. Canama.

Anisothyris Hauxwelli, H. Woodward, *loc. cit.* p. 105, t. 5. f. 7.

There is no doubt this is the shell referred to in Dr. Woodward's paper, closely as it resembles *A. tenuis*.

Loc. Canama.

Anisothyris (Pachydon) tumida, Ether. (Pl. VII. fig. 2.)

Shell thick, tumid, obtusely triangular, equivalve, inequilateral, delicately wrinkled, with a shining epidermis; posterior area slightly flattened; anterior region nearly vertical or obtusely rounded; ventral margin much rounded; umbonal region thick; umbones incurved, contiguous; lunular area deep. Cardinal tooth deltoid, acute at the apex, and slightly erect; hinge-pit deep; lateral tooth thick, elongated; pallial impression simple; oral and anal scars placed very far forward and backward.

The umbonal region differs from that of *Corbula* in the spiral arrangement of the umbones, which are much incurved, and by the interlocking of the tooth in the left valve at the uppermost part of the lunule into that of the right valve*.

Corbula canamaensis, Ether. (Pl. VII. figs. 3, 3*a*.)

I have no means of determining whether this be a new species or not; the forms are so similar, and specific differences amongst them too slight to be observed from figures, unless specimens for comparison are before us. I give it a local geographical name, and figure the shell in case other specimens are collected from the same wide area; probably this form is estuarine. *Corbula* (*Potamomya*) *labiata* (*Azara*, D'Orb.), from the La Plata, and also from the Pampas and other places in the Argentine Republic, may be this species or a variety. Although this shell resembles *Anisothyris erecta*, Conr., and the figure by Dr. Böttger, Jahrb. k.-k. geol. Reichsanst. 1878, t. 14. f. 12, I still believe it to be quite distinct.

Loc. Canama.

Thracia?

One valve (left) only of this genus occurs. Although probably a mature shell, it is a small species; no name can be given to it.

Loc. Canama.

Lutraria?

Like the above (*Thracia*); only one valve of some small species occurs. Both appear to be marine genera; but we know not under what condition they were deposited or became associated with the estuarine and freshwater fossils. I name them with doubt.

Loc. Canama.

Anodon, sp.

Two fragments only testify to the freshwater condition of the strata in which they occur. The shell of this species must have been thick and large.

Loc. Cliffs a few miles below Canama.

Unio.

We have the anterior portion only of an elongated species. Umbo very anterior, eroded, having one large elongated tooth and slightly rugose posterior markings; one long posterior hinge-tooth occupies more than half the length of the shell. Shell thick.

Loc. Cliffs a few miles below Canama.

* Dr. H. Woodward, in his paper upon the Tertiary Shells of the Amazon valley, under the genus *Pachydon*, notices many affinities and differences between the above genus and certain allied forms, such as *Corbula*, *Azara*, *Neæra*, &c.

Gastropoda.

Pseudolacuna*, Böttger, 1878, Jahrbuch kaiserlich-königlichen geologischen Reichsanstalt, Wien, 1878.

Pseudolacuna macroptera, Böttg. *loc. cit.* (Pl. VII. fig. 12.)

Shell small, smooth, composed of six whorls; spire conical; the body-whorl greatly enlarged; left or columellar lip thick, reflected, possessing a single central tooth on the sigmoidal columella, and a smaller callosity on the upper portion; aperture elongated, somewhat trigonal and expanded, and acute or angular centrally, pointed at both extremities, emarginate at the base, or the anterior canal slightly recurved; outer or right lip thick.

This shell resembles in outline the genus *Alycæus* of Gray, but the columellar tooth, elongated aperture, thickened peristome, and reflected callosity on the columella remove it from that genus.

Loc. Canama.

Natica ——?

Three specimens which appear to belong to this genus are amongst the shells collected. They are thick and heavy for so small a species, and appear to me to be somewhat abnormal forms of *Natica*.

Shell thick, smooth, glazed, and dense; whorls five, ventricose; sutures deep; body-whorl large; aperture elongated; left or columellar lip thick; near posterior canal much thickened; right lip slightly waved; umbilicus (?) small.

Loc. Canama.

Neritina puncta, Ether. (Pl. VII. fig. 9.)

Shell small, semiglobose, thick; outer lip of peristome much expanded; surface of shell covered by dark, nearly equal-sized, spots, which appear to be epidermal or cuticular (they disappear with the removal or destruction of the outer shelly covering); columella vertical, with six or seven obscure teeth along its edge; the pigment-dots are arranged in lines springing from the apex, as in *Neritina ziczac*, and follow the lines of shell-growth. Although the markings may have no specific value, I nevertheless refer to them as a means of recognizing the shell in the same deposits.

Loc. Canama (in yellow clay).

Neritina ziczac, Ether. (Pl. VII. figs. 10, 10*a*.)

Shell semiglobose, broader than high; aperture lunate; outer lip expanded, thin, or acute; columella broad, flat, and straight, having

* I had proposed the name *Alycæodonta* for this shell, naming the species after Mr. B. Brown. I find, however, that Dr. Oskar Böttger, of Frankfort, has already described it, giving it the above name (*Pseudolacuna macroptera*). There can be no doubt it is Dr. Böttger's genus. We both apparently gave a new generic name to this shell; but priority must be given to Dr. Böttger, on account of date of publication, as, since my notice of the shell, the description by Dr. Böttger has appeared, which necessitates my withdrawal of the name *Alycæodonta*.

numerous small denticulations along its vertical edge; columellar side of body-whorl covered by a glossy expanded fold, nearly equalling in size or expansion the aperture-opening; outer surface of shell glossy, and covered with wavy, subangular, or zigzag lines, all emanating from the apex of the shell and ranging vertically down the expanded body-whorl.

Loc. Canama.

Odostomia, sp.

Three specimens of this genus occur. They are not in a condition to be named specifically.

Loc. Canama.

Hydrobia dubia, Ether. (? Paludestrina). (Pl. VII. fig. 11.)

We have forms of this genus, or one strongly resembling it; they do not appear to have been noticed by Gabb or Conrad. Whorls five, smooth, rounded; outer lip thin, the inner slightly reflected over the umbilicus; body-whorl large; sutural constrictions deep. I can hardly detect any difference between this and our *Hydrobia pupa*, and, as may be expected, many *Rissoæ* may be mistaken for it also. There are only two specimens, not well preserved, and I name them *with much doubt.*

Loc. Canama.

Isæa?, Conrad.

Isæa, sp., allied to *I. Ortoni*, Gabb.

Mesalia, sp., Amer. Journ. Conch. vol. iv. p. 198.

Isæa, Conrad, Amer. Journ. Conch. vol. vi. p. 193, t. 10. f. 10–13 (1870–71).

Two small shells seem to me to belong to the above species. Mr. Gabb's specimens were too imperfect to show some characters; ours are little better, and fail to show the mouth.

Loc. Canama.

Dyris, Conrad.

D. gracilis, Amer. Journ. Conch. vol. vi. p. 195, t. 10. f. 8.

Conrad figures and describes a slender shell, to which I refer our four specimens. The figure is of little value; but the short description agrees with our forms.

Loc. Canama.

Assiminea, Leach.

A. crassa, Ether.

Shell thick, composed of five ventricose whorls; sutures deep; body-whorl large, somewhat subangular in outline; inner or columellar lip thick and reflexed over the columella.

The shell-structure in these *Assimineæ* is thicker than usual, which may be due to their habit of life. To refer them to any British species would lead to error, for the want of better evidence and knowledge of the animal.

Loc. Canama.

Fenella, Adams.

Only one specimen of this genus (fam. Rissoidæ) appears amongst the small shells in the collection; no specific name can be appended.

Shell small, elongated, composed of seven whorls, those of the spire having *two* concentric lines near the base of each whorl, the body-whorl possessing three or four; aperture elongated; columella thick. Length $\frac{3}{16}$ inch.

Loc. Canama.

Cerithium coronatum, Ether. (Pl. VII. fig. 5.)

Shell elongated; whorls ten, the first six or seven smooth, or nearly so, the remaining whorls ornamented with tubercles and coarse lines; tubercles arranged in a single row along the shoulder of each whorl below the sutural line; outer lip notched close to the shoulder of the whorl and suture in a line with the line of nodes or tubercles; inner or columellar lip reflected; base of the body-whorl with four or five strongly marked concentric lines and a few fainter ones near the anterior canal, and crossed by fine lines of growth.

Loc. Canama.

Melanopsis? Brownii, Ether. (Pl. VII. fig. 4.)

There are some eight or ten specimens of this species; but I have nothing to compare them with. The genus is represented by a large number of species distributed world-wide; it apparently, with the other molluscan remains of the Amazon valley, was estuarine in habit.

Spec. char.—Shell turreted, clongated; whorls five, sides vertical; sulcus or suture at junction of the whorls depressed, the sutural edge elevated; upper whorls doubly carinated; body-whorl concentrically banded by nearly equidistant lines, slightly rugose at the base, here and there possessing a varice; anterior canal slightly notched; outer lip toothed; columellar lip slightly reflected and thick.

This shell much resembles a *Melania*, and but for the siphonal notch might be referred to that genus or its subgenus *Plotia*.

Loc. Canama.

Melania tricarinata, Ether. (Pl. VII. fig. 6.)

Shell small, elongated; whorls nine, ventricose, bevelled, and deeply constricted on the upper part or shoulder of each whorl; three carinæ, or distinct lines, occur on all the whorls except the last or body-whorl, which possesses four; aperture ovate; anterior canal short, very slightly notched. Length $\frac{1}{4}$ inch.

Loc. Canama.

Melania scalarioides, Ether. (Pl. VII. fig. 8.)

Shell small, turreted, ribbed, or strongly costated; whorls seven, ventricose; sutural constrictions deep; the varices, or costæ, are nodular about the middle of each varice, producing on each whorl a kind of median keel or projection; aperture oblique or ovate. Length $\frac{3}{16}$ inch.

This shell resembles *Prososthenia Schwartzi* (Neumayr), Sandberger, 'Land- und Süsswasser-Conchylien,' p. 673, t. 32. f. 2. I may almost say it is the same species, if we may trust the figure in Sandberger's plate. I have doubts, however, about its even being a *Melania*. Nevertheless I name it *M. scalarioides*, at the same time referring to the above work for comparison.

Loc. Canama.

Melania bicarinata, Ether. (Pl. VII. fig. 7.)

Shell small, elongated; whorls seven; two carinæ occur on all except the body-whorl, which has three; considerable space occurs between the double lines, and this is occupied by a smooth area, which apparently has no markings; aperture elongated; columella obtusely carinated and thickened. Length $\frac{1}{4}$ inch.

Loc. Canama.

Myliobatis, sp., or Zygobatis. (Pl. VII. fig. 13.)

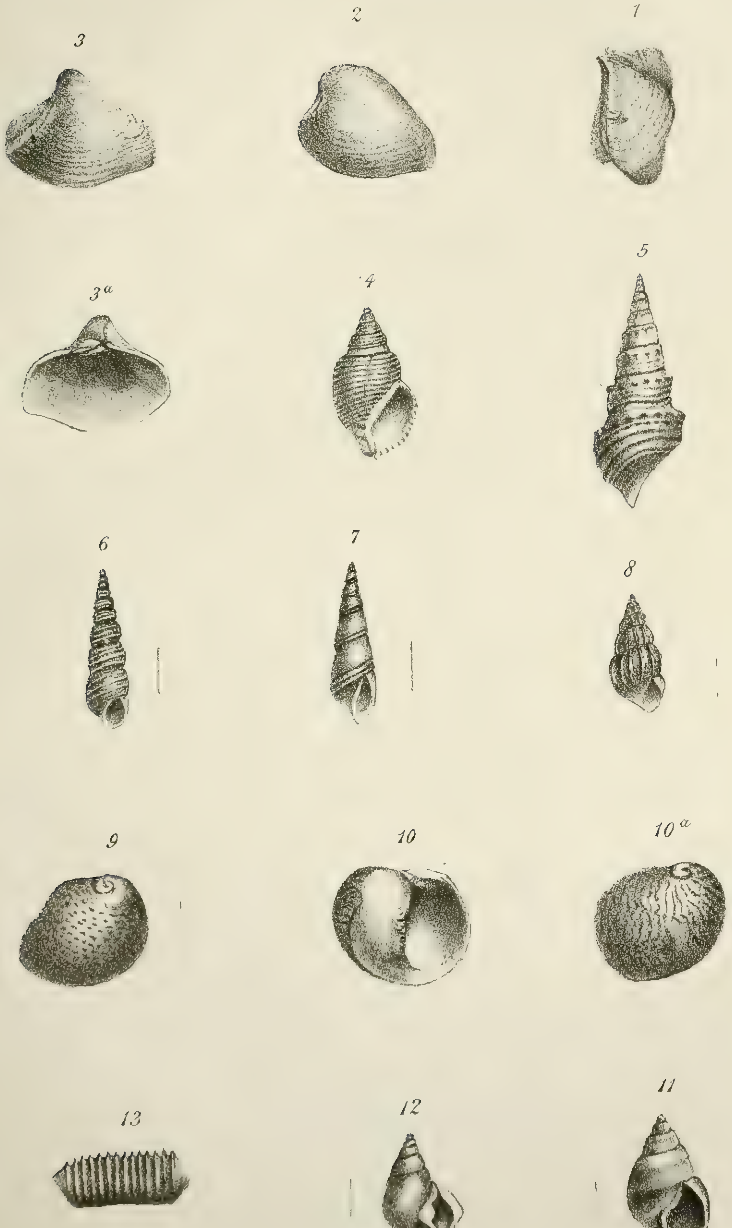
A single plate only (median or lateral) of a palatal tooth; how it came into the freshwater beds of Canama is doubtful, although the "rays" are said to occur high up in the Amazon river. It may, however, have been derived from some Eocene beds within the area.

Loc. Canama (from the lignite bed).

EXPLANATION OF PLATE VII.

Fig. 1. *Dreissena acuta*, Ether.
2. *Anisothyris* (*Pachydon*) *tumida*, Ether.
3. *Corbula canamaensis*, Ether.
4. *Melanopsis*? *Brownii*, Ether.
5. *Cerithium coronatum*, Ether.
6. *Melania tricarinata*, Ether.
7. *Melania bicarinata*, Ether.
8. *Melania scalarioides*, Ether.
9. *Neritina puncta*, Ether.
10. *Neritina ziczac*, Ether.
11. *Hydrobia dubia*, Ether.
12. *Pseudolacuna macroptera*, Böttg.
13. *Myliobatis* or *Zygobatis*, sp. (plate of a palatal tooth).

The short lines appended to some of the figures indicate the size of the specimens; the rest are of the natural size.



G. Sharman ad nat. del. et lith.

Hanhart imp

AMAZONIAN TERTIARY FOSSILS.

7. *On the* Upper-Greensand Coral Fauna *of* Haldon, Devonshire.

By Professor P. Martin Duncan, M.B. Lond., F.R.S., &c.
(Read November 20, 1878.)

[Plate VIII.]

MM. Milne-Edwards and Jules Haime, writing in 1850, in their celebrated 'Monograph of the British Fossil Corals,' stated that "the class of Polypi had not, in all probability, numerous representatives in the beds where the Upper Greensand was deposited; for we have as yet seen only four British species belonging to that formation; and the English geologists do not appear to have met with many more. Most of the fossils belong to the family Astræidæ, and have been found at Haldon, at Blackdown, or at Warminster"*.

During the twenty-eight years which have elapsed, so many specimens of fossil corals have been discovered in the English Upper-Greensand series that the coral fauna of that age has become an important one, and requires more careful examination by palæontologists.

MM. Milne-Edwards and Jules Haime described a few specimens which had been collected and studied, to a certain extent, by Mr. R. Godwin-Austen and Prof. John Morris. Thus *Peplosmilia Austeni*, Edw. & H., of Haldon, was described by the French naturalists from Mr. Austen's specimen, and two species, called by Mr. Godwin-Austen *Astræa elegans* and *Astræa escharoides*, were mentioned in the Monograph; but as the specimens were not available, the forms were not delineated.

The Blackdown Greensand contained Morris's *Turbinolia compressa*, which became *Trochosmilia tuberosa*, Edw. & H.; and *Parastræa*, now *Favia striata*, Edw. & H., came from the same locality. The Warminster Greensand yielded *Micrabacia coronula*, Goldfuss, sp., to the researches of the distinguished zoophytologists.

Some time afterwards the same authors published a description of *Smilotrochus Austeni*, Edw. & H., from the Farringdon Greensand, and altered the generic title of the Trochosmilian form from Haldon to *Smilotrochus tuberosus*, Edw. & H. One new form was thus added to the list.

In 1869 and in 1870 the portion of the 'Supplement to the British Fossil Corals' relating to the corals of the Upper-Greensand series was published by the Palæontographical Society, and considerable additions were made by me to the fauna from Haldon. The coral fauna of the Cambridge Greensand was also described; moreover an Irish coral species was determined from a similar geological horizon.

The Haldon species had been carefully collected by Mr. W. Vicary, F.G.S.; and the Cambridge Greensand corals were placed in my hands by Mr. James Carter and the Rev. Thomas Wiltshire. The results

* MM. Milne-Edwards and Jules Haime, Palæontolog. Soc., Monog. Brit. Foss. Corals, part i. 1850.

of their examination, published in the above-mentioned Monograph, showed that the following species were distinguishable:—

Placosmilia cuneiformis, *Edw. & H.*	Cyathophora monticularia, *D'Orb.*
—— Parkinsoni, *Edw. & H.*	Favia minutissima, *Duncan.*
—— magnifica, *Duncan.*	Astrocœnia decaphylla, *Edw. & H.*
—— depressa, *E. de From.*	Isastræa haldonensis, *Duncan.*

These eight species are from Haldon.

The specimens from the Cambridge Greensand are:—

Smilotrochus elongatus, *Duncan.*	Onchotrochus Carteri, *Duncan.*
—— angulatus, *Duncan.*	

And Farringdon yielded *Smilotrochus Austeni*, Edw. & H.

The corals of the Cambridge and Farringdon Greensands are small, simple, and probably lived in a few fathoms of water, with their bases in sand or mud; but those of Haldon, mentioned above, tell a different story, the truth of which is enhanced by the later collections of Mr. W. Vicary. Not only are the simple corals, the *Placosmiliæ*, and *Peplosmiliæ*, for instance, large forms (and, indeed, some are as large as the ordinary simple tropical corals of the present day), but the last four in the Haldon list indicate the conditions of a fringing reef. The *Isastræa* and the *Astrocœnia* were vigorous forms, and with the *Favia* and *Cyathophora* were true limestone-builders.

During the last few weeks Mr. W. Vicary has placed his collection again at my service; and I find that the list of species requires much addition, and that some of the new forms are very remarkable.

The following is the list of the new species from Haldon described in this communication:—

Trochosmilia varians, *Reuss.*	Oroseris haldonensis, sp. nov.
Haldonia Vicaryi, sp. nov.	Actinacis stellulata, sp. nov.
Stelloria incrustans, sp. nov.	—— insignis, sp. nov.
Baryhelia reticulata, sp. nov.	Trochoseris constricta, sp. nov.
Thamnastræa belgica, *Edw. & H.*	—— Morrisi, sp. nov.
—— Ramsayi, sp. nov.	Heliopora cærulea, *Grimm.*

These twelve species, with the eight noticed already, and the first one described by MM. Milne-Edwards and Jules Haime, form the twenty-one species of the Haldon Greensand coral fauna. In order to comprehend the nature of this fauna it is necessary to consider the morphology of the species as explained in their description.

Description of new Species of Corals from the Haldon Greensand, and notices of the previously described forms lately found there.

MADREPORARIA APOROSA.

Family ASTRÆIDÆ.

Group Trochosmiliaceæ.

Trochosmilia varians, Reuss, Denkschr. der Wiener Akad. der Wiss. t. vii. p. 88, pl. 6. figs. 7–11 (1854).

The corallum is upright, straight, and has a large base; its height varies in different specimens. The costæ are alternately rather projecting close to the calicular margin, and are formed by simple series of granulations. The calice is elliptical in outline, the axes being as 1 : $1\frac{1}{2}$. There are four or five cycles of septa, and the septa are unequal and stout. The species is from the Gosau Cretaceous series of the age of the French Craie tuffeau.

English Locality. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

Group Eusmilinæ aggregatæ.

Haldonia, gen. nov.

The corallum is massive; the corallites are united by their walls; the calices are circular in outline, and there is no columella. Pali exist before the primary septa. The costæ are well developed, and do not unite with those of other calices, or pass from one calice to another. The endotheca is abundant, and closes the calice inferiorly as if by false tabulæ.

Haldonia Vicaryi, sp. nov. (Pl. VIII. figs. 2, 3.)

The corallum is massive, with a broad incrusting base and a slightly convex surface. The calices are separated by a slight depression, are rather raised, deep, and widely open. The costæ are well developed, slightly erect, larger than the septa, long, straight, broad, separate, widest without and rounded above; those of the first and second cycles are the largest, the primaries exceeding the secondaries. The septa are slender, but well developed, long vertically, and not exsert; they are unequal, and form three cycles in six systems; the primaries are the longest, and reach furthest towards the axial space. The pali are small, distinct, and narrow, but they are largely granular and broadly ridged, and are placed just within the primaries. The breadth of the calices is $\frac{1}{10}$ inch.

Loc. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

Group Lithophylliaceæ meandroidæ, Edw. & H.

Stelloria incrustans, sp. nov. (Pl. VIII. figs. 4, 5.)

The corallum incrusts shells or littoral concrete; it is flat, slightly uneven, gibbous, and depressed here and there, and covers much space. The valleys are short, straight, often radiating, sinuous, or shorter and gyrose; they are very narrow, but are deep and without columella, and are closed at some depth by an endotheca resembling tabulæ, which do not, however, quite reach across. The collines are very narrow, sharp; and the septa join above on a wavy ridge; they reach but a small distance from the colline, but are long vertically, and are subequal and placed at regular intervals, and are crowded and stout. The endotheca is situated deeply, and extends more or less across the valley. Width of a valley and two collines from $\frac{1}{20}$ to $\frac{1}{10}$ inch.

Loc. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

Family OCULINIDÆ.

BARYHELIA RETICULATA, sp. nov. (Pl. VIII. fig. 1.)

The corallum is massive, short, and irregularly ramose. The calices are few in number, are placed without any definite order, and are irregularly separate; some are sunken in the cœnenchyma, and others are on short conical eminences; they are deep, with solid walls, and there are six large septa, and a rudimentary one exists between some of the larger. There is no columella, and there are no pali. The surface of the cœnenchyma is microscopically reticulated, and the meshes are small and irregular, but very distinct, the ridges being thin and short. There are no costæ. The diameter of the calices is from $\frac{1}{12}$ to $\frac{1}{10}$ inch.

Loc. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

MADREPORARIA PERFORATA.

Family FUNGIDÆ.

Subfamily LOPHOSERINÆ, Edw. & H.

THAMNASTRÆA BELGICA, Edw. & H.

This species has not been satisfactorily diagnosed by MM. Milne-Edwards and Jules Haime; but the forms under consideration from Haldon, which appear to be stunted specimens of it, show the following characters:—The corallum is in the form of a gibbous, thin, incrusting lamina. Calices very small, less than $\frac{1}{20}$ inch in diameter, shallow, with a papillary columella. Septa broadly dentate above, stout, subequal, the primaries being the longest. The costæ are bifurcations of the septa.

In the collection of W. Vicary, Esq., F.G.S., Exeter.

THAMNASTRÆA RAMSAYI, sp. nov. (Pl. VIII. fig. 6.)

The corallum is convex above; the calices are small (less than $\frac{1}{10}$ inch in diameter), often crowded, and now and then forming short series. The columella is large and trabecular, with a few papillæ. The septa, twenty-four in number, are slender, unequal, some not reaching the columella, and the costæ are more numerous than the septa.

Loc. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

OROSERIS HALDONENSIS, sp. nov. (Pl. VIII. figs. 9 & 10.)

The corallum is large, not very thick; it incrusts and has a subplane surface. The calices are in small series separated by well-developed short collines, or isolated and in linear groups and separated by a colline. The calices are irregular in shape, rather deep, and there is no columella or barely the vestige of one. The septa are usually 24 in number; and the costæ are close, subequal, long, thin, and much more numerous than the septa, two or three uniting to form the septum. The trabeculæ are well developed. There are 48 costæ, as a rule, and others which are on the collines besides, to each ordinary calice. Breadth of calice $\frac{1}{10}$–$\frac{2}{10}$ inch.

Loc. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

Subfamily Turbinarinæ, Edw. & H.

Actinacis stellulata, sp. nov. (Pl. VIII. fig. 7.)

The corallum is incrusting and moderately thick. The cœnenchyma is well developed, and separates the calices, which are circular in outline, shallow, and not well defined on account of the continuation of the septo-costal system into neighbouring calices. The columella is small, but distinct. The pali connect twelve septa with the columella, and are subequal. There are two cycles of septa, and the laminæ, as well as the costal prolongations, are trabecular, and there are stout, low, long, broad and rounded spines on their free upper surface. The intercalicular space is covered with costæ; thin ornamented and intercostal spaces. The breadth of two calices and an interspace is $\frac{4}{10}$ of an inch.

Loc. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

Actinacis insignis, sp. nov. (Pl. VIII. fig. 8.)

The corallum is flat, low, and incrusting. The septa, from 12–18 in number, unite by their pali in an axial ring. The costæ, more numerous than the septa, are crowded, and are joined by synapticulæ. The septa are minutely trabecular. Breadth of calice about $\frac{1}{10}$ inch.

Loc. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

Section Simplices.

Trochoseris constricta, sp. nov. (Pl. VIII. figs. 11 & 12.)

The corallum is straight and constricted between the broad base and the equally broad and widely open shallow calice. The costæ are small, very numerous, close, slightly unequal, largely granulate, and projecting outwards at the margin, where they are largest. The septa are numerous (120), close, arched, long; the higher orders unite with the next, and these with the tertiary, forming groups. The primary septa are separate, and many septa dip into the shallow axial space. The synapticulæ are rare; the columella is very small and papillary. The length of the corallum is $\frac{6}{10}$, and the breadth $\frac{5}{10}$ inch.

Loc. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

TROCHOSERIS MORRISI, sp. nov. (Pl. VIII. figs. 13–15.)

The corallum is conical and short; the broad, circular, widely open, shallow calice is much broader than the length of the whole. The septa are numerous, close, granular laterally and superficially, and unite in groups; the largest reach the axial space and correspond externally with costæ. The smaller septa occasionally fuse into the sides of the larger, besides simply joining them. The axial space is long and deep, the columella is minutely papillary and small, and the synapticulæ are scarce but distinct. Length of corallum $\frac{5}{10}$ inch; breadth of calice $\frac{7}{10}$ inch.

Loc. Haldon. In the collection of W. Vicary, Esq., F.G.S., Exeter.

ALCYONARIA TABULATA.

HELIOPORA CÆRULEA, Grimm. (Pl. VIII. figs. 16–18.)

The corallum is massive and in thick laminæ, which are either flat or gibbous on the surface.

Cœnenchyma largely developed, and intertubular projections very small. Larger tubes wide apart, irregular, circular in outline, and with from 12 to 18 very slightly projecting septa. Tabulæ bent downwards.

There is a small variety of the species with a rounded surface and smaller tubes.

Loc. Haldon Greensand. In the collection of W. Vicary, Esq., F.G.S., Exeter.

Remarks on the Species.

The Trochosmilian belongs to a group which may be said to be characteristic of the Hippurite Chalk and Craie tuffeau.

Baryhelia is a remarkable genus of the Oculinidæ without columella, pali, and costæ. Its species hitherto described have great calices, and they have been found in the Craie tuffeau. The new form has only generic alliances with them.

Haldonia is a new genus, and may be said to be a *Cyathophora* with pali; but the costæ are not continuous. The species is a very beautiful form, and conforms to the type of the age.

Stelloria is a genus restricted to the Craie tuffeau of Le Mans, Ile d'Aix, Gosau, and Piesting, in Europe; but it is closely allied to the *Cœloriæ* of the Red Sea and Pacific and of the West-Indian Miocene. A *Stelloria*, not without its affinities to the Haldon form, is described by Stoliczka from the Turonian of South India. The new species is very common; and although its specimens do not grow into very large forms, yet the presence of small forms is very significant so far as external conditions are concerned.

The species of *Thamnastræa* are stunted forms; they incrust other substances; and one of them has the peculiarity (which is common to several Haldon species of different genera) of having more costæ than septa from the latter branching.

The species of *Actinacis* are very interesting; they are perforate corals allied to the Turbinarians of the Red Sea and Pacific, through *Astræopora* of the European Eocene deposits. All the hitherto known species here come from the Cretaceous series at Gosau and Figuières, which are the geological equivalents of Haldon; but the new species differ from the others, and have the granules or spinules between the calices, and which are in the position of costæ, in greater number than the septa.

Oroseris has hitherto been known as a genus of Jurassic age, and of the Oligocene or Eocene and Miocene. D'Orbigny has described a doubtful species from the Neocomian, and that now presented clearly fills up a part of the gap in the continuity of descent. The genus is extinct. The costæ are double the septa in number.

The species of the genus *Trochoseris* have a great range in time and space. The first which appeared was in the Hippurite Chalk and came from Gosau; the type was continued into the Eocene, and a recent species lives amongst the Philippines. The new species are thoroughly distinct from the others.

Heliopora, formerly a tabulate Madreporarian genus, has now, under the admirable study of Moseley, been placed amongst the Alcyonaria. Its only living species is the blue *Heliopora* of the Pacific reefs, which is, usually, in the shape of lobed tufts or digitate fronds. Moseley has shown that its septa are very short and vary from 12 to 16. Several fossil Tabulata closely resembling *Heliopora cærulea*, Grimm, sp., have been described; and it is certainly curious that some nine of them should have come from the horizon of Gosau and Uchaux in the Hippurite Chalk. Others are supra-cretaceous, some being found in the Eocene. Reuss, apparently believing that a modern genus could not have been represented in the age of *Hippurites*, called one *Polytremacis*, and established several species; but MM. Milne-Edwards and Jules Haime restored some of the forms to *Heliopora*. The distinction was, that either the septa were 24 in number, or that there were traces of costæ, or that the septa were long- or short-pointed. These are not generic distinctions. *Polytremacis* is really *Heliopora*, although its species lived in the Turonian and Eocene. They are all probably descendants of *Heliolites* of the Palæozoic age.

The Haldon fossils cannot be distinguished from the incrusting form of recent *Heliopora cærulea*, and the shape of the corallum and some minor differences are the only distinctions between it and the type of MM. Milne-Edwards and Jules Haime. An incrusting form is in the British Museum. The colour of the fossil is rusty red.

Remarks on the Fauna as a whole.

The coral fauna of Haldon appears to be the northern expression of that of the French and Central-European deposits, which are the equivalents of the British Upper Greensand. It has but slight affinity with that of the Cambridge Greensand area, where the conditions do not appear to have been those favourable for a fringing reef. The Haldon deposit, so far as the corals are concerned, was a shallow-water one, and the zoophytes grew upon the rolled, broken, littoral concrete of the age. Almost all the species were incrusting; and yet some specimens are bulky, and, before the subsequent silicification, doubtless formed considerable masses of limestone.

A recent coral fauna possessing the genera whose morphology is closely allied to those of Haldon would indubitably be regarded as a tropical fringing-reef assemblage, requiring a mean surface temperature of at least 74° F. The condition of the comminuted shells and the presence of rolled pebbles amongst the supporting rock of the corals of Haldon testify to the energetic action of the sea there. Such a condition would be favourable to the growth of the compound and true reef-builders of the age. The fauna is a poor representation of that of Gosau; but the facies is the same. Its alliances with distant faunas are somewhat remarkable. *Astrocœnia decaphylla* is very common in all the Upper-Greensand reefs, and the Southern-Indian and the West-Indian deposits of that age contain it. *Stelloria* is also represented in the Southern-Indian * rocks by a closely allied species, although those of the intermediate deposits of Gosau are only generally allied with the Haldon form. The *Isastræa* I described some years since from Haldon is a multiseptate form akin to some from Gosau and to *Isastræa expansa* of Stoliczka from Southern India. Finally the small *Thamnastrææ* of the distant deposits are closely allied to those of Haldon.

Covered eventually by the chalk, this old littoral coral tract of this island must have sunk beneath the waves, and then the overcreep of the deep-sea ooze set in. But a deep limestone was not formed, and probably because the rate of subsidence was greater than the corresponding rate of upward coral-growth.

DESCRIPTION OF PLATE VIII.

Fig. 1. *Baryhelia reticulata*, sp. nov., calice and cœnenchyma, magnified.
2. *Haldonia Vicaryi*, sp. nov., calices, magnified.
3. The same, vertical section, showing septa and pali.
4. *Stelloria incrustans*, sp. nov., part of surface, nat. size.
5. The same, magnified.
6. *Thamnastræa Ramsayi*, sp. nov., showing septa and colline, calices, magnified.
7. *Actinacis stellulata*, sp. nov., calices and interspace, magnified.
8. *Actinacis insignis*, sp. nov., calices, magnified.
9. *Oroseris haldonensis*, sp. nov., part of corallum, nat. size.
10. The same, calices, magnified.
11. *Trochoseris constricta*, sp. nov., nat. size.
12. The same, part of calice and septa, magnified.
13. *Trochoseris Morrisi*, sp. nov., nat. size.
14. The same, calice, magnified.
15. The same, synapticulæ, magnified.
16. *Heliopora cærulea*, upper surface of corallum, natural size.
17. The same, a calice, magnified.
18. The same, tabulæ, magnified.

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* Ferd. Stoliczka, "Cret. Fauna of Southern India," Pal. Indica, ser. 4, vol. iv. pl. viii. figs. 4 & 5.

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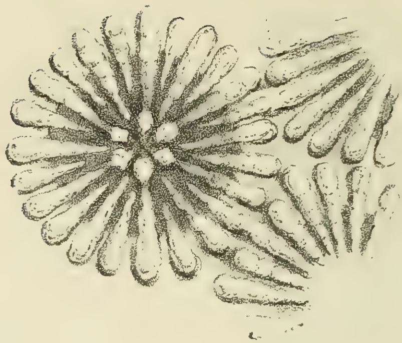

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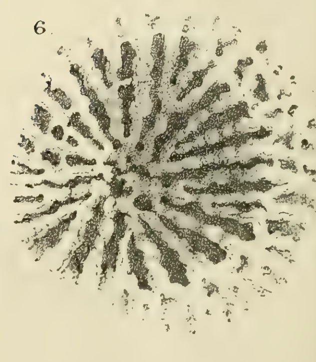

G.R. De Wilde del. P.M. Duncan dir.

CORALS F

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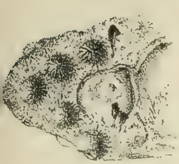

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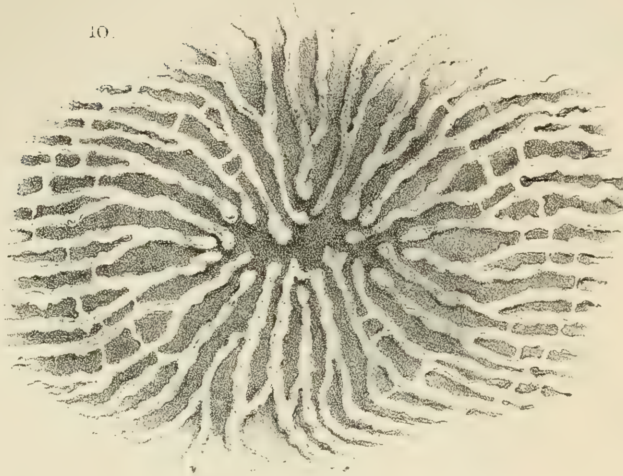

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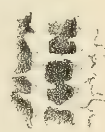

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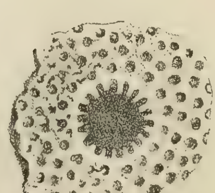
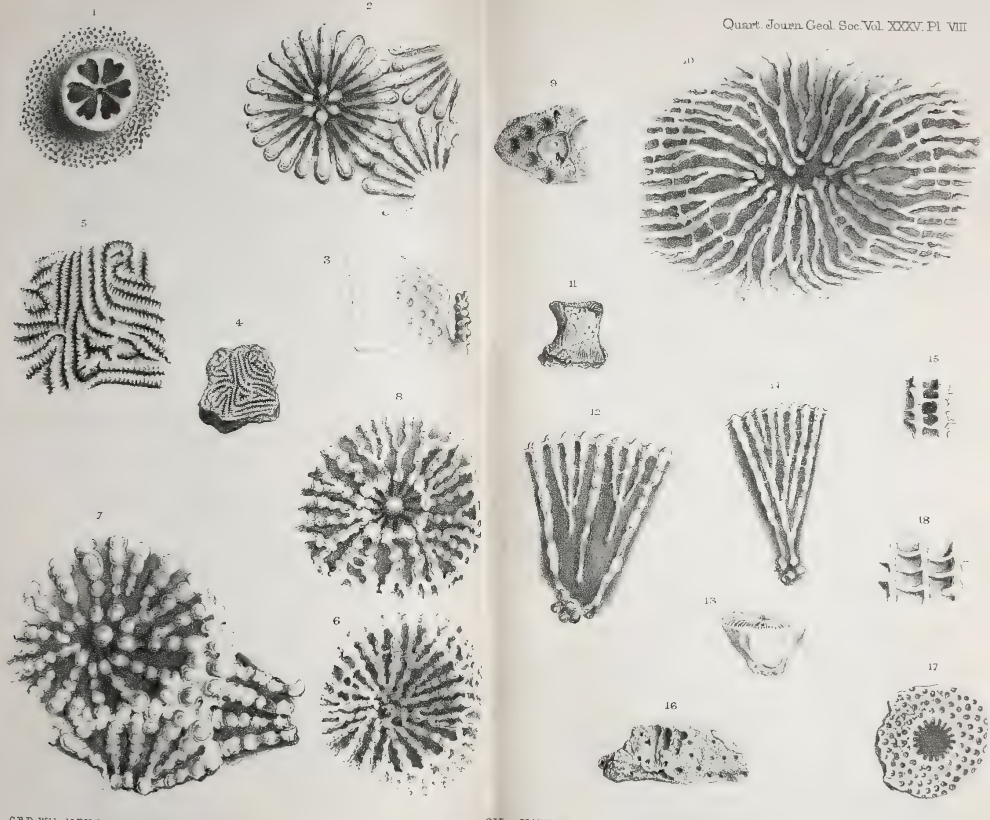


16.

HALDON.

West Newman & Cº imp.



C.R. De Wilde del. P.M. Duncan dir.

CORALS FROM HALDON.

West Newman & Co. imp.

Discussion.

Rev. J. F. Blake asked whether any Upper Greensand species was regarded by Prof. Duncan as continuous; and whether there were not communications between the smaller and larger zooid tubes in the recent *Heliopora*.

The Chairman said that the age of the Haldon beds had to be decided very much by the coral fauna, as there were few greater stratigraphical unconformities in the British Isles. It was difficult, from the silicified character of the rock, to make out some of the characters of the corals. As regards the molluscan fauna, these beds have about equal claims to be called Neocomian, Gault, and Upper Greensand. The evidence of the corals, therefore, was of great value; they seemed to show a deeper-sea condition than did the Mollusca. Nothing at Lyme Regis or along the south coast paralleled the Haldon deposits; they appeared to be on a higher horizon than the Gault beds of Black Ven. Hence the paper was of great value and importance, and of peculiar interest, for the correlation which it suggested with other European areas. It was a worthy addition to the work which the author had previously done in the publications of the Palæontographical Society.

Prof. Duncan said that he did regard the species as continuous, and gave examples of continuous species, and stated that the structure of the hard parts resembled that of the recent specimens. Species might have migrated from localities which became unfavourable to those which were more favourable, as subsidence and upheaval progressively took place in different localities.

8. Glacial Periods. By J. F. Campbell, Esq., F.G.S.

(Read June 20, 1877.)

I. *Introductory.*

1. I first saw a glacier in the Alps in August 1841, when travelling was more difficult than it is now. The term "Glacial Period" is not much older, and now is commonly used as if it were a proved historical event. Advanced glacialists speculate on the geological effects of an "Ice-cap" which extended from the North Pole to the Equator, which nearly filled the bed of the ocean, which surrounded Britain with a wall of ice and a freshwater moat, blocked up the drainage of continents, extinguished life on earth, or left only a few survivors in hollows nearly dried up by the evaporation of oceans needed to make the polar snow-heaps from which the "Ice-caps" spread over the earth during the "Glacial Period." Astronomical causes (changes in the sun, in the paths of planets, and in their axes of rotation) have been summoned to account for the climate imagined. All these theories rest upon some observed facts. Since more facts have been collected, the majority of observers, field-geologists, and travellers have given up the "Ice-cap;" but many geologists, and the public in general, still continue to use the term "Glacial Period" without limitation. It has long appeared to me that our Society ought to have an opinion on this branch of superficial geology. In order to start a debate on the subject, I venture to offer this paper to the Society, and to state my opinion. *My opinion is, that no geological record exists of any abnormal "Glacial Period" colder than the present world's climate. But if the term "Glacial Period" be used with a limitation such as "local," or "Alpine," or "European," I have nothing to object.*

2. I will shortly state how that opinion was formed, so that the worth of it may be estimated by those who differ from it. 3. Since 1836 I have travelled a long way, and I have sketched a great deal, striving to copy on paper landscapes which were pictured in my eyes so as to aid memory of form. Ever since I first saw glaciers and their marks, I have studied glaciation wherever I have been. 4. In 1865 the results of observations made in Europe, in Iceland, and in America were published in 'Frost and Fire,' vol. ii. 5. In the same year observations made on the coasts of Labrador and Newfoundland, in Canada, and in the United States were published in 'A short American Tramp,' 1 vol. 6. In May 1873 a paper published in the 'Quarterly Journal of the Geological Society of London,' on the Glaciation of Ireland, stated facts, opinions based on them, and problems. I had hunted ice-marks from Cape Clear to Edinburgh. 7. In November 1873 a paper in the same Journal, on the Glacial Phenomena of the Hebrides, stated facts recently gathered, and difficulties in accounting for them. 8. In November 1874 a third paper in the same Journal, "About Polar Glaciation," gave the results

of a journey round the North Cape, through Archangel and Astrakhan and the Caucasus, and round the south of Europe. In 1873 I followed the tracks of polar ice from the Arctic basin southwards till I lost the track in Russia. 9. In March 1876, a paper about the Period of Polar Glaciation was published in my 'Circular Notes,' 2 vols. It stated an opinion founded upon much study and observation during thirty-five years after seeking for marks of polar glaciation round the world. In July 1874 I set out with this proposition, "*If an Ice-cap ever existed, marks of it ought to be found on all meridians*;" upon facts observed in a year I founded an opinion in July 1875 and published it. 10. In July 1876, a paper about firths, dales, lakes, and cañons was published in 'Nature.' 11. In September 1876 wishing to test these, my opinions, in the Himalayas, I started for India. After hunting over a country selected by myself with the counsel of Mr. H. B. Medlicott, in charge of the Indian Geological Survey, I wrote letters which were published by the Asiatic Society of Bengal. 12. The following paper contains opinions based chiefly on my own observations and facts, and on studies since I left school, after spending nearly six months in India and some weeks in Lombardy, and after crossing about 180° of longitude on the journey out and home. 13. For some of the observed facts on which my opinion is based, I beg to refer to the publications above mentioned and to this paper. I have a great many rubbings taken from glaciated rock-surfaces to show the directions in which ice moved, and many other records of observations on a collection of maps, in manuscript journals, and stored otherwise. I write this to give grounds for stating the opinion of an amateur upon a large geological question, which must be answered by facts.

II. *Introductory.*

14. I may say in a few words what my facts seem to teach. I have learned to think of this world as a very little place. It is represented in the Museum of Practical Geology by a grain of small shot distant some yards from a 12-inch shell, with grains of snipe-dust and larger numbers to represent moons, planets, and a solar system on a comprehensible scale of distance and size. I have crossed the Arctic circle fourteen times, the tropic of Cancer four times, the equator twice, 360° of longitude in travelling round the world, and in 1876–77 a quarter of a circle of longitude thrice. I have shaken off childish ideas of vastness and unattainable distances which hamper geological thought. I have learned to think of dimensions to scale; of geography as it is taught on a school globe, not as distorted in Mercator's 'Projection;' of the world as a heated ball moving in space, which space, according to astronomers, is cold enough to keep water solid, but a ball so warmed from without by the sun's rays as to keep water generally between 90° and freezing, between evaporation, condensation, and solidity, as steam, vapour, water, and ice. The materials of which the world is made are governed by laws which apply to them in all quantities, small and great. Gases, vapours, and fluids vary in weight and

density according to temperature, and they are kept in motion outside of the world's solid surface chiefly by the sun's rays. That power works the engine which carves the world's surface. Most solids float in their fluids; ice floats in water; cooled lava floats in melted lava. The world is hot enough within to vaporize water, and to fuse the solids of which the outer crust is made. Steam escapes from hot springs, and lava wells up through rents in all known latitudes. I believe now that the world was fluid, like a grain of shot; that it cooled first outside as shot cools, and that it is still cooling in cold space and shrinking as it cools, so that the skin of it wrinkles. I hold that folded strata result from the lateral crushing of a heavy outer crust which surrounds a shrinking hot interior, and that earthquakes and changes of level and volcanic outbursts also result from the cooling of the world in cold space and from consequent shrinkage. That is induction and a question for argument. It is a question of *fact* to be solved by observation of facts, whether there is or is not upon the surface a record of any "period," or "periods," during which the world's outer solid or fluid surface was hotter or colder than it is now, and whether the quantities of vapour, water, and ice were respectively greater or less. That is a question of geological periods which can be settled by gathering facts in superficial and in deeper geology; and this paper is intended to treat "Glacial Periods" as doubtful matters of fact in the science. 15. Fresh and worn surfaces are as characteristic as any other form. Botanists, conchologists, anatomists, mineralogists, and geologists try to distinguish plants, shells, bones, crystals, and beds of rock by their shape *at sight*. All my life I have been striving to learn to recognize fresh, fused, or fractured surfaces, and surfaces worn by water, by ice, or otherwise, so as to distinguish them at sight. At first mountains seemed only bigger hills, and so they appear to many observers; but in fact Etna differs from the Alps as much as a growing palm-tree differs from a lot of bent, cross-grained, gnarled, worn, warped, tarred oak-planks in the bottom of an old, broken, klinker-built boat, keel upwards on a sand bank in a snowstorm. To my eye now Etna is a volcano *at sight*. Stones differently worn are as characteristic as fossil shells are to a palæontologist. After learning my lesson for forty years, I think that I am now able to distinguish a volcanic from a glaciated country *at sight*, and to be pretty nearly sure of a surface which retains marks of fracture or fusion, or of erosion by water, or by ice, when I can examine it closely.

16. Rivers flow from their condensing sources. Ice-action begins at colder spots. Shasta bute, in California, is a recent volcanic cone like Etna, with a small glacier near the top. Ice-action began there when the hot cone had grown high enough and cooled enough to condense enough of snow. Etna has not yet reached that cooling stage, though it condenses snow in abundance. Snæfell, in Iceland, is coated with ice. Round Shasta and Snæfell the distance to which ice has reached is shown by worn surfaces, and the fact can be ascertained by walking round the volcanic cones. The Alps became a

range of mountains by the crumpling-up of sedimentary beds. By seeking for worn glaciated surfaces, and for angular and scratched stones, transported by ice, it has been ascertained with tolerable certainty how far ice travelled from the Alpine snowshed after the Alps had grown high enough to condense enough of snow to make glaciers. It took many able men many long years to map these glacial records of one European chain of hills. As with volcanic cones and mountain-chains, so it is with the globe. The record can be read by going round the point from which the radiating polar ice now floats toward the equator to known limits. By seeking glaciated rock-surfaces and glaciated stones all round the world, it may be ascertained how far polar ice has reached. But it will take more men and a longer time to map even this branch of superficial geology. I have tried to do as much as I could systematically.

17. Before going to India in September 1876, I had seen for myself that the shape of a glaciated country differs conspicuously from the shape of a country where fluid water, falling, flowing, or stagnant, in showers, streams, lakes, or in the sea, has been the chief wearing engine. Where "lakes" and "firths" are conspicuous geographical features, I have always seen rounded tops and wide hollows of curved section, ⌒ ◡. Curved outlines are conspicuous features in every landscape in Scandinavia, in Scotland, in Finland, in the Alps, and in parts of North America. On the map and *at sight* these are glaciated countries. On closer examination I have found glaciated rock-surfaces and scratched stones, and all marks characteristic of glacial erosion. Where I could find few marks of glacial action, or none at all, after careful search, as in California and in Japan, Ceylon, and Java, and on recent volcanic cones, straight lines and angles are marked features in every landscape ($\vee$ $\wedge$), and there lakes and firths are exceedingly rare. Maps by form suggest a probability; the first sight of a country increases that probability; a careful search on a few chosen spots is enough to ground an opinion as to the fact of "glacial action" or "pluvial erosion" in a given region. The lesson learned in travelling with a purpose was an alphabet of "form" by which to read a record of the action of various engines which have covered the world's surface. All sedimentary geology is based upon the erosion of that surface. That was my lesson. Having learned it, I wanted to read the record carved on the Himalayas, to see India, and to test my own opinions about glacial periods there. So I took stock of knowledge previously gathered, and started.

18. As appears in the papers referred to for facts, I had gradually advanced from Swiss glaciers and their old marks to "POLAR GLACIATION," which does, in fact, extend from the North Cape of Europe down to Cape Clear, from Archangel down to Nijni Novgorod, and down to the neighbourhood of St. Louis on the Mississippi, in America. Having ascertained the fact of "Polar Glaciation," I had to consider the possibility of *continental ice-sheets* and of *polar ice-caps*. According to theories still supported by many able geologists, solid glaciers have covered continents; solid ice has extended from the

poles, nearly, if not quite, to the equator, on all meridians, like the shell of an egg, during successive "glacial periods." I found that I had, in fact, to account for some marks of polar glaciation extending 53° from the pole in one direction. After going round Europe in 1873, and afterwards round the world in 1874–75, seeking marks of polar ice everywhere, it seemed to me that records of northern polar glaciation are chiefly marine and confined to the Atlantic basin. But I had seen cause to alter opinion so often that I wished to test this conclusion in India. By climbing mountains, and by looking up to inaccessible peaks, I had realized the fact that an atmospheric glacial climate does, in fact, surround the earth, like the shell of an egg, and may touch it in any latitude. By sailing about the ocean I realized that one cold local marine polar climate reaches lat. 37° at the surface; and I had learned that cold frosty climates underlie tropical heat in the depths of the sea, because cold water is heavier than hot water, till near the freezing-point*. Cold on the world's surface on which we live and travel is distributed according to latitude. But cold is also distributed according to altitude in the air and to depth in the sea; and it is distributed locally at the sea-level by the circulation of air and sea. Dove's isotherms do not coincide with circles of latitude. It seemed to me that old local cold *climates*, like those which now exist in low latitudes, suffice to account for all the records of glaciation that I had read before going to read Indian records. The proved bending of the earth's crust explains the transfer of a cold condensing area from one spot on the world to another; for the crust may have touched the shells of cold which are above the normal sea-level in the air, and below it in the deep sea, by bending upwards or downwards. By bending, the solid crust must have repeatedly changed the course of circulation in air and sea so as to change the climate at different places in the same latitude, at least as much as any difference that now exists.

19. Any abnormal local cold climate suffices to account for any old record of equal cold in a like latitude after it has been proved that the distance between the earth's centre and outer solid shell has varied locally. That is proved by marine fossils. Existing local cold climate about the South Pole may account for local records of cold in like latitudes in the northern hemisphere, because it has been proved by fossils that the relative position of sea and land has frequently changed. For example, about lat. 65° S. sea-coasts which now are scarcely accessible because of heavy ice may account for great mounds of washed glacial drift which I have seen about lat. 65° N. in Finland and in Northern Russia, where also recent sea-shells prove a recent rise in land which now is part of Northern Europe and was part of a sea-bottom. Terraced countries (like Northern Europe, and like hills on the Western Caspian shore along the base of the Caucasus), recent shells, and other marks indicate a general submergence of the plains of Europe. I think that submergence is

* Details are given in a paper by Mr. Prestwich, which travelled with me to India.

sufficient to account for the colder Alpine and Scandinavian climate which is recorded in Europe, and which now belongs to the Arctic current of the Atlantic and to countries near it—to Greenland, to Labrador, to Newfoundland, and to the coasts of North America.

About lat. 45° S., glaciers in New Zealand, considered with shells found under moraines in Northern Italy, and with the effect produced on climate by the Arctic, current of the Atlantic, may account for marks of glaciers found near Cannes in the South of France by Mr. Moggridge and for the large old glaciers of Northern Italy.

About lat. 40° N. small Caucasian glaciers account for marks of glaciers found in America, or for any which may be found in Asia or elsewhere about the same latitude.

About lat. 37° N. ice now drifting in the Atlantic may account for the transport of northern drift southward, over plains, to St Louis in America, or into the plains of Africa. If these African plains where recent shells are found, when last submerged, were in the course of a cold polar current which passed near hills on which glaciers grew, and were within reach of drifting ice, then any record of cold is explained by a local marine cold climate near the same latitude in the southern hemisphere.

About lat. 36° S. enormous masses of drifting ice now are distributing southern drift of glacial origin in some parts of the southern hemisphere which are now submerged, and which are in the course of cold drift. In other submerged southern regions, about lat. 36° S., no icebergs have been found. Modern marine drift is local north and south of the equator. That modern local marine southern drift in lat. 36° S. may account for old local northern drift from the pole to lat. 36° N., if it appears otherwise that the northern region was sunk during its cold period, as the southern region now is. It does so appear in many parts of the northern world, notably in Europe. Recent sea-shells and old northern drift, present submergence, and local cold climate coincide in latitude down to lat. 36° N.

From about 37° N. to 27° N. glaciers abound in the Himalayas. Many of them are on or near rocks which were formed at the bottom of a sea where Ammonites and other sea-creatures died. The crust, in folding, probably sank as much as it rose. Anywhere within 27° of the equator an old record of cold may be explained by the glaciers of India and by existing local cold climates elsewhere in the world north or south between 27° and 90°. That was, and now is, my theory based upon observed facts.

Within 8° of the line Livingstone found marks near Lake Tanganyika, in Southern Africa, which he attributed to African glaciers. Mr. Belt* found marks in Nicaragua which he also attributed to glacial action. I have seen marks in Ceylon which are like glacial marks. Agassiz found marks of a glacier which filled the valley of the Amazon, upon which marks he built his famous theory of

* This very able observer was lost to science in 1878; I have to regret a friend and an adversary in glacial arguments, who was always fair and honest.

ice-caps. Wishing to judge for myself, I found no glacial record in Ceylon. I have not been to Nicaragua, or to the Amazon, or to Central Africa. But given a region of great condensation and sufficient altitude within the influence of a cold stream of air or of water in any latitude, then that which is a fact in Nepal may explain any local record of glaciation near the same latitude, in Africa, or in Nicaragua, or in South America, or anywhere near the line. In fact, Kilimandjaro and Mount Kenia, close to the equator in Africa, are capped with snow. One is an active volcano liable to grow higher or sink lower during eruptions. So glaciers may have existed there at the equator. It is a question of fact.

As sea-water under the line now is colder than 32° F. at the sea-bottom, land under the line now raised, which was at the bottom of the sea, may bear record of a cold submarine climate without travelling out of the world's geological records into astronomy. But I needed more facts and more records, so I went to India to seek them. It seemed to me, in September 1876, that cold local climates which resulted of old from changes like those which have certainly occurred suffice to explain the ice-record which I have learned to read and have tried to translate. Drifting ice now floats towards the equator as far as any "erratic" that I had seen; glaciers now exist nearer to the equator than any old glacier-mark that I had been able to find for myself before I set out.

20. That was the state of my facts, and my theory based upon them, a theory which I was prepared to abandon and wished to test. On these facts, and on this method of reasoning from my facts, I had framed these propositions:—

(a) "*If the "ice-cap" ever came down from the north pole to the equator, it must have come down from Central Asia upon India.*"

(b) "*If a late glacial period has in fact left a record in Europe and America and in Asia, it ought to be legible in India. Glacier-marks ought to found on the hills far beyond the present limits of glaciers. Erratics carried on ice-rafts afloat on rivers or lakes, or in the sea, ought to be found south of lat.* 37° *in plains.*"

(c) "*If the glacial period was general and recent, existing glaciers must have been larger everywhere, in something like the same proportion, in the Alps, in Northern India, and elsewhere in the northern hemisphere.*"

To see for myself whether I could or could not discover a glacial record to confute or confirm my own opinion, I intended to be one of my studies when I started for India in September 1876. I wished, above all, to see the country about the sources of the chief rivers, Siccim, and the highest mountains in the world.

The following are the results obtained in India in 1875–76, and opinions based on observations made since 1840, along the routes which I have marked roughly on a globe. The value of this opinion must be judged by the Society to which I have the honour to belong, if they are pleased to accept this paper.

Summary.

The general result of sections III., IV., V. is that Indian glaciers are near about as large as they have been since the deposition of the crumpled Tertiary beds which are called "Nahuns" and "Shivaliks." "The glacial period" is dated "Postpliocene." The Indian ground traversed extends from Ceylon to Kangra, near lat. 32° N., and includes Lower Himalayan slopes between the river Ravee, lat. 32° N., and Darjeeling in lat. 27° 28′ near long. 90° E.

The result of section V. is the same for the Caucasus, about 40° N., and for the Rocky Mountains, about lat. 36° to 37°. About lat. 45°–46° in Northern Italy glaciers certainly were a great deal larger in Postpliocene times. There is reason to believe that glaciers existed as far south as Calabria, near lat. 30°, in "Miocene" times; that is, about the latitude of Simla and Hirdwar. The general conclusion is in section VI., and the result of the whole paper is in the first paragraph and in the last. The facts are in sections III. to VI.; and to them I beg to refer readers who wish to test my conclusions.

III. *India.*

21. 5° to 18° N. lat. I will give my observations in geographical order, working northwards from the torrid zone to ice, crossing the track of the "ice-cap" eastwards and westwards.

In May 1875 I travelled to Ceylon, and went to the highest point in the island, 8326 feet above the sea, at Pedro Tullagulla. Frosts occur in winter at hill-stations there, and the climate is cool. I could find no mark of glacial action between 5° and 10° north latitude. That which I observed in Ceylon is described in the paper numbered (9). The rock is chiefly gneiss. I found all marks of weathering and of "pluvial erosion," and some forms in gneiss like "roches moutonnées" with "perched blocks" of gneiss on them. These result from weathering *in situ* and from the structure of gneiss.

22. In February 1877 I went from Madras by rail to the Nilghiri hills. The plains where I saw them are on gneiss, with low hills of gneiss rising like islands in the plains. Their outlines are hollow curves  like the sides of a tent, and their shapes result from the wearing of rains. The western Ghàts have long spurs, of like outline, extending like promontories and chains of islands eastward into the plains. They extend chiefly on the strike of the gneiss. Seen end on, these hills are topped by spires, of which some overhang the base on the dip. Seen sideways, these spires appear as long undulating ridges. They are the edges of harder beds in weathered gneiss. I went up to Coonoor, and to Ootacomund, and to the top of Dodopetta, 8760 feet above the sea and the highest point in Southern India. Frosts occur in these hill-regions, and the climate is cool within 11° of the line. The hills which I saw are gneiss, and their highest points and ridges are the hardest beds washed bare by the rains. Seen from above, outlines are hollow curves , not rounded , as they are in glaciated countries.

All exposed rock-surfaces are discoloured and partially decomposed to a considerable depth by the action of frost, heat, rain, and air. These weathered surfaces are scaling off and crumbling. The hill-sides are strewed with large blocks of gneiss, which are weathering, scaling, and crumbling, like the solid rocks, *in situ*, where they fell, or rolled, or were slowly weathered out of softer rock. The scales, which weather off and crumble, decompose till crystals of felspar, quartz, and mica, &c. separate and break up. The felspar turns to kaolin, the quartz to sand, the colouring-matter of mica, hornblende, &c. turns to rust. Rains sort and pack these decomposed minerals, wash them down hill, and bury gneiss blocks in sheets of kaolin, in sheets of gravel, in coloured clays, and in "*laterite*." The materials of the decomposed gneiss, packed in sheets on the hill-sides, cover the slopes. The result is that some of the higher grounds are like glacial work. As in Ceylon, I am satisfied that these hill forms are due to weathering *in situ*. The lower slopes, where rains have space to gather into larger streams, are deeply furrowed by long V-shaped gorges, in whose steep sides the structure of the gneiss is well seen. These greater furrows clearly are records of "pluvial erosion." At Newera Ellya, in Ceylon, and at Ootacomund in the Nilghiris, artificial lakes have been made by building walls across water-furrows. The plan of a lake so made is very different from that of a mountain-tarn in a glaciated country. The water-line is angular, not curved. I could find nothing glacial between Madras and the highest point in Southern India which is within sight of the western sea. Two experts well acquainted with the country, the Curator of the Madras Museum and the officer who engineered most of the hill-roads, confirmed my opinion. No marks of glacial action in this region are known to them. I heard much of glacial action in the country. I could find none; but I can understand mistaking "laterite" for "boulder-clay," and some weathered surfaces for "roches moutonnées."

23. On the 8th, 9th, and 10th of March, 1877, I crossed from Madras to Bombay. The Madras side is a plain. Where the hills begin, steep slopes are furrowed by rains and streams. The structure of the rock was clearly seen in conical hills and in long ridges. I took the rock to be gneiss. The upper plateau is an undulating country with isolated hills of granite in all stages of weathering. The last stage is a cairn, or ridge of loose stones, or, where these have been crumbled to dust, a low dome or boss of granite. At first sight many of these forms are like glacial work; but after passing many it is clearly seen that the work is "*weathering* in situ." The dome shape is the structure of the rock. The surface is not worn by the grinding of ice; for it often passes beneath upper layers in all stages of weathering, from cracked surfaces to isolated stones. The isolated stones are not "erratics"; they are but remnants of an upper layer weathered away by rains. About midway between the coasts, near the branch railway to Hyderabad, trap is reached, and the form of the country changes. The Ghât on the west side gives a section of about 2000 feet of beds of trap. Above and below the

edge of the plateau are all the forms which are commonly produced by the weathering of trap,—" stairs " (*trappa*), cones, pyramids, cubical masses, spires, peaks, jagged sierras, and such like, and through them all run the horizontal layers of this great outpouring of igneous rock. The granite country is like the Sierra Nevada above the plains of California. The trap country is like the Cascade range in Oregon, without the volcanic cones; it is like parts of Iceland, the Faroe Islands, the north of Skye, the Isle of Mull, and part of Ireland, where igneous rocks have weathered. I saw no marks of glacial action between Madras and Bombay. I saw clear records of long-continued pluvial denudation, the work of an engine which acts vertically and wears down hills, and spreads their ruins on plains and plateaux. The edges of the Indian plateau are furrowed by streams and worn into shapes which depend in some degree upon the structure of the material which is carved.

Up to lat. 18° I saw nothing to indicate glacial action in the shape of the surface of India. The strange forms of weathered granite in the country have been explained by a legend. When Sita, the wife of Rama, was carried off to Ceylon, a bridge was needed by the armies of Rama. His allies, the monkeys, fetched stones from the Himalayas and built Adam's bridge. The ruins are in Palk's Strait. Piles of spare materials were left about Hyderabad in cairns and ridges. I have often heard these same mounds attributed to glacial action; but Indian geologists generally attribute them to weathering *in situ*, as I do.

24. About lat. 17° 20′ to 19° 53′ N., not far from Nágpúr, in Central India, a deposit of the age of Indian coal or " bottom Tertiary " has been discovered and named " the Talchir Boulder Formation." Mr. Fedden, of the Geological Survey, has described this deposit. He attributes it to the action of " ground-ice " moving from S.W. northwards.

Lat. 36° S. is the present limit of floating ice. 54° S. and 19° N. make 73° from that limit to the Talchir deposit, which is a long way. The nearest glacier northwards, 33° N., is distant, say, 14°. Between 36° S. and 33° N. I know of nothing else that looks so like glacial work on this meridian. Other beds in this series, provisionally dated " Lower Triassic," have all marks of deposition in water. Samples of scratched stones in the Calcutta Museum, and the paper of Mr. Fedden, argue that ice did in fact score rocks and move scored stones within the tropics about the time when climate there was fitted for the growth of tropical coal-plants. I did not travel to the Talchir deposits. I had not the pleasure of meeting Mr. Fedden. The boulders at Calcutta were first rolled and then rubbed on one side only, whereas moraine stones generally are scratched on all sides. I have seen surfaces in the walls of mines produced by frequent movements in the solid crust which are very like glacial polishing. In India especially landslips and earthquakes have to be considered in accounting for polishing and scoring. Some geologists ascribe all polished surfaces, which glacialists attribute to ice, to slips. Great disturbance in all this region is proved by igneous rocks and by the dip of metamorphic gneiss. Since the caves of Elephanta were hewn out of trap, the level of the floor has changed; so that water poured on an idol flows in the opposite direction from that which the sculptors intended. Mr. Judd has shown that great volcanic cones once stood on spots which now are in "the Hebrides." Their age is proved by fragments of sedimentary rocks preserved in sheets of trap and basalt. Where trap rocks cover a vast area to a great depth in India, it is possible that volcanic cones in proportion may have risen high enough to reach the cold climate which now breeds glaciers in lat. 27°–28° N., only 10° further north. That is one possible explanation for these old Talchir boulders which occurs to me. It has been found that water colder than the freezing-point of fresh water is at the bottom of the Indian Ocean now under the line and north of it. It has been supposed that this cold layer of sea-water is flowing northwards from the Antarctic ice, and displacing surface-water warmed to 80° or even 90° by the sun in the Indian Ocean. Surface-currents which flow southwards along the African coast prove marine circulation and a water supply equal to the waste. It is well known to fishermen and sealers that icebergs founder, and that "anchor-ice" grows at the bottom of the sea off Newfoundland and the Labrador. Though ice floats, it may be sunk by stones or anchored to them. It seems possible that an antarctic current of cold water moving northwards at the bottom of the sea may roll foundered icebergs, and move sheets of anchor-ice loaded with stones, even beneath warm tropical seas. It is possible, but very improbable, that sunken ice should travel 73°. Mr. Fedden sees nothing in the Talchir boulder-deposit to indicate the action of a continental ice-sheet or of a local glacier. He suggests the action of ground-ice in shallow water. But these supposed records of a cold climate coincide in position with tropical coal-plants. The two records do not agree if the events recorded are supposed to have happened near the same sea-level. The case is a problem; but existing conditions of climate that best agree with the record are the deep-sea cold of the Indian Ocean and the hot tropical climate at the surface and on shore. These give a difference vertically equal to the difference between the climates of Bombay and the North Cape of Europe at the sea-level, or between the existing climates of the plains of India and of hills near them which rise to the level of perpetual snow in Nepal. (Mr. Fedden's paper and a rubbing taken from a boulder described in it accompanied this paper, with a moraine-stone from Ivrea, for contrast.) This exceptional find does not concern the recent "glacial period" or superficial geology; it belongs to the age of the Indian coal. If these boulders are in fact glaciated, they prove that the world's climate there was somehow cold enough for ice to exist within the tropics, while it was also hot enough at the same place for the growth of coal-plants—a very long time ago. Even a change in the position of the earth's axis would not explain this double record of great heat and great cold.

25. 18° to 31° N. lat. In the end of September 1876 I landed at Bombay and travelled by rail to Allahabad. The rocks seen were

chiefly trap. I was told by fellow travellers of marks of "the ice period" south of Bombay described by competent geologists; I suppose that the Talchir boulder-formation was meant. I saw nothing like glacial work in this long cast eastwards to the junction of the Ganges and Jumna, about lat. 25° N. If the ice-cap had passed that way, erratics of some northern kind ought to remain on the trap, and trap boulders ought to be found south of the trap on granite and gneiss. I saw none.

26. The next cast westwards up to lat. 30° N., to Umballa, is all on river-deposits. I saw neither rock nor large stone. The whole land is sand and mud, which is moved by every shower and breeze.

27. From Umballa I drove over the plains to Kalka at the base of the hills and sixty miles up hill to Simla, persuaded that I should find ice-marks near glaciers. The Himalayan region is a slope about 200 miles wide, between the upper plateau of Asia and the plains of India. On the scale of the Survey maps, four miles to the inch, the profile would be roughly expressed by a bank $1\frac{1}{4}$ inch high and 4 feet broad, sloping to nothing. Any school map shows that an ice-cap must have come down that slope if they both existed during a recent glacial period. I looked at every stone and heap of stones about the foot hills, expecting to find some glacial mark; I looked at every hill-top, expecting to find some remnant of a glacial record between the river-gorges. In the paper numbered (8) is an account of a like search made in the Caucasus in September 1874, with like expectations and a like result, at about 10° further north. There a ridge of high mountains, about 800 miles long, crosses the track of the ice-cap east and west, and bears no record of its passage southwards. I stayed at Simla for some time and found no sign of glacial action of any kind up to about 9000 feet. From places near Simla I saw hills within a circle of about 200 miles' diameter. My plan was to carry a map and a compass to a hill-top, place the compass on my spot, and identify hills by their bearings with the aid of people who knew them. I saw great snow-slopes above known glaciers which lie at the sources of the Jumna and Ganges below higher grounds. Having learned local geography, the next step was to sketch the landscape and study form. I saw everywhere on the ground traversed, and as far as I could see with a good glass in the clear air of these regions, the marks of great floods of rain which have furrowed the whole Himalayan slope. All the ridges which divide streams are sharp and steep, Λ, as the ridge of a house; all the furrows are deep V-shaped, angular, steep gutters, like the gutter between two steep roofs, W. My landscapes were all angular. I could not discover one rounded hill or hollow, one "saddle" or "hog-back," from Simla, or from places near it to which I could travel. The excellent maps of the Great Trigonometrical Survey of India showed that some of the largest and deepest valleys in the region run eastward and westward towards opposite ends of the slope. I could see the border-land of Thibet and hills near the sources of the five chief rivers which drain these hills, the Brahmapootra, Indus, Sutlej, Ganges, and Jumna. The highest

ground visible is a jagged sierra of pyramidal angular points, amongst which are the glaciers. On the map the glaciers are like the fronds of a fern, and rest in furrows like snow in roofs. That view alone was enough to prove that the ice-cap had left no visible record of its passage from polar to equatorial regions on the Himalayan slope.

But such is the hold of the term "Glacial period" on general conversation, that I repeatedly heard of glacial marks where I found none when I sought them near Simla.

28. From Simla I went back to the railroad, and eastward to Saharumpore, and thence over the plains and up the hills to Dehra, Mossurie, and Landour, to a spot which is 7511 feet above the sea, between the Ganges and Jumna. Thence I got a second wide view, over the lower hills and river-basins, of snowy peaks and ridges which divide the Ganges and Jumna basins from the Sutlej gorge, which trends E.–W. Below their snow-slopes are glaciers of which I had photographs. The maps gave their positions and present dimensions, which are about as great as glaciers now are in the southern Alps. Eastward from Landour I clearly saw Nunda Devi, 27,669 feet high; and on a quarter of my horizon the peaks of Budrinàth, Kidarnàth, Gangutri, Jumnutri, Bunderpanch*, and others, which divide the Sutlej valley northwards from the Ganges and Jumna basins. I had seen many of these from near Simla, and I saw them better from Landour. The whole country visible within a circle of nearly 200 miles diameter is like the Simla country; it is deeply furrowed by rains. The highest ridges visible are sierras of extraordinary steepness and sharpness. Nunda Devi seems to be another E.–W. ridge seen end on. It was like a steeple, or a high steep gable in a town with high-pitched roofs. It is a great mountain-range, with flat sides and clean fractures, too steep for snow to rest upon. The ice-cap must have passed over this E.–W. ridge, 25,000 feet high, after crossing the Sutlej valley and another sierra about as high as Nunda Devi. The nearer and lower ridges are like it, on a smaller scale; they are scarcely wide enough on the top for a road, and they are furrowed on all their steep sides by ravines of all sizes. Furrows are furrowed till the smallest are like furrows in a ploughed field. The whole country visible has the same angular shape, and the pattern is the same whatever the size of it may be. A fern laid on paper may give some notion of a map of this region. All sections are angular. Manifestly there was no mark of an ice-cap in sight from Landour.

29. The shape into which these rocks weather, as usual, seems to depend in some measure on their internal structure. At Simla and at Landour the rocks have a tendency to break in directions which make flat-sided pyramidal peaks and steep ridges. A glance at any good map shows clearly that running water has run down the slope as it runs down on pan-tiles, but that it is afterwards caught in long gutters, which run nearly parallel to the general trend of the North-western Himalayan range, or E.–W. The same is true of the Cau-

* Monkey's tail. The hill is supposed to be like a monkey, a sort of representation of the monkey god.

casus: after the water has run down from the hills, it gathers into four chief streams, which run east and west along the base of the hills as a gutter does under the eaves of a steep roof. All that I have been able to learn about the geology of these two mountain-ranges shows that wearing by rains and rivers is guided by the slope, but it is modified in direction by the structure of the rock, which is carved accordingly. The Geological Survey of India is not completed; but, so far as I am informed, the Himalayan ridges and furrows are carved out of beds which are much crumpled and faulted, and which include sedimentary fossiliferous rocks of many periods, recent and very old, from Tertiary rocks to Silurian shales. Recurring earthquake-waves may have something to do with the joints and cleavage and fracture of these rocks.

The Work of Rivers.—I had no local maps; I could get none of the district at the office of the Great Trigonometrical Survey of India, which is at Dehra. I was there referred by the Directors to Calcutta. When I got unfinished maps there, the area drained at Hirdwar is roughly a figure bounded by a quarter of a circle, with a radius of about 80 miles. The edges of this ribbed saucer are "snowy peaks" and a zone more than 20,000 feet high. Glaciers are marked on the maps about the edge of this hollow. Most of them are on the north side, towards the Sutlej.

It is the custom of surveyors in a mountain country to follow levels and to draw contour lines. Sheep-paths and goats' tracks and bridle-paths are laid out on the same principle. A sea-coast is a "contour line," and roads in the Himalayas wind about in search of a level to walk upon. A straight course would be a continual climb up or down. In the 'General Report on the Operations of the Great Trigonometrical Survey of India during 1874–75,' at p. 46 (23), "Kumaun and Garhwal Survey," Mr. F. C. Ryall, the reporter, divides his district into zones or belts, which are, as I suppose, tracts of country between "contour lines." These "belts" surround the headwaters of the Ganges and neighbouring basins towards Nepal. The watershed which I saw, and sketched from a distance, is a sierra of peaks, comparable to the Lofoten Isles in Norway for sharpness. Beyond that ridge is the Sutlej, flowing westward over high undulating ground, on a steppe which has been seen by the surveyors. The river plunges suddenly down from the frontier. One of the surveyors, Mr. Pocock, got to a height of 22,040 feet; another spoke of a friend who had reached to 24,000 feet. These exalted persons saw a great deal of the world with practised eyes, and I respect them and their information greatly.

§ 1. The first zone on the Indian side of the watershed is about 15 miles wide. The ground there undulates, as it does in Thibet. The land is utterly barren, very cold, and glacial. In that mountain region river-basins and minor ridges average from 14,000 to 20,000 feet above the sea-level. In all mountain countries known to me there is a region of "high Alpine valleys" near the watershed, in which water flows slowly, on gradual slopes. Contour lines drawn at regular intervals of altitude are wide apart. These are about the base of grounds on which contour lines are close together, and take the shape of irregular closed figures about peaks.

§ 2. The next "belt" below 14,000 feet is from 10 to 17 miles wide. In it are "needles," of which Nunda Devi is 25,669 feet high; and there are very narrow deep valleys. Of one gorge the reporter says:—"The steepness of the gorge may be conceived when it is understood that the direct horizontal distance from Hasaling snowy peak to the Gori River is rather less than $1\frac{3}{4}$ mile, and that it towers 14,000 feet above it." That gives a base of 9160 feet, and a vertical side of 14,000 feet, which sides give a steep third side to the triangle. My sketches from Landour give some distant idea of these hill-sides. In all mountain countries streams that have cut "cañons" flow in hollows of this kind, which are deep, or long, or short in proportion to their age. They are valleys of erosion, and end above at a waterfall in general.

§ 3. Zone the third is described as a region of "spurs," 6 to 7 miles wide, at an average height of 12,000 feet. By this I suppose that Mr. Ryall means the land left between the cañons in zone the second.

In these three zones, between 25,000 and 12,000 feet, the surveyors are called "a snow party," and glaciers are mentioned incidentally as difficulties walked over. Alpine climbers will recognize in this description the steep ground about the sources of European rivers in the Alps, where glaciers are at work now.

§ 4. The next region is about 50 miles wide, at an average height of 7000 feet. It is "much waterworn;" that is to say, a wide slope is very deeply furrowed by branches of the larger and longer rivers, which come from the watersheds through belts which are measured by about 38 horizontal miles and 18,000 vertical feet. I measured slopes near Simla which make an angle of near about 70°; 45° and 30° are usual slopes. At Darjeeling the valley is 6000 feet deep, and the base of one side is about 4 miles. Surveyor's levels cross furrows by flashing rays at an average of 7000 feet above the sea. The tops suit European constitutions, so they dwell in this "belt."

§ 5. The last "zone" is the "Shivalik zone," with an average breadth of 8 miles and a height of 4000 feet.

The plain region begins at about 1000 feet, and extends some thousands of miles to the Ganges delta. Within three "belts," 38 miles wide, are glaciers. In the remaining lower belts, 58 miles broad, ought to be old glacier-marks, if the country ever was like Lombardy during a general Glacial period. On similar ground I found only marks of pluvial erosion. My distant conclusions correspond to the work of those young athletes who risked their lives in climbing, and were nearly starved, though Government servants, equipped with camps, and clothed with the majesty of the British Raj.

It is the custom of Anglo-Indians who go to Simla for health to make expeditions into "the interior." They travel on roads constructed by engineers which follow ridges between streams, and follow the Sutlej valley where the higher ridge is furrowed by branch streams in the upper zones. The roads go for passes, and the rivers do the same. I conversed with many travellers who had explored this road. I could not explore it myself; for the way was blocked by the Viceregal train. Miss Gordon Cumming has described this route up to Chini, near the frontier of Thibet, with the pen and pencil of a clever artist, in her book called 'From the Hebrides to the Himalayas' (London 1876). The author of 'The Abode of Snow' also describes this route. Every river that flows from a high source, and every rill that flows on a slope, at some part of its course, has a zone of waterfalls. The water there is digging with all its power. The steppe from which it falls is gradually worn away. Steps and falls grow higher, and recede up stream, till walls of an amphitheatre are nearly reached. Scotchmen call it a corrie, Welshmen a comb. As the falls retire, the length of the watercourse above them decreases, and the quantity of water and its power of digging. The whole process can be watched between tides on a sandy beach. The "*waterfall zone*" in the Himalayas is close up to the watershed, from which I gather that the watercourses are very old. The waterfalls at Simla are close to the watershed at the sources of small branches of two systems of streams. One flows to the Bay of Bengal, the other to the Indian Ocean. The waterfall zone of the Sutlej, "the corrie," is many marches up close to Thibet. So it is in the Ganges basin, and so it is in Siccim and in Bhotan. Where glaciers end thereabouts streams fall suddenly down into "corries" like the Yosemite valley, on a grander scale *.

30. *Hirdwar.*—After waiting for some days, sketching and watching the marvellous landscape from Landour, I went down to Dehra, and through the Dùn to Hirdwar. That is a sacred place, where the Ganges leaves the hills. At the sources of the Ganges are glaciers, and peaks above them on the edge of the basin are visible from Hirdwar. I have sketches of them. If these glaciers ever extended far during a Glacial period, some marks ought to be found about the place where a river as big as the chief river of Lombardy at its greatest size escapes from the great basin, whose jagged edges and steep sides I had seen from Landour, where frosts and deep snows occur frequently. In a like position in Italy, near Turin, are ramparts of glacial débris, which are hills higher than hills at Hirdwar. I had seen them from the railway on the way out. I have read of them, and I went to look at them on my return. I had seen the shape of the dales above the great lakes of the Alps, up to the watershed, in 1841. Hirdwar is 1124 feet above the sea. The edge of the basin is nearly 20,000 feet higher, and the area is large and comparable to the area of the Val d'Aosta, on the Lago Maggiore. A Glacial period would lower the snow-line everywhere, and lengthen all glaciers, and might fill the Ganges basin with ice, because a local cold climate filled the Alpine dales. I stayed at Hirdwar for several days, and could find no sign of glacial action

* This account of the Lower Himalayan slopes towards the east coincides with that of the country in which the war is now going on, according to travellers who have described that region.—*January* 11, 1879.

whatsoever. I heard a great deal about "marks of the Glacial period" in the Ganges basin from travellers after I left the country. In the jungles and in this vast country may be many things that I did not find.

31. I rode to Roorkee along the banks of the new Ganges canal. In digging it great masses of stuff have been raised from considerable depths to make a canal comparable for size to the Suez Canal, to give room for a stream about as great as the Thames is at Windsor. I found only mud, sand, pebbles, and abundance of large, smooth, egg-shaped, rolled stones of considerable size. I could not find one stone with scratches on it or with flat sides, or one angular erratic near the canal. I could find nothing glacial about the end of the Ganges basin. I could hear of nothing glacial from the surveyors with whom I conversed at Dehra. I had photographs of glaciers, and of glens near them, about the headwaters of the Ganges and Sutlej. In them I could see nothing to suggest the former action of large glaciers like those which have left their spoor in every valley in the Alps, in Scandinavia, in Scotland, and in Ireland. In some few pictures only I could trace marks which seem to indicate a former extension of glaciers which exist. Captain Senior, Superintendent of Native Army Schools, who made the pictures, said that old glacier-marks which he identified on the ground extend *only a few miles from the ice in this region*. The surveyors who mapped the ground confirmed what I saw and heard. The Ganges glaciers, and others in this region, hang about the steep broken edges of great deep basins; and there is nothing to show that glaciers ever filled these basins, as European hollows were filled of old.

There was no sign of an ice-cap at either of these hill-stations; and opposite to the Ganges basin were no signs of that Glacial period to which European ice-marks are usually attributed. On my return to Europe I went to the Val d'Aosta to look at old moraines. The result of the comparison is in Section V.

32. My next cast was westward in the plains. I travelled by rail to Lahore, about lat. 32°, crossing the Jumna, the Sutlej, and the Bias rivers about 50 miles from the hills. I saw no glaciated stones in the plains or near the banks of these three great rivers. All three rise amongst glaciers. The Sutlej flows E.–W. from lakes close to the sources of the Indus and Brahmapootra in Thibet, and many of its branches come from glaciers which are on the outside of the Ganges basin. At these four points between the Ganges and the Ravee there is nothing at the foot of the Himalayas comparable to the glacial débris of Lombardy or the erratics of the American plains. There is nothing visible but sand and mud between Allahabad and Lahore.

33. *Kangra**.—About long. 74° E. I turned back to Umritsir, and drove 70 miles over plains to Puttankote. That place is close to the Ravee and to the foot hills, and within sight of the hills in Cashmere. The Ravee rises amongst large glaciers; but there is

* See paper mentioned, paragraph 11.

nothing like glacial work opposite to this great river-basin in the plains.

34. In skirting the base of the hills to Noorpoor, I crossed several large streams, sought carefully, and found only rolled stones.

35. I went through the Kangra district, where I had been led to expect signs of glaciation at a low level. The Dhaoladhar range is 16,000 feet high and about 80 miles long. It is deeply furrowed. A geological map, given to me afterwards by Mr. Medlicott at Calcutta, shows that the tops of the sierra are granite, against which lean beds of schists and slates, dipping at a high angle towards the plains. The deepest furrows cut through the edges of these beds at right angles to the strike, from the granite tops to the foot of the range.

The Kangra "valley" is a broad slope undulating towards the plains. I had seen this range clearly from Simla, distant about 100 miles. Those who have seen the Alps from the Rigi and Faulhorn, or from Turin or Novara, or any other great mountain-range from a distance, know that the distant view gives a better idea of the general shape of the mountains than nearer views. The whole steep face of this great range was like a steep bank after heavy rain. There was no sign of a great glacier passing along the base of it, out of the Sutlej valley, from east to west. Such a glacier, if ever it existed, must have left a conspicuous mark. So far as I have been able to learn from surveyors, geologists, travellers, photographers, and photographs, there are no marks of a big glacier in the Sutlej valley, so far as it has been explored; but existing glaciers are close at hand.

When I got to the Kangra slopes, the tops were covered with new snow, which made every ridge and furrow conspicuous. The range is like ground seen from Simla and Landour. The landscape is a series of angular forms, like a ploughed field on a steep slope. Kangra is on a steep high ridge, 2449 feet above the sea, distant about 12 miles from the high range. The view is something like the view from Turin for distance and extent. When evening lights and shadows and sunset colours play upon the great hill-face opposite, details of form come out with extraordinary clearness, and the landscape is one of the most beautiful that I ever beheld. Near the top are three conspicuous patches of old snow, on smoothed rocks, which are not furrowed like the ground near them. These I suppose to be the old beds of small glaciers, if they are not glaciers hidden by snow and stones. The snow is full of large stones, clearly visible with a telescope. These patches come down to about 12,000 feet. They rest on granite, according to the map. Below these are three deep furrows of the usual angular V pattern, which come down to the Kangra slopes, and from them spread Δ-shaped masses, which look like deltas from any distance sufficient to make the course of the streams visible from the snows to the slopes. In travelling eastwards along the hill-foot, from Noorpoor to Kangra, many water-courses are crossed. Of these some come from the highest granite ridge, some from lower parts of the ridge. In some of the former class I found long trains of unusually large stones, chiefly granite, washed out of deltas and left in streams. At first sight these, by their great size, suggested glacial action. They have been described as "erratics," and the deposits in which they occur as "moraines" of the Glacial period. I therefore sought carefully, but I could find none of the known marks. The Kangra big stones are all smoothed, dinted, and rounded; the biggest are next to the range. The size decreases as the distance increases and the slope grows less. They are not arranged like moraines near Turin or elsewhere, but spread like stuff of the same kind at the foot of Pike's Peak in America, and at the end of the Dariel Pass in the Northern Caucasus The deltas to which these trains of big stones belong all spread like fans from the jaws of deep, steep ravines near high, steep hills, and they are all washed and rolled by floods of water.

Dhada is a rest-house at the foot of the high range, in the very jaws of a deep V-ravine, which comes from the biggest old snow-patch that I could see on the range from Simla or from Kangra, or from any point that was passed in travelling away from the Dhaoladhar range, or in passing along the foot of it. The stream comes out of a deep, steep corrie of large area. At the very apex of the delta a gravel-pit beside a road gave a section of the deposit, which a very accomplished geologist has described as one of the Kangra "moraines." The solid rock under the loose stuff was newly laid bare. It is *not* glaciated. The whole of the stuff was sorted by running water, and the big stones strewed on the top evidently are the largest and heaviest in an old-river deposit laid bare by late rains, which have washed away smaller stuff. There was no moraine-stuff in the section—no clay and no scratched stones anywhere*.

The unusual size of these big stones has to be accounted for. Every lake and every snow-patch is a condenser. A lake is in Cashmere which was a great deal bigger, as shown by old margins. When it was bigger there probably was more rain in the whole region and more snow. In the lake-regions of Italy rainfall and climates vary notably within short distances. I found it so in April 1877.

The local rainfall about Kangra is now about 102 inches, and the slope is about 12,000 feet in four horizontal miles. The rain falls in about six months. Local rainfall varies greatly now in India. In Thibet, behind Himalayan slopes, it is said that no rain falls. In Scinde a few inches fall in a year. 62 inches is the average of places in the hills within sight of Kangra. 102, 125, 200, and from 500 to 800 inches have been recorded in different hill-regions in India. The rainfall of a given spot there seems to depend upon its position with reference to the wind, which comes from the Southern Ocean, and is called the monsoon, and with reference to ground over which that damp air passes before it reaches the place. The Kangra rainfall may have been stored up. In very steep, deeply-furrowed

* See Section V. for a real moraine at Ivrea.

ground snow-slides must frequently occur, and form "bunds" in narrow ravines, so as to gather a head of water. Landslips occur frequently; and they do, in fact, dam up watercourses, and form lakes, and accumulate water-power till they are burst by it. Earthquakes frequently occur in the Himalayas; one occurred at Darjeeling in February 1877. Numerous couloirs of old snow, formed in ravines, reach far down the hill-faces above the Kangra slopes, and are planes inclined at a very steep slope on which big stones might roll. Plenty of probable and of existing causes suffice for the transfer of big stones from the parent granite on the ridge down to their present sites on the Kangra slopes, a few miles from the hills. It took 37 steps to pace round one of the larger sort near the hills. Some are worshipped; and it is easy to see how a glacialist might attribute their transport to ice, while the people ascribe it to their divinities. I found small blocks of the same granite nearly 30 miles away, in the high gravels of a river which rises above Dhada in a snow-patch visible from Kangra and Simla. I believe that water moved the whole stream of rolled stones, great and small.

Between Dhada and Bhagsu, in crossing many streams which come from the lower high slaty ranges which rest against the granite, I could find no specimen of granite in a walk of 11 miles at the foot of the range. But further west a larger river comes from another snow-patch on the granite, and it flows amongst a great profusion of very large granite stones, washed clear of smaller stuff. These facts seem conclusive. Great water-power is sufficient to account for the big stones. In 1876 a very large stone was moved about a hundred yards by a sudden flood at Kalka, near Simla. Two washermen were washed from the stone and drowned. The cause of the flood was simply a heavy shower which poured into a steep angular river-basin of small area, and suddenly gushed out like water from a spout upon the apex of a delta which spreads on the plains over a distance of ten miles down to the Gugger river. The largest stones in that delta are next to the steep hills, and look like glacial work at first sight; they are comparable to the smaller sizes of big stones at Kangra. The rest of the Kalka delta is a river-deposit of rolled stones, gradually decreasing in size till the plain is reached. Thence the whole land is fine sand and mud down to Calcutta. There is nothing there like the amphitheatre of moraines at Ivrea. Similar deltas spread opposite to every river which I saw near the lower ranges of the Himalayas. They are conspicuous, even on maps on a scale of eight miles to one inch, between the Ganges and the Ravee.

36. *Summary.*—By visiting three hill-stations in the north-west, I saw points distant from each other about 400 miles. Having formed an idea of distant spots visible from Simla, I went to two of them, and verified my conclusions on the ground, at Landour and at Kangra, which are about 200 miles apart. I saw the shape of the Himalayan slope, and was convinced that no trace of the "ice-cap" remains between Thibet and the plains in the region seen. The ice-cap, in moving southwards, must have crossed the Dhaoladhar range,

which is as steep as the Caucasus and about as high. It must have crossed the deep Sutlej valley and the sierras which divide it from the Ganges basin.

Secondly. I went to the Ganges basin, and saw enough to be sure that it has not been filled with ice like Alpine valleys and Scandinavian dales, which were filled, and that recently.

Thirdly. I skirted the base of the hills in the plains, from the Ganges to the Ravee, and saw nothing comparable to the glacial-plain deposits of North America, or those of Europe, although " the snows " are visible from the plains.

Fourthly. I went to a range 16,000 feet high and 80 miles long. At 100, 70, 40, and 12 miles distance, and at the foot of the steep ridge, I found no trace of glacial action. I found none between the plains which end at about 1000 feet above the sea and spots which are from 7000 to 10,000 feet above the sea, and on the road to the borders of Thibet. Within sight of Indian glaciers I saw no sign of glaciation.

Fifthly. I found on the map that glaciers abound about a degree north of Kangra, near lat. 33° N., at about 12,000 feet above the sea. These are marked as 10 to 15 miles long now. In that region are lakes and flats called "maidans." Further north, about latitude 36°–37°, glaciers are still larger. They may all have been larger than they are; but they have left no record on the lower hills to prove that their size was greater in proportion to the size of glaciers attributed to the Glacial period. Scandinavian and Alpine ice has shrunk by many meridian degrees. Old Himalayan glaciers have left no mark within a few miles. It seemed as reasonable to account for the length of an icicle by a Glacial period as to summon that cause to account for any extension of Indian ice of which I was able to obtain proofs, from maps and surveyors, geologists and papers, photography and photographers, and travellers. I could hear of nothing to alter an opinion based on this personal inspection of the ground between Point de Galle, in Ceylon, and the Dhaoladhar ranges above the Kangra slopes.

37. I had no time to go on to Cashmere, unless I gave up Delhi and Darjeeling. I did not travel to glaciers: one such expedition is work for a month, and needs much preparation.

The Viceroy had from 1100 to 1700 coolies, and took more than a month to travel from Simla to the Ravee along the lower ranges of the Himalayas with his camp. I saw the point reached from the starting-point distant about 100 miles. I did not aim at discovering how much further any particular Indian glacier may have flowed. That geological work is in able hands. I did not wish to test the conclusions of other observers, to contradict or to confirm their observations. I wanted to look myself at a great deal of ground in a short time, so as to know the general shape of it, and to examine carefully a few spots selected as the best for my purpose. Having seen Hirdwar at the end of the Ganges basin and Dhada at the mouth of the Kangra gorge, I went to no more spots of the kind.

Between lat. 5° and 32° I found nothing in India to prove any great change in the existing climate of the world *.

38. After this cast in the hills I took several casts in the plains, working eastwards towards the most southern glaciers in the northern half of the world. I travelled to Saharumpore, and thence to Agra. There is no sign of glacial action about the banks of the Jumna, or in the plains seen on that journey. I could not see a big stone, I could hardly find a pebble as big as a nut in the river-beds. I travelled to Cawnpore on the Ganges, and to Lucknow on the Gumti, and westwards on the Oude and Rohilcund line by Bareilly to Alleyghur and to Delhi. I chose that route because it skirts the base of the Himalayas, crossing numerous streams which flow from Nepal and are said to rise in glaciers. Gradients marked along the line are from 1 in 500 to 1 in 3333. The country, though undulating, seems to be a vast plain of sand and mud, spread by the streams and levelled by local rains. Water is reached at small depths and is raised from wells for irrigation. The only hard stuff found in this plain region is "kunka," which seems to be a limestone-pan growing from aqueous solution by crystallization. The "laterite" of Southern India is something of the same kind. At Delhi, as in the Deccan and in Southern India and in Ceylon, I found something to account for the "moraines" of Central India, of which I heard much and saw nothing. "The ridge," famous in the siege of Delhi, is broken sandstone arched like broken ice on a rolling wave. If this be the work of an earthquake-wave, the movement was from S.E. or N.W., as it was in the other places where recent earthquake-waves have recorded their passage along the base of the hills in broken buildings and in broken hills. In Lyell's 'Principles of Geology,' under the head "Cutch," the rise of such a ridge is described. The ridge runs from N.E. to S.W., and is about 100 feet higher than the plains. The bed of the Jumna is sand and mud, and the old sandstone is the same. The arched beds are jointed, and the angles are weathered. A little more weathering *in situ* will make a ridge of stones and something like the shape of

* I was told by Major Godwin-Austen at Calcutta that the valley of Cashmere was a great lake, as proved by freshwater shells and terraced water-margins. From information given by many other observers I had been led to suspect that the river Jeelum had cut a drain, and partially dried a lake, whose old terraced margins are conspicuous in Cashmere. Shells found by an expert are conclusive, and confirm local tradition.

"On the Lacustrine or Karéwah Deposits of Kashmere." By H. Haversham Godwin-Austen, Capt. H.M. 24th Reg., Kashmere Survey. Read June 23, 1858. Quart. Journ. Geol. Soc. vol. xv. p. 221.

By the same author. "Geological Notes on Part of the North-western Himalayas." *Op. cit.* vol. xx. p. 383.

These two papers describe deposits which seem to resemble the Kangra deposits, and prove by fossils that some of the rocks of the higher ranges of the north-western Himalayas were formed in an ancient sea.

In mountains north of Cashmere glaciers still are of vast size about lat. 37°. The same able observer who found the shells and saw these glaciers, also found marks of ice-action near the valley of Cashmere as low down as 5000 feet above the sea (Journal of the Geological Society for 1864).

a moraine. The rocks by their composition indicate the action of water on fine sand, like the action of the Jumna on its bed. From Delhi I went eastwards by the Oude and Rohilcund line to Fyzabad Ajudia and Benares, finding everywhere the same geological engine at work—rain—in rivers and under ground. I went by the loop line to Sahibgunge, on the Ganges, and thirty-five miles up stream in a steamer. The sections made by a river which here is six miles wide in the rains, in islands which it is building and destroying and moving seawards, show false bedding and all those marks of water work which I saw in the soft beds of the "Shivaliks" and the Delhi brown sandstones. I saw no pebbles in these Ganges sections or in the dry bed of the river. I suppose, therefore, that pebble-beds were formed near high ground where running water has more power. The highest mountains in the world were seen from Sahibgunge on the 10th of February, distant about 200 miles northwards. At Sahibgunge is a low range of whinstone hills much furrowed by rains; rolled stones are gathered for ballast and for other uses. All that I saw were waterworn. I could see nothing like a terraced sea-margin there or on the foot hills of the Himalayas opposite or anywhere in India. The terraces of Cashmere are therefore marks made by the lake, not marks of the sea. I have heard them quoted as marks of "the Deluge." From the Ganges to the foot hills for 140 miles the land is alluvial, with scarce a pebble in the river-beds.

The Terai at the hill-foot is a belt of jungle like the country near Dehra. As at three other hill-stations the Himalayas rise steeply from the Terai, and they are equally furrowed. High up in these furrows rest stones as big as the biggest at Kangra. They are remnants of landslips left by rains which washed down finer stuff into the Terai. The rocks are chiefly gneiss, which weathers to a brown mud, with mica in it and quartz grains. I recognized these decomposed materials on my return, blowing in clouds before a strong breeze, about the banks of the Ganges. The wind rippled the sand and packed mica in the troughs of miniature waves. In many other parts of India sand-drifts are on a large scale. In accounting for the plains the action of the wind must be considered. At twenty miles from the hills, within sight of the snows, river-gravels are small pebbles of gneiss. From Hooker's Journals and the accounts of residents and travellers I learned that the largest river-beds in this part of India are of the same character. There are no large stones, no deposits of glacial boulders, even about the exit of the Brahmapootra, which rises close to the sources of the Indus and Sutlej and flows eastward through Thibet till it finds a passage into the Indian plains. So far as I can read the record on the plains between Ravee and the Brahmapootra, there never has been a large Thibetan glacier behind the Himalayas. There is nothing about the Punjab, as in Assam, and there is nothing about the mouth of the Yangtsekiang in China or the Pearl River in Canton to show that Central Asia was under a "continental ice-sheet." It is often mentioned in books. The mouths of all the great Asian rivers that flow eastward and westward and southward are like the Ganges delta. The delta of the Dwina is strewed with glacial drift. The Ganges delta clearly is a mass of fine materials chiefly washed down from the Himalayas by rains and deposited in the sea.

39. *Siccim.*—In travelling 40 miles from the plains up to Darjeeling on foot and on horseback I found only marks of great pluvial erosion. If Kanchinjunga were many thousands of feet lower, and if the plains of India were level with this hill-station and reached to Thibet, the views of Kanchinjunga and Siccim might be compared to the famed look-out from the church-tower at Novara in Lombardy. Darjeeling is 7167 feet above the sea, and a hill behind the station on the same ridge is 8606. The rainfall at places near is about 200 inches. These spots are on the edge of the basin of the Teesta, which is about 80 miles long, 50 miles wide, and 27,000 feet deep, according to the map. From Darjeeling the ridge slopes down about 6000 feet in four horizontal miles to the Rungeet, which is a branch of the Teesta. The whole drainage escapes into the Terai through a narrow V gorge. On the opposite north bank of the Rungeet, Kanchinjunga and a range of high grounds extending E.W. slopes upwards. The highest peak is 28,150 feet high, distant 44 miles on the map. Behind the range is that of Mount Everest, the highest in the world, masked by Kanchinjunga. The rest of the edge of this great hollow is a high jagged sierra towards Thibet, and a ridge about as high as the Darjeeling ridge, which divides the Teesta basin from the next basin which is eastward, in Bhotan. Beyond the southern edge of the Siccim basin there is no land southwards except the low plains of India. The basin of Siccim therefore holds a confined lake of air which belongs to the cold regions of high central Asia, as the waters in it belong to surrounding snows. The result is that a regularly intermitting cold wind pours out of these Himalayan basins with their rivers. At Hirdwar the wind is called the "Dalu," and is regular for months. It begins some three hours after sunset and ends about three hours after sunrise. At Dhada a similar river of cold air flows out of the gorge, and is visible with mist from Kangra in the morning. The lower air in these basins often is full of clouds and haze and dense mists, while the air above 7000 to 8000 feet is clear. At sunrise the river-courses in Siccim for eighty miles are often filled with flat grey clouds to a depth of some thousands of feet. They mark out the course of the stream of cold air; they also mark out the course for local glaciers, if they were now to fill these gorges on the scale of glaciers which filled Scandinavian dales during the Scandinavian local glacial period. When the air is warm at sunrise this deluge of mist often is 6000 or 7000 feet deep. Then it shows what the basin would be like if a glacial period filled it with vapour carried by winds from the southern ocean condensed and frozen. Sometimes it is possible to look out from these Indian hill-stations, over flat clouds which roof the plains, and to realize what is meant by a "continental ice-sheet" ten thousand feet thick and an ice-cap smothering the world. When the risen sun shines into the Teesta basin the lake of vapour boils. Clouds rise and climb up all

southern slopes, and up the face of Kanchinjunga, till they reach the tops and the ice, and rise high above the solid earth to 30,000 or 40,000 feet and fly away. By watching for a fortnight I managed to see most of this Teesta basin and its edges and hills, in Bhotan 25,000 feet high, distant more than 200 miles beyond the edge of Siccim. I could see three glaciers on the southern face of Kanchinjunga with their cracks and moraines, and with large blocks of fallen stone resting upon them in fresh snow. The biggest glacier is only about 8 miles long on the map. Away towards Thibet, I saw greater snow-slopes at the edge of the Teesta basin, and recognized the ground described by Hooker and Dr. Campbell, by Mr. W. T. Blanford and others. It is a narrow high country of glaciers and old glacier-marks, with numerous small lakes in it, all near to the highest grounds about the serrated edge of the basin 70 or 80 miles away. All the rest of the hollow, about 2000 square miles, below 12,000 or 14,000 feet, is one great series of rain-furrows like those which I had seen in the north-west at three other hill-stations. The Darjeeling ridge is like the roof of a house, 6000 feet high, and all the other ridges are like it. The beds of gneiss pass horizontally through sections made at the top of the Λ to make room for a house to stand on the ridge. Eastward at sunrise I saw a serrated ridge of snow-hills at the watershed of Thibet, and a series of ridges with a pretty regular slope southward, to show what the Himalayan slope may have been like before it was furrowed by rains. As icicles under the eaves are to the roof of a house, so are these big glaciers to the rest of the hill-country. They may have shrunk, they may be growing locally or generally; but these glaciers of Siccim, which are the nearest to the equator of any known, are near their extreme size. There are no marks of any glaciers on the scale of the morning mists, which mark out the beds for glaciers on the scale required by the Glacial period in India. The place where the Teesta enters the Terai is incomparable to Ivrea in Italy (see Section V. for the records of glaciers there).

40. This may show that climate does not depend upon latitude. At Darjeeling my glass marked 23° at sunrise on the 6th of February, 1877; on the 8th, 40 miles away, it marked 58° in the Terai. At Calcutta it marked 60° for a week at sunrise, while snow fell heavily at 7000 feet at Darjeeling. On ground only 44 miles away from Darjeeling, at 28,150 feet, the snow never melts, and glaciers exist. At Calcutta punkhas are used, while the Bhotias wear blanket-frocks and furs, and cover their brown faces with black unguents to prevent frost-bite. A local glacial climate is between lat. 28° and 27° N. I left a region of mist and cloud for a place where horses wear solar topes and die of sunstroke in the streets; within two months I was about lat. 45° or 46°, where my glass read about 50° at the foot of the Alps at sunrise. The climate at Aosta is not much colder than the climate at Darjeeling. My glass was at 35° and it snowed heavily at Ivrea on the 17th of April. Snow lay on Mount Ida, on Etna, and Calabria in the same month; and snow fell at Malta in the end of March about the latitude of Cashmere.

41. *Summary.*—"*If the ice-cap ever came down from the north pole to the equator, it must have come down from Central Asia over the Himalayas.*" There is no trace of it on a band of country measured by fifteen degrees of longitude between points in Cashmere and in Bhotan. There is no trace of it in the Caucasus, in the Crimea, in the Alps, or in the Rocky Mountains of America. If a late "Glacial period" existed all record of it that remains below lat. 32° in India is on a narrow belt some few miles wide, and possibly 6000 feet deep, round the edges of river-basins, and near glaciers which I saw at a distance from four hill-stations in the Himalayas, from Kangra, Simla, Landour, and Darjeeling.

42. *Weather.*—Glaciers flow like rivers, and like them are subject to speates and inundations which depend upon the weather. The first glacier I ever touched had taken a late fit of advancing, and had ploughed up green pastures and turf. It had then melted away, leaving stones which it carried on the surface upon stones over which it had passed. There was a wide hollow area of bare wet muddy rubbish in front of the ice. After 1841 most glaciers on the north side of the Alps advanced, and many of them ploughed up pastures. After a time most of them retired. Those which had come down steep slopes now end at the top, a long way and a stiff climb above their old limit. Those which had advanced are now a great deal shorter than they were, and their limits are marked by their moraines, and remembered for the damage done. I have no statistics; but the facts are well known to Alpine travellers. I have no explanation to offer; but this change manifestly depends upon "*the weather*," not upon astronomical causes. From some atmospheric cause the rainfall of Southern India failed, and caused a famine in 1876 and 1877, while the winter in Britain was unusually wet and the land was flooded.

That is enough to show that marked changes in Himalayan glaciers may also result from common atmospheric causes, and that the amount of change recorded does not require an abnormal Glacial period. Since 1841 a small Caucasian glacier slid and tumbled down at a fork upon a branch, which advanced a long way and threatened the road in the Dariel pass. For that reason the glacier was surveyed, and the changes were recorded. The Caucasian glacier and the Alpine glaciers have gone on flowing as usual, and their changes have been noted. Changes in Himalayan glaciers have not been noted, but they resemble river-floods. Within certain limits they depend upon the weather. Within the life of men still living the weather on the west coast of Scotland has changed for the worse, so as to destroy some garden plants altogether and to spoil crops. The change has been noted only by those whom it chiefly concerned, by men who have lived at the place all their lives; the rest of mankind probably know nothing about these changes of Scotch climate. According to Icelandic Sagas, the coasts of Greenland once were accessible and habitable, where floating ice now makes navigation almost impracticable, where cultivation has ceased altogether, and civilized men have ceased to live. Yet the world's climate remains the same, so far as men know. These changes, great and small, recent and remote, are all *local*, and, so far as I know, they are atmospheric. When at Simla in October 1876, "the end of the S.W. monsoon came after date." I saw it come. On the 9th a lot of small clouds floating above the hills at about 25,000 feet came from Thibet; the N.E. wind had begun. The sky was clear above in the N.E. wind above 7000 feet. Below Simla on the plains the air was damp, thick, hot, and stagnant. Thunder-storms flashed at night. The 10th and the 11th were alike. The N.E. dry wind poured slowly down the Himalayan slopes. On the 12th it rained and thundered at Simla. On the 13th and 14th it poured. The 15th and 16th were fine days. On the 17th it rained. On the 18th, 19th, and 20th it was clear about Simla. After that the air was clear and dry for many months about the hills. On the 8th a heavy fall of rain began at Allahabad; eight inches fell in 24 hours. On the 12th there was bad weather further south; along the coast Vizapatam was inundated, sepoy lines were destroyed, and many lives were lost. On the 21st a great circular storm took an abnormal course in the Bay of Bengal, and the wave which it dragged along swamped the coast of the Ganges delta. About 300,000 persons perished. But all this was the result of a slight variation in the world's "weather," a cold "down rush" of air stirred up still air and precipitated moisture. An equal quantity of snow would have made a glacier grow abnormally, as I suppose, because of the weather. At page 248, vol. i. of Hooker's Journals, from 8000 to 10000 feet is said to be the limit of ancient glacial marks observed in Siccim and Nepal. The largest and lowest moraines were on very steep ground on the northern shaded side of the Kanchinjunga range behind Jumnoo. A small glacier is on the southern sunny slope of that peak, which is 25,804 feet high, and larger glaciers are on the north side. From 13,000 to 14,000 feet is about the limit of existing glaciers in these regions, according to the distinguished author who discovered and described them. That gives a marginal difference of 6000 feet at most. According to Hooker, glaciers in the N.W. Himalayas reach from 8000 to 7000 feet. According to Major Godwin-Austen marks are found at 5000 feet above the sea. That gives a difference of 3000 feet at most. But cliffs on Kanchinjunga which are so steep that snow cannot rest on them, are nearly as high as this margin of from 6000 to 3000 feet of vertical shrinking. But 14,000 feet of height may mean two and three quarters or four miles on a map, in the highest Himalayan regions where glaciers exist and where old marks are found. A sudden débâcle would send down a moraine that far; a glacier might slip as much. Photographs of Indian ice show the same character which is seen from Darjeeling. The glaciers end in narrow **V** gorges, and then turn into streams which flow on very steep slopes. In Scandinavia glaciers commonly end in wide flat dales ◡, in which their streams have cut small shallow water-furrows. Old marks of Scandinavian glaciers extend from the ice to the sea, along flat dales into fjords, and out of them up over islands as far as islands rise above the sea, for some hundred of miles. There is one continuous record of ice-action engraved upon solid rocks from the Dovrefjeld to the mouth of the Christiania fjord. The whole of Finland is glaciated, and Finnish erratics are far down in Northern Germany. If this and Alpine ice-work on a large scale be due to a "Glacial period," similar work ought to be found near the Kanchinjunga glaciers; but there is nothing of the kind there or in India anywhere south of lat. 32° 30′. In the paper numbered 8, in mention of a débâcle caused by an earthquake at Ararat, a flood of snow ice, water, mud, and great stones flowed twelve miles along a flat valley in a few hours, and there left a record which can hardly be distinguished from normal glacier work. Such a débâcle might go down 12,000 feet in India. Earthquakes frequently occur in the Himalayas and near them. One happened in February 1877 beside Kanchinjunga, where glaciers hang at an edge. This cause and consequent abnormal débâcles must be considered in accounting for masses of rubbish which look like moraines in improbable places. Major Godwin-Austen found marks amongst lower hills near the head of the Bay of Bengal, which he then supposed to be "moraines." He found no scratched stones in them. Hooker found no glacial marks at the foot of higher hills further north in the same line; I found none up to lat. 32°. I think it possible that even Major Godwin-Austen, a skilled observer, may have been influenced by the prevailing belief in the "Glacial period," which has so often influenced me.

Since the glacial theory took hold, the first impulse commonly is to account for any abnormal deposit of large stones and débris by glacial action; but when the work of floods has been seen, that impulse is checked. I have learned that by many mistakes of my own. Weather has changed the position of ice in the Alps, in the Caucasus, and in the sea within living memory and historic times; but the world's climate remains the same nevertheless, so far as meteorologists inform us.

IV. *India.—Pluvial Erosion.*

43. So far I have been obliged to follow the example of old Nicholas Horrebow in his chapter on Snakes:—"There are no snakes in Iceland;" and I saw no records of a glacial period in India. That which I did see and hear of is vast pluvial erosion proportioned to vast yearly floods. The side of one gorge measured by a surveyor rises 14,000 feet in a mile and three quarters on the map. I saw Nunda Devi, Jumnutri, Gungutri, Kanchinjunga, the Dhaoladhar slopes, and others which are on this sort of scale. About 14,000 feet in four horizontal miles is the slope at Kangra.

All the hill-country that I looked over is furrowed like a ploughed field; and where I was able to trace the structure of the rock, every furrow was carved out of the solid. Every furrow that reaches to a plain ends at the apex of a large growing delta (Δ). Given years enough, and the largest of these Himalayan furrows would result from the cause which cuts the smallest during showers. In North America the Grand Cañon of the Colorado is all water-work, according to experts. In Asia the Sutlej valley and others are on a greater scale of length and depth. But such carving implies chips in proportion and long time for slow work.

The foot hills of the Himalayas are "Tertiary rocks," generally known as Shivaliks. They belong to periods of large animals. In Europe such animals belong to the period dated Pliocene ; Shivalik fossils are dated Miocene at the British Museum; Mr. Medlicott's map gives subdivisions. Taken together they are of great thickness ; Mr. Theobald estimates them at ten thousand feet. They have been crumpled up against older beds in the higher ranges and faulted parallel to the folds according to the map. Sections are exposed in river-courses and along roads ; they consist of brown and grey soft sandstones and mudstones, with beds of hard rolled pebbles interstratified and associated with the soft sandstones. In travelling up and down hill at four hill-stations, I crossed these Shivaliks eight times, where fresh sections were exposed. In these beds I saw all known marks of the action of water flowing from the hills towards the plains. I saw false-bedding as conspicuous as it is in the banks of the Ganges, in sandstones and mudstones like Ganges sand and mud. I saw pebbles sized and packed like eggs in a basket, with the long axis pointing towards the plains, and decreasing in size as the distance from the hills increased on a journey of 70 miles from Kangra to Hosiarpur. When first I saw these pebble-beds near Dehra, having no knowledge of them at all, I took them for high river-gravels. When first I saw the beds near Kangra in the dusk I thought I had found boulder-clay and a moraine.

In the bent faulted folds of this series of rocks is a clear record of action like that of rivers which now flow through the Shivalik hills to the plains. Taken together, all existing Himalayan rivers are building a compound delta which is as wide as the length of the range, long. 72°–100° E. The Terai is a region of wet ground twenty or thirty miles wide at some places, where water is close under the surface, where grasses grow thickly to a height of twenty feet in a tangled rank forest bound with creepers. In that unhealthy region great wild beasts abound—elephants, rhinoceroses, tigers and the prey of tigers, wild cattle of great size, deer, and so on. This belt of wild country or "Jungal" coincides with the growing and mingling deltas which the rains are incessantly washing out of furrows, which rivers deepen and scour incessantly or periodically, according to their length and size. The Tertiary rocks, when I got to know them better, seemed to be a portion of an old plain terai of deltas crumpled up and broken. The "Collino" of Turin and hills south of the Caucasus are something of the same kind, and the formation extends far south in Italy. But if this be so, then all this mass of rolled stuff, mud, sand, gravel, pebbles, shingle, and large rolled stones, Tertiary and Recent stuff of the same kind, the Kangra big stones, the Kalka stone of 1876, the lowest bed in the Shivalik series, and the last grain of mud in the Bay of Bengal are chips recording chiefly Himalayan erosion. The stuff was carved out of the valleys, and chiefly by rains. I have been told on the ground that the Shivaliks are "Moraines of the Glacial period," and that the Turin Miocene marine deposit records the action of ice. I could find no trace of glacial action in these Tertiary rocks of India.

The fossils of the series have been described. Lists comprise elephants of many kinds, rhinoceros, camels, alligators, gigantic tortoises, carnivora and their prey, extinct creatures closely allied to those which haunt the hot delta region of the Terai, below the foot hills in the plains. I saw a camel expiring on the shingle of a river-bed near Noorpoor, to show how the bones of his ancestors got buried by floods of old. So far as I can learn, no marine remains have been found amongst these Tertiary rocks, and no scratched stones. I watched for old sea-margins everywhere, and saw nothing like the terraced forms which are so conspicuous in other parts of the world, where sea-shells prove raised sea-margins, and show that the level of the sea and land has recently changed. Ceylon has risen, the Runn of Cutch has certainly gone down in late times. So far as I can judge from my own inspection of these Shivaliks, and from reading and conversation with experts, there is nothing in this Tertiary geological record to show that any great change of climate or level has occurred in the region next below the Himalayas since the Shivaliks began to be deposited there by rivers. All signs of a long-continued aqueous erosion in a hot climate abound in the record. The chips are proportioned to the carving which I saw, and which I believed to be the work of rain when I left the hills. There is no sign of a glacial period in the Tertiary rocks or in the superficial geology of India, so far as I have been able to learn. The "Talchir boulders" (21) associated with Indian coal in lower Tertiary rocks within the tropics remain to be explained. I strongly suspect that striation will turn out to be caused by something non-glacial, and that the term "Glacial period" has biassed opinion in this case.

V. *Europe.—Comparison.*

44. On the way from London to India, *viâ* Brindisi, a great deal of the world's surface is rapidly seen between lat. 50° and 40° N. Any wide surface which nearly coincides with the curve of the sea suggests the sea. The plains of France have been little eroded by rivers; they end at the semblance of an old coast-line at the station next to the Alps; thence the hills have the shape of glaciation. They are carved out of crumpled folds in beds of rock, most of which were deposited at the bottom of the sea. In similar latitudes on the opposite coasts of Newfoundland marine ice in all conditions is at work on a large scale. If the land were as high as the Alps, glaciers would probably reach the sea. J. Milne, Esq., F.G.S., now Professor of Geology in Japan, describes what he noticed in Newfoundland*. What I noticed there is described in 'Frost and Fire,' 1862.

* 'Geological Magazine,' July, August, and September, 1876.

Folds in the structure of disturbed rocks are very plainly seen on both sides of the Atlantic, and they do not correspond to the outer surface on either side of the ocean. From the valley of the Rhone and from Lake Bourget, at Aix-les-Bains, all the way up to Mount Cenis, up a rise of about 2300 feet, and down again to the plains of Lombardy, at Rivoli, glacial marks were conspicuous during an express-train run of about 10 hours. Moraines and moraine stuff, big stones, glaciated rock-surfaces, and later water-furrows, with their deltas, are conspicuous between the tunnel and Turin, in the valley and on its sides and in railway-works: the record is very plain. I judged that a glacier was more than 2000 feet deep when it reached the plain at Rivoli. That plain, again, suggests standing water by its flatness; it looks like a bit of the bottom of the sea. From the size of the water-furrows, the Italian glacier melted a long time ago. All these ridges and rock-grooves bear records of erosion by flowing ice and by running water. They certainly are not folds in the folded beds of which these highlands are made. The latest glacial record has been partially destroyed by water; but so long as scratched stones and erratics remain on the surface and ridges and grooves retain their curved section, this record may be deciphered by experts. It has been read by many. From the base of the Alps to the end of Italy water-furrows become more and more conspicuous; but from the general outline of these highlands, it seems probable that experts may yet find ice-marks where snow falls. Snow falls and outlasts summer on Greek hills and on Candia, whose top is about level with Darjeeling. Snow fell at Malta in April, 1877. On the American coast of the Atlantic ice was at work down to the latitude of Suez, 30°, about Charleston. But the world's climate had not altered generally.

The slopes of Vesuvius, Stromboli, and Etna, the coasts of the Red Sea, and the Arabian volcanic island of Gib-el-tir, are newly-formed volcanic surfaces or spots in the hottest and driest of known climates. There is no question of recent glacial action on these surfaces. The wearing certainly is water-work with which to compare other worn surfaces. The African Red-Sea coast is chiefly horizontal-bedded rock, much furrowed vertically by occasional heavy rains. Gib-el-tir is surrounded by a raised sea-margin, comparable to others on the Atlantic coast or elsewhere, between the North Cape of Europe and the base of the Alps. This volcanic island has been raised bodily after it had been worn all round by waves at the old sea-level. One side is a "Cliff and Talus," a recent fracture undermined by waves and furrowed by rains. The fresh fracture has been freshly worn and shows the structure of a cone of eruption which is 900 feet high, and smokes occasionally still, according to the charts.

The temperature of sea-water was 90°, according to the log of the engineer of the 'Hydaspes,' in September 1876, at the end of the Red Sea.

On my return to Europe in April 1877, only two months from Darjeeling, I took a cast through Northern Italy to compare the base of the Alps, about lat. 45°–46° N., with the base of the Himalayas between 27° and 32° N., with the Rocky Mountains about 36° N., and with the base of the Caucasus about 40° N. From Genoa the railway goes from the sea-level up a watercourse to a watershed and down another river-course to the plains. These main streams flow in channels with steep rocky sides, cut through bedded rocks at the bottom of curved hollows U, which have also been scooped out of the solid. The sides of these curved hollows are furrowed by branch ravines V of angular section cut by smaller streams. Near Cannes are glacial marks. Near Genoa are remnants of thick deposits of large stones supposed to be glacial work. I suppose that the general shape of these wide valleys of curved section is due to old glacial erosion, and the smaller angular furrows to more recent rains. I saw no valley of like section in the Caucasus or in any part of India. I noticed nothing else from the train between Genoa and Alexandria. Thence the line runs westward to Turin, and thence I went eastward as far as Arona. The plain country is as flat as India; but pebbles abound in Lombardy, whereas there are none in the Indian plains. Stones used for road-making about Turin differ in shape from Shivalik pebbles used for the same purpose, in that most of them have flat sides and some are scratched.

I took the liberty of waiting on Signor Gastaldi, who was kind enough to show me maps of the country north of Turin and to explain them, and to give me some recent publications on glacial subjects. Moraines near Rivoli were conspicuous objects from the train which carried me down from Mount Cenis to Turin, on my way to India in September 1876. About Ivrea the glacial stuff mapped by Signor Gastaldi extends far into the plains. It also approaches Turin from the north and east. It seems as if an estuary of large glaciers had converged along the headwaters of the River Po on Lombardy. Moraines rest upon clay which contains marine shells, of which many kinds still live in the Mediterranean and elsewhere. Similar marine deposits underlie similar glacial stuff at Como and elsewhere. These marine beds are dated "Pliocene." No such beds had been found along the base of the Himalayas when I was at Calcutta. I heard of no such beds when I was at Tiflis. Hills on the right bank of the river at Turin are dated "Miocene." They are made up of beds of clay, sand, rolled shingle, scratched stones, and larger, subangular, smooth blocks, to some of which sea-shells adhere. It is a marine formation with glaciated stones in it. The roads are mended and buildings are made with stones taken from the beds. For height, position, shape, and structure the Turin "Collino" is comparable to lower ranges in the Caucasus near Tiflis and to the Shivaliks between Dehra and Roorkee, between Kangra and Hosiarpur (see 27, 32, 39). These Italian outliers differ from the others in the shape and size of the stones and in the marine fossils. The formation is said to extend to Calabria, near to the latitude of Simla. From these "Miocene" beds to the moraines of existing glaciers these Italian deposits record the action of ice, according to Italian experts. I could find nothing glacial in similar beds south of the Caucasus or south of the Himalayas. It is enough for me to know, from the writings of accomplished geologists, that the plains of Italy were under the sea while glaciers existed on the Alps, at least once before large recent glaciers deposited moraines upon beds of sea-shells north of Turin and Milan, about latitude 45°–46° N. My theory is *that a large local submergence of Europe let in the cold Arctic stream, and so produced a local European cold climate for a time, during which "local European glacial periods" Alpine and other European glaciers grew large and flowed far, and reached the sea-level or near it about lat.* 45°–46° *N.* It is certain that parts of Italy, Norway, and Scotland have risen within the period of history. Land may have sunk and risen many times while beds of many geological dates were formed, and some were folded and crumpled in Italy, in the Caucasus, and in India. I suppose that the last general rise in the European area, which is proved by recent and Pliocene shells, shunted the cold stream and its climate westwards to the American side of the Atlantic, and by so doing restored the old temperate climate to Europe, and made the Alpine glaciers shrink to Mont Blanc, Monte Rosa, and other high grounds, where they remain. The Italian record supports this theory.

On the 9th and 10th of April it rained heavily and snowed on the hills. On the 11th I went up a thousand feet to an old telegraph-tower at Alpina. On three hundred degrees of my horizon I saw snowy mountains. A slight change of climate would bring back glacial conditions. The shape of the Alps is conspicuously different from the shape of the Himalayas. The slopes are not nearly so steep, the ravines are not so steep, so numerous, or so regular, the larger hollows are much wider, the tops are rounder and broader. The landscape generally has fewer angles and straight lines in it and more curves. At a few spots only I could see ridges and furrows of the normal Himalayan pattern, the work of recent rains. The 12th, 13th, 14th, and 15th of April were clear, and the new snow made every detail of form conspicuous. From Turin, from the train, from hills near Ivrea, and from Novara I saw the Alpine range as I saw the Himalayan ranges only two months before. The sharpest points in the Alps are rather conical than pyramidal. The sky-line is less deeply notched. The sierra is more like a worn blunt cross-cut saw with short teeth than a run-saw with long regular teeth. The lower slopes seen sideways fade away to the plains instead of plunging down steeply. Seen from Novara westward, the range of Monte Rosa is more like the Himalayan tops. The strata are seen dipping southwards, and their flat slabs have weathered into pyramidal tops. But even these slopes are not nearly so steep as the sides of Nunda Devi and Kanchinjunga. If the island of Candia were in the plains of Lombardy, and Novara on the top of Ida, 7624 feet above the sea, and if Monte Rosa were 12,944 feet higher than it is, then the famous Italian view of the Alps might be compared to the view from Darjeeling. Here and there ridges and furrows and peaks of the Indian pattern are visible; but they are exceptional shapes in the Alps, not a rule almost without exception, as they are in India. Once for all, the general shape of the Alps, which are glaciated, differs conspicuously from the shape of the Himalayas and the Caucasus. I found a scratched pebble on the Turin Collino. The shape of the larger stones, which are dug out of the hill in large numbers for sale, is subangular. This upheaved marine formation dated " Miocene " suggests the action of rivers and the sea on glaciated stones. The stones of the Shivaliks suggest the action of running water only. Experts identify the Miocene Turin stones with parent rocks in the Alus. So the Alps existed and glaciers were on them in Miocene times. The Himalayas also existed before the Shivalik beds were formed; but these beds bear no record of any great change in the Indian climate or of large glaciers. *At sight* the Alps are glaciated, and the lower Himalayas are not.

On the 12th of April I went to Ivrea. The place is situated, like Hirdwar and Dhada (27, 30), on the banks of a considerable stream which rises amongst glaciers, and, at the place where water gathered in a considerable basin, pours on the plain. From Hirdwar to the Ganges glacier is about a hundred miles. From Dhada to old snow is about four miles. From Caluso to the Col du Géant is, roughly, about a hundred kilometres, say sixty miles. To the north of the Ganges basin is the Buspa valley with glaciers in it flowing northwards towards the Sutlej. To the north of the Col du Géant is the Mer de Glace flowing northwards towards the Rhone. To the north of Dhada on the next slope beyond the Dhaoladhar range are many large glaciers which flow towards the Ravee. In 1841 I walked over the Mer de Glace and the Col du Géant and saw small glaciers above Aosta shedding their moraines southwards. Thence down to Ivrea glacier-marks are conspicuous all the way. That I learned in 1841. Given a Glacial period, then the Ganges valley ought to be like the Val d'Aosta, and Hirdwar like Ivrea, the Sutlej valley like the Rhone, and the Lake of Geneva like the country near Puttankote on the Ravee, because of existing glaciers at these places. About Tiflis there ought to be similar records of a Glacial period, because glaciers are on the northern slope of the Caucasus now; but the facts contradict theory. The glacial record is not general.

At Caluso a tunnel cut through a considerable hill of rolled stones is the entrance to a horseshoe-amphitheatre. A blue moraine-lake, Candia, one of four lakes of the same kind, is within, and a beautiful rich warm country of orchards in flower, green cornfields, and trellised vines, where nightingales were singing. I found cacti, birches, heather, and mountain pinks growing together, and the sun was powerful, though snow lay thickly about 2000 feet higher. In India this would be a Terai and a jungle haunted by elephants. This Italian plain country was haunted by elephants, for their bones are buried in recent soils. Indian elephants might live there now; for they flourish in a like climate in Cashmere. East and west of the river Dora are the lateral moraines of the Val d'Aosta abutting against the open jaws of the gorge. All the rains that have fallen since they were shot out sideways from the delta of ice have scarcely furrowed these wonderful ridges. The left or east moraine is on the outer side of a curve and is the longest. It is from 1500 to 2000 feet high where it rests against the mountain near Andrate. It is 1080 feet high where the Biela or Mongrando road crosses. It slopes from Andrate down to the plains regularly for 25 kilometres. It joins a curved rampart which sweeps round to Caluso for about 25 kilometres and there joins the west lateral moraine which rises to the opposite mountain, and so walls in a small glaciated low country with three sides equal to 25 kilometres each. From Caluso to Ivrea is 20 kilometres, thence to Aosta by road 67, and thence it is a long walk to the Col du Géant and the ice. About Ivrea a band of bare rocks crosses from mountain to mountain and nearly from moraine to moraine. Through it the river has cut a channel. This region is ice-ground, grooved, and polished in the direction of the Val d'Aosta, with erratics perched here and there on the tops, and it is hollowed out into rock-basins which hold at least four small lakes. There are eight lakes within the moraine ramparts ; there are none outside. I went to Chiaverano and saw two in rock-basins and the usual grooves made by glaciers. Immediately above these glaciated rocks is the left lateral moraine, and near the top of it is a stone, if it be a loose stone, far bigger than any of the Kangra big stones. It is bigger than neighbouring farm-houses and it has a name. Near it is a water-furrow in which the structure of this mountain-moraine is clearly seen. The Biela road is only six years old. The sides of it give fresh sections of the hill-side for a height of 1080 feet and a distance of several miles. From top to bottom the materials are alike. I found scratched stones at the base near Bolengo, halfway up, and on the top of the ridge. I found samples apparently of all the rocks between Ivrea and the Col du Géant, of all ages, shapes, and sizes, granite, crystalline and soft, large angular blocks, and subangular, smooth, rough, scratched, and polished ; great and small, rolled, water-worn pebbles ; sands and soils promiscuously heaped together, piled in the shape which is taken by rubbish now being heaved out by coolies at Madras to make a breakwater. This is " a moraine." It is something very different from the Kangra " deltas." I saw no shells, but I take them on trust. I saw stratified stuff low down. There can be no question about the translation of my part of this record. A glacier flowed from the Col du Géant to the lakes of Viverone and Candia. It was 100 kilometres long (say sixty miles) and was about 2000 feet deep, and five kilometres wide at the top, when it passed over the bare rocks on which Ivrea stands. As soon as it escaped from the gorge it spread out like a fan 25 kilometres wide upon the plain now walled in by the moraines. I suppose that the rampart of rocks at Ivrea protected certain soft marine beds of " Pliocene " age lower down, on which this particular glacier flattened out, sunk down, spread, and melted. I know a Norwegian glacier, " Supedle dals üs brae," in Sogne, which is spreading upon the soil of a dale and pressing on it and melting without advancing or ploughing or digging, because the power is expended. This Aosta glacier certainly ground the rocks in the Val d'Aosta, and it went up hill and down, and in and out of hollows. It scooped out four small lake-basins, and made a deep hollow in the rocks behind Ivrea, which hollow probably held a large lake before the right lateral moraine was damaged by rivers. The rock-section of the Val d'Aosta is unlike the section of any gorge that I have seen in the Caucasus or in the Himalayas; but it is like the sections of many narrow Scotch glens and Norwegian dales. The shape of the rocks is different; the stuff transported is different and differently arranged. The shape of the mountains is very different, taken as a range, or singly, or in detail. In short, *at sight* and after close examination, these lower southern Alpine slopes are glaciated, and the lower Caucasus and Himalayas and Californian slopes are not. But glaciers now exist on all these ranges, and the ranges have all existed since Miocene times, according to experts. But if so, a general Pliocene or Postpliocene glacial period ought to have made all glaciers grow on the same scale on all the ranges. The Ganges basin ought to be like the basin of the Dora, and the Ravee basin like it, or like the country near Chamounix. So far as my knowledge and power of comparison extend, nothing can well be more different. I went up the Lago Maggiore in a steamer from Arona to Locarno, 62 kilometres in six hours, and back again. My object was to compare one large Alpine rock-groove with another in the Himalayas at Darjeeling. In India I lived for a fortnight on the edge of a spoon-shaped furrowed hollow some 80 miles long, and generally looked down upon a roof of cloud. I lived under a roof of cloud for a week in Italy, and the clouds sent down rain and snow in the middle of April. I lived in a spoon-shaped hollow about as big as the valley of Siccim. Both are rock-basins in that their edges are solid rock. But the Italian spoon is deep within, and holds a lake whose surface is level with the plain; whereas the Indian spoon, though far deeper, has a continuous slope for 80 miles, and ends at a narrow gorge, like the Val d'Aosta at Ivrea. If the Siccim spoon were mended by a moraine as big as the moraines at Ivrea, it would hold a lake proportional to the depth of the dam. It would hold a lake if another fold of flat Terai were to be crumpled up against the foot hills after the Shivalik fashion. If the Thibet end sunk enough, Siccim would be a lake. If the Swiss end of the Italian spoon, were raised enough, the Lago Maggiore would flow out. Any amount of damming or tilting required to fill or to empty these hollows has been far exceeded by the crumpling of strata formed at the sea-bottom between Arona and Siccim. But no possible damming or tilting could make these two hollows alike. They are both valleys of erosion, *at sight.* The Italian geologists who know their country best have no doubt about their valleys; I have none, after seeing the land above water on a broad belt which surrounds the world. *At sight* the Italian rock-grooves have been greatly worn by glaciers and, since the *local* glacial period, by water. At sight the Indian grooves have been eroded by water alone. Immediately behind Locarno, which is at the fork of two long valleys, on steep ground, which I take to be an old moraine, are many deep water-furrows of the Himalayan pattern on a small scale. The flat point below Locarno, which is creeping out into the lake, manifestly is a compound delta of pebbles washed into the chief rock-groove, which is full of water and was full of ice up to the far higher level of the moraine stuff. The cloud roof of the 18th and 19th of April marked out the shape of the ice. The cloud roof in Siccim marked out a different shape, like that of the artificial lake at Ootacomund, a sharp angular zigzag line of coast like that of the Black Sea below the Caucasus, instead of a curved coast like that of the Italian lake, or of a Scotch firth, or a Norwegian or American fjord. In Greenland under ice there can be no furrowing by side streams. In Scandinavia the side furrows in dales are shallow and far apart; they are deeper and nearer together in Scotland. In Italy they seem to be deeper, and each has a delta proportional to its size. Many of the little towns are built on these deltas, with a bridge at the apex in the jaws of the gorge. In the Caucasus, about the same latitude, these water-furrows are deeper by far; but they are separated by wide slopes and undulating tablelands. In the Rocky Mountains the furrows are cañons, deeper and further apart. In the Himalayas the water-furrows are almost invariably separated by ridges of exceeding sharpness, like furrows and ridges in ploughed land. *From this comparison I drew the conclusion that the last Alpine glacial period was European*, not *Asiatic, and* not *American; that it was local*, *not general.* I saw all these mountain-ranges between Sept. 1873 and April 1877; I began in 1841 near the place where I ended, near the snow-sheds of the Alps, fresh from Kanchinjunga. On the 21st I went back to Turin on a very fine bright clear day, at first through a jungle of birch, and over the moraines of the Lago Maggiore glacier, which make an amphitheatre of stony gravelly ridges, which extend as far as I could see eastward, and fringe the lake-district. They fade away to the plain near Novara, a slope of gravel. At the base of it begins irrigation, like rice-flats in the East, from canals like the Ganges canal in miniature. On the 22nd I started for London and got there in 37 hours. While travelling swiftly to Calais, Atlantic weather and a heavy shower met the train, and a stormy sea-wind drove drops diagonally athwart a window. They wriggled like long-tailed tadpoles on the glass, leaving joints of their tails behind them. The glass dried and these occurrences were recorded on the window in dust, sorted by wind and water. Tracks all over the world's surface are records equally clear for those who have learned to read them, by seeing them written. The tracks of ice and of water are as clearly written upon the world's surface in India and in Europe; but I have failed to discover any record of a Glacial period upon the surface of the globe.

VI. *Conclusion.*

45. All that I have learned about ice and ice-marks since 1840 teaches that "the Glacial period" is terrestrial, not celestial; meteorological, not astronomical; that old glacial marks record local changes of climate on the large scale which resulted from local

changes of level, and from consequent changes in the position of land and sea, and of currents of air and water, like those which now circulate. I hold to "continuity." The cold Atlantic current now makes Greenland the chief condenser in the northern hemisphere; and consequently an area about as great as India is there smothered in ice, which flows down to the sea-level in latitude 60° N., and drifts away to lat. 37°. The warm Atlantic current now flows northwards along the coast of Europe, and consequently the sea is clear of ice beyond lat. 71° N. These two very different climates on opposite coasts result from oceanic and atmospheric circulation. But Scandinavia was like Greenland. It has risen above its old level, which is conspicuously marked along the whole coast. Great abundance of sea-shells proves the change. The cold Arctic current once passed southwards, to the east of Scandinavia, instead of to the east of Greenland. It is shunted by a rise of land. Scandinavian ice which now is perched on a few high spots was at some late time as heavy, as deep, and as wide as ice now is in Greenland. That I consider proved by records inscribed on the whole peninsula. At that time, as I now suppose, Scandinavia was the chief northern condenser, with glaciers launched about lat. 60° N., drifting to 37°. Greenland may then have been, like Scandinavia, a land with few glaciers and a climate as warm. Corn grows near the North Cape. Greenland ice drifts to latitude 37°. American plains are strewed with large glaciated stones and rolled gravels down to latitude 37°. If these plains were sea-bottoms, as some parts of them certainly were, because of their marine fossils, the cold stream which is now felt near Florida would swing westwards over the plains, carry drift, and cool the climates of lands near it, near the Rocky Mountains, as it does now in Florida*. When the cold stream passed over Northern Russia it probably fixed the condensing area. Erratics in Poland and in Northern Germany probably were dropped from icebergs and ice-rafts like those which now drift in the Atlantic in the same latitude. The margins of the European ocean are marked by terraces on hill-sides in Britain and in Scandinavia, on the Caucasus, and, as I believe, on the Alps. Recent and Tertiary sea-shells have been found high up and far inland in Scandinavia, in Northern Russia, in Britain, in Italy, and elsewhere. As I translate this geological record inscribed upon opposite coasts and mountains, it means late large local changes in the relative positions of sea and land, and consequent local changes in climate, like those which are proved by marine fossils of all ages. Above lat. 33° N., about long. 77° to 76° E., north of Kangra, in the Himalayas, is a large condensing area, high enough for large glaciers to form in great abundance. They grow there, because that high region now is in the course of a damp wind, which passes over Sind without condensing. When that part of the circulating atmosphere has passed over the condenser, it has little moisture left in it. Further north is a "rainless district;" and high hills beyond it, far north in Asia, grow no glaciers

* I have to thank Dr. Hayden for many valuable publications of the American Geological Survey.

in the latitudes of Greenland. That existing local glacial Asian climate is due to elevation and to atmospheric circulation. But some of the rocks in that region were formed at the bottom of a warm sea; for they contain *Ammonites.* Others are Silurian. That local Asian glacial climate results not from a glacial period, but from a great local change in level, and in the position of land and sea; it is a result of normal atmospheric circulation, evaporation, and condensation, which must have gone on during geological time. I suppose that like changes have produced like effects throughout sedimentary geology. Scratched stones are in Permian rocks; there may have been Lawrentian glaciers without any abnormal period of cold. So long as my knowledge of ice-records only reached to the borders of the Atlantic basin, something abnormal seemed necessary to account for the facts; but when I found that these large records are local, nothing abnormal was needed. Things as they are account for things as they were. No signs of large glaciers are anywhere near lat. 37° N. about the Pacific basin on either side, in the Californian plains, in Oregon, or in Japan, or China about Shanghai, Hong-Kong, or Canton. I could find nothing glacial at Singapore, or in Java, or in Ceylon, or in India up to lat. 32° N.; but from lat. 27°–28° northwards, on the hills, sedimentary rocks which formed at the sea-bottom, and are the tops of the Himalayas, are high enough now to condense vapour into glaciers even in the same latitudes as the deserts of Arabia and the hottest regions on earth. Between August 1873 and May 1877 I went round Europe, round the world, and through India, searching for records of the ice-cap in vain. Instead of finding drifted stones nearer to the equator than drifting ice, which a glacial period requires, I have only been able to find drifted stones as far south as drifting ice, and only in one place, near St. Louis. I have sought in vain for evidence to prove that the world's climate has been colder, which I have been taught and once believed. Because all my facts taken together tell against Glacial periods, I have ceased to believe in them. Because these facts very clearly disprove the case made for the northern "Ice-cap," I refuse to accept an improbable theory as if it were probable or true. With these theories stand or fall those which were invented to account for them.

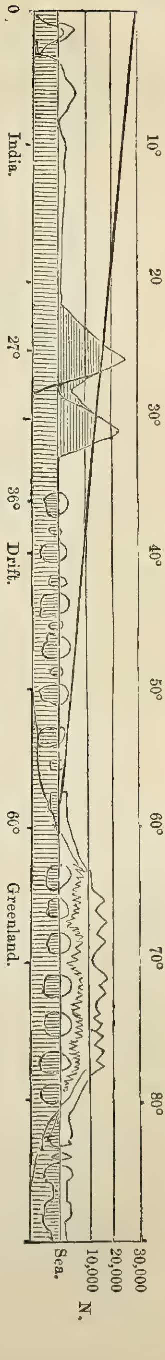
Vast sheets of polar ice did not climb over the Alps, the Caucasus, the Himalayas, and the Rocky Mountains, leaving sharp ridges there between 11,000, 18,000, and 28,000 feet high. There is no record of the passage of any such ice-sheet in gaps between these mountain-chains, at Constantinople, about the Caspian, in the Punjàb, on the shores of the Pacific Ocean. Polar glaciation and records of it belong to the Atlantic basin. I hold that the present "Period" has existed on earth since the globe cooled a very long time ago, and that it will go on growing to the coldness of outer space while the world lasts.

I beg to refer to the papers above mentioned and to this paper for facts on which my conclusion is based.

My opinion is that the present is at least as cold as any "period" *of which there is any geological record, and that it has endured ever since any part of the earth's surface was high enough and cold enough to be a condenser of snow. I hold that the record of sedimentary geology is continuous, and does not record periods of great cold.* I will exchange my opinion for an equivalent of facts; meantime I submit it with my facts to the Society to which I have the honour to belong, after studying the subject for nearly forty years*.

I have tried to express the facts relied upon by a diagram. The diagonal line expresses height above the sea-level. At 60° glaciers now enter the sea. Icebergs drift in the sea to 37° N. and to 36° S. Glaciers now exist in the Himalayas at 27° N.

The limits of ancient glacial action, recorded by marks, do not extend beyond these latitudes, so far as I have been able to discover.



P.S.—January 13, 1879.—Since this paper was presented in May 1877, I have cruised about the Hebrides several times, and printed a paper on the Parallel Roads of Glenroy, which I hold to be "sea-margins," like others on Scotch and other coasts. I have been up the Nile beyond Thebes, in Syria, at Jerusalem, and along the coast of Asia Minor. I sought carefully and found no records of glacial action about that part of the Mediterranean. I am prepared to maintain that the Nile valley, the Red Sea, and the Valley of the Jordan differ from "firths;" that the Dead Sea and neighbouring lakes, the Caspian, and the Black Sea are not "lakes of glacial erosion," but hollows otherwise formed, probably by great movements and bending in the earth's crust. These are indicated by sea-shells at Suez and otherwise. I have read much on the subject of glacial action, nothing that shakes my confidence in the conclusions stated in this paper, but a good deal which leads me to hope that many leading geologists at home and abroad will be of my opinion if they read this abstract of the geological work of some forty years.

* A globe coloured to show the present position of ice, so far as known to the author, was shown on the 26th of June, 1877, at the rooms of the Society, together with books of sketches and rubbings, geological and other maps, in illustration of this paper. These were removed on the 30th of June, and can be referred to at Niddry Lodge, Kensington, W.

9. *On the* Range *of the* Mammoth *in* Space *and* Time. By W. Boyd Dawkins, Esq., M.A., F.R.S., Professor of Geology and Palæontology in Owens College. (Read November 6, 1878.)

Contents.

1. *Introduction.*

The Mammoth is one of the most important animals for purposes of classification, on account of the large size and abundance of its remains, and because of its range in ancient times over more than one half of the land-surface of the world. According to some authorities, among whom may be reckoned M. Lartet*, it is taken to characterize an early stage in the history of the Palæolithic caverns of France and Belgium, and according to others, among whom may be reckoned Dr. James Geikie †, to have found its way into Europe after the Glacial period; it is supposed to have disappeared from Europe before the close of the Glacial period. In Dr. Falconer's ‡ opinion it was a Pre- as well as a Postglacial inhabitant of Britain, a view which I was unable to accept on the evidence offered at that time §. The new materials, however, accumulated during the last ten years render it advisable to reexamine the evidence by the light of a wider experience. The results of a reexamination which are brought before the Society this evening show that Dr. Falconer's conclusion as to the Mammoth being Preglacial in Britain is fully justified; and the additional details brought together since his death merely serve to fill in to some extent the picture of the life and times of the mammoth, without affecting the outlines drawn by the hand of the master ||. They show that the animal lived in Cheshire and the South of England, and probably also in Scotland, before the deposition of the Boulder-clays by glaciers and icebergs, and that it roamed over the region now covered by the North Sea, in company with the *Elephas meridionalis*, *Cervus Sedgwickii* (= *C. dicranios*, Nesti), and other animals of the forest-bed of Norfolk and Suffolk.

2. *The Mammoth Preglacial in the South of England.*

The first case to be examined is that of the elephant found in Sussex. The memorable paper of Mr. Godwin-Austen, on "The Newer

* Comptes Rendus, xlvi. Séance 22 Février, 1858.

† 'Ice Age.'

‡ Palæont. Mem. ii. p. 240.

§ Popular Science Review, 1868, p. 275; Geological Magazine, July 1868.

|| Palæont. Mem. ii. p. 239.

Tertiary Deposits of the Sussex Coast," brought before the Society in 1857 *, called attention to the fact that a layer of glacial clay with erratics, some of very large size, was to be seen in the low and broken line of cliffs extending from Pagham Harbour on the east, past the little village of Selsea, to Bracklesham on the west, and that this rested on a deposit of estuarine mud, below which were lenticular patches of red ferruginous gravel lying on the eroded surface of the Eocene strata. In "the mud-bed," from time to time, many bones and teeth of elephant, found in juxtaposition, prove that whole carcasses had decayed in this spot. These were originally assigned to the mammoth; but on subsequent examination by Dr. Falconer they turned out to belong to his new species, the narrow-toothed, straight-tusked *Elephas antiquus*. Although the mammoth has been quoted from this horizon in 1870 † by Mr. Godwin-Austen, and in 1878 by the editors of the new edition of Dixon's 'Geology of Sussex,' I am unable to obtain any further evidence on the point, and it is very probable that the species is not the mammoth, but the *Elephas antiquus*.

Whatever doubts may be thrown on the occurrence of the mammoth in Preglacial strata at Selsea, its presence in Hertfordshire before the period of the Boulder-clay was proved in 1858 ‡ by the discovery, by Prof. Prestwich, of a tooth and tusk in a bed of gravel underneath the Boulder-clay of Bricket Wood in the railway-cutting between Watford and St. Albans. The animal, therefore, was living within the area of the London Basin before it was submerged beneath the sea, on which the icebergs were carried as far south as the line of the Thames, or, in other words, before the time when the drift of icebergs in Britain arrived at its maximum extension to the south. In this sense, then, it may be said to be Preglacial in the South of England.

3. *The Mammoth Preglacial in Scotland.*

Several cases of the discovery of its remains in the Boulder-clays and subjacent deposits render it very probable that it was also an inhabitant of Scotland in Preglacial times. Nine or ten tusks and a molar tooth have been discovered from time to time, in a peaty clay underneath the "till," at Woodhill quarry §, Kilmaurs, Ayrshire, along with the antlers of reindeer, and various insects and freshwater plants (pond-weed and ranunculus), under conditions shown in the following section (fig. 1). From their position below the Boulder-clay these remains are considered by Dr. Bryce, from whose paper the above section is borrowed, as well as by Mr. Young, to be preglacial. Dr. James Geikie, however, refers this stratum of Boulder-clay to the later ‖ of the two Scotch Boulder-clays, and

* Quart. Journ. Geol. Soc. (1857), xiii. p. 50.

† *Ibid.* (1871), xxvii. p. 26.

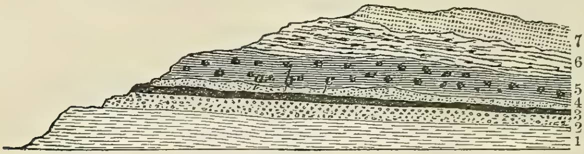
‡ Geologist, 1858, p. 268.

§ Dr. Bryce, Quart. Journ. Geol. Soc. xxi. p. 213; Mr. J. Young, 'The Antiquity of Man,' p. 292 (last edit.); Prof. Archibald Geikie, "Phen. of Glacial Drift of Scotland," Trans. Geol. Soc. Glasgow, i. part ii.

‖ Dr. James Geikie, 'Ice Age,' 2nd edit. p. 160.

places the stratum with the mammoth in his "Interglacial period." A second example of the discovery of mammoth in association with the Boulder-clays is that of a tusk found, at a depth of fifteen to

Fig. 1.—*Section of Drift-beds at Kilmaurs.*



1. Sandstone of the Coal-formation, rising in a low cliff from the banks of Carmel Water.
2. Gravel.
3. Clay.
4. Sand.
5. Boulder-clay.
6. Upper Drifts.
7. Subsoil and surface-soil.

twenty feet from the surface, by the eminent engineer Mr. Bald*, at Clifton Hall, in the valley of the Forth, at the beginning of this century. A third instance is offered also by the remains at Chapel Hall, near Airdrie, in laminated sand under the "till." These cases are taken by Mr. Jamieson to prove that the mammoth lived in Scotland before Glacial conditions had set in in Northern Britain; and his conclusion seems to me to be probably true.

4. *The Mammoth Preglacial in Cheshire.*

If, however, the true relation of the strata with mammoths in the above cases to the lowest Glacial deposits of Scotland be considered doubtful, the Preglacial age of the mammoth in Cheshire is definitely set at rest by the discovery made by Mr. Bloxsom in March 1878, in sinking a shaft for the new Victoria Salt Co. near Northwich. The travelling cylinder used in the operation cut through the fossil-tooth of "some gigantic animal," which was sent to me for identification. It proved, on comparison with remains in the British Museum, to be a fragment of the last lower true molar of the mammoth, left side, composed of the last seven plates with the talon, and measuring 5·5 inches long by 2·5 and 1·8 broad. From an examination of the matrix it had evidently been imbedded in a fine sand highly charged with dark carbonaceous particles.

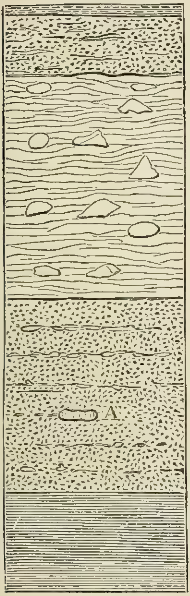
The precise conditions of its discovery are shown in the following section (fig. 2), the details of which have been furnished by the kindness of Mr. Bloxsom. The tooth was found at a depth of sixty-five feet from the surface of the ground, in the sand No. 1, at the point marked A in the figure.

The overlying Boulder-clay, as may be seen from the horizontal geological section, sheet 64, made by Prof. Hull, extends without a break from Northwich to Aston; it reappears near Millington Hall, and extends, except where it is cut through by the river Bollin, under the middle-drift sand and gravel of Bowdon, and thence in a

* Mr. Bald, Wernerian Soc. Mem. Edinb. iv. p. 58.

north-easterly direction over Manchester, until it plunges under the same series of sands at Cheetham Hill. These middle sands in their turn are capped by the upper Boulder-clay of Newton, Fairfield, and Droylesden to the east of Manchester. The Boulder-clay of North-

Fig. 2.—*Section of New Victoria Salt-Company's Shaft, Northwich.* (Scale $\frac{1}{30}$ inch to 1 foot.)



Soil, 2 feet.

3. Brown sand and clay, 9 feet.

2. Brown Boulder-clay of Lower Series, 37 feet.

1. Quicksand, with layers of pebbles, 32 feet. A = Mammoth tooth.

Red Marl of Keuper, 16 feet. (72 feet to Rock-salt.)

wich, therefore, is the lower of the two Boulder-clays of the Lancashire and Cheshire plain, and the sand beneath it with the mammoth belongs to a yet earlier age, or, in other words, is older than the first phase of the Glacial period, of which traces have been met with on the western side of the Pennine chain.

The series of sands and gravels underneath the lower Boulder-clay has been proved by Mr. Binney* to be very persistent in Lancashire underneath the lower Boulder-clay, resting very generally on the eroded surface of the Carboniferous, Permian, and Triassic rocks. A section recently exposed close to Birch Church, Rusholme, proves that it is more than fifteen feet thick on the south side of Manchester. The sharp sand and rounded pebbles of which it is composed render its marine origin very probable, the only fossil hitherto discovered in it being the tooth above described.

The remains of the mammoth have been found on the borders of

* Proceedings Lit. and Phil. Soc. Manchester, 19 March and 12 Nov. 1872; Statistical Society of Manchester, 1841.

the Lancashire and Cheshire district; in Derbyshire, in a cleft of the Mountain Limestone at Dove Holes near Buxton (Binney); in a cave at Gelly Dale near Castleton (Pennington and myself); and in Staffordshire at Copenhall near Crewe, in a cutting of the London and North-western Railway (Sir P. Egerton). In all these cases the relation of the deposit in which the remains were found to the Boulder-clays is uncertain.

5. *The Mammoth a member of the Fauna of the Forest-bed.*

The Mammoth was considered by Dr. Falconer to be a member of the peculiar fauna of the Preglacial Forest-bed, because its remains were met with in the same mineral condition as the other Forest-bed Mammalia cast up by the sea at the foot of the Norfolk cliffs. In 1868* I saw reason to doubt this conclusion, and to believe that they were derived from the Postglacial gravels on the top of the cliffs, or from the late Pleistocene ossiferous deposit on the Dogger Bank. Since that time, however, I have been led, from the examination of specimens which Dr. Falconer never saw, and from a consideration of the associated fauna, to hold that his judgment in this case is probably correct. The objection that the animal may have been derived from newer deposits is met by the fact that the Forest-bed fauna contains no less than eighteen out of a total of twenty-six mammals which are proved to have been its contemporaries by discoveries in other places. The mammoth, as Dr. Falconer pointed out, was of an elastic constitution, so that its presence in a group of animals not now living in cold countries is not rendered improbable by its habits of life. The probability also is considerably strengthened by the fact of its being proved to have been an inhabitant of Britain before the Glacial period, from the above-mentioned discoveries in the south and west of England and in Scotland.

6. *The Mammoth in Britain before, during, and after the Glacial period.*

In the late Pleistocene deposits of Britain the mammoth is the most abundant animal, being found in eighty-two cases out of 148 localities tabulated† in an essay brought before this Society in 1869, and very generally along with the reindeer. Some of the river-deposits, such as those of Hoxne and Bedford, are clearly of Postglacial age, in the sense of being after the layer of Boulder-clay, considered by Mr. Searles Wood the newerof the two clays. It has also been found in abundance in the lower brick-earths of the Thames valley, at Ilford, Erith, and Crayford, which probably belong to a period before the Glacial age‡. It is also, as has been shown in the preceding pages, Preglacial in Cheshire, Hertfordshire, and Norfolk, and probably also in Scotland. From these considerations it follows that, while the temperature was becoming sufficiently lowered to

* "Range of the Mammoth," Pop. Sci. Rev. 1868, p. 285; "The Age of the Mammoth," Geol. Mag. v., July 1868.

† Quart. Journ. Geol. Soc. xxv. p. 192 *et seq.* ‡ *Ibid.* xxiii. p. 91 *et seq.*

allow of large masses of ice depositing their burdens over Britain north of the Lower Severn and the Thames, the animal would be pushed southwards into other districts where the climate was not so severe. In other words, it may be termed Glacial. When the conditions of life became less severe the animal found its way along the river-valleys of this country as far north as Yorkshire on the east, and the line of the Trent and Holyhead on the west. North of this line it is conspicuous by its absence from Postglacial deposits of sand and gravel. For this I should be inclined to account on the hypothesis that this area was defended from the invasion of the mammoths, and, it may be added, of the associated animals *, by a system of glaciers radiating from the hills of Wales, Cumberland, the Pennine Chain, and Scotland, which did not melt away much before the mammoth became extinct, and possibly also by a submergence of the low districts.

In these remarks ossiferous caverns containing the remains of the mammoth have purposely been omitted, because it is impossible to tell with certainty their precise relation to the Glacial period.

7. *Range in Europe, Asia, and America.*

The caverns and river-deposits of France present us with traces of the mammoth in enormous abundance, and the animal is known to have ranged into Spain †, from the discovery of specimens in the zinc-mines of Santander. Thanks to M. Lartet and Dr. Falconer, it has long been known to have lived in the neighbourhood of Rome at a time when the volcanoes of Central Italy were active, and poured currents of lava and threw clouds of ashes over the site of the imperial city. It is abundant in northern and southern Germany, but it has not been found north of a line passing through Hamburg, or in any part of Scandinavia or Finland. It occurs in the auriferous gravels of the Urals; and in Siberia, as is well known, it formerly existed in countless herds, being buried in the morasses in large numbers, in the same manner as the Irish Elks at the bottom of the Irish peat-bogs. The admirable preservation of some of the carcasses is undoubtedly due to their having been entombed directly after death, and then quickly frozen up, a process which need not necessarily imply, as Mr. Howorth has lately suggested that it does imply, climatal conditions unlike those of the present time in Siberia. In unusually warm springs, the warm waters borne down by the great rivers from their southern warm sources thaw the frozen morasses with incredible rapidity, so that the hard ice-bound "tundra" becomes quickly converted into a treacherous bog. In

* Dawkins, 'Cave-hunting,' p. 406.

† The other localities in Spain for the mammoth, given by Prof. Calderon (Quart. Journ. Geol. Soc. xxxiii. p. 129), are doubtful, because the proboscidean remains in Miocene and Pliocene strata, referred by various Spanish authors to that species, are accepted without criticism. Those from Santander have been described by Prof. Sullivan and O'Reilly, and determined by Prof. Leith Adams to belong to the mammoth.

the exceptionally warm season of 1846*, the mammoth discovered by Lieut. Benkendorf on the banks of the Indigirka was thawed out of the tundra until it was revealed to the astonished eyes of the beholder, standing on its feet in the position in which it had been bogged. Had any elks or reindeer been in that spot at that time they might have been entombed in the same way, and preserved by the frosts of the winter till they were liberated again by the rare chance of their place of sepulture being invaded by warm floods from the south. The thaw in that year proceeded so rapidly that Lieut. Benkendorf and his Cossacks narrowly escaped the alternative of being entombed in the soft morass, or of being swept out northwards into the Arctic Sea, as his mammoth was, to join the vast assembly of mammoths and reindeer and other animals which have been swept down in a similar fashion.

The remains of the animal occur throughout Russian Asia; and the singular notice of fossil ivory being brought for sale at Khiva, by an enterprising Arabian traveller, Abou-el-Cassim, in the middle of the tenth century, applies to the mammoth from the old Bulgaria on the Lower Volga†.

Nor is a variety of the mammoth absent from Asia Minor, since the remains of an elephant (*E. armeniacus*), discovered near Erzeroum, have been determined by Dr. Falconer to be intermediate between the mammoth and the Indian elephant. And it is an interesting fact to note that in Asia Minor, as in the Pleistocene of Europe, it is associated with the horse, stag, bison, and woolly (?) rhinoceros, all of which are described by Dr. Brandt from Persia in 1870.

The elephant‡ was living in the valley of the Euphrates in the sixteenth century before Christ, when that district was invaded by the Egyptians, since a great hunting of elephants by the Pharaoh, Thothmes III., in the neighbourhood of Nineveh, has been recorded in an Egyptian inscription published by M. Chabas. This important discovery brings *Elephas armeniacus* into the same geographical region as the Indian elephant (whichever variety or species those in question may have been), and shows that the fossil and living elephants of Asia in ancient times were not separated from each other by impassable geographical barriers or wide spaces of mountain and desert.

* Middendorf, 'Sibirische Reise,' iv. 'Die Thierwelt Sibiriens,' p. 1082. 4to. 1867. This account is translated in my essay on the "Range of the Mammoth" quoted above.

† 'Les Peuples du Caucase, ou Voyage d'Abou-el-Cassim,' par M. C. D'Ohsson, page 80. "On trouve souvent dans la Boulgarie des os (fossiles) d'une grandeur prodigieuse. J'ai vu une dent qui avait deux palmes de large sur quatre de long, et un crâne qui ressemblait à une hutte (arabe). On y déterre des dents semblables aux défenses d'éléphants, blanche comme la neige et pesant jusqu'à deux cents *menns*. On ne sait pas à quel animal elles ont appartenu, mais on les transporte dans le Khoragur (Kiva), où elles se vendent à grand prix. On en fait des peignes, des vases et d'autres objets, comme on façonne l'ivoire; toutefois cette substance est plus dure que l'ivoire; jamais elle ne se brise."

This is extracted by the learned D'Ohsson from an Arabic manuscript of the middle of the tenth century.

‡ Chabas, 'Études sur l'Antiquité Historique d'après les sources égyptiennes,' 2nd edit. p. 124.

The animal ranged over the whole of North America, from the frozen cliffs of Eschscholtz Bay as far south as the Isthmus of Darien—the *Elephas americanus* of Leidy * and the *E. Columbi* † of Falconer (*E. texianus*, Owen) being mere varieties of the same sort as those observable in the European mammoths, founded merely on the relative width and coarseness of the plates composing the grinders; while the *E. Jacksoni* of Billings merely supplies a slight variation in the form of the lower jaw.

Thus the mammoth ranged in ancient times over nearly the whole of the land of the northern hemisphere; and it is most important to note a singular fact in the distribution of the varieties with grinders composed respectively of narrow and wide plates. Just as in Euro-Asia the variety with its grinders composed of narrow plates has its headquarters in the north, and is replaced in Asia Minor by the variety with wide plates in its grinders (the *E. armeniacus* of Dr. Falconer), so in America is the narrow-plated form replaced in the southern parts of the continent by the *E. Columbi*. These differences may be the result of the use of different food in the northern and southern regions.

8. *Relation to Indian Elephant.*

The next point to be considered is the relation of the mammoth to the Indian elephant on the other side of the barrier of deserts and mountains of Central Asia. On analyzing all the characters of the dentition, we find that the ridge-formula and the succession of the teeth are the same, and that the last grinders are so alike that a lower molar of *E. indicus* has been figured by one of our most distinguished anatomists as that of a mammoth ‡. In Dr. Falconer's classification, *Elephas Columbi*, *E. indicus*, and *E. armeniacus* are grouped together, their teeth being built on the same plan §, "Colliculi approximati, machæridibus valde undulatis;" while next to them comes *E. primigenius*, "Colliculi confertissimi, adamante valde attenuato, machæridibus vix undulatis." The differences expressed in these definitions seem to me to be merely of degree, and not of kind. Nor are the differences in the skeletons greater than those of the dentition. The possession of hair and wool depends, to a large extent, on climate, so that the covering of the Siberian mammoth cannot be taken to be a specific character.

On the present evidence the two seem to me to be so closely related that the mammoth may be taken as the ancestor of the Indian elephant; and it is highly probable that the latter has put on those trifling characters by which it is distinguished in the untold ages of its sojourn in the tropical forests of India—characters, be it remembered, of the same order as those observed in the dentition of *Elephas Columbi* of the warmer regions of North America, and the *E. arme-*

* 'U.S. Geol. Survey of the Territories,' F. V. Hayden, vol. i.; Leidy, 'Extinct Vertebrate Fauna of W. Territories,' p. 238.

† For the details relating to these forms, see Falconer, Pal. Mem. ii. p. 212.

‡ Owen, Brit. Foss. Mammals, fig. 90.

§ Pal. Mem. ii. p. 14.

niacus of Asia Minor. I feel inclined to view them as two well-marked varieties rather than as two distinct species.

Discussion.

Dr. Leith Adams stated that teeth from Ohio in the Royal College of Surgeons and in Paris were certainly those of the Mammoth, although Prof. Marsh has asserted that the Mammoth has not been found south of the Columbia river and east of the Rocky Mountains. He thought it possible that *Elephas Columbi*, *E. armeniacus*, and *E. indicus* might be the same species, but that *E. primigenius* was distinctly different. The Mammoth was more nearly allied to the Asiatic than any other elephant. He gave instances of thick- and thin-plated teeth occurring in the same district in Britain; in none did we, however, get crowns like the teeth of the Indian elephant. Hence he did not think there was evidence at present for running all these species together.

Mr. Charlesworth commented on some popular representations of the Mammoth; and asked if Prof. Dawkins thought the elephant's teeth in the Norwich Crag were those of *E. primigenius*.

Prof. Owen asked whether the evidence for the discovery of the tooth of *E. primigenius* under the Lower Boulder-clay was satisfactory, instancing mistakes that had been made in the case of *Cervus megaceros*, which had been asserted, though on defective evidence, to occur in the peat-bogs, whereas it appeared that really it was in the underlying shell-marl.

Mr. J. Evans said that a Committee had been appointed at the last Meeting of the British Association at Dublin to investigate the occurrence of the *Cervus megaceros* in Ireland. He would have been glad if Prof. Boyd Dawkins had also attempted to trace the pedigree of the Mammoth upwards as well as downwards. He could not accept Mr. Howorth's view of a cataclysmic cause for the destruction of the Siberian Mammoth and the preservation of its remains.

Prof. Seeley stated that Dr. Falconer considered *Elephas primigenius* very closely allied to *E. indicus*; in fact he always examined the mineral character of the specimen, as the speaker had seen when he went over a large collection made by Prof. Sedgwick, and contained in the Woodwardian Museum.

Dr. Hicks asked as to the nature of the Boulder-clay and whether the blocks contained in it were angular or rounded. He inquired whether the evidence was sufficiently satisfactory that it belonged to the Lower Boulder-clay, and was not simply derived from it in subsequent changes.

Prof. Hughes said that he doubted the glacial origin of any of the series of deposits described by Prof. Boyd Dawkins, and stated that the Boulder-clays of Cheshire only belonged to the later part of the Glacial epoch. They were marine and resorted. He thought the same of the Hertfordshire drift.

Dr. Woodward said that he had recently been along the Norfolk coast with Mr. Gunn, who still adhered to his opinion that *Elephas primigenius* was not found in the Forest-bed. He called attention to the probable commingling of Indian and African types in the valley of the Euphrates, as shown by the Assyrian sculptures.

Prof. Boyd Dawkins, in answer to Prof. Owen, said that the section of the deposits near Northwich in which the Mammoth tooth was found was made by the engineer who had made the boring and had sent him specimens; and he gave reasons for holding that the Boulder-clay was not *remanié*, but the true Lower Boulder-clay. It contains numbers of large striated blocks from Cumberland and Scotland, and no marine shells. That was the case in the clay he had described, which extended from Northwich to Manchester, and had nothing to do with that of Cheshire referred to by Prof. Hughes. He did not know that there was any important difference between the blocks in the Upper and Lower Boulder-clay. He thought that if Prof. Leith Adams would examine the teeth in the museums of Florence, Bologna, and Lyons, he would find that the narrow-plated Mammoth teeth did shade off into wide-plated varieties, and that the species was not so definite as he appeared to think. As regarded *Cervus megaceros,* it occurred in Ballybetale bog in peaty mud above the clay, and extended up to close below the upper friable peat. The elephant of the Crag was probably *E. meridionalis.*

10. *On the* Association *of* Dwarf Crocodiles (*Nannosuchus* and *Theriosuchus pusillus*, e. g.) *with the* Diminutive Mammals *of the* Purbeck Shales. By Professor Richard Owen, C.B., F.R.S., F.G.S., &c. (Read November 6, 1878.)

[Plate IX.]

Agreeably with an intimation at the close of the Monograph (No. VIII.) "On the Fossil Reptilia of the Wealden and Purbeck Formations," which appeared in the volume of the Palæontographical Society issued in 1878 (p. 15), I communicated to the Geological Society of London * a paper in which ideas suggested by the subjects of that Monograph on certain relations of Mesozoic and Neozoic Crocodilia to their prey were more fully detailed, and an instructive discussion was thereupon raised agreeably with the writer's design.

To his assumption that the mammalian prey of Neozoic Crocodiles were non-existent in Mesozoic times, an experienced palæontologist objected that such were in existence at those periods, and coexisted with the Teleosaurs and other amphicœlian Crocodiles †.

It had not occurred to me that the mammalian prey of the Neozoic Crocodiles ‡, which I had in view, and which were exemplified in my mind and meaning by the Tiger, the Buffalo, and similarly large unguiculate and ungulate species, could be represented or suggested by the extinct mammals from the Purbeck and Stonesfield strata, in the restoration of which, and the vindication of their claims to warm-blooded and mammiferous eminence, no small proportion of past palæontological work had been submitted by me in former days to the Geological Society §.

Subsequent additions to our knowledge of Mesozoic mammals have not revealed any species approaching in size to the Ichneumons ‖, which haunt the banks of the Nile, the Indus, or the Ganges. Such Viverrines are disdained by the large Crocodilia of these rivers; at least the vermiform mammals are not known to fall a prey to them, or to call for the exertions, emerged or submerged, which the subduing of the struggles of a tiger or buffalo require. On the contrary, the attitude of the Crocodile to the small mammal is reversed; the Ichneumon is the enemy and destroyer, in relation, at least, to

* February 6, 1878; Quart. Journ. Geol. Soc. vol. xxxiv. p. 421.

† "Mr. Hulke observed that with respect to Prof. Owen's idea that warm-blooded animals were not preyed on by the Mesosuchian Crocodiles, it could not be doubted that such did actually exist contemporaneously with them."—*Quart. Journ. Geol. Soc.* 1878, vol. xxxiv. p. 428.

‡ "Large species of warm-blooded mammals," *tom. cit.* p. 423. "The advent in Tertiary time of large mammalian quadrupeds browsing or prowling along the shores," &c. p. 426.

§ Trans. of the Geol. Soc. 4to, 2nd series, vol. vi. p. 47, pl. 5; Proc. of Geol. Soc 8vo, 1838, p. 17; Quart. Journ. Geol. Soc. vol. x. p. 426 (1854).

‖ *Herpestes ichneumon*, Cuv., 5 feet in length.

the eggs and newly hatched brood, of the cold-blooded amphibious giant.

When, therefore, my cogitations had been turned to any possible relations of a Phascolothere* or a Triconodon† to the amphicœlian Crocodilia of the Oolitic or Wealden periods, I thought of the diminutive contemporaneous mammals as reducers of the numbers of such Crocodiles, assuming that the reptiles may have sought the banks or shores to oviposit, and that their eggs and wriggling brood may have tempted the small predatory marsupials, as those of the procœlian Crocodiles do their contemporaneous species of *Herpestes*.

Pursuing, however, my researches on the Crocodilia of the Purbeck series, I have come, as I believe, upon a relation of them to their contemporary diminutive mammals at once most interesting and unsuspected. The Spalacotheres, Peralestes, Stylodons, Triconodons, &c. of the freshwater deposits of the "Feather-bed" may well have been the prey of the Crocodiles of the period; for these Crocodiles were reduced to dimensions which forbade them to disdain such succulent morsels, and, at the same time, they were suitably armed and limbed for the capture of the little marsupials.

The characters of one of these dwarf Crocodiles I now propose briefly to submit to the Geological Society; fuller details and illustrations of this and other small crocodilian genera and species will appear in the forthcoming volume of the Palæontographical Society.

The subjects of the annexed Plate (Pl. IX.), all of the natural size, are selected from numerous evidences of the species, which I propose to name *Theriosuchus*‡ *pusillus*.

These and other Crocodilian evidences of the Purbeck period have been brought to light, or completely exposed, by operations upon the residuary slabs of "Feather-bed" marl which accompanied the Becklesian collection to the British Museum, when the negotiations for the purchase of the whole were concluded.

They are very numerous, chiefly consisting of scattered teeth, scutes, vertebræ, and detached limb-bones, but likewise of a few skulls and mandibles, and, in one or two instances, of considerable portions of naturally connected skeletons. The scattered parts associated with these have served for the ascription to their several species of answerable bones, teeth, and scutes not so associated.

At the first aspect, detecting in the scattered groups of scutes specimens showing the peg (Pl. IX. fig. 10, *a*) and groove (fig. 11, *b*), it seemed as if remains of some young specimens of *Goniopholis* had been brought to light. The condition, however, of two of the skulls, one of which has yielded the subjects of figs. 1, 2, 3, Pl. IX., enabled a comparison to be made which determined their specific and, by

* 'Researches on the Fossil Remains of the Extinct Mammals of Australia,' &c. 4to, 1877, vol. i. p. 16, pl. i. figs. 26, 26*a*.

† *Op. cit.* vol. i. pp. 58, 64, pl. iii. figs. 7, 7*a*, 11–19.

‡ Gr. θηρίον, wild beast; σοῦχος, Egyptian name of crocodile.

their dentition, generic distinction from both *Goniopholis** and *Petrosuchus*†.

The number of maxillary and mandibular specimens, of which three are figured in Pl. IX. figs. 4, 5 and 7, exemplified a degree of constancy in size which begat a conviction that such was a character of the species; and, diminutive as were the Reptilia in question, their characters were indisputably those of the order Crocodilia. One of them, by the size and shape of certain teeth, came nearer to *Goniopholis*; another, by the same characters, resembled *Petrosuchus*; but the differences were such as could not have been obliterated by growth or age.

Theriosuchus approaches, like *Goniopholis*, nearer to the type of the broad-faced Alligators in the proportion of the antorbital part of the skull (fig. 1, *o*, *n*); but the dentition is more modified than in any other known Crocodile, recent or extinct, and approaches nearer to that which characterizes the Theriodont order of Triassic Reptilia‡.

The premaxillary teeth, five in number in each bone, are small; the three middle ones subequal, the first and fifth smaller; the maxillary teeth are divisible into laniaries (fig. 3, *l*) and carnassials or trenchant molars (ib. *m*). The first maxillary tooth is small, the second and third gain quickly in size, the latter (fig. 5, *a*) assuming the character of a canine; the fourth tooth (ib. *b*, and fig. 6, *b*) is a still larger canine; the fifth (fig. 6, *c*) and sixth (*d*) decrease in size somewhat suddenly, but in length rather than breadth of crown, and terminate the series projecting from the convex part of the alveolar border of the maxillary; the tooth *c* or *d* may be said to terminate the laniary series. Beyond *d* the teeth lose length and slightly gain in breadth; the crown assumes a triangular, laterally compressed or lamellate form, and the enamel is traversed, on the outside, by fine but distinct lines (fig. 6, *e*).

Of these sectorial or carnassial molars, some of the detached specimens of maxillary bones (figs. 4 and 5) indicate as many as eight or nine. The broad base or root of each tooth is not inserted into a separate socket, but is lodged in a recess of the outer alveolar wall; moreover the partitions between these recesses are low or partial, and the teeth appear to have been applied thereto, without being so completely confluent therewith as in the pleurodont mode of fixation of the teeth in certain lizards§. Hence in some of the specimens of the maxillary bone the incisors and canines only are retained, being rooted each in its own complete socket, while the molars have fallen out, and their partially separated recesses are shown as in the figures cited.

In the lower jaw the foremost tooth is rather larger than those which interlock with the middle premaxillary or 'incisor' teeth above; but not any of the succeeding laniary teeth attain the size

* 'Monograph of Purbeck Reptilia,' Pal. vol. 4to, 1878, pls. i.–iv.
† *Ib. ib.* p. 10, pl. vi.
‡ Quart. Journ. Geol. Soc. 1876, vol. xxxii. p. 99.
§ See 'Odontography,' p. 266.

of the upper canines. The twelfth tooth, counting backwards, assumes the lamellate triangular shape of striate crown characteristic of the superior sectorials; and the inferior ones were lodged, like those above, in a common depression of an outer alveolar wall, developing the ridges dividing such depression into the dental recesses, as shown in fig. 7.

This approximation to a lacertian dental character might seem ground for something more than a family section of the Order Crocodilia. But the quasi-pleurodont attachment of the hinder teeth in *Theriosuchus* is only an extension of the character affecting some of those teeth in existing species of Crocodile*, and successional teeth, or their indications, are in crocodilian relation with the roots of the teeth to be displaced.

In the cranial platform of *Theriosuchus*, fig. 1, the median parietal part of the hind border is less convex, and the two outer parts are more concave, by reason of the further backward production of the mastoids (12), than in the contemporary dwarf Crocodile which I have called *Nannosuchus*. The lateral borders of the sculptured part of the platform are more convex than in *Goniopholis* or *Petrosuchus*. This is owing to the greater proportion of the outer and posterior angles of the platform, which is abruptly depressed below the level of the sculptured surface of the mastoid, and which becomes smooth like the contiguous and lower-placed tympanic. This character, shown in the subject of fig. 1, Plate IX., usefully indicated fragmentary parts of the skull of other individuals of the species. The supratemporal vacuities (T) are relatively larger than in *Goniopholis*. The intervening tract of the parietal (7), more canaliculate than in the larger species, is divided by a mid ridge in two of the cranial specimens, and partially so in the more complete skull, fig. 1. No palpebral ossicle is preserved in the orbit, *o*; the pointed ends of the nasals are produced so as to divide the outer nostril into two (fig. 1, *n*, *n*), as in some specimens of *Crocodilus niger*; were this a character of generic value it might unite *Theriosuchus* with *Halcrosia*, Gray†.

The alveolar part of the maxillary in which the canines are developed makes a corresponding convex extension of its outer border, as in *Goniopholis*. The extent of the 'symphysis mandibulæ' and the angle of divarication of the same are shown in fig. 2.

The matrix being removed from the palatal surface of the skull, fig. 2, exposed the orifice of the Eustachian canal, *e*, the palato-naris, *pn*, the pterygoids, 24, the palatines, 20, portions of the palatal plates of the maxillary, 21, and the pterygo-maxillary vacuities, *y*. The vertebræ, fig. 12, of *Theriosuchus* are amphiplatyan. The humerus, fig. 8, and the femur, fig. 9, have the Crocodilian structure.

* I have noted it in the *Alligator niger*. "No. 765. The right ramus of the lower jaw, from which the posterior part of the inner alveolar wall has been removed, showing the five posterior teeth lodged in a common alveolar groove." Osteological Catalogue, Museum of the Royal College of Surgeons, 4to, vol. i. p. 167 (1853).

† Trans. Zool. Soc. vol. vi. p. 135.

In *Theriosuchus* the breadth and shortness of the antorbital part of the skull, in proportion to the part behind, exceeds that in any modern broad-snouted Crocodile. Even in the young 'Crocodile à deux arrêtes,' figured in plate i. of Cuvier's 'Ossemens Fossiles'*, a transverse line across the fore part of the orbits equally bisects the skull, omitting the mandible. In *Theriosuchus* the same line leaves in advance six thirteenth parts of the length of the skull.

This proportion suggested at first view the immature state of the individual. But of the numerous evidences of *Theriosuchus pusillus*, none were larger than those figured in Plate IX., and several other fragmentary evidences of the species had come from still smaller individuals.

I conclude, therefore, that, as in the case of most species notable for their diminutive size, immature characters of the larger species of the genus are associated with such dwarfishness of the adults.

I estimate the average length of a mature *Theriosuchus* at 18 inches. The length of the skull, taken as that of the mandible, is 3 inches 6 lines. In the articulated skeleton of a modern Crocodile the angle of the lower jaw extends to the third cervical vertebra. In *Alligator lucius* the trunk, from the third cervical to the last sacral vertebra inclusive, is nearly equal to two lengths of the skull; the length of the tail is $2\frac{1}{3}$ lengths of the skull. The trunk of *Theriosuchus*, so defined, includes two lengths of the skull; the tail, as indicated by a portion of skeleton preserved, equalled $2\frac{1}{3}$ lengths of the skull. In the long-jawed Gavials and Teleosaurs the trunk includes about $1\frac{1}{4}$ length of the skull; but the tail is proportionally longer than in the short- and thick-jawed Crocodiles.

The actions and consequences of a *Theriosuchus* submerged with "a warm-blooded animal" of the size of a shrew or rat in its mouth might not excite the physiologist to analyze results and relations to palato-narial arrangements. The case is otherwise with a "large and powerful mammalian quadruped" in that predicament; its amphibious captor would not escape choking by the mere "closure of the external nostrils."

Let any F.G.S., with his head under water, hold his nose and open his mouth, and he will experience some trouble at the glottis.

The exclusion of water from the lungs is truly the important matter; and I fear my allusion to the mechanism for that purpose, which is peculiar to the Neozoic Crocodiles†, was too brief to dispel a possible haziness of conception of such mechanism.

A Crocodile, having seized and submerged a tiger or a buffalo, admits the water into its wide unlabiate mouth by the spaces to which the thickness of the part gripped keeps asunder the upper and the lower jaws. Thus the part of the mouth not occupied by the prey is filled with the fluid in which the mammal is being dragged and drowned.

* Quarto, tome v. 2e partie.

† Quart. Journ. Geol. Soc. vol. xxxiv. p. 423.

Admitting, for Mr. Hulke's argument, that the outer nostrils of a Crocodile, with their dense tegumentary boundary, could, like those of a seal, be shut by the action of a sphincter, exclusion by such narial opening of the watery element would not affect its entry by the mouth forced open by the seized and struggling mammal.

The question is, supposing the water to be stopped out of the anterior aperture, how is it to be excluded from the posterior one of the narial canal and at the same time from the entry of the windpipe?

And here comes the point for consideration in the comparison of Mesozoic and Neozoic Crocodiles with relation to their enemies and their prey.

In all the Crocodiles contemporary with "large mammals" there is a double valvular structure at the back of the mouth which prevents the water that may fill and be flowing through the mouth from getting into either the hinder nostril or into the glottis. One valve is fleshy and membranous; it hangs from the hind part of the palate, and answers to our "velum palati:" the other valve is peculiarly Crocodilian, at least in size and shape; it is a broad gristly plate which rises from the root of the tongue, carrying with it a covering of the lingual integument; and, when the palatal valve is applied to it, they form together a complete partition-wall, closing the back of the mouth, between which and the back nostril it is situated; it may be compared to a broad epiglottis, shutting off the glottis from the mouth.

To make this complex mechanical structure available, the back nostril is singularly reduced in size, and such reduction is shown in the skull. The small relative palato-narial orifice in procœlian or Neozoic Crocodilia is truly striking when contrasted with the size of the palato-nares in lizards and in amphicœlian or Mesozoic Crocodilia *.

But this is not the only character or condition of the procœlian palato-naris which renders the adaptation of the valvular machinery available for its purpose. In Neozoic Crocodiles the palato-naris is placed far back—further back than the basihyal—and its plane, instead of being horizontal, is tilted up at the angle, which makes the operation of the two parts, or "folding-doors" of the partition, most effective in closing the oral chamber posteriorly †.

What the modifications of the soft soluble parts of the hyoid and

* This, indeed, deceived De Blainville and Bronn as to the homology of the palato-nares in *Teleosaurus*; see 'Abhandlungen über die Gavialartigen Reptilien der Lias-Formation,' fol. 1841, pp. 12, 16, 24.

† See my "Anatomy of the Sharp-nosed Crocodile (*Croc. acutus*, Cuv.)," in the Proceedings of the Committee of Science &c. of the Zoological Society of London, October 25, 1831, part i. p. 139—in which, after comparison with the Egyptian Crocodile (*Croc. suchus*, Geof.), I "explained the uses of the apparent closure of the fauces, in which, on looking into the mouth, no orifice or passage for the food was perceptible; and remarked on the necessity for so

palate may have been in amphicœlian Crocodiles we may never know; but the large relative size, the forward position, and the horizontal plane of the bony openings oppose the application thereto of any such special and complex valvular structures as anatomy has revealed in existing Crocodiles.

If the submergence of the Crocodile with its "large mammalian" prey should continue so long as to render it needful for the reptile to "take a fresh breath," it can protrude its prominent snout from the surface and inhale a current of air which will traverse the long "meatus" and enter the glottis by the chamber common to nose and windpipe, which is shut out from the mouth by the modifications of a "velum palati" and "epiglottis" above explained. The same effect results from the "uninterrupted tube" in the procœlian Crocodiles as in that of the Cetacea. A teleologist must admit that "the contrivance is admirable;" it is equally effectual in both cases, and a Paley might expatiate upon the diversity of means by which the end is attained.

But we have no ground for inferring such means from the structure of the bony palate in the fossilized skulls of the amphicœlians; nor does our present knowledge of mammalian life in the Mesozoic periods encourage any belief that it was needed.

EXPLANATION OF PLATE IX.

Fig. 1. Upper view of skull of *Theriosuchus pusillus*.
Fig. 2. Under view of the same skull.
Fig. 3. Side view of the same skull.
Fig. 4. Left maxillary, inner side view, young individual, of *Theriosuchus*.
Fig. 5. Right maxillary, outer side view, of full-grown individual.
Fig. 6. Crowns of large canine and three following teeth, magnified.
Fig. 7. Dentary bone and fragments of mandible, inner side view.
Fig. 8. Portions of humerus, ulna, and radius.
Fig. 9. Femur.
Fig. 10. Outer surface of medio-dorsal scutes.
Fig. 11. Inner surface of ditto.
Fig. 12. Two dorsal vertebræ, under view.

All the figures, save 6, are of the natural size.

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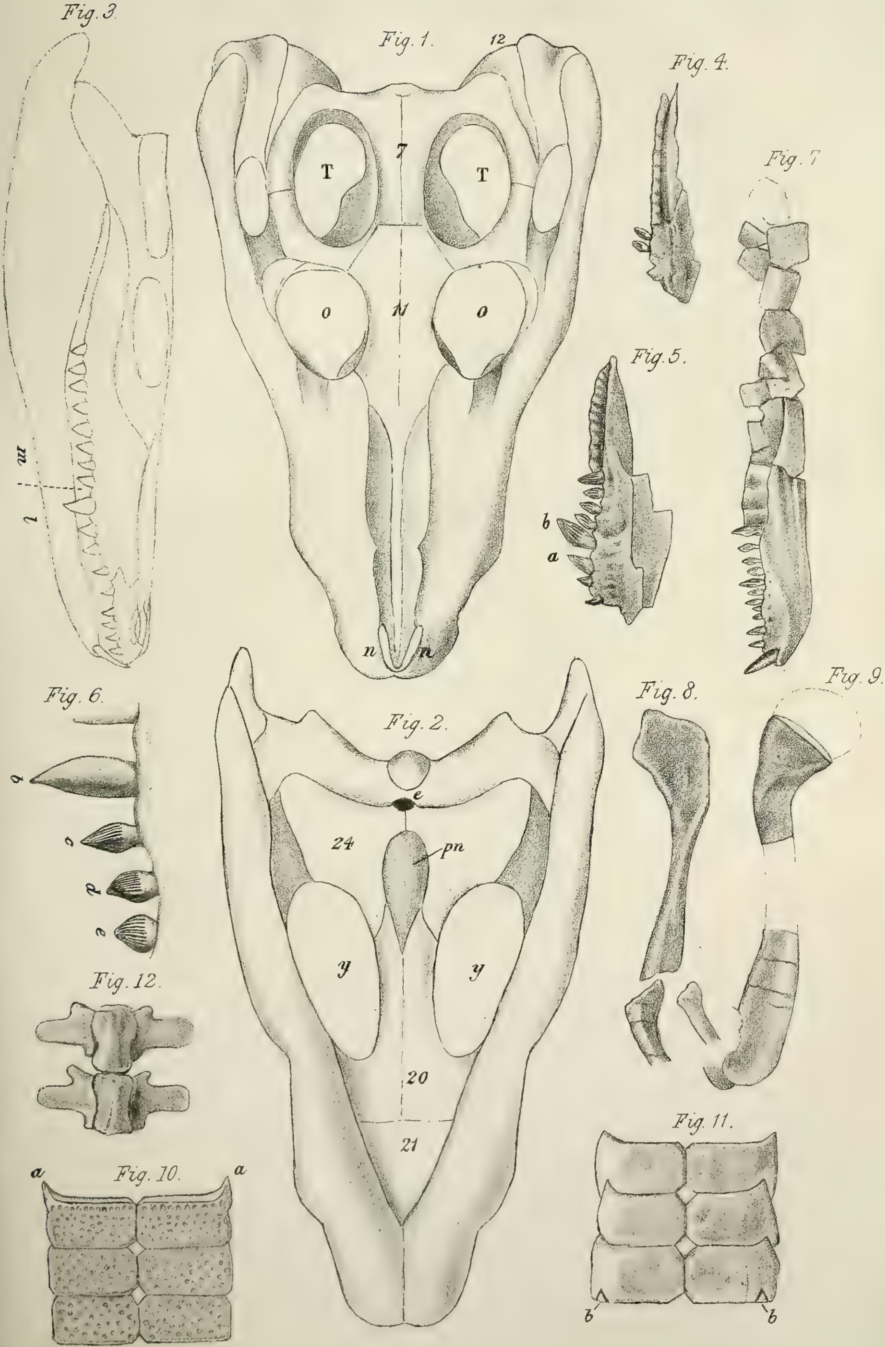
complete a safeguard of the larynx in an animal breathing air, but destroying its living prey by submersion in water."

Geoffroy St.-Hilaire, 'Description des Reptiles de l'Egypte,' p. 236.

Hunter had left a preparation demonstrating the same structure, which is described in the 'Catalogue of the Physiological Series in the Museum of the Royal College of Surgeons,' 4to, 1832, vol. iii. p. 72, Prep. No. 1466.

See also Cuvier, 'Leçons d'Anat. Comparée,' 8vo, tome iv. (1805), p. 284. "Les ouvertures internes des narines sont très en arrière dans cet animal, contre l'ordinaire des autres reptiles," which other reptiles include the Crocodiles not procœlian or Neozoic.



A.S.Foord lith.

Hanhart imp.

DWARF CROCODILES.

Discussion.

Mr. Hulke remarked on the resemblance of the under and upper sides of the skull described to that of *Goniopholis*.

Prof. Seeley demurred to the nomenclature employed by the author in describing teeth, and especially to his statement that in this and other Crocodilians there were several canines.

Prof. Owen stated that he had used the term *canine* in reference to the relative size and form of the teeth of Crocodiles, and not to their position in the jaws.

11. A Microscopical Study *of some* Huronian Clay-slates. By Dr. Arthur Wichmann. (Read June 19, 1878.)

[Communicated by the President.]

Introduction.

Greater attention has lately been paid to the microscopical study of clay-slates and slate-clays, giving rise to a number of researches the results of which may be found in the classical paper of Zirkel*. The principal object of these investigations has been to discuss the origin and formation of the crystalline constituents contained in clay-slates, and they have chiefly extended from Silurian and Devonian to rocks of the recent period. Such clay-slates as belong to Archæan districts might also claim the privilege of a certain interest, especially as the presence of these crystalline constituents has been used to solve geological problems. The clay-slates which I have examined occur in the Huronian region of Lake Superior. The respective rocks are in the collection of Major T. B. Brooks, Marquette, Michigan, who placed them at my disposal, chiefly for the sake of microscopical examination.

Hermann Credner in his paper†, "Die vorsilurischen Gebilde der 'Oberen Halbinsel' von Michigan, in Nord-Amerika," gives us a partial description of the geological appearance of these rocks. Further information may be obtained from the Geological Survey of Michigan‡, to which we shall refer hereafter.

Those clay-slates which appear in the Huronian region are found to be separate strata, deposited on the upper strata of quartzite, extending, as Herm. Credner states §, to a depth of 8500 feet, and forming layers between the quartzite and dolomite. They chiefly represent true clay-slates, not different in appearance from those of other geological periods. Subordinate strata are formed by hard brittle novaculite (whetstone), of a yellowish-grey colour. Carbonaceous slates and shales are generally found in black masses, and may be added to the slate-clays.

The following Table by T. B. Brooks and Herm. Credner shows the relations and classification of the clay-slate strata.

* Pogg. Ann. cxliv. 1871, p. 319.

† Zeitschrift d. deutschen geol. Ges. 1869, p. 534.

‡ Michigan Geolog. Survey, vol. i. & ii. (New York).

§ *Loc. cit.* p. 553.

Huronian System.

T. B. Brooks*.

I., II., III., IV.	Beds of siliceous ferruginous schists, alternating with chloritic schists and diorite.
V.	Quartzite, sometimes containing marble and beds of *argillite* and *novaculite.*
VI., VIII., X.	Siliceous ferruginous schists.
VII., IX., XI.	Dioritic rocks.
XIII.	Specular and magnetic ore associated with mixed ore and magnesian schist.
XIV.	Quartzite often conglomeratic.
XV.	*Clay-slate* or *argillite.*
XVI.	Uncertain: it contains sometimes some soft hæmatite.
XVII.	Anthophyllitic schist containing iron and manganese.
XVIII.	Doubtful.
XIX.	Mica-schist, containing staurolite, andalusite, and garnets.
XX.	Granite‡.

Herm. Credner†.

		feet.
I.	Quartzite and chlorite schists.	2500–3500 (I.–IV.)
II.	Diorites alternating with siliceous, ferruginous, and manganous schists and quartzite	
III.	Talcose and chloritic schists and magnetic iron-ore	
IV.	Siliceous ferruginous schists and specular ore with beds of serpentine	
V.	Crystalline dolomitic limestone, containing beds of *clay-slate* and chlorite schists; many layers of quartzite	2500–3000
VI.	Siliceous ferruginous schists	600–1000
VII.	Chlorite schists with beds of ferruginous schists	1200
VIII.	*Clay-slate* containing beds of quartzite	8500
IX.	Chlorite schists with beds of diorite	1300
X.	Talcose schists containing dolomitic limestone, quartz-schists, and beds of diorite	800
XI.	Diorite	2300
XII.	Talcose schists	1500

T. B. Brooks, in his classification, refers solely to the conditions of the Marquette region, because the concordance with the Menominee region is not yet ascertained.

A. *Clay-slate* §.

Hardly any difference can be perceived between the external appearance of these rocks and those of later periods. Although their

* Michigan Geolog. Survey, vol. i. p. 83. † *Loc. cit.*
‡ Amer. Journ. of Science and Arts, vol. xi. March 1875.
§ Mich. Geol. Survey, vol. i. p. 111.

usual colour is dark brown or black, they sometimes appear of a faint red tint. Their specific gravity is on the average 2·75.

Our microscopical investigations have also proved a composition corresponding with that of clay-slates of other formations. We at first perceive a *colourless isotropic ground-mass*, in *which the other constituents are apparently imbedded*, whilst throughout *are found dust-like particles* of a deep grey colour, which represent the chief constituent, and consist probably of clay-substances, the greater part of them probably of kaolin. Sorby* has adverted to the fact that the extremely minute granules of kaolin of clays, when mounted in Canada balsam, may be almost or quite invisible (these two substances having nearly the same indices of refraction), whereas when examined in water there is no difficulty in recognizing these granules. Now and then quartz occurs in the form of small fragments, which are easily to be recognized by polarized light. *Felspar* is very rarely seen, and even then only in very indistinct fragments, whilst mica is more frequently found. *Reddish-brown particles of hydrated oxide of iron* are not unfrequent. The *black flakes,* which appear very often, consist of *coal*; they disappear when the clay-slate is placed before the blowpipe-flame. A difference is observed in the proportion of the crystalline constituents. The *microlites* of an unknown mineralogical nature called "clay-slate needles," which appear in *great numbers in the German clay-slates*, *are here entirely absent.*

Besides a few other minerals, *hæmatite* and *tourmaline* frequently appear. Most beautiful individuals of *tourmaline* are found in a clay-slate (S. 32, T. 40, R. 36, Wisconsin †) as perfect crystals, as well as in fragments, 0·015–0·06 millim. in length, and 0·003–0·025 millim. in breadth. In accordance with the investigations of Anger ‡ and Svedmark §, we may state that a comparatively frequent hemimorphism of crystals occurs; their colour is greyish green, and they show a strong dichroism when tested with a single Nicol's prism. Crystalline fragments are often found near one another, so that the original crystal can be reconstructed in imagination without any difficulty. Tourmaline is also found in exquisite crystals, as well as in fragments, in other clay-slates from Wisconsin (S. 28, T. 39, R. 18, and S. 14, T. 40, R. 18). This mineral occurs less frequently in the clay-slates of Michigan; and in some specimens from the Chocolate-Marble Quarry, Marquette, it was entirely absent. Besides tourmaline, small yellowish-brown and red transparent crystals, which remind us vividly of zircon, as described by Zirkel ||, were perceived in clay-slate from Slate River, Michigan.

Hæmatite appears in exceedingly small, well-shaped, hexagonal laminæ. Some are transparent, of a blood-red colour, but the greater number are opaque. This mineral also occurs in varying

* Microscop. Journ., March 1877.

† These numbers indicate the localities from which the specimens were derived, as marked upon the Survey Maps.

‡ Tschermak, Mineralog. Mittheil. 1875, p. 162.

§ Geol. Förening. Stockholm, 1877, No. 38.

|| Neues Jahrb. f. Mineralog. etc., 1875, p. 628.

quantities in thin sections which come from the same locality, but it is always present.

The occurrence of *narrow, rod-like, colourless* crystals in some specimens is very striking; but being very small, they cannot be identified with a distinct mineral. It may be that they belong to the class of *felspars.* On an average they are 0·01 millim. in length. They are deposited parallel to the slate-plane, and appear one-coloured by polarized light. Specimens with distinct crystals occur in the Chocolate-Marble Quarry, Michigan; they occur also very abundantly in the novaculites which are yet to be described.

Mica can be recognized as a crystalline constituent chiefly when it is found in *radiating fragments*; otherwise it is difficult to recognize it as either a clastic or a crystalline constituent. It is found in almost colourless thin laminæ, which often exhibit a fibrous structure like sericite. Many attempts have been made to identify these laminæ with talc; but to justify this, magnesia ought to be contained in greater quantity in these rocks. It is very remarkable that the mica-laminæ should be only sometimes deposited parallel to the slate-plane; such is the case with a clay-slate near centre of S. 13, T. 50, R. 32, Michigan.

Some parts of the ground-mass show a crystalline structure. This is only to be seen by polarized light, because these parts consist of an aggregation of irregular spots, bluish and bluish-grey in colour, and vanish by degrees into the amorphous ground-mass. It is possible that these parts represent either *quartz* or a *crystalline silicate.*

Calcite cannot be considered a constituent of these clay-slates, although thin veins of this mineral are found interspersed within the rocks.

T. B. Brooks* mentions a clay-slate containing garnet, which was discovered at Champion Mine, Michigan.

Zirkel† has not ascertained whether the colourless ground-mass, which represents the cement of all constituents, is opal or a porodine-amorphous silicate. Some time ago‡ we expressed our opinion that it might be a porodine-amorphous silicate, amorphous quartz of ante-Tertiary age not being known. Besides, clay-slate is charged with too little silica (50 to 64 per cent.) to encourage us to consider the cement as opal.

B. *Novaculite* (*Whetstone*).

Novaculite is a very hard brittle clay-slate, generally of a yellowish-grey colour. The abundant presence of crystalline aggregates in contrast with the decreased amorphous ground-mass is proved by the microscope. These aggregations, which account for the well-known hardness of this slate, consist chiefly of *quartz.* Besides these, various kinds of crystals and fragments of *tourmaline* are found, the latter also appearing in form of microlites. *Blood-red laminæ of hæmatite, often possessing a distinct hexagonal form, are*

* *Loc. cit.*

† Mikroskop. Beschaff. p. 493 (1873).

‡ N. Jahrb. f. Min. 1876, p. 917.

not unfrequent. Colourless folia of mica are deposited, mostly parallel to the slate-plane. GARNET appears, in addition to these minerals, in more or less abundance. It has been already discovered by Zirkel in a novaculite from Recht, in the Ardennes, and also by Svedmark in a Cambrian clay-slate from Lemmingtorp, in Eastgotland. *The comparatively great hardness of novaculite may be accounted for partly by the presence of garnet. This mineral generally* appears in *the form of rounded grains*, seldom in distinctly defined crystals (rhombic dodecahedra). They are easily recognized, being *colourless or of a yellowish colour*, and possessing a rough surface. The garnets are much fissured, mostly free from any inclusions, and are recognized as perfectly isotropic bodies when seen under crossed Nicols. The above-mentioned narrow, rod-like, colourless crystals also appear in novaculite. The crystalline aggregations partly consist of quartz; partly they may represent an indeterminate silicate. The deep-grey dust-like substance is also present, but in much less quantity than in true clay-slate.

Typical specimens occur in Whetstone Quarry, Teal Lake, and Chocolate-Marble Quarry, Michigan.

C. *Carbonaceous Shales and Slates.*

There is little in these rocks to repay microscopical examination, but in a geological point of view they are of the greatest importance in the Huronian system. They are black slates and shales, which are proved before the blowpipe to contain considerable quantities of coal. In some cases the amount is found *to be* 22·51 *per cent.** We can only account for their existence by the destruction and disintegration of some former organic substance which had been deposited with the clay mud at the bottom of the sea. This may be done by the same reasoning by which we trace the presence of coal in later periods. It can also be proved that, at least in the upper strata of the Archæan formation, organisms must have existed. Julien† believes that he has found even a fucoidal impression in such a slate. Their spec. gravity, 2·06, is considerably lower than that of true clay-slate.

In thin sections black opaque particles of coal form the largest proportion; they are of quite irregular forms and mostly grouped together; small flakes of coal are also found in abundance in the amorphous clay-slate substance. This is especially the case in some specimens from S.E. Smith Mine, Marquette, Michigan. A peculiar arrangement of the coal-particles is seen in a slate from S. 11, T. 39, R. 19, Wisconsin; they have been deposited parallel to the slate-plane in such a manner that one layer consists chiefly of coal-particles. The slate containing most coal is that from L'Anse Iron Range, Michigan. Besides the constituents already mentioned, fragmentary folia of colourless mica sometimes occur. Pyrites here and there is not of unfrequent occurrence.

It is proved by these examinations that in the before-mentioned

* Mich. Geol. Survey, vol. i. p. 116. † *Ibid.* vol. ii. p. 5

varieties of clay-slates the so-called clay-slate needles are not present. The crystalline constituents are chiefly tourmaline, hæmatite, and quartz. The other constituents of the clay-slate, as well as their structure, agree in general with former investigations. In novaculite garnets are present. In the carbonaceous slates and shales crystalline constituents seldom appear. The former existence of organisms may be inferred from the presence of coal.

D. *Probable origin of the Crystalline Constituents in Clay-slate.*

Having studied the structure and the different constituents of our clay-slates, we must now consider the probable origin of the crystalline minerals. Three possibilities of origin may be accepted:—

1. The crystalline constituents may be regarded as the produce of the chemical action of the ocean.

2. They may be attributed to processes of metamorphism which took place after the solidification of these rocks.

3. They may have been formed after the deposition of clay-slate mud, whilst this was still in a plastic state.

The supposition that the crystalline constituents already existed in the rocks which supplied the material for the formation of clay-slate will scarcely find an advocate. The formation of tourmaline with its distinct outlines, being in complete contrast to that of the clastic constituents, contradicts such a theory. The crystalline nature being recognized by all authors, such a possibility need not be brought under consideration.

1. We find a complete statement of the first theory in a paper by G. R. Credner*. It is very important that the propositions adduced in it should undergo a minute examination, because from them the most important consequences ensue; whilst we must acknowledge that in accepting generally this principle, we have come much nearer the explanation of the origin of the crystalline schists. The results of the paper of G. R. Credner are contained in the following propositions† :—

(1) "Crystalline products of segregation, such as Zirkel has demonstrated in the Silurian and Devonian clay- and roofing-slates side by side with their clastic constituents are not confined to the above-mentioned rocks of the two oldest Palæozoic formations, but rather form a more or less essential constituent of every slate- and clay-rock hitherto examined of all (even the most recent) periods."

(2) "*In general*, in the rocks investigated, the part taken by these crystalline segregations in the formation of the rock decreases *pari passu* with the geological age. A Mesozoic clay-rock consequently consists of far more clastic and less crystalline material than a Palæozoic one. Carboniferous slates stand in the same relation to those of the Devonian and Silurian. Isolated exceptional cases may have local causes."

We do not readily agree to this. The number of examined spe-

* Zeitschrift f. d. ges. Naturw. 1874, p. 505. † *Ibid.* p. 522.

cimens is by far too small to fix such a law, especially if we consider that even among these there are some exceptions. G. R. Credner examined only two specimens of clay from the Tertiary period. He found in clay from the Isle of Wight very numerous microlites, whilst in a Tertiary clay from Dolau, near Halle, Germany, he only observed very few and minute crystalline constituents. At the same time we must add that it is very difficult to decide on the proportion of the crystalline constituents in clay-slate and slate-clay.

If we agree that this statement is correct, it follows that the older sedimentary rocks are the richer they must be in crystalline constituents, till we finally conclude that a period must have existed in which the secretions of the ocean were so great that the production of crystalline constituents must have been due to them; and it is at this that G. R. Credner evidently aims. In this manner, also, the important question respecting the origin of crystalline schists would be solved. We should like first to point out that the secretory capability of the ocean requires confirmation; for up to the present time no proof of this property has been given, and therefore the idea cannot be admitted into the discussion. Nor has it been proved that any change has taken place in the chemical composition of the ocean during the course of geological periods. Thus, for instance, the clay-slate of S. 28, T. 39, R. 18, Wisconsin, is regularly deposited between chlorite-schist and actinolite-schist, so that, according to G. R. Credner's theory, the ocean held successively in solution or suspension first chlorite, then clay, then actinolite, a fact which certainly has not been proved.

It has also been demonstrated by the above-mentioned investigations that the proportion of crystalline constituents by no means coincides with this theory. If some clay-slates are extraordinarily rich in crystalline constituents there are others which contain but small quantities, and consequently we have no means of correctly ascertaining the proportion. Still greater force is given to this argument by the fact that we made more numerous examinations of the Huronian clay-slates from Michigan and Wisconsin than G. R. Credner did of those from the Carboniferous period down to the Diluvium.

(3) "These crystalline structures have not originated in consequence of any later metamorphic actions whatever upon the formed rock; they rather owe their origin (as proved by

a. Their position parallel to the bedding-planes, and

b. Their not unfrequent radial grouping around a clastic fragment of rock which serves as a nucleus) to a *primary* segregation from the same waters from which mechanically transported mineral particles were simultaneously deposited to form muddy sediment."

These supposed proofs can on no account be permitted to pass as such; for the deposition parallel to the slate-plane may be explained by either theory. For whether the crystalline constituents be a product of the secretion of the ocean, or whether they have been formed in the still plastic mud, or owe their origin to metamorphic influences, they will in general occupy such a position either by the pressure of the superincumbent layers, or, if they were formed after the settling of the rocks, because parallel to the slate-plane they find the least relative resistance. The radiating grouping can still less pass as proof. Even if we allow the possibility that while a fragment is sinking in the ocean, it can unite with other minerals which become crystallized, it must be clear to every one that the motion of the water would very quickly separate them again. According to G. R. Credner's own statement it was impossible in some of his preparations to discover the manner of accretion of any crystalline formations, because the particles have been again separated by the action of water during the preparation of the object. When even in a glass of water such mechanical effects are apparent, how much more must they become so in the ocean?

2. We might seek a further explanation of the origin of these crystalline constituents in metamorphic processes, which possibly had some influence after the solidification of the clay-slate mud. This origin is especially urged by Delesse*. The chief objection to this theory is found in the existence of broken and reunited particles. The being broken *per se* would not contradict metamorphism, were it not that the material which reunites the fragments is composed of the same clastic clay-slate substance.

3. This aids in the confirmation of a third theory, which supposes the formation of the crystalline constituents to have taken place while the rocks were still plastic. This view is still further supported by the fact that new-formed materials are discovered in groups round some fragments. According to his close examination, Zirkel first proposed the theory that the crystalline constituents either had been formed during the deposition of the mud or at least before its solidification. More recently Svedmark, in his paper on Cambrian clay-slate, has stated that the garnets were formed whilst the clay-slate was still soft and plastic. Sorby † also states that the green grains of glauconite ought rather to be attributed to chemical action occurring *either during or soon after deposition*, like the minute crystals met with in some of the dredgings from the Pacific ocean. As the result of our investigations this opinion may be confirmed ‡. Later metamorphic processes are not to be excluded. We would especially draw attention here to the fact that chlorite-, mica-, hornblende-, sericite-, and other schists contain tourmaline and hæmatite of the same appearance as true clay-slates. It is probable that these minerals existed in the crystalline schists before the origin of the rest. If we want to place the metamorphic processes in their

* Revue de Géologie dans les années 1873 et 1874 (Paris, 1876), p. 203.

† Monthly Microsc. Journ., Feb. 1877.

‡ I regret to have received the interesting paper of Renard on the Belgian Whetstones ('Mémoire sur la structure et la composition du coticule,' Bruxelles, 1877) after this paper was already finished. Renard mentions also the abundance of tourmaline and garnet in these rocks, and has also expressed the opinion that these constituents were formed during the deposition of the sediments (*loc. cit.* p. 38).

proper place, we should do so in ranging them as a fourth phase in the production of the actual condition of sedimentary rocks :—

1. Deposition of mud.
2. Formation of minerals during the plastic state.
3. Formation of rock as clay-slate (solidification of the material).
4. Metamorphic processes.

The organic remains which had been deposited with the mud caused the formation of the carbonaceous particles. They might possibly have caused also the formation of pyrites by reduction of solutions of sulphate of iron.

There is one mineral occupying a strange position with regard to the occurrence and the formation of the other crystalline constituents. It does not appear in distinct crystals, but forms aggregations which are only to be observed with polarized light, and vanish by degrees into the amorphous ground-mass. It is as possible that it represents a silicate as that it is quartz. It seems to have been formed during the solidification of the rock, and is similar in appearance to the ground-mass of some crystalline schists.

It is only by comparing crystalline, semicrystalline, and clastic sedimentary rocks that we shall arrive by degrees at a satisfactory explanation of the origin of the crystalline schists which make up the greater part of the Archæan formations.

12. *On some* Mica-traps *from the* Kendal *and* Sedbergh Districts.

By Rev. T. G. Bonney, M.A., F.R.S., Sec.G.S., Professor of Geology at University College, London, and Fellow of St. John's College, Cambridge, and F. T. S. Houghton, Esq., B.A., Scholar of St. John's College, Cambridge. (Read December 4, 1878.)

Under the convenient generic term mica-trap the Geological Survey of England has included a group of rocks which are generally rich in that mineral, and occur among the older Palæozoic strata of the north-west of England. These rocks are found in dykes usually of no great thickness, and often very imperfectly exposed; and they have been mapped on quarter-sheet 98 N.E., and in the adjacent corners of the yet unpublished 98 S.E. and 97 S.W. A brief notice of the dykes is also given in the accompanying memoirs, 'Kirkby Lonsdale,' p. 42, and 'Kendal and Sedbergh,' p. 16. Without microscopic examination and chemical analysis, it was not possible, as a rule, to attempt a more exact nomenclature, so that, in our opinion, the use of the term mica-trap, like felstone, greenstone, &c., is not only convenient, but justifiable, where for any reason a more exact investigation is not practicable at the time. The present paper, although very far from being a complete history of all the mica-traps of North-western England, may form, it is hoped, a first chapter in it, and be the means of evoking further contributions to the lithology of this interesting and not very common group of rocks *.

Mica-traps, so far as we are aware, are either very rare or wholly absent in Britain to the south of the Cumbrian district, and in that they are rarely found in the vicinity of the principal lakes, but are almost confined to the eastern part of Westmoreland and the north-western of Yorkshire, always occurring in Silurian rocks †. They are also met with among the Lower Silurian strata of the southern uplands of Scotland, and in several localities in Ireland, where also they are intrusive in the older Palæozoic rocks ‡. Mica-traps also occur in the Channel Islands, Saxony, the Vosges Mountains, Baden, and North-western France, also in the Pyrenees and West-central France. Specimens from some of these districts have been used for comparison §.

* For the lithological work herein Prof. Bonney is responsible, for the chemical analyses Mr. Houghton. A few of the dykes have been examined in the field by the former, under the guidance of Professor Hughes, without whose minute local knowledge it would have been hardly possible to find one or two exposures. For most of the other specimens, and for notes on their relations to the stratified rocks, the authors are indebted to the kindness of their friend J. E. Marr, Esq., B.A., F.G.S., Scholar of St. John's College, to whom they tender their best thanks.

† Messrs. Gunn and Clough, Quart. Journ. Geol. Soc. vol. xxxiv. p. 30, expressly state that they never occur in the Carboniferous strata.

‡ Hull, 'On Building-stones,' &c. p. 84, *cf.* p. 9.

§ So far as we can judge from the figure, the rock described by Mr. J. H.

The principal subordinate members of the mica-trap group have been named by many petrologists minette and kersantite *, the former denoting those where the felspathic constituent is chiefly orthoclase †, the latter chiefly plagioclase ‡. After this subdivision great diversity appears in the use of the terms, little regard being paid to the crystalline condition of the ground-mass.

By Prof. Rosenbusch § the term minette is used as equivalent to mica-syenite, and kersantite to mica-diorite, or at least as denoting the more conspicuously micaceous varieties of these rocks. The group corresponding generally with the latter in chemical composition, but differing from it in having a micro- or crypto-crystalline ground-mass, is named by him kersantite-porphyrite; but we do not find a term for the corresponding rock in the former group. For this, then, we propose the analogous term minette-felsite ‖. It is quite possible that one or two of the rocks which we are describing in this paper may once have had even a glassy base; but in their present condition we do not feel able to affirm this positively, as the structure has been so much obscured by subsequent decomposition and micro-mineralogical change.

The amount of this has frequently been very great, some of the original constituents having been replaced wholly, or almost wholly, by pseudomorphic or other secondary products. We have thus often been obliged to speak very doubtfully as to the original nature of some constituents.

A few preliminary remarks on some of the minerals observed in these rocks may save time in the subsequent descriptions.

Mica.—This mineral is abundant in almost all the specimens. It is usually in very good preservation, though occasionally partly replaced by a greenish mineral, doubtless some hydrous magnesian silicate, partly by a nearly colourless mineral (a hydrous potash mica ?). It is brown in colour, most markedly so when viewed normally to the basal pinacoid. Sections transverse to this plane are markedly dichroic, changing from an olive-brown to an almost colourless tint. These sections have a strong analyzing action. They have generally a border darker than the interior. In some specimens enclosures of other minerals are comparatively rare, in others rather abundant. These are grains and belonites of iron peroxide, and colourless needles (apatite ?), sometimes apparently smaller crystals of mica.

Collins under a new name appears to be (as stated in the discussion after this paper by Mr. W. W. Smyth) only a variety of mica-trap. See also Mr. J. A. Phillips, Quart. Journ. Geol. Soc. vol. xxxi. p. 337.

* There does not appear to be any essential difference between kersantite and kersanton.

† For list of localities where this rock is reported to occur, see Zirkel, 'Lehrbuch der Petrographie,' vol. i. p. 606.

‡ For list of localities, see Zirkel, *ibid.* vol. ii. p. 36.

§ 'Mikroskopische Physiographie,' vol. ii. p. v.

‖ On the analogy of quartz-porphyry &c. one should say minette-porphyry; but the term porphyry has been so vaguely applied that I venture to think it should be dropped altogether from scientific nomenclature, and quartz-felsite substituted for it.—T. G. B.

Layers of calcite, interposed between the cleavage-planes, may also be observed, as figured by Prof. Zirkel *.

Augite.—Associated with the mica, in more or less abundance, is a mineral which is herein generally described as augite. In some cases it undoubtedly is this mineral, the characteristic section perpendicular to *c* being very conspicuous; in others, however, the form (at any rate now) is indefinite. The crystal is almost always replaced by secondary products. In some (and here we note the external form to be, as a rule, better preserved) there is chiefly viridite (a feebly doubly-refracting variety, probably delessite or some serpentinous mineral); in other cases calcite or dolomite predominate, with some indications of viridite and another secondary mineral (possibly also magnesian), which exhibits a rather indistinct microgranular structure, and is doubly refracting, showing dull milky-blue tints. A somewhat similar result of decomposition in the case of hornblende is figured by Prof. Zirkel †.

Calcite is present in many of these rocks, showing the characteristic cleavage; but not seldom associated with it, and sometimes predominant, is an apparently different mineral, which is more probably dolomite. The form of the crystalline grains is more regular, the cleavage-planes are less distinctly marked, and the colours more brilliant than is usual in calcite. A study of numerous slides containing calcite, and several of dolomitic rocks from various localities, among others the Italian Tyrol, seems to prove that dolomite, when pure, commonly occurs in rather regular polygonal or rounded grains, while in the case of calcite these are irregular. In the former the cleavage-planes are less conspicuous than in the latter; but the grains, when lying in the right position (with crossed Nicols), are beautifully coloured, showing a bright apple-green and its complementary pink, while the tints of calcite are dull. For these reasons, which are given at length, as the writer has not seen them noted in the ordinary text-books, he considers much of the mineral in these mica-traps to be dolomite, to which also we may perhaps assign a number of very minute bright-coloured granules which are disseminated over the slides.

Opacite and *ferrite* are employed in the sense assigned to them by Prof. Zirkel ‡,—the former denoting "black, entirely opaque, amorphous grains and scales," which are very frequently metallic oxides, especially of iron; the latter "yellowish, reddish, or brownish, amorphous, earthy substances, which are not unfrequently pseudomorphous after iron-bearing minerals, probably very often hæmatite or limonite." We have, however, included in the former term grains which are not strictly amorphous, but either rather too small or not so placed as to have their form determined with accuracy.

With two exceptions, the mica-traps here described lie in an irregular band, extending from Windermere to a few miles east of Sed-

* U.S. Geol. Expl. of Fortieth Parallel, 'Microscopic Petrography,' pl. v. fig. 1.

† *Loc. cit.* pl. iii. figs. 2, 3.

‡ *Loc. cit.* p. 12.

bergh, and are described nearly as they would be met with in travelling from west to east.

(1) *Dyke ¾ mile from Windermere Station.*

Characters.—Macroscopic. A compact ground-mass of ash-grey colour, enclosing numerous crystals of a dark-brown mica, most of which have a silvery lustre, apparently produced by their adherent films—probably a decomposition product. The mica crystals are commonly more or less hexagonal in form, and about 0·1 inch diameter.

Microscopic. The rock, at first sight, appears to have a clear pale-brown glassy base, containing numerous microliths, generally acicular. Closer inspection reveals in the apparent glass more or less faint indications of a crypto-crystalline structure. With crossed Nicols this is rendered more distinct, innumerable microliths making their appearance. These show but faint light, and much of the field remains dark; but on rotating the stage new groups of microliths appear in the dark parts, while those formerly observed disappear. It may therefore be doubted whether any true glass now remains; but it is highly probable that formerly such existed, and that the rock has been devitrified.

In the above we have calcite or dolomite abundantly present, both in the ground-mass in fine granules, and in separate crystalline grains up to about 0·01 inch in diameter; brown mica (biotite) abundant in crystals of various size; granules of some iron peroxide, rather decomposed, not rare; dolomite, and a nearly colourless hydrous mica (?); numerous grains composed of dolomite and serpentinous viridite. Among these we find sections corresponding closely with the familiar form of augite when cut perpendicular to *c*.

The following is an analysis of the rock:—

Water	2·59
CO_2	6·39
SiO_2	44·44
Al_2O_3	17·85
Fe_2O_3	4·82
FeO	3·62
MnO	tr.
CaO	7·54
MgO	7·57
K_2O	4·78
Na_2O	0·99
	100·59

The proportion of K to Na is in favour of naming the rock minette-felsite; but the percentage of SiO_2 seems low, and that of Fe and Ca high, for a rock containing orthoclase. It occurs intrusive in Bannisdale Slates, is exposed in a railway-cutting, being about 1 foot thick, and is only visible on the south side. The rock in contact is but little altered. The mica-crystals in the dyke and the principal joint-planes are parallel to the sides. Some 2 feet from this is another dyke, also about a foot wide, which does not reach the surface, and is doubtless an offshoot.

(2) *Dyke, Barley Bridge, Staveley.*

Characters.—Macroscopic. A rather compact, pale reddish-grey rock, of decomposed aspect, with numerous specks of pale celadon-green and very minute glimmering lines.

Microscopic. The ground-mass is rather decomposed and of a light brick-red, from ferruginous staining; but it was once probably either microcrystalline throughout, or exhibited a glassy base thickly crowded with acicular felspar-microliths, which still show traces of fluidal structure. There are many grains of iron peroxide (? hæmatite), and numerous grains or crystals of a mineral which is replaced partly by calcite and partly by a pellucid pale-green serpentinous mineral. One or two evidently have once included portions of the ground-mass. On the whole, it seems probable that this has been augite rather than hornblende. There are also a fair number of scales of brown mica.

The general character of this rock, and its comparative poverty in mica, make it better to remove it from the mica-traps, and name it a porphyrite.

This dyke occurs exposed in the bed of the Kent, cutting the Bannisdale Slates at right angles to the bedding-planes, and hardly altering them. It is about 2 feet wide.

(3) *Dyke, Gill Bank, $1\frac{1}{4}$ mile N.N.E. of Staveley.*

Characters.—Macroscopic. Appears to be a finely crystalline mixture of a dull-red felspar and dark-green mineral resembling hornblende, with a few small scales of black mica, having the general aspect of a very fine-grained syenite. It weathers a rusty-brown colour.

Microscopic. The rock has evidently been much altered subsequent to crystallization, but it appears to have been crystalline throughout. The felspar is much decomposed, stained reddish brown, being both frequently pierced with needles of zeolite and associated with secondary quartz. The common form of the crystals, and faint indication of twins, make it very probable that most of these are plagioclase. There are several small scales of brown mica, some needles of apatite, numerous crystalline grains and belonites of iron peroxide, probably hæmatite, and a considerable quantity of a rather fibrous dull green mineral, almost certainly decomposed hornblende, associated sometimes with a little calcite (?). Analysis:—

Water	2·87
CO_2	4·84
SiO_2	46·17
Al_2O_3	16·95
Fe_2O_3	5·46
FeO	0·83
MnO	0·10
CaO	10·23
MgO	7·13
K_2O	3·96
Na_2O	2·42
	100·96

Although the present condition of the rock makes it difficult to speak with certainty, we may venture, notwithstanding the amount of potash, to call it a diorite rather than a syenite. At any rate the amount of mica is not sufficient to warrant our retaining it among the mica-traps.

This dyke is intrusive in Bannisdale Slates. It is more than 20 feet wide, can be traced along the course of a stream for several hundred yards, and probably extends much further. It includes a large fragment of the Bannisdale beds, but neither this nor the adjacent rock are much altered.

(4) *Dyke, Stile-end Farm, between Kentmere and Long Sleddale*.*

Characters.—Macroscopic. The rock appears very finely crystalline, the component minerals being much too small for recognition, and is of a dark-grey colour.

Microscopic. The rock is a crystalline mixture of plagioclase (labradorite), hornblende, and iron peroxide (probably hæmatite). The first occurs in long, narrow, twinned crystals, like those common in dolerite. The second, partly in small well-defined prisms, of a clear olive-brown colour, rather free from ferruginous microliths (this variety is strongly dichroic); partly as a more filmy, fibrous, less well-defined, pale green variety, which barely shows dichroism, is associated with ferruginous microliths, occurring both together with and apart from the other, and having much more the aspect of a secondary product. It is possible that there may be also some little biotite. The iron-peroxide occurs both as grains of a more or less definite crystalline outline, and as isolated or aggregated minute rods or clubs (such as are figured by Bŏricky†). Belonites are numerous, almost certainly of secondary origin. They pierce through both the felspar and hornblende, and are commonly from ·0001 to ·0003 inch in diameter. One or two of the largest seem to be of a very pale green colour, and resemble actinolite. If not this mineral, they must be zeolite. Apatite seems very scarce. Besides the above there are some larger crystals. Of these one set are much decom-

* About 5 miles to N. of Staveley, and so out of the line.

† Böhm. Basalt. pl. i.

posed, and so semiopaque. What remains is clear, not dichroic, and more resembles augite than any thing else. The other, still clearer, rather fibrous, and very pale green, is probably a variety of hornblende, resembling a secondary product.

The following is an analysis of this rock :—

Water	3·52
CO_2	1·16
SiO_2	49·52
Al_2O_3	17·97
Fe_2O_3	5·06
FeO	2·61
MnO	0·40
CaO	7·80
MgO	6·17
K_2O	2·34
Na_2O	2·52
	99·07

The hornblendic character of this rock requires us to remove it from the mica-trap group, and class it with the more basic diorites.

This dyke is intrusive in Coniston Limestone, which is indurated for a distance of a few feet, and stands up above the dyke, which is weathered away (surface-colour rusty brown), and protrudes here and there from the grass, being about 4 feet wide, and traceable for about 20 or 30 yards.

(5) *Dyke, Kendal Road,* 250 *yards from 3rd milestone.*

Characters.—Macroscopic. A general resemblance to No. (1), except that the colour is browner, and the mica-plates often larger, being not seldom 0·4 inch in diameter; the lustre also is less silvery.

Microscopic. An obscurely crypto-crystalline ground-mass, with some resemblance to that of No. (1), containing many filmy brown scales and fibres, probably of mica, with granular ferrite, and perhaps some apatite. Some of the belonites may be pale-coloured hornblende. There are a few grains of quartz, probably secondary. The mica has a general correspondence with that in No. (1). The principal differences between the two slides is that this is without any conspicuous calcite or dolomite, or indications of augite or hornblende.

The analysis is as follows :—

Water	2·21
CO_2	1·83
SiO_2	61·12
Al_2O_3	15·99
Fe_2O_3	0·84
FeO	1·70
MnO	tr.
CaO	5·12
MgO	4·93
K_2O	4·80
Na_2O	2·04
	100·58

The potash probably belongs in part to the biotite, so, having regard to the large amount of lime present, it is clear the rock must be near to the plagioclase or kersantite group; but still it is better to name it minette-felsite.

It weathers rusty brown, and occurs in Bannisdale Slates, being 2 or 3 feet wide, much decomposed, breaking into large tabular masses along joints parallel to the sides, to which also the mica-flakes are often parallel. The adjacent rock seems hardly altered.

(6) *Dyke on Railway, W. of Docker Garth.*

Characters.—Macroscopic. A compact grey rock, full of minute scales of brownish mica, with a rather silvery lustre, and indications of small felspar crystals. Specimen traversed by a vein of pink calcite.

Microscopic. The ground-mass appears to be micro-crystalline; but in parts there is indication of the presence of true crystalline structure, the outlines of felspar crystals being dimly discernible. These are often traced out by lines and clots of opacite. The ground-mass is much stained by ferrite, and traversed by acicular microliths, so that the original structure has been greatly obliterated. Mica is abundant, also dusty green patches of some decomposition-product, grains of iron peroxide (some magnetite), and some augite.

An analysis gives :—

Water	3·83
CO_2	tr.
SiO_2	48·57
Al_2O_3	18·52
Fe_2O_3	1·60
FeO	6·87
MnO	0·60
CaO	2·79
MgO	8·97
K_2O	3·71
Na_2O	1·59
	97·05

The rock, then, appears to be a minette-felsite.

The dyke is in a line of fault in the Bannisdale Slates, being about 2 or 3 yards wide. It weathers to a grey powdery mass, and is traversed by numerous calcite veins.

(7) *Dyke S. of Haygarth, Docker Fell.* No. I.

Characters.—Macroscopic. A compact, very dark purplish-grey ground-mass, with numerous scales, generally considerably less than 0·1 inch, of brown-black mica, with bright lustre.

Microscopic. A clear ground-mass, containing numerous minute belonites, mica-scales, and grains of ferrite, which appears to have a micro-crystalline structure throughout. In this are numerous crystals of biotite, frequently hexagonal in form, much freer from calcite and enclosures than in No. II. There are a few grains of calcite and a few of some saussuritic mineral (the former may be a pseudomorphic product after augite, the latter, perhaps, after felspar) and plates of mica are around, so as to border them, and, in one or two of the larger, small plates are included. There are one or two grains of quartz present, generally bordered by a dull granulated ring. They contain a few minute cavities. In one case the grain is a compound one. Their appearance suggests the possibility of their having been caught up by the molten rock. Associated with one of these in a part of the slide is a crystal of plagioclase apparently broken up, the fragments being twisted into different positions.

The following is an analysis :—

Water	2·35
CO_2	0·66
SiO_2	58·34
Al_2O_3	16·33
Fe_2O_3	2·28
FeO	3·88
MnO	0·14
CaO	5·65
MgO	3·34
K_2O	5·55
Na_2O	2·20
	100·72

This shows the rock to be a minette-felsite.

(8) *Dyke S. of Haygarth, Docker Fell.* No. II.

Characters.—Macroscopic. A compact ground-mass of a reddish chocolate-brown colour, pretty full of scales of mica up to about 0·1 inch, but occasionally much larger. The mica is of a brown-black colour, with a bright, rather silvery lustre.

Microscopic. A crypto-crystalline, almost glassy base, stained brown with ferrite, and containing very many minute scales, as well as numerous more or less regularly formed plates of olive-brown biotite, frequently containing minute acicular, granular, or platy enclosures, being sometimes ferrite, sometimes perhaps smaller scales of mica, arranged generally along the planes of principal cleavage, giving rich colours with crossed Nicols. Nearly colourless crystalline grains, now composed of calcite or dolomite, with a little viridite and other secondary products, are common. The general appearance suggests that they are pseudomorphs after augite; and in one or two the angles of transverse sections of the crystal correspond fairly well with those of that mineral. We also find crystalline grains of a ferruginous mineral, probably hæmatite.

The following is an analysis :—

Water	3·01
CO_2	2·01
SiO_2	47·88
Al_2O_3	19·14
Fe_2O_3	4·33
FeO	1·67
MnO	0·35
CaO	6·16
MgO	6·36
K_2O	5·54
Na_2O	2·45
	98·90

The analysis seems to place this rock with the minette-felsites, but there is evidently a very considerable portion of plagioclase felspar present with the orthoclase.

The dyke now is not clearly exposed at the place where it is mapped by the Survey, so these specimens were collected from boulders on that spot, some blackish, others brownish in colour. The difference in the analyses is remarkable, and shows that they can hardly be from the same rock, but that there must be more than one dyke close by. The adjoining sedimentary rock belongs to the Kirkby-Moor Flags.

(9) *Dyke in River Lune, S.W. of Sedbergh.*

Characters.—Macroscopic. A compact dark ground-mass, full of crystals of dark-brown mica, up to about $\frac{1}{8}$ inch in diameter.

Microscopic.—The ground-mass shows great decomposition. At present it may be described as a compound mass of earthy-looking dust, often gathered into clots, and occasionally associated into crystal-like forms, interwoven, as it were, with colourless needles (some probably apatite), grains of opacite, flakes of mica, and surrounded by a colourless base. It is, however, more than doubtful whether any true glass is present; and careful examination makes it appear probable that the whole has once been crystallized, though finely, and felspar has been the principal constituent, but that the forms of the crystals have been almost obliterated by decomposition. So far as can be inferred from the outlines still to be traced, they most probably were plagioclase. In this ground-mass crystals of biotite abound, up to about ·03 inch in diameter, and numerous grains, as usual, of another mineral. These grains are traversed by irregular cracks, lined with a filmy olive-brown serpentinous mineral, and rather resemble altered olivine; but two or three fairly well preserve the outlines of augite. In some the other replacing mineral is calcite (or dolomite), in the majority the granular (? serpentinous) mineral mentioned above. We may then class this rock as a decomposed kersantite*.

(10) *Uldale Head* †.

Characters.—Macroscopic. A compact dull brownish-grey rock, containing many small crystals of biotite, and a few small pale-grey crystals. In another specimen (which seems more decomposed, and is of a paler colour) the mica crystals occasionally attain a larger size, one or two being about 0·25 inch.

Microscopic. The ground-mass of this rock appears to consist of a glassy base crowded with microliths. These are:—(*a*) colourless microliths, probably felspar, and possibly, in some cases, augite; (*b*) brown mica; (*c*) ferrite and opacite. In this base are scattered larger grains of iron peroxide (? hæmatite), the usual crystals of biotite (rather free from enclosures), and a nearly equal number of grains and crystals of augite, altered in the usual way, but in one or two cases showing the characteristic outline of the section perpendicular to *c*. One of these contains acicular ferrite, which has been arranged parallel to the planes of prismatic cleavage; but most are clear. The decomposition-products are rather variable, but there is little calcite or dolomite. Plagioclase is not certainly recognizable; but (so far as an opinion can be formed from microscopic examination) the rock is probably a kersantite-porphyrite.

It is intrusive in Coniston Grits, forming a dyke probably some yards wide, but the sides are not exposed. It is generally much decomposed, being in places almost a sand. Fragments of the Grit are occasionally included.

(11) *Holbeck Gill.*

Characters.—Macroscopic. A rather pale reddish-grey, dusty-looking rock, containing numerous small crystals of dark mica, with rather silvery lustre and a few pale-green specks. On a polished surface it has a minutely crystalline aspect. The rock is much decomposed; external surfaces are rather redder than the rest.

* I believe this specimen to be from a dyke in Coniston Flags, but have no information beyond the label on the specimen, which has been in my possession for some years.—T. G. B.

† E. of River Lune, considerably to N. of the general line of those we are describing.

Microscopic. Much decomposed, but apparently a crystalline mixture of plagioclase felspar and biotite, with grains of iron peroxide (some at least being magnetite) and a few grains of altered augite. The felspar is greatly decomposed, full in parts of earthy secondary products and colourless belonites, probably also of secondary origin (some, however, may be apatite), with occasional clear spaces of an isotropic mineral. The mica is frequently in hexagonal plates, rather unusually dark brown in colour, with a good many ferruginous enclosures—in one or two cases parts of the crystals are rendered quite opaque by them.

The rock accordingly appears to be a kersantite. It forms a narrow dyke in the Coniston Grits.

(12) *Highest Dyke, Helm Gill, near Dent.*

Characters.—Macroscopic. A compact dark-grey ground-mass of felspathic aspect, containing numerous scales of black mica, varying up to about 0·1 inch diameter. Here and there is a small pinkish crystal resembling felspar.

Microscopic. The transparent base exhibits with crossed Nicols a rather obscure microcrystalline structure, the better-defined crystals being prismatic in form, with a tendency to a fan-like grouping. In this are some grains of magnetite, a great number of crystals of biotite, as usual, and a number of somewhat irregular pale-green grains of rather variable structure. They are often rudely defined at the exterior by small mica-plates and ferruginous grains, containing also small grains of both and numerous minute belonites. The green mineral is feebly dichroic and doubly refracting. Probably they have been augite or hornblende. Minute specks of calcite or dolomite abound in them, and are largely disseminated in the slide.

A partial analysis shows that this rock is decidedly different in chemical composition from the next; this, however, is to a considerable extent due to the much smaller amount of $CaCO_3$. As the potash is considerably in excess of the soda, we may group it with the minette-felsites.

(13) *Lowest Dyke, Helm Gill, near Sedbergh.*

Characters.—Macroscopic. Generally similar to the last, but slightly less conspicuously micaceous.

Microscopic. This presents some differences. The ground-mass is more crowded with microliths of various kinds, so that it has a more granular aspect; and the greenish grains in it are larger, paler, and rather more clearly defined. They are occupied by an aggregate of dolomite and almost colourless serpentinous mineral. The ground-mass also is full of minute bright specks (dolomite?); it was evidently never distinctly crystalline, and is now, so far as can be seen, microcrystalline, suggesting orthoclase rather than plagioclase.

The following is an analysis:—

Water	3·69
CO_2	13·13
SiO_2	32·31
Al_2O_3	12·15
Fe_2O_3	1·97
FeO	5·99
MnO	0·13
CaO	17·68
MgO	8·24
K_2O	4·09
Na_2O	0·43
	99·81

Its general appearance and the proportions of potash and soda seem to justify us in calling this rock a minette-felsite; but the percentage of silica, even when allowance is made for the large percentage of calcic carbonate (probably in great part due to infiltration), is low for an orthoclase rock. If all the CO_2 is in combination with the CaO, that would imply about 29·5 of $CaCO_3$; and removing this, the silica percentage would rise to about 46.

These two dykes belong to a group of about four which are exposed in and near the little stream of Helm Gill, on the north side of the valley above Dent. They are generally from 2 to 3 feet thick, and similar in character, those from which specimens were taken being the most different. They weather a deep warm brown, with a roughish surface and slightly rounded outline. The rock is extremely tough. They are intrusive in the Coniston Limestone.

The rock beneath the upper dyke is an impure limestone. It is much indurated, and contains specks of a bright green mineral resembling smaragdite. A more argillaceous rock lower down was only a little indurated and rather broken.

(14) *Cross Haw Beck.*

Characters.—Macroscopic. A rather pale violet-grey, dusty-looking rock, containing numerous small crystals of black mica, and occasional small scales of a pale-brown mica, with silvery lustre. A polished surface, however, shows it to be a crystalline mass of a dead-white felspathic mineral, a greenish-grey mineral, and black mica.

Microscopic. The rock has probably been a crystalline mixture of felspar, biotite, iron peroxide, and augite, but it has undergone much alteration. The first suggests orthoclase, but is greatly altered, the second and third minerals only being at all well preserved; the last is commonly replaced by calcite and various decomposition-products. In some cases the mineral still retains a cleavage resembling that of augite, but has lost its usual influence on polarized light—a thing which I have elsewhere noted in decomposed augitic rocks. There is also probably a little potash-mica.

The rock, then, may be named minette. It forms a narrow dyke, imperfectly exposed, in the bed of a stream in the Coniston Flags.

(15) *First Tributary (on W.) to Backside Beck, Westerdale.*

Character.—Macroscopic. The rock is compact in texture, and dull grey in colour, of rather decomposed aspect. The felspathic ground-mass is crowded pretty thickly with minute scales of mica, with a rather silvery lustre. The rock is traversed here and there by thin veins of quartz.

Microscopic. A cryptocrystalline felspathic ground-mass, with a general resemblance to those from Helm Gill. Much brown mica (some of the smaller plates of a green colour), some apatite, several grains of iron peroxide (? ilmenite), and a considerable number of crystals and grains resembling those in the lower Helm-Gill rock, and probably pseudomorphs after augite. Calcite is undoubtedly present in a vein, and there is probably some disseminated dolomite.

The rock is probably a minette-felsite. The dyke is a narrow one, and is intrusive in Coniston Limestone.

(16) *Wattle Gill, Westerdale.*

Characters.—Macroscopic. A compact dark rock, containing a quantity of black mica, generally in small crystals, rarely exceeding 0·1 inch diameter, and some scattered crystals, occasionally a little longer, of a pale-grey colour. Weathers brown.

Microscopic. Very similar to those of the rock from Uldale Head, except that extremely little, if any, of the base remains in a glassy condition. A separate description is hardly necessary. Here also there is variety in the pseudomorphous products replacing the augite crystals and grains. One which affords a perfectly characteristic 8-sided section, with the usual rectangularity of the alternate sides, is mainly occupied by a pale olive-brown, hardly dichroic mineral, which with crossed Nicols appears an aggregate of several minute minerals. In the majority, however (which in form are less characteristic), dolomite appears to predominate. It contains numerous enclosures, three or four being brown mica, and some, apparently, portions of the base, containing (felspar?) microliths.

The dyke is a narrow one, intrusive in Coniston Limestone, and is probably kersantite-porphyrite.

(17) *Dyke from the upper part of Westerdale.*

Characters.—Macroscopic. A compact, dull greenish-grey rock, with some darker specks, and a great number of mica-scales, almost too minute to be visible to the unaided eye, of silvery aspect, so that it is by no means a conspicuously micaceous rock. It is evidently much decomposed, and weathers a rusty brown.

Microscopic. There has probably been a glassy base crowded with microliths of felspar, augite, mica, and ferrite; but the present condition of the rock makes it difficult to speak confidently. In this are numerous small crystals of biotite, rather full of enclosures, often with interstitial calcite (?), also, possibly, large grains of some white mica, iron peroxide, and numerous crystalline grains of either augite or hornblende, chiefly replaced by viridite (serp. var.), and some calcite or dolomite. Some colourless crystals may be pseudomorphs after felspar, but they have rather the aspect of a micaceous or pyroxenic mineral.

The general aspect of the rock suggests affinities with the basic group, so that it probably is a kersantite-porphyrite. It forms a narrow dyke at the base of the Coniston Flags, near to a rather salmon-coloured indurated slate in the upper part of Westerdale.

Tabulating the above results, we accordingly have the following classification of these mica-traps, though it must be remembered that some of those named minette-felsite are probably near the plagioclase group. Indeed the majority, as will have been seen from our examination, cannot be considered very typical examples of the species to which they are referred :—

	No. of description.
Minette.	
Cross Haw Beck	(14)
Kersantite.	
Bed of Lune	(9)
Holbeck Gill	(11)
Diorite (micaceous).	
Gill Bank	(3)
Stile-end Farm	(4)
Minette-felsite.	
Near Windermere Station	(1)
Kendal Road	(5)
Railway, Docker Garth	(6)
South of Haygarth	(7) & (8)
Helm Gill	(12) & (13)
Backside Beck	(15)
Kersantite-porphyrite.	
Uldale Head	(10)
Wattle Gill	(16)
Westerdale	(17)
Porphyrite.	
Barley Bridge	(2)

One remark only need be made in conclusion. It has been suggested that possibly some of these mica-traps may not be true igneous rocks, but the result of metamorphism, by the assimilation of portions of the adjacent sedimentary rock, through the action of gases or of hot water (holding various minerals in solution) communicating along lines of fissures with the joints. The cases which we were able to examine in the field did not appear to favour this view ; and if any confidence can be placed in microscopical investigation, there is nothing in favour of and every thing against it. If the word igneous be used in its ordinary sense, there need not be the slightest hesitation in classing these mica-traps with the igneous rocks. From the above descriptions it would seem probable that most of them solidified at no great depth. Hence, as their geologic age is certainly later than the Upper Silurian, and is very probably Precarboniferous, we should be disposed to refer them to some part of the Old Red Sandstone epoch, and that probably not the earliest, connected, it may be, in some sort with those volcanic disturbances which have left such conspicuous monuments in Scotland.

Discussion.

The President thought that very commonly the method suggested by the author for discriminating between calcite and dolomite under the microscope was not applicable to limestone rocks.

Mr. Rutley said he was acquainted with the rocks described, and that he entirely agreed with the author in his conclusions. He pointed out that many of the Lake-District dykes mapped by the Geological Survey as felstones should be regarded as such, or as micaceous eurites.

Prof. Seeley thanked Prof. Bonney for clearing up many of the difficulties connected with minette which he had himself in vain endeavoured to grapple with without the aid of the microscope. He offered the suggestion that some minettes may have been formed by the consolidation of masses of volcanic dust that had fallen and filled, or been compressed or washed into, fissures. He cited instances in the Eifel of masses of volcanic dust containing crystals of mica and other minerals in every stage of development, so as to present an external approximation to minette. He suggested that some of the specimens which were described by Prof. Bonney, containing, as they did, so large a proportion of carbonate of lime and other evidences of decomposition, might have so originated.

Dr. Hicks asked if the dykes of minette altered the adjoining rocks. He suggested that they might result from the metamorphism of mica-slate, and have been forced from below into fissures.

Mr. Rutley confirmed the true eruptive character of the dykes and bosses of minette referred to in the paper.

Dr. Sheibner had lately studied the minettes of the Vosges, and was able to confirm Prof. Bonney's views as to the true igneous origin of those rocks. In the Vosges similar dykes occur in the Precarboniferous greywacke and clay-slates of the Vosges, and the rocks on either side are perceptibly altered.

Mr. W. W. Smyth stated that somewhat similar micaceous rocks had been described by Mr. Collins as occurring a few miles E. of Truro in Cornwall, and as being plutonic rocks constituting very flat-lying dykes. For those rocks Mr. Collins had, perhaps unfortunately, proposed a number of new local names.

Prof. Bonney replied to the President that, although the characters described in dolomite were not always found, yet when found they distinguished it from calcite. His real difficulty in dealing with these rocks was owing to the indistinct crystallization or destruction of the felspars. He did not know whether he ought to treat Prof. Seeley's suggestion as serious, especially as he had not examined the volcanic dust with the microscope. He said that the dykes in question sometimes narrowed from below upwards, and none of them ever contained any trace in microscopic sections of the clearly marked features of volcanic dust, which were seldom obliterated in altered rocks. He replied in the same way to Dr. Hicks's suggestion, and stated that there were not the smallest grounds for regarding these as otherwise than truly igneous rocks.

13. *Notes on* PLEURODUS AFFINIS, sp. ined., Agassiz, *and* DESCRIPTION *of* THREE SPINES *of* CESTRACIONTS *from the* LOWER COAL-MEASURES. By J. W. DAVIS, Esq., F.G.S., F.S.A. (Read November 20, 1878.)

[PLATE X.]

Two years ago I had the pleasure of reading a paper to this Society describing a thin stratum of shale known to extend over an area of several miles, immediately above the Better-bed coal in the neighbourhood of Clifton and Low Moor, south-east of Halifax. The stratum averages from a quarter to three eighths of an inch in thickness, and is almost entirely composed of the fragmentary remains of fishes and Labyrinthodonts. Between thirty and forty species of fishes have been found, and are enumerated in the paper already referred to*.

PLEURODUS AFFINIS, sp. ined., Ag. (Pl. X. figs. 1–11.)

Associated with these, several specimens of a peculiar Ichthyodorulite have been found during the last four or five years. Three of the specimens are well preserved, one of them nearly perfect and well separated from the matrix; and there are also several others in a more or less broken condition.

The length of the largest and most perfect example (fig. 10) is two inches and one tenth, and its greatest breadth, about the middle of the spine, is four tenths of an inch; from this point it tapers gradually in each direction to the basal and apical extremities. The anterior margin of the spine forms a gentle uniform curve from the base to the point; on the posterior aspect the curvature is much more rapid from the point to the broadest part, thence it recontracts in an uneven line and ends in a somewhat rounded base about two tenths of an inch in diameter. The whole of the spine is much compressed laterally. The surface is marked by a series of fine longitudinal striæ, fibrous in appearance, most distinctly marked on the basal end of the spine, and gradually disappearing towards the apex, which is quite smooth (fig. 11). Fully half the spine appears to have been buried in the integument or muscles of the fish. Along the back there is a cavity extending from the base one inch and three tenths, which probably enveloped and protected the dorsal fin. Higher, the cavity becomes enclosed and is ovate in form, remaining in a position much nearer the back than the front of the spine.

Associated with these spines are numerous teeth, and there is every reason to believe that they have belonged to the same fishes.

The teeth (figs. 1–8) are obliquely ovate in form, produced so as to form a coronal ridge along the longer axis; the front part of the tooth is narrow, almost pointed, but becomes wider and more rounded backwards. From the semi-pointed coronal ridge in the front part the

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

sides are spread out from the base to about the same width as the hinder portion of the tooth. These lateral wing-like processes are cut or notched transversely to the axis of the tooth. The notches vary in number from four to eight. There is also considerable variation in the form of the teeth themselves; some are narrower, others broader, in proportion to their length. An average tooth is from six to eight tenths of an inch in length, the breadth equalling half the length. The majority are covered with a greyish-white enamel and are ornamented with inosculating delicate transverse ridges which occasionally assume a reticulated character, especially near the edge of the lateral process. In a large proportion a finely pitted or punctured surface takes the place of the ridges; and more rarely the two are combined and give a most exquisite texture to the enamel. The anterior central part of the coronal ridge is frequently worn down to a flat surface in the larger and apparently older teeth; and in the teeth exhibiting this character a much greater degree of curvature may be noticed; the tooth, the base of which is, as a rule, rather flat, assumes quite a crescent shape, as in Pl. X. figs. 6–8.

By the kindness of Mr. J. Ward, of Loughton, I have been able to compare my specimens with two or three from the Staffordshire coal-field. One of these is in connexion with a few fragments of teeth, which are probably those of *Helodus simplex*, Ag.; and if this be the case, there is certainly a great resemblance between the two sets of spines. The teeth of *Helodus*, however, are almost unknown in the Bone-bed, whilst nearly two hundred teeth of *Pleurodus* are in my possession, which have been found in immediate juxtaposition with the spines. That the latter are the spines of *Pleurodus* receives some support from the fact that Messrs. Hancock and Atthey found in the Coal-measures at Newsham a small spine connected by shagreen with the teeth of *Pleurodus Rankinii*. The specimen is described in Nat. Hist. Trans. of Northumberland and Durham, vol. iv. part ii. page 408. From the illustration which accompanys the description of the fish-remains, the spine appears to be imperfect, and has lost the basal part; in other respects it bears a very exact resemblance to the exposed part of the spines from Clifton.

It is described as being five eighths of an inch in length and situated at the anterior extremity of the dorsal fin. The fish is represented as being a little more than three inches from the head to the tail, and nearly two inches in depth a little behind the head. The position of the head is indicated by the presence of teeth, which are in a disturbed condition and probably about ten or twelve in number. No bones are distinguishable, the skeleton having been entirely cartilaginous. The whole of the specimen is covered with shagreen, the tubercles being very minute and much scattered. The teeth are two tenths of an inch long, "boss-like in form, somewhat elongated, and ridged or carinated along the longer axis; the sides are considerably expanded in the centre, the expansions dying out towards the end of the tooth." A specimen, twice the size of this, is mentioned as having been found at Kenton, which, it is suggested, may belong to another species.

Comparing the Newcastle specimen with those from the Halifax district, the difference in the size of the spines and teeth indicates that the *Pleurodus* occurring in the latter was nearly or quite a foot in length; and the difference in the form of the teeth (those from the Better-bed coal being much more elongated, and not laterally expanded like the smaller teeth described by Hancock and Atthey) appears to give support to the determination of L. Agassiz that there are two species of *Pleurodus*, and that the subject of this description should retain the name of *P. affinis*, Agassiz.

That the spines and teeth have not been found connected by shagreen in the Bone-bed will be easily understood when it is considered that the remains of much more bony fishes, such as *Megalichthys* or *Cœlacanthus*, are rarely found connected together, and that the spines and other hard parts are frequently broken and fragmentary. The circumstances attending this deposition indicate a shallow littoral area much disturbed by waves and currents. *Pleurodus*, being entirely cartilaginous, would have a very poor chance of being preserved in a perfect and connected condition, the soft cartilaginous parts quickly decomposing, and the teeth and spines becoming scattered by the waves.

Since writing the above description, I have found, in the cabinet of my friend Mr. W. P. Sladen, a very fine and large specimen of the spine of *Pleurodus* (fig. 9); and although it is not from the Bone-bed, it may be well to mention it at the present time. In all essential particulars it answers to the description already given of the fin-ray of *Pleurodus affinis*, except in its large size. Its length is three inches, and its breadth seven tenths of an inch. The point and a part of the base are broken off, so that had the spine been perfect, it could not have been less than 3·7 inches long. It was found above the Black-bed coal at Dudley Hill, near Bradford, Yorkshire.

Hoplonchus elegans, n. gen. et sp. (Pl. X. figs. 12–14.)

Eight more or less perfect specimens of this Ichthyodorulite, besides a few fragmentary ones, have been found and are at present in my collection. The genus is enumerated in the list of fossil fish occurring in the Bone-bed above the Better-bed coal in the paper already referred to, and to it I then applied the name of *Hoplonchus*. Four of the specimens are larger, stronger, and straighter than the remaining four, the latter being much curved and more rapidly converging to a fine point. The larger spines (figs. 13, 14) are about 1·5 inch in length; of this, 1·1 was exposed, and the remaining ·4 inch formed the base, which was imbedded in the integument of the fish. The line dividing the two parts forms a curve from the dorsal margin towards the base at an angle of about 60° to the length of the spine. The greatest breadth is ·2 inch at the junction of the basal and exposed part; from this point the breadth gradually diminishes to the apex; the anterior face is nearly straight, the posterior slightly curved. The fin-ray is laterally compressed, and ornamented by a slightly varying number of longitudinal striations; midway between the apex and the basal line they number four or five, and these gradually converge towards the apex; in the opposite direction the number is increased by bifurcation to ten or even twelve. The striæ or costæ are covered with smooth black enamel, which towards the base is produced into minute beak-like or knotty prominences. The intercostal spaces are more fibrous in appearance, and are as nearly as possible the same width as the costæ. The most anterior ridge is separated by a wider intercostal space than the others, and is produced so as to form a carina, or keel, extending along the whole length of the exposed part of the spine. The posterior portion appears to be excavated only a short distance from the base towards the apex; and the remaining portion is protected by seven recurved, pointed denticles, long in proportion to the size of the spine, and widely separated. The basal or implanted part of the spine is conical in form and presents the usual fibrous structure.

The smaller spines (fig. 12) are in many respects similar to those already described; they have the same graceful ornamentation of the lateral and anterior faces, and the posterior surface has a row of pointed denticles. They differ, however, in being smaller, rarely exceeding an inch in length, and are less than proportionately broad. Their curvature is very considerable compared with that of the larger ones; they are almost sickle-shaped; and from the middle portion of the spine the edges converge rapidly to the apex, which forms an acute point.

After a careful comparison of the two forms with examples of recent fishes, the supposition appears reasonable that the fish to which they were attached may have had two dorsal fins, the larger and straighter spines pertaining to the anterior one, and the shorter curved spine to the posterior dorsal fin. A very similar arrangement may be seen in the existing *Spinax acanthias*, in the Cretaceous *Drepanephorus canaliculatus* described by Sir Philip Egerton in the 13th Decade of the Geological Survey of the United Kingdom, pl. 9, and in *Palæospinax priscus*, 13th Decade, pl. 7.

The new genus *Hoplonchus* is most closely allied to the genera *Homacanthus*, *Leptacanthus*, and *Onchus* of Agassiz*, and to a new genus recently described in the 'Memoirs of the American Geological Survey of Illinois' by Messrs. Orestes St. John and A. H. Worthen, and named by them *Acondylacanthus*. From *Onchus tenuistriatus*, which is described by Agassiz as straight or feebly arched, with smooth and uniform longitudinal ridges, and having the base bevelled to a point, *Hoplonchus* differs in having recurved denticles at intervals along the posterior face.

The genus *Leptacanthus* is described as long and narrow, with very numerous fine longitudinal striæ, and also two rows of closely set minute denticles along the posterior margin. The striæ do not form decided furrows; and in *L. semistriatus* there is a small space free of ridges along each side near the posterior row of denticles. The species known to Agassiz were from the Jurassic and Liassic

* Recherches sur les poissons fossiles, par Louis Agassiz. Monographie des poissons fossiles du vieux grès rouge, par L. Agassiz.

rocks. Some years afterwards two species were referred to this genus by M'Coy* from the Mountain Limestone of Derbyshire and Northumberland respectively. The Illinois *Acondylacanthus* bears a close resemblance to *Leptacanthus* of Agassiz. Both genera are long in proportion to their width, and are laterally ornamented by numerous longitudinal striæ. Their postero-lateral angles in each case bear a row of closely set recurved denticles. *Hoplonchus* differs much in all these respects; it is a smaller spine, and in proportion to its length is broader, and more rapidly and gracefully tapers to a point; the striæ are much less numerous, are better defined, and regular in position. *Hoplonchus* is further distinguished by the crenulations on the ganoid ridges, which do not occur in either of the other genera.

Homacanthus is the name given by Agassiz to a small Ichthyodorulite from the Devonian formation of Russia. Its flanks are ornamented by longitudinal homogeneous furrows, and its posterior margins are armed with a double row of minute denticles. It is distinguished from *Leptacanthus* by the small number of the ridges, and the much greater breadth of the spine compared with its length. M. Agassiz, in the 'Poissons fossiles du vieux grès rouge,' says, "the great difference which distinguishes them is, that the furrows or ridges of *Homacanthus* extend over the whole surface of the spine as far as the denticles of the posterior edge, whilst in those of *Leptacanthus* the ranges of teeth are preceded by a smooth space." This character, however, does not hold good with all the species placed by Agassiz under the genus *Leptacanthus*. M'Coy, who added two species, *H. macrodus* and *H. microdus* †, to the *H. arcuatus* of Agassiz, remarks that "the genus is by no means a well-defined one; but when confined to these three species, it has a sufficiently distinct facies." The species figured by M'Coy are both from the Mountain Limestone of Armagh. They are both imperfect.

The smaller and decidedly curved fin-rays of *Hoplonchus*, which it is here suggested may have been attached to a posterior dorsal fin, certainly bear a great resemblance to the spines of *Homacanthus*; and excepting that they are more gracefully proportioned, the small number of striæ and the recurved sharply-pointed denticles might indicate that the genera were the same, and it is possible that future researches may necessitate the union of *Homacanthus* and *Hoplonchus*.

CTENACANTHUS ÆQUISTRIATUS, sp. nov. (Pl. X. fig. 15.)

The length of this spine is nearly six inches. It is gently curved, the anterior margin being somewhat more so than the posterior one. The length of the latter is $3\frac{7}{10}$ inches from the line dividing the exposed part of the spine from the base, which, when living, was imbedded in the body of the fish; the length of the anterior margin is $4\frac{7}{10}$ inches. The dividing line forms a curve at an angle of about 45° to the length of the spine. The greatest width at the junction

* 'British Palæozoic Rocks and Fossils,' by Sedgwick and M'Coy, p. 633, pl. iii. G. figs. 13–16.

† *Op. cit.*

of the exposed with the imbedded part of the spine is $\frac{8}{10}$ of an inch, measured at right angles to the length. From this point to the apex the width diminishes gradually in the lower and middle portions of the spine; but the margins converge more rapidly in the upper part, and the spine ends in an acute point. The base, which presents the usual fibrous structure, tapers rapidly to a roundish extremity and is conical in form. The spine is compressed laterally; but on account of its being imbedded in the matrix, the form of a transverse section cannot be ascertained. The exposed side is ornamented with a series of evenly parallel ridges. There is no appearance of the anterior outline being produced to form a carina. Near the base the ridges are thirteen in number; they run longitudinally parallel with the anterior margin of the spine, the result being that they die out or disappear along the latero-posterior margin without inosculation. At the apex, only the two most anterior ridges remain and form a fine point. The ridges are narrower than the intermediate furrows, and are divided along their summit into minute papilla-like tubercles, which are tipped with ganoine. The posterior angle does not appear to be very thick. It is armed along the entire length of the exposed part with numerous small obtuse denticles separated from each other by about their own diameter; they differ from the posterior denticles of *C. hybodoides*, Eg., in being quite dissociated from the ridges.

The spines of *Ctenacanthus* to which this one bears the greatest resemblance are those of *C. denticulatus* of M'Coy *. There is, however, considerable dissimilarity between the two forms; *C. denticulatus* is longer in proportion to its breadth, and much more elongated towards the apex. The ridges run parallel with the dorsal margin of the spine as well as the anterior, the intervening ones being produced by bifurcation. The sides of each ridge are denticulated with sharp recurved teeth extending halfway across the intervening spaces, the denticle on one side being connected with that on the other by a slightly oblique fold across the ridge. The denticles along the latero-posterior angles are larger and more pointed.

I have delayed the description of this Ichthyodorulite for some time in the hope that some other specimens might be found; but none having been added to my own or other collections, I think the characters of this specimen sufficiently clear and distinct to warrant its addition as a new species, and propose for it the name *C. æquistriatus*.

PHRICACANTHUS † BISERIALIS, n. gen. et sp. (Pl. X. figs. 16, 17.)

Spine of medium size, about 4·3 inches in length; its greatest diameter is ·3 inch. It curves gently backwards. The exposed part is covered by minute longitudinal striations; the furrows slightly broader than the ridges and minutely pitted at their base. An internal cavity, circular in form, extends from the base nearly the whole length of the spine. The opening at the basal end appears

* 'British Palæozoic Rocks and Fossils,' by Sedgwick and M'Coy, p. 256, pl. iii. K. fig. 16.

† From φρίξ, a ripple, and ἄκανθα, a thorn.

to be terminal. The walls of this cavity, forming the base of the spine, were thin, and in the specimen they have been crushed by the superincumbent matrix. The upper half of the spine retains its normal form, is circular, curves more rapidly, and gradually diminishes in diameter to a blunt point. From the point, extending about two inches along the dorsal aspect, there is a double row of eight or nine widely separated protuberances or denticles. In the lower part the denticles are ·2 inch in breadth, but nearer the apex they gradually diminish to about half that size; they are broad at the base, laterally compressed, and rapidly converge to a very obtuse point. They are separated by spaces occupying a rather larger area than the denticles. The latter occur alternately, the projection on one side of the spine being opposite to the depression on the other.

The spine was enumerated in the list of fish-remains from the *Bone-beds* (No. 11). At that time, I referred to it as possessing only one row of denticles on the posterior face. Since that was written I have ascertained that there is a double row.

From the genus *Orthacanthus*, which appears to approach it nearest in general character, this Ichthyodorulite presents considerable differences in its general outline, and more especially in the peculiar form and large size of the posterior denticles. *Orthacanthus*, as defined by Prof. Agassiz, is a straight spine; this one is slightly curved. Mr. J. S. Newberry, in the Report on the palæontology of Ohio, has described and figured a curved spine, *Orthacanthus arcuatus*, which he considers identical in structure with Prof. Agassiz's *O. cylindricus*, and consequently has united with it in the same genus, recent discoveries merely proving that the name was not well chosen.

Orthacanthus arcuatus is, however, very distinct from the spine I am describing. The greatest discrepancy is in the form of the denticles ranged on either side of the dorsal aspect of the spine. In *Orthacanthus cylindricus*, Agass., and in each species since described, the teeth are more or less hooked, pointed and close together; but in this instance none of these characteristics will apply. The denticles are widely separated, rounded, and blunt; to such an extent is this the case, that the term denticle is scarcely applicable, as they have more the character of waving projections alternately produced, first right then left, from the dorsal surface of the spine. In consideration of this peculiarity, I suggest that the spine receive the generic and specific name of *Phricacanthus biserialis*.

EXPLANATION OF PLATE X.

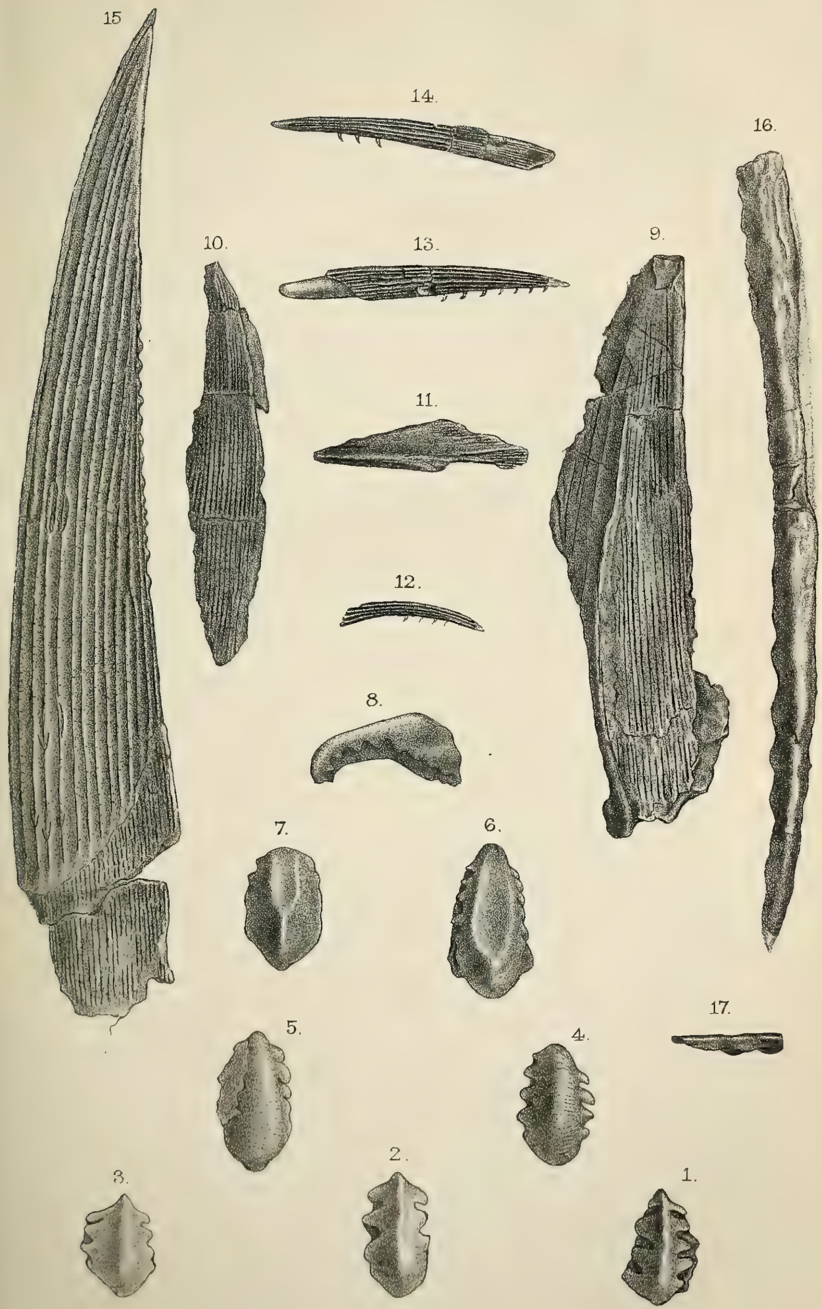
Figs. 1–8. Teeth of *Pleurodus affinis*, Ag.
Figs. 9–11. Spines of *Pleurodus affinis*, Ag.
Figs. 12–14. Spines of *Hoplonchus elegans*.
Fig. 15. Spine of *Ctenacanthus æquistriatus*.
Fig. 16. Spine of *Phricacanthus biserialis*.
Fig. 17. Anterior extremity of fig. 16 separated from the matrix.

Discussion.

Prof. Duncan asked for further information as to the geological relations of the bed containing these remains, and the conditions under which the fish lived.

Prof. Morris also wished to learn what were the exact relations of this band of fish-bearing shale and the underlying spore-coal of the "Better bed" in the Carboniferous series.

Mr. Davis, in reply, said that the fish-remains above the Better-bed coal are always extremely fragmentary and almost comminuted. Specimens any thing like perfect are very rare. He suggested that the coal, after having been formed on land, probably became the bed of a lake or an open shore-line. He remarked that this thin bed extended uniformly over a very considerable area. In reply to Prof. Morris he stated that the Geological Survey had adopted a different line of division between the Middle and Lower Coal-measures from that formerly suggested by Prof. Phillips. He pointed out that marine and freshwater species of fish appeared to coexist in the Carboniferous beds, and compared this with the analogous case of the Lake of Nicaragua, as described by the late Mr. Belt. Freshwater forms of sharks are not unknown in the Ganges and other rivers.



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CARBONIFEROUS FISH-SPINES AND TEETH.

14. Description *of* fragmentary Indications *of a* huge kind *of* Theriodont Reptile (*Titanosuchus* ferox,* Ow.) *from* Beaufort West, Gough Tract, Cape of Good Hope. By Professor Owen, C.B., F.R.S., F.G.S., &c. (Read January 8, 1879.)

[Plate XI.]

In a series of fossil remains from the Gough and Karroo tracts in South Africa, transmitted by Thomas Bain, Esq., Inspector of Roads, Cape of Good Hope, to the British Museum (May 1878), boxes nos. 1 and 2 were invoiced as containing "Loose bones and fragments of bones of a large Saurian, found lying on the surface at Kooda-skop, Gough."

No bone was entire; all were broken portions more or less water-worn and much weathered. A more seemingly hopeless lot of fossils I never before took in hand.

Indistinct traces of broken teeth, here and there, were the sole guide to a nearer recognition of the parts containing them, and suggested a way of treatment by which a clearer insight of their nature might be obtained. Omitting some tentative procedures, I venture to submit the following results.

One fragment had most resemblance to the right premaxillary part of an upper crocodilioid jaw. The indications of teeth on the worn and broken alveolar surface were too obscure for useful description, and a lapidary's section was accordingly taken across those traces at a deeper level. The implanted parts of the following teeth were thus brought into view. The foremost (Pl. XI. fig. 3) presented a full elliptical section 30 millims. by 18 millims., with pulp-cavity (ib. *p*) 16 millims. by 10 millims. As the worn symphysial surface of the bone showed a trace of the root of this tooth, I had it ground down so as to expose its extent, as shown in fig. 4. A length of the basal part of an implanted root, $1\frac{2}{3}$ inch, or 40 millims., was thus brought into view, gradually diminishing to a solid apex of dentine, and seemingly showing the pulp-cavity restricted to the expanded part, but it was probably continued into the base of the exserted crown, which had been here broken away.

The second tooth showed an inequilateral triangular shape, with rounded angles; the long diameter, transverse to the alveolar border, was 20 millims.; the short diameter across the middle of the tooth was 15 millims.; the pulp-cavity was 12 millims. by 5 millims.

The third tooth presented an oval section 18 millims. by 12 millims., with a pulp-cavity 12 millims. by 6 millims., the long axis being transverse to the course of the alveoli.

Beyond this were less distinct traces of two other and smaller incisors, though the latter inference is affected by the section crossing nearer the end of the root.

* *Titan* and *souchos*, Egyptian name of Crocodile.

In the thickness of the premaxillary, on the inner side of the three middle incisors, were indications of alveoli of successional teeth. Those near the third and fourth incisor were subcircular spaces filled with the black matrix; that next the second incisor contained the apex of a tooth-germ showing a thin investment of enamel. It was of a semicircular form, with the base feebly undulated and the angles slightly produced. From this I inferred that the crown of the tooth, near its apex, was biporcate, the ridges being in front and behind, and dividing the outer more convex from the inner much less convex sides of the crown. The two diameters of this apical section are 10 millims. and 6 millims. The formative cavity, which is filled outside the tooth with black matrix, is 13 millims. by 11 millims. The soft tissues of the tooth-capsule and periost originally occupied this space. There was an indication of a similar nidus of a successional incisor near the section of the foremost tooth, *i* 1.

Another transverse section of a part of the alveolar border of this premaxillary which projected beyond the line of the foregoing section, crossed the third incisor at or near the base of the crown. It showed an indication of the anterior coronal ridge or production of the dentine, which, further on in the crown, would have supported the beginning of the enamel ridge; but such support of the opposite or posterior ridge had subsided, and the dentine presented there a convex outline. The two diameters of the section are 30 millims. and 20 millims. No enamel is shown in any of the sections save that of the apex of the crown of the successional incisor. From this fossil I inferred that I might be on the trace of a Theriodont with the upper incisive formula of *Gorgonops*, viz. *i* 5—5 *.

A diligent quest and comparison of the other fragmentary representations of what Mr. Bain regarded and reported as "loose bones and fragments of bones of," I presume, the same "large Saurian" led to the recognition of the portion of the left maxillary, the subject of fig. 1. It includes the trace of the socket of the canine, *s*, with part of the base or root of that tooth, *c*, and of its pulp-cavity, *p*, which contained some infiltrated matrix.

The widest part of what was left of the socket is 35 millims. across; but it does not include all the outer wall; and the transverse curve of the retained portion of the tooth indicates a more considerable circumference than is here shown.

The length of the preserved part of the socket is $4\frac{1}{4}$ inches; but the outlet, with those of the sockets of the succeeding molars, has been broken away. The bases of three of these molars, in what remained of their sockets, were obvious, and a section along the rest of the alveolar border (fig. 2) brought into view eight others of similar shape and size.

The foremost of the molars (fig. 1, *m* 1) appears to have protruded close to the canine. The fore-and-aft diameter of its preserved base is 15 millims.; that of the pulp-cavity is 8 millims. The

* 'Descriptive and Illustrated Catalogue of the Fossil Reptilia of South Africa,' 4to, 1876, p. 27, pl. xxi. fig. 2, *i* 1, 2, 3, 4, 5.

second molar, *m* 2, projecting at an interval of 2 millims. from the first, presents the same dimensions: the transverse diameter given by this better-preserved tooth-fang is 10 millims. The third molar, at an interval of 3 millims., has diameters of 11 millims. and 9 millims.

After this the molar intervals vary from 3 millims. to 6 millims. The elliptical section of the tooth-root is preserved with very little variation from the diameters of the third molar. Remains of eleven of these small subequal molars are shown in the portion of upper jaw figured in fig. 1, Pl. XI.

The crowns of these teeth, like those of the incisors, would be broader than the exposed roots, and probably occupied space equal to the intervals left between those roots; but, with this assumption, the molars are smaller than the incisors, as is the case in *Lycosaurus pardalis**.

The number of the molars, supposing the whole to have been preserved in the maxillary fragment described, would be very nearly that in the small Theriodont *Galesaurus* †; and, as the hind fracture of the fossil has crossed the eleventh molar, it may well have been succeeded by a twelfth, as in *Galesaurus*, if not by more, as seems to have been the case in *Gorgonops*, from the proportional length of the maxillary of *G. torvus*, Ow.

I took advantage of the hind fracture of the maxillary fossil under description to get a clearer view of the mode of implantation of what seemed to be the terminal half of the root of the eleventh molar. It ended, like the first incisor, in an obtuse point, where the pulp-cavity was obliterated. No trace of a successional germ or its nidus was exhibited in this section (Pl. XI. fig. 5).

The next more easily recognizable fossil was the anterior end of the left ramus of a lower jaw (Pl. XI. fig. 6). The rough symphysial articular surface is 4 inches in vertical, $2\frac{1}{2}$ inches in transverse diameter; but part of the upper border has been worn away. The length of the fragment is 7 inches, the height $4\frac{1}{4}$, the thickness behind the symphysis $2\frac{1}{2}$ inches. The outer surface is convex and pretty even, with some small, scattered, vascular canals; the inner surface is impressed by a splenial groove, 8 lines in breadth, but rapidly contracting where it enters and is lost in the symphysial surface. The alveolar border (*a*, *a*) about 2 inches in breadth, had been subject to abrasion, and showed but feeble indications of teeth or sockets.

Of this border I had the section made which is the subject of fig. 6, when the following parts were demonstrated.

The foremost tooth, *i* 1, was too partially and obscurely represented for description.

The next tooth (*i* 2) presented, in section, an oval figure, with the great end outwards, 21 millims. in long diameter, 15 millims. in greatest breadth, with a pulp-cavity (ib. *p*) of similar form measuring 10 millims. by 7 millims. This tooth was situated about $1\frac{1}{2}$ inch from the fore end of the jaw, and 10 millims. from the first incisor.

* *Op. cit.* p. 15, pl. xiv. fig. 2. † *Op. cit.* p. 23, pl. xviii. fig. 9.

The third tooth (ib. *i* 3) was, in section, more nearly elliptical, with the long axis transverse to the jaw, 20 millims. by 12 millims. in the two diameters. An interval of 10 millims. separated it from the second tooth, *i* 2.

The fourth tooth (ib. *i* 4), less regularly elliptical in section, was 23 millims. by 17 millims. in the two diameters, which held the same relation to the alveolar border as the preceding teeth. The pulp-cavity, *p*, of the fourth tooth was 14 millims. by 10 millims. The interval between this and the third tooth was 18 millims.

The fifth tooth (ib. *c*) showed a great increase of size, the two diameters being 2 inches by $1\frac{1}{3}$ inch, or 50 millims. by 35 millims.; its section presented a less regular oblong shape, and the long diameter was inclined toward the longitudinal course of the alveolar border. The long diameter of the pulp-cavity, *p*, is 34 millims.; the transverse or short one is 20 millims.

The thickness of the dentinal wall was pretty uniformly 10 millims. The indications of the osseous walls of the sockets of these teeth are marked *o*, *o*, in fig. 6.

Comparing the evidence of the anterior teeth of the fossil mandible with the teeth in the corresponding part of that of existing reptiles, I found the nearest correspondence in *Crocodilus vulgaris*, Cuv.

The mandibular symphysis varies in shape and relative length in existing Crocodilia, its shortness distinguishing the genera *Crocodilus* and *Alligator* from the genus *Gavialis*. But it offers characters in regard to shape and proportions in different species of the broad-faced section of the order, where it is of least extent. It is shorter, for example, in proportion to its depth or vertical diameter, in *Crocodilus vulgaris*, Cuv., than in *Crocodilus bombifrons* and *Crocodilus palustris*; and in its symphysial character I found that the present fragment of *Titanosuchus* most resembled a specimen of *Crocodilus vulgaris* from a river opening upon the west coast of Africa.

In Crocodilia the inner surface of the dentary element is impressed by a longitudinal groove which terminates forwards by indenting the symphysial surface. A similar groove indents the correspondiug surface of the dentary bone of *Titanosuchus*. It is, however, situated nearer the lower margin of the bone, less deeply indents the symphysial surface, and the lower border of the groove is less produced than in the recent Crocodiles compared.

The seemingly lower position of the groove which, from its being covered, in Crocodiles, by the splenial element, I have called "splenial," is due, in *Titanosuchus*, to the downward inclination of the inner alveolar wall of the incisive series of teeth. In the Crocodilian mandibles compared this wall extends horizontally inwards for some way before bending down to the inner grooved surface, rendering such inner surface of minor relative extent than in *Titanosuchus*. The part marked *h*, fig. 6, sloping downwards to the groove, answers to a nearly horizontal flattened upper surface in *Crocodilus vulgaris*.

In most existing broad-faced Crocodiles three teeth, reckoned as incisors, precede the fourth, which by its size and shape is called the "anterior canine;" but the first of the incisors is relatively larger than in *Titanosuchus*. In *Crocodilus bombifrons* it is almost as large as the fourth or canine tooth; and, by its superiority in size to the second and third incisors, might merit the name of an anterior canine. In *Crocodilus vulgaris* the first tooth is not so large, relatively, as in *Crocodilus bombifrons*, but is larger relatively than in *Titanosuchus*. The second and third incisors are relatively smaller than in *Titanosuchus* and are placed wider apart. It must be noted, however, that the section exposing this part of the dentition of *Titanosuchus* (Pl. XI. fig. 6) crosses, not the crowns, but the implanted parts of the teeth. Still such part of root would bear a proportion to the crown which suggested the above comparison with the broad-faced Crocodilia.

Beyond the canine (ib. *c*) were indications of teeth of smaller relative size than those in *Crocodilus vulgaris*. Making a horizontal section at the requisite lower level, the crowns of three such molars were brought into view (fig. 6, *m* 1, *m* 2, *m* 3).

A portion of a left mandibular ramus, 5 inches in length, was found to fit so well to the fractured end of the fossil just described as to show it to be part of the same dentary element. In this supplementary portion were exposed, by a similar horizontal section to that which brought to view the preceding molars, a series of seven such teeth (fig. 7, *m* 4–10) showing little difference of size amongst themselves. Their alveoli opened upon a horizontal border, and their arrangement showed as little lateral as of vertical deviation from a straight line. All these teeth are situated close to the inner alveolar wall or inner side of the upper border of the jaw, leaving an extent of the outer part of that border of from 6 to 12 millims. in breadth.

The first socket of this series (fig. 6, *m* 1) is 10 millims. behind that of the canine; the second, *m* 2, is but $1\frac{1}{2}$ millim. from the first; and the third is 2 millims. from that of the second. The next interval is 3 millims. in extent; then follow intervals varying from 4 millims. to 10 millims. The roots of the anterior teeth show, in transverse section, an elliptical form, with the long axis parallel to that of the jaw; those of the posterior teeth are circular in section, or nearly so.

The diameters of the fourth molar are 9 millims. and 6 millims.; the eighth and ninth molars are circles of 7 millims. in diameter.

Thus was obtained evidence of the concurrence of dental characters in the lower jaw with those exemplified in the portions of upper jaw (figs. 1 & 2) of *Titanosuchus*. The osteological differences above specified between the symphysial and the dentary element of the present genus and that of the Crocodilia compared might not have been regarded as of ordinal value; but the number and near equality of size of the inferior incisors of *Titanosuchus* would have suggested its affinity to some genus less differentiated in Triassic times from the later and true Crocodilia, if the number, size, equality, and even ranking of the molar series had not more decisively demonstrated the Theriodont character of the fossils.

It might, indeed, be objected that the evidence of the size and shape of the teeth in *Titanosuchus* is partial or defective; and I admit that the indications of the molar series, like those of the canine and incisor teeth, are of the implanted fangs. The shapes of their respective crowns are matters of inference from analogy; but the closest analogy in the reptilian series is with the Theriodont group.

*Lycosaurus pardalis** exemplifies a similar proportion of molars as compared with incisors. *Galeosaurus planiceps*† shows the uniform character and straight alveolar supporting frame of the molar series.

It is reasonable to infer that the crowns of this series, in *Titanosuchus*, would show a less disproportionate size than might be deduced from the roots. But these, with the alveolar frames enclosing them, afford sufficient evidence of the absence of that repetition of the canine-like characters of shape and relative size in certain teeth of the series, which characters are associated with the undulatory course of the alveolar border of the jaw in true Crocodiles; while the earlier Teleosaurian type and its existing representative in the Gavials have no teeth recognizable by differential shapes or sizes as incisors and canines from the series of equable and similarly shaped teeth supported by their long and slender jaws.

I have, however, finally to refer to another Theriodont character, which, with the humeral one‡, exemplifies a nearer affinity to the carnivorous Mammalia than is recognizable in any known modification of the Crocodilian order.

If, for example, a vertical section be made of the tooth of a Crocodile answering to the canine in *Titanosuchus*, its root does not contract or solidify as it descends in the socket, but it ends in an open basis of the hollow cone, whose apex terminates the more solid crown of the tooth. Communicating with the inner side of the socket is a larger or smaller reserve socket lodging the matrix of the successional tooth.

Every Crocodilian tooth shows more or less of this character, associated with the relatively shorter duration of the teeth in use and their speedy shedding and replacement by successional teeth. In the Theriodontia the teeth, at least in full-grown specimens, are longer retained and develop roots, which contract as they sink in the socket and become more or less closed at the implanted end, like the permanent teeth in diphyodont Mammalia.

In a portion of the right maxillary of *Titanosuchus* containing the implanted root of the canine, this was exposed by chiselling away the socket to the end of the root, which gradually contracted from a breadth of $1\frac{1}{2}$ inch (40 millims.) to that of 25 millims., when the fang rounded off to terminate obtusely. The external wall of the pulp-cavity of the canine had been in part broken away in the

* *Op. cit.* p. 15, pl. xiv. fig. 2. † *Ib.* p. 23, pl. xviii.

‡ Quart. Journ. Geol. Soc. vol. xxxii. p. 96, pl. xi. fig. 6, *h*, *k*.

fossil; and the cavity was further exposed to its termination, which became closed at a distance of half an inch from the obtuse and consolidated end of the root. No trace of a reserve alveolus or rudiment of a successional canine could be discerned.

To test this character in the opposing inferior canine, a more decisive step was taken.

A vertical section was made across the canine transversely to the axis of the jaw, and an extent of the root of that tooth of 2 inches 9 lines (68 millims.) was exposed, as in fig. 8, Pl. XI. From a breadth of 35 millims. the root gradually contracted to one of 10 millims. and terminated obtusely at *r*; the pulp-cavity *p*, 18 millims. across at the upper part of the section, contracted to a breadth of 5 millims., and closed obtusely 8 millims. from the end of the root, which presented a solid imperforate body of dentine. The thickness of the dentinal wall, *s*, of the pulp-cavity at the lower third part of the root is 5 millims.; it increases to 9 millims. at the upper part. Thus the remains of the pulp occupy a closed cavity, save, probably, to some minute channels for the passage of blood-vessels, which, however, were not demonstrated in this section.

The part of the root toward the inner side of the dentary bone describes a sigmoid curve in the section, being convex at the upper half and concave at the lower half, the fang slightly bulging toward that side; the opposite side descends at almost a straight line to the obtuse end.

The socket, which is indicated by the black matrix, shows a similar form in the section, and also the extent which was occupied by vascular membrane or other substance between the tooth and jawbone. On the inner side of the section the interspace increases from a breadth of 2 millims. at the upper part to one of 5 millims. along about two thirds of the descending root; it then diminishes to less than 1 millim. round the obtuse end of the root. On the outer side of the root the pulp-cavity also gains width as the root descends, but in a less degree than on the opposite side; its greatest breadth, at one inch distance from the obtuse end, is 4 millims., and it gradually narrows towards both ends of the exposed root, but most so at the closed end.

Here, therefore, was demonstrated what was very plainly indicated in the more curved fang of the upper canine, that the pulp-cavity contracted and became closed before attaining the end of the implanted root, and that in both cases the root terminated solidly and obtusely. That no trace existed of any provision for a successor was more plainly demonstrated in the section which is the subject of fig. 8. If no other evidence than a canine tooth of *Titanosuchus* had come under observation, it might well have been inferred to be the second or permanent one of a huge carnivorous mammal.

Comparing the subject of fig. 6, at the commencement of this quest, and when the uncut symphysial part of the lower jaw of *Titanosuchus* suggested Crocodilian affinity, I found no other example of recent or extinct Crocodile comparable in bulk to the South-African fossil in hand, save that huge Miocene Gavial from the Siwalik sandstone, which Hugh Falconer made known to us under the name of *Leptorhynchus crassidens* *.

Amongst the more fragmentary evidences of this species was a portion of the lower jaw corresponding with the subject of fig. 6, Pl. XI., and lodging a canine tooth of equal size. I therefore caused a similar section to be made of this tooth and its socket. The canine in place had its summit worn to a certain obtuseness; it had evidently been some time in use; but no long or tapering root descended from the crown. The implanted base was widely open, and within the similar wide and conical pulp-cavity had passed the crown of the next tooth in succession. Of this crown the apical cap or shell was calcified, the base widely open, and the pulp, replaced by discoloured matrix, had occupied the cavity of the growing tooth. On the inner side of the base of this cavity a reserve socket had begun to be formed around the matrix of a third tooth, or second in succession to the one in use. The track of the germ, originally budded off from the base of the old matrix, was reduced to a linear canal extending from the base of the socket into which the successional tooth had pushed its way, to that which was due to the absorption through pressure of the growing matrix of the tooth destined in its turn to force its way into the hollow beneath the young tooth.

The contrast between the Theriodont and the Crocodilian reptile in this important dental character was strikingly manifested in the sections of the large homologous tooth.

I proceeded next to test the same character in the incisor and molar teeth. Figure 4, as before stated, represents the section of the root of the anterior upper incisor of *Titanosuchus ferox*. Here, as in the canine, the root at first gradually diminished, and then more quickly contracted to a rather blunt point, *r*. The pulp-cavity, *p*, became closed at a greater relative distance from this point than in the canine.

Similar longitudinal or vertical sections were made of molar teeth from both ends of their series with similar results, as is exemplified in fig. 5 of an eleventh molar of the upper jaw, and by fig. 9 of a third lower molar. In the latter tooth the pulp-cavity, *p*, extends nearer to the closed end of the root than in the other sections.

The evidence of successional teeth in the case of the upper incisors has already been given; but they are developed in distinct sockets, and do not penetrate wide unclosed pulp-cavities of the teeth in place and use, as in the Crocodilia.

Whether the more mammalian character of succession operates in the canine and molar teeth, as in the incisor series, no evidence has been extracted from the present Titanosuchian fossils.

The ordinal character of the Crocodilian tooth, as above exemplified in recent and extinct species, I long ago defined, as consisting in the slight enlargement, or maintenance of the same breadth, of the root to its base, which is deeply excavated by a conical pulp-cavity extending into the crown, and is commonly either perforated or notched at its concave or inner side †.

* Palæontological Memoirs, 8vo, i. 1868, p. 279.

† 'Odontography,' vol. i. p. 291, pl. 75. figs. 1, 2, 4 *a*, 5.

In *Ichthyosaurus* the pulp-cavity may be partially obliterated in the root while it is retained in the basal part of the crown of a tooth*; but the base is sapped by the successional tooth, which penetrates its predecessor and seems to push it out†. The root, in fully formed or old teeth, contracts slightly at the implanted end.

In *Iguanodon* the tooth-root is less broad than the crown, and assumes a subcylindrical shape‡; but such root seldom contracts as it descends, and never dwindles to a point; it is invaded and pressed upon by the crown of the successional teeth, developed in germ-sockets at the intervals left by the narrow roots of the teeth in place, which roots undergo absorption as the tooth they support is in course of being displaced by its successor §.

The Pliosaur and Iguanodon exemplified, in my experience, the extremes of deviation from the developmental phenomena of the teeth of existing Crocodiles and Lizards prior to the discovery of the Theriodont type of Reptilia.

In the few rare, and at that time unique, examples of the order described in my 'Catalogue of the Fossil Reptilia of South Africa,' but one instance showed, by its fractured state, the implanted part of the canine ||; and this did not appear to afford adequate ground for adding the condition of tooth-root and limited succession of teeth to the other mammalian characters assigned to the order¶. But I now know that a long deeply implanted root of the canine tapering to a blunt point, with the widest part of the pulp-cavity at the base, in or near to the crown, is a natural structure and an ordinal characteristic by which the Theriodontia differ from the Dinosauria and Enaliosauria, and in a still greater degree from the Crocodilia; and this character must be added to the serrate and trenchant border of the crown of the canine, to the entocondylar perforation of the humerus, and to the general carnivorous type of the dentition—in which the incisors, defined by position, are more equable in size than in Crocodilia, while the canine, large and laniariform, is single on each side of both jaws, with the crown of the lower canine crossing in front of the upper one; this, moreover, is followed by a series of small, subequal, subtrenchant, pointed molars.

In all such groups, as our knowledge thereof extended, we commonly became acquainted with and perplexed by aberrant forms; and such were diminutive species associated under the generic name of *Procolophon*, and which, in my 'Catalogue' of 1876, I left at the fag-end of the type species of Theriodontia, while at the same time pointing out in *Procolophon minor*, for example, the "linear osseous narial septum" (p. 26), and duly representing that differential character from the Mononarials in pl. xx. fig. 11—noting also

* Odontography, p. 376, pl. 73. fig. 8 *a*.

† *Ib.* p. 280, pl. 73. fig. 7: and see 'Monograph of the Fossil Reptilia of the Cretaceous Formations,' Pal. vol. 1851, pl. iv. figs. 7, 8, 9.

‡ *Ib.* p. 249, pl. 70. figs. 1, 2, 4.

§ 'Monograph on Wealden Reptiles.' Palæontographical volume issued in 1874, p. 3, pl. i. fig. 8, *a*, *b*, *b*.

|| *Lycosaurus pardalis*, *op. cit.* p. 16, pl. xiv. fig. 1, *c*.

¶ *Op. cit.* pp. 15 & 75.

that "there is no tooth in either upper or lower jaw resembling a canine by superiority of size" (*ib.* p. 26). But as every tooth was implanted by a contracting and basally closed root, without a trace of having been assailed by a successional tooth, of which, as a cavity of reserve, there was no trace, I concluded to leave the Procolophons with the Theriodonts; nor do I know yet where better to place them in the rapidly expanding Reptilian class.

The addition to that class which is now brought before the Society may be characterized as follows:—

Order Theriodontia.

Genus Titanosuchus.

Dental character:—i. $\frac{5-5}{4-4}$, c. $\frac{1-1}{1-1}$, m. $\frac{11-11}{10-10}$ or $\frac{\quad}{11-11}$.

Species *Titanosuchus ferox*.

The skull is shown by the portions of maxillæ with the alveoli of the molar series to have been shorter and deeper than in *Gorgonops*; the mandible at its symphysial end was thicker in proportion to its depth than in *Tigrisuchus*, *Cynosuchus*, and *Galesaurus*. The degree of correspondence with those eminently carnivorous genera in every comparable character supports the inference that the crowns of the incisors, canines, and molars presented the same destructive laniariform character in the present gigantic representative of the order.

The breadth of the crown of the largest incisor in *Titanosuchus ferox* is six times that of the largest incisor of *Lycosaurus curvimola**. If the crown of that tooth was laniariform in *Titanosuchus* as in *Lycosaurus*, its length may have exceeded 3 inches. The breadth of the base, or of the root near the base, of the upper canine in *Titanosuchus* is three times that of the corresponding tooth in *Lycosaurus*, and the length of the crown would be not less than 4 inches.

This tooth in *Titanosuchus* was less compressed than in *Cynodraco*†, was of a stronger build, fitted for overcoming greater resistance. We have, in fact, in *Titanosuchus* a carnivore of a more carnassial type than the *Machairodus* or other Felines; for there is not even an exceptional tubercular or grinding-tooth of any size; and I feel entitled to hazard this negative proposition on the grounds on which the fossil is referred to its order. It most probably found its prey in the huge contemporary Pareiosaurs, Oudenodonts, and Tapinocephalans of its South-African locality.

* Catalogue, *ut suprà*, p. 71, pl. lxviii.
† Quart. Journ. Geol. Soc. vol. xxxii. pl. xi. figs. 2, 3.

Fig. 3.

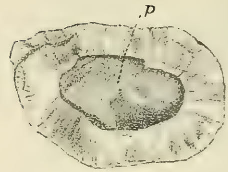


Fig. 6.

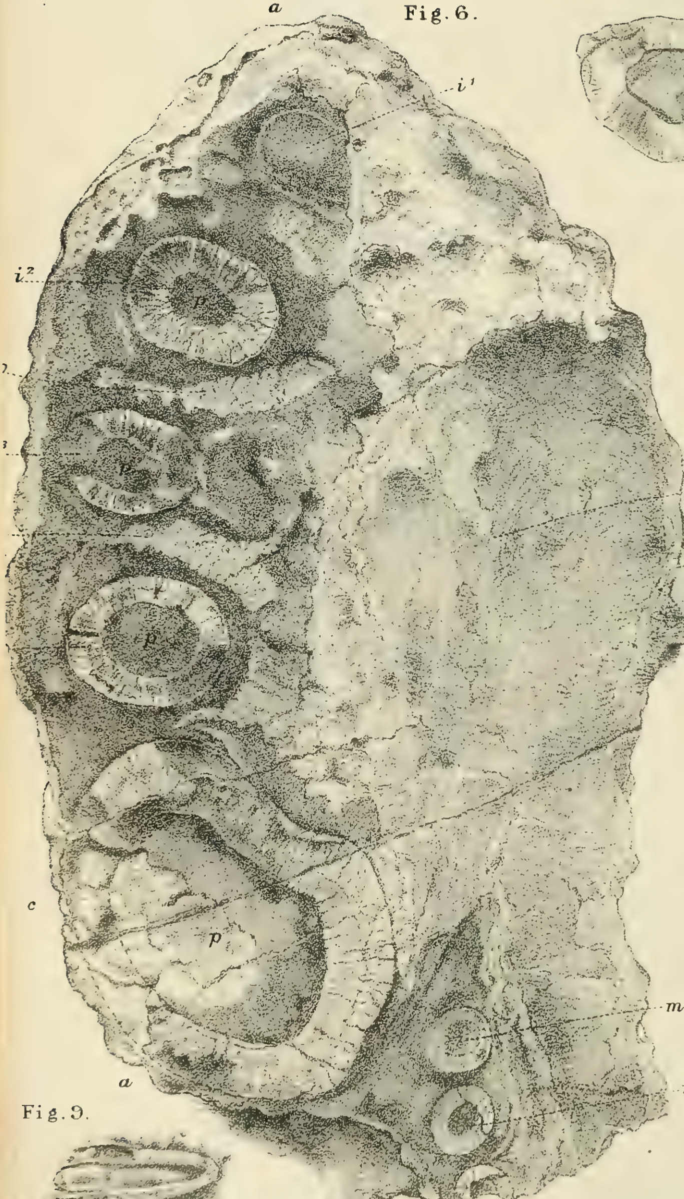
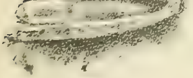


Fig. 7.

Fig. 9.



. Foord lith.

TITANOSU

. 5.

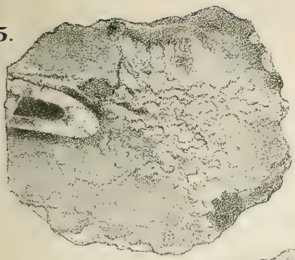


Fig. 1.

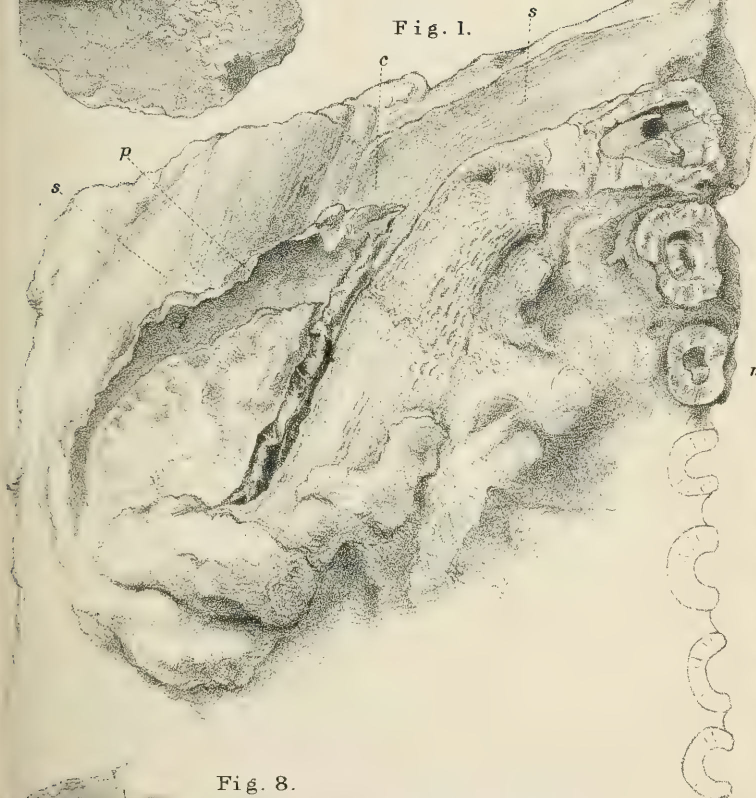
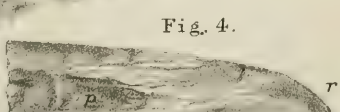


Fig. 2.

Fig. 8.

Fig. 4.



Mintern Bros imp.

FEROX.

Foord lith.

Mintern Bros imp.

TITANOSUCHUS FEROX.

EXPLANATION OF PLATE XI.

Titanosuchus ferox.

Fig. 1. Inner side view of a portion of the left maxillary.
2. Horizontal or transverse section of the alveolar border and implanted roots of the molar teeth of the same maxillary.
3. Transverse section of the root of the first upper incisor.
4. Longitudinal section of the root of the same tooth.
5. Longitudinal section of the root of the eleventh molar of the left maxillary.
6. Symphysial end of left mandibular ramus, with the alveolar border in horizontal section.
7. Horizontal section of the alveolar border and roots of the molars of the same mandibular ramus.
8. Vertical or longitudinal section of the implanted root of the canine of the same ramus.
9. Longitudinal section of the root of the third molar of the same ramus.

(All the figures are of the natural size.)

Discussion.

The President congratulated the Society on receiving such a number of valuable papers from Prof. Owen.

Prof. Seeley spoke of the great clearness of description by which, even in the absence of the specimens, Prof. Owen had been able to bring the matter before the Society. He remarked, however, on the difficulty of arriving at reliable conclusions from specimens in which not a single crown of a tooth was preserved. He pointed out that the fang of the teeth of *Ichthyosaurus*, *Plesiosaurus*, and other forms of extinct Reptilia was often found to be closed, and with no trace of a successional tooth. He thought that this absence of a successional tooth was not sufficient to warrant the establishment of a new order of reptiles to receive this species, and that the characters of the specimen were so far Crocodilian that, if it had been found in England, it would have been included in the Crocodilia.

Mr. Hulke supported Prof. Seeley in his objections, and in confirmation of these stated that in *Iguanodon* and *Hypsilophodon* the tooth-fang was often found closed, and without any trace of a successional tooth. The same was true occasionally of *Goniopholis*.

Prof. Owen always felt pleasure in submitting the results of his studies to the Geological Society, because that was to submit them to the competent criticism of his fellow workers in the same field. He expressed doubt (until actual specimens were shown him) that any *Goniopholis* teeth had been found without traces of successional teeth below them. He defended his foundation of the group of Theriodonts from the mode of the implantation of the teeth in their jaws. He stated that the materials on which this paper was founded are a portion of the valuable series of specimens (900 in number) obtained by Mr. T. Bain, the son of the well-known explorer, who had received a grant of £200 from the Treasury to aid him in searching for and transporting these South-African fossils.

15. *On the* Upper Part *of the* Cambrian (*Sedgwick*) *and* Base *of the* Silurian *in* North Wales. By Mr. Thomas Ruddy. (Read June 19, 1878.)

[Communicated by Prof. T. McK. Hughes.]

In the following paper it is proposed to describe in detail some sections in the neighbourhood of Corwen and Bala, pointing out the fossils which in that district characterize the different zones of the upper part of the Cambrian and the lower part of the Silurian.

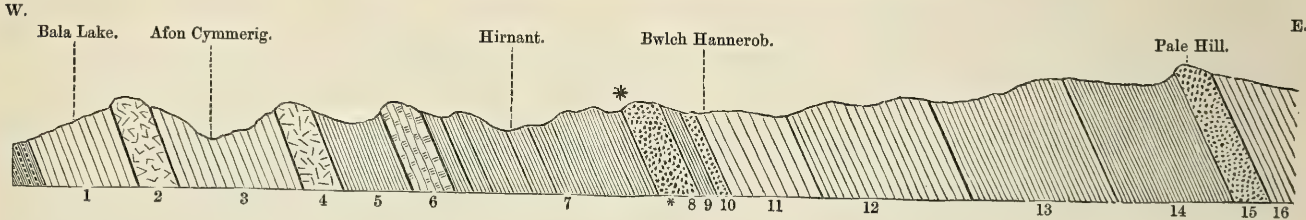
The sections are not drawn to scale, being merely diagrammatic to show the sequence in each locality.

Section I. (fig. 1).—On the southern shore of Bala Lake, the rocks jutting out of the side of the hill consist of rubbly shale with a general dip to the south or south-east. Near the brow of the hill we find what is called an ash-bed of no great thickness, but well known in the neighbourhood, as it is quarried for building-purposes. In the shales immediately above this ash-bed, near Bala, we have the true zone of *Orthis alternata* (Section I., bed 3). When searching for this zone on the north of Bala at Fronderw, I was informed by the farmer that he had removed an outcrop of rock which interfered with his ploughing. The stones he used for building a wall, and on examination I found the face of the wall covered with *Orthis alternata*. Associated with it were *Orthis elegantula*, a few specimens of *Orthis flabellulum* and *O. vespertilio, Beyrichia complicata* and *Illænus Davisii*; this last species and a few others we find in every zone.

The *Orthis-alternata* zone rises again in the Berwyns. Near Milltir Gerrig, on the Llangynog road, the upper felspathic ash-bed crosses the road. Above this we find rubbly shales, then a brecciated ash-bed twenty feet in thickness, and above it shales in which *Orthis alternata* is again abundant. Associated with it I got *Orthis elegantula, Leptæna sericea, Beyrichia complicata, Nebulipora lens, Favosites fibrosus, Modiolopsis modiolaris*, and *Cythere umbonata*?

Above the limestone (No. 6) there is a great thickness of shale (No. 7) varying much in character, in which we find but few traces of fossils until we get near to the place marked Bwlch Hannerob, where, about 3000 feet above the Bala limestone (see Mem. Geol. Surv. vol. iii. p. 86), we find a bed of grit or sandstone, from 15 to 20 feet in thickness, with occasionally small calcareous concretions. In the grits and in the hard blue shales (Nos. 8, 9, 10, 11) there are plenty of fossils, but these are confined to a few species. In a little quarry recently opened I found those in the list appended to fig. 1, which proves this series to be the equivalent of the Hirnant Limestone. Above the hard blue shales and grit we find fine soft blue slates, which immediately underlie the Tarannon shale (No. 13); but I found no fossils here until I had got to the base of the Wenlock series (No. 14), where there are plenty of Graptolites. In a quarry very recently opened for building-purposes, on the Palé estate, near the

Fig. 1.—*Generalized Section from Bala Lake to Pale Hill.*



1. Rubbly shale.
2. Bala ash, about 2 feet.
3. Shales, full of *Orthis alternata*: containing also *O. elegantula*, *O. vespertilio*, *O. flabellulum* (rare), *Leptæna sericea*, *Beyrichia complicata*, *Illænus Davisii*, *Modiolopsis* sp. Same bed seen again in Berwyns near Milltir Gerrig, on Llangynog road, where we find the upper felspathic ash crossing the road above thin rubbly shales, and above them a brecciated ash, about 20 feet thick, on which lie shales in which *Orthis alternata* is abundant. In these shales *O. elegantula*, *Leptæna sericea*, *Beyrichia complicata*, *Nebulipora lens*, *Favosites fibrosus*, *Modiolopsis modiolaris*, and *Cythere umbonata* (?) also occur.
4. Upper ash-bed.
5. Fossiliferous shales.
6. Bala Limestone (for fossils, see description of Sect. II. 6, Gelligrin).
7. Massive, comparatively barren shales.

* 3000 feet above the Bala Limestone (see Mem. Geol. Surv. vol. iii. p. 86).

8. Hard compact grit, 8 feet.
9. Hard blue shales, 5 feet.
10. Soft decomposing grits, 9 feet.
11. Hard blue shales passing into fine slaty shales above.

(8–11: Hirnant beds, consisting of fossiliferous grits and shales.)

In Hirnant beds at Bwlch Hannerob, two miles north of Aberhirnant, the following fossils were found:—*Orthis hirnantensis*, *O. sagittifera*, *O. elegantula*, *O. testudinaria*, *O. biforata*, *Lingula ovata*, *Orthonota*, *Favosites fibrosus*, *Homalonotus bisulcatus*, *Glyptocrinus basalis*.

12. Soft blue slaty shales, no fossils, 250–300 feet.
13. Tarannon shale, 300 feet.
14. Hard blue shale, 300 feet; much iron-pyrites near top; Graptolites abundant in lower part: *G. priodon* abundant, *Graptolithus* sp. common, *Retiolites Geinitzianus* frequent, *Orthoceras primævum*, *Orthoceras* sp., *Holopella gregaria* (?), *Rhynchonella* (?).
15. Grits, with fragments, Encrinite-stems, and other fossils.
16. Shales.

14, 15, & 16 are included in what are usually known as Denbigh Grits.

river Dee, I found *Graptolithus priodon* in abundance, a small variety or species with a broad shaft and straight cells, *Retiolites Geinitzianus*, *Orthoceras primævum*, *Orthoceras* sp., a few univalves and bivalves of small size, Encrinites, &c.

This bed, which is of considerable thickness, rises again about two miles up the Berwyn road, where it is found resting on the Tarannon shales and containing the same fossils. It varies much in character, for on the Berwyn road it consists of fine slates, whereas these are represented by hard blue shales near the river Dee.

Although I have examined the débris at various openings in the interbedded grits and shales above the Graptolite zone, I have only found Encrinite stems and a few fragments of small bivalves.

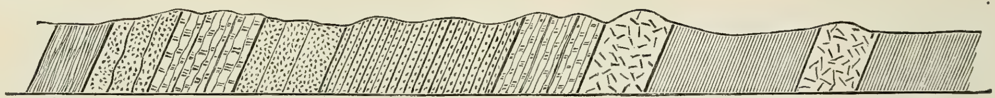
Section II. (fig. 2).—Returning to the south side of the lake we first find a thin bed of calcareous ash (No. 9), and associated with it layers over six inches in thickness full of *Leptæna sericea*. Scattered throughout are fine specimens of *Strophomena expansa*, of which this seems to be the true zone. Up to the next ash-bed (No. 7) the same fossils are sparsely distributed. Among them we find *Lingula ovata*, but not commonly, and a small species of *Ctenodonta* agreeing with that figured as *Ct. obliqua* in Murchison's 'Siluria' (fifth edition, p. 196).

The ash-bed No. 7 is fossiliferous, but of no particular interest. No. 6 is a very well-marked zone. It consists of sandy limestone twelve feet in thickness, effervescing with acid. This is the true zone of *Orthis vespertilio* and *O. spiriferoides*, both being equally abundant here and seldom found in higher beds. Here we also find *Orthis biforata*, *Cyclonema*, and well-preserved specimens of *Nebulipora lens*.

This bed is very persistent in character, for we find it again at Garnedd occupying the same position, and it rises again in the Berwyns, where it is well described by D. C. Davies in a paper on the Berwyn Phosphate Mine (Quart. Journ. Geol. Soc. 1875, vol. xxxi. p. 357).

In the sandy shales, No. 5, we find plenty of broken specimens of Trilobites, such as *Calymene*, *Homalonotus*, *Cybele*, *Phacops*, and *Asaphus Powisii*, the latter being common. The beds 2 and 4 are identical in character, being composed of coarse sand; here we find beautiful large specimens of *Orthis calligramma*; *Strophomena depressa* and a few of its variety *undata*; *Lingula ovata* frequent; less commonly *Modiolopsis pyrus* and a small *Discina*-like shell. Near the bed of hard crystalline limestone, where the sand is much charged with lime, we find numerous large specimens of *Orthis Actoniæ*, a few of *Conularia Sowerbyi*, and layers of *Stenopora* (*Favosites*) *fibrosa* over a foot in thickness. The bed of limestone (No. 3) is from 18 to 20 feet in thickness, and is of a hard intractable nature. In the fine shales (No. 1) immediately above the bed of coarse sand, the fossils suddenly cease or become very small in size: the only thing of interest I found was a short piece of an Orthoceratite with a large bead-like siphuncle, agreeing with the description of the *Ormoceras* in the Cambridge Catalogue, p. 71. We found but a small number of Cephalopoda and Univalves; but if we

Fig. 2.—*Section near Gelligrin, South of Bala Lake.*



1. Fine shales passing up into barren shales. *Ormoceras?*, *Leptæna sericea*, *Orthis elegantula.*
2. Coarse sand: *Orthis calligramma* (large), *O. Actoniæ*, *Strophomena depressa*, *St. depressa*, var. *undata*, *Lingula ovata*, *Palæarca (Modiolopsis) modiolaris*, *Modiolopsis pyrus*, *Discina* sp., *Conularia Sowerbyi*, *Favosites* (*Stenopora*) *fibrosus.*
3. Crystalline Limestone with fossils, 18 feet to 20 feet.
4. Same character and fossils as no. 2.
5. Sandy shales, with *Asaphus Powisii* (common), *Homalonotus Cybele*, *Calymene*, *Phacops apiculatus*, *Encrinurus*, *Lichas laxatus*, *Trinucleus concentricus*, *Orthis Actoniæ*, *O. calligramma*, *O. elegantula*, *Bellerophon bilobatus*, *Rhaphistoma*, *Leptæna sericea*, *Crania divaricata*, *Beyrichia complicata.*
6. Sandy limestone (= bed at Garnedd, = bed described by D. C. Davies, Quart. Journ. Geol. Soc., Aug. 1875): *Orthis spiriferoides* (common), *O. vespertilio* (common), *O. elegantula*, *Leptæna sericea*, *L. tranversalis*, *Strophomena depressa*, *St. expansa*, *Orthis biforata*, *O. Actoniæ*, *Cyclonema crebristria*, *Nebulipora lens*, *Trinucleus concentricus*, *Tentaculites anglicus.*
7. Fossiliferous ash-bed.
8. Fine shales: *Orthis elegantula*, *O. calligramma*, *O. flabellulum* (scarce), *Strophomena expansa*, *St. depressa*, *Lingula ovata*, *Leptæna sericea*, *Ctenodonta obliqua?*, *Palæarca obscura*, *Beyrichia complicata.*
9. Calcareous ash-bed: *Leptæna sericea* (abundant), *Strophomena expansa*, *Orthis elegantula*, *O. calligramma* (small), *O. vespertilio*, Encrinite-stems, *Trinucleus concentricus.*
10. Fossiliferous shales.

cross over to the Bala limestone at Rhiwlas, we shall find them abundant and of several species.

SECTION III. (fig. 3).—Crossing over the river to a spot a little north of the Bala road, in Bodweni Wood, we find a bed which I would refer to the Hirnant group. It consists of 15 feet of grit, in which I found *Orthis biforata* abundantly. As far as my experience goes, this fossil is much more plentiful in the Hirnant than the underlying beds. Associated with it were a few poor specimens of *Orthis hirnantensis*, *O. sagittifera*, *Arca edmondiiformis*, and a species which is either *Modiolopsis obscura* or *M. orbicularis*. In the wood opposite, about a quarter of a mile south of the river, we get on to the grits again and find plenty of fossils, consisting of *Orthis hirnantensis*, *O. sagittifera*, *O. biforata*, and *O. elegantula*, with an occasional *Homalonotus*.

The grits are much disturbed by faults and end abruptly every few yards; but they can be traced to Bwlch Hannerob, which I have already described (Section I. Nos. 8–10). These grits are the same as those coloured Lower Llandovery on the Geol. Survey map; but this patch is not alluded to in the Mem. Geol. Surv. vol. iii. Following the line of the grits we lose them under the peat; but they again appear on the brow of the hill at the back of Aberhirnant, a little above the road leading up to Maeshir. This is the patch alluded to in the Mem. Geol. Surv. vol. iii. p. 85. We find here the undoubted Hirnant Limestone in the form of a few concretionary lumps associated with the usual grits, and both yielding fossils plentifully. The commoner fossils found by me here are *Orthis hirnantensis*, *O. sagittifera*, *O. biforata*, *O. elegantula*, *Arca edmondiiformis*, and *Modiolopsis pyrus*.

I have no doubt that the *Orthis turgida* said to occur in the Hirnant limestone was only a turgid specimen of *O. sagittifera*, of which I find plenty of distorted and turgid forms. I found here a small univalve resembling *Holopea exserta* of the Rhiwlas limestone.

In addition to the usual list of Hirnant fossils given in Mem. Geol. Surv. vol. iii. p. 86, I have obtained one species of *Lingula*, two of *Modiolopsis*, or else allied to them, two species of corals and one Trilobite; also a univalve like *Holopea*.

A little lower, at the back of Aberhirnant, there is another patch of grits and limestones with the usual Hirnant fossils. Here it ends; but I have found it again at Craig-Moel-Ddinas, about a mile further west, in the Hirnant valley, where I obtained *Orthis sagittifera*, *O. hirnantensis*, and *O. elegantula* in a gritty pisolitic mass of rock. Half a mile further, at Moel Ddinas, where excavations were recently made in search of slates, in the same line of strike I got out of hard blue shales fine specimens of *Orthis sagittifera* of large size, and a few specimens of *O. hirnantensis*.

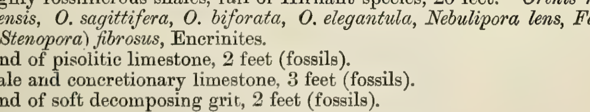
Fig. 3.—*Section in Bodweni Wood, North of the Dee.*

1. Soft blue slaty shales which usually underlie the Tarannon shale.
2. Hard compact grit, 15 feet. 2 *c*. Band of soft decomposing grit, 9 inches thick. The fossils found a short way into the hard grit (compare Sect. I., bed no. 10). *Orthis biforata* (plentiful), *O. hirnantensis*, *O. sagittifera* (scarce), *Palæarca* (*Modiolopsis*) sp., either *obscura* or *orbicularis*, *Arca edmondiiformis*, *Favosites* (*Stenopora*) *fibrosus*, an Encrinite.
3. Shales (=bed no. 7 of Sect. I.).

Section IV. (fig. 4).—The Hirnant beds again appear in a small quarry on the side of the hill west of Cwm-yr-Aethnen, where there is a fossiliferous pisolitic dark-coloured limestone, No. 3. Under the limestone there is 20 feet of highly fossiliferous shales, in which I got two small specimens of *Nebulipora lens* in addition to the usual Hirnant species. Above the limestone is a band of rubbly shales with concretionary limestones, No. 4, and above that a band of soft decomposing grit, No. 5, with shales above it, all of them being fossiliferous.

A little further west, on the brow of the hill, another patch appears containing the usual fossils, and here it is altogether lost (see Mem. Geol. Surv. vol. iii.).

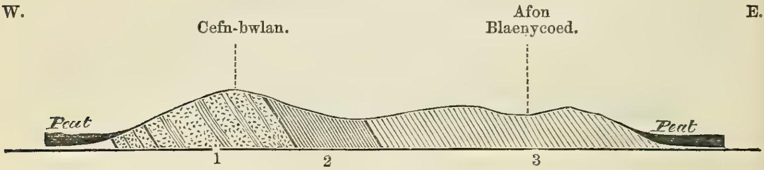
Fig. 4.—*Section near Cwm-yr-Aethnen.*



1. Shales (=no. 7 of Sect. I.).
2. Highly fossiliferous shales, full of Hirnant species, 20 feet. *Orthis hirnantensis*, *O. sagittifera*, *O. biforata*, *O. elegantula*, *Nebulipora lens*, *Favosites* (*Stenopora*) *fibrosus*, Encrinites.
3. Band of pisolitic limestone, 2 feet (fossils).
4. Shale and concretionary limestone, 3 feet (fossils).
5. Band of soft decomposing grit, 2 feet (fossils).
6. Fossiliferous shales passing up into slaty shales.
7. Soft blue slaty shale underlying the Tarannon shale.

Section V. (fig. 5).—Believing that the Hirnant and Lower Llandovery Grits would turn out to be identical, I went across to Cefn-bwlan, at the head of the Llanwddyn valley, where the Lower Llandovery Grits are said first to appear (see Mem. Geol. Surv. vol. iii. p. 206). Here I found the usual Tarannon shales (No. 3) cropping out of the bed of the brook; under that a bed of fine blue shales (No. 2); and under these, cropping out of the peat, we have hard compact grits with interbedded shales (No. 1). It is but a small patch rising out of the peat. These Lower Llandovery Grits occupy the same stratigraphical position and have the same lithological character as the Hirnant beds; but I am as yet unable from fossil evidence to connect these two beds of grit. I think, however, that I have proved that the Hirnant grits and limestones are not confined to the Hirnant valley, but can be traced to the north of the river Dee.

Fig. 5.—*Section at Cefn-bwlan.*



1. Lower Llandovery Grits and shales (?=Hirnant Grits).
2. Soft blue slaty shales, 50 feet, like those above the Hirnant Grits; but the Hirnant Grits, near the river Dee, are 300 feet thick, and in Hirnant valley not less than 250 feet.
3. Tarannon shale, about 150 feet.

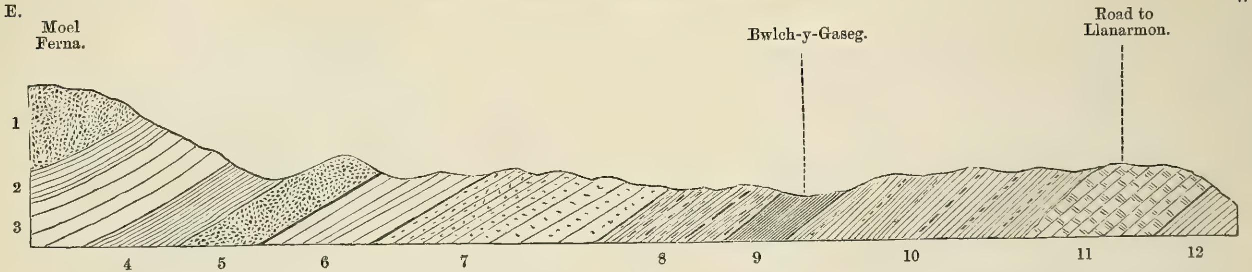
This Section is taken at the south side of the fault of Cefn-bwlan, near the head of the Llanwddyn valley in Montgomeryshire.

Section VI. (fig. 6).—Starting from the Railway Station at Cynwyd, a little village west of Corwen, we ascend the mountain road by the side of Afon Trystion, passing the picturesque gorge and falls of Cynwyd, until we arrive at a small square plantation on the roadside about two miles from the village. Here we are sure to find plenty of Trilobites, chiefly *Calymene senaria*, beautifully preserved in a dark and light grey shale with a few small calcareous concretions (No. 11). Associated with the Trilobites are numbers of bivalves, chiefly of small size, a few specimens of *Conularia*, an occasional *Rhaphistoma* and *Ctenodonta*, with plenty of the narrow branching forms of *Favosites* (*Stenopora*) *fibrosus*.

It was here I found a single shell of a small but beautifully sculptured *Strophomena*, probably either *St. antiquata* or *corrugatella*. This is undoubtedly the equivalent of the Bala Limestone.

Proceeding to the upper road which leads towards Moel Ferna, we pass over upwards of 200 feet of shale (No. 10) containing few traces of fossils, until we get to Bwlch-y-Gaseg. At the foot of the hill we find a thin bed of shale (No. 9) containing *Remopleurides Colbii*, *Calymene senaria*, *Trinucleus seticornis*, and *T. concentricus* in great perfection; also *Orthoceras vagans*, which is chiefly confined to the limestone at Rhiwlas and the circular outlier above Llangower, south of Bala Lake. In this bed I found several specimens of *Conularia* of various species. The next zone (No. 8) is easily known by the abundance of corals which it contains, many of the species appearing for the first time in the Bala beds. Associated with the corals are many other rare and beautiful fossils (see list appended to figure). Zone No. 7 is of a more sandy and massive character; here the corals are scarcer and smaller, but an abundance

Fig. 6.—*Section South-west of Corwen.*



1. Denbigh grits.
2. Graptolite shales (fossils same as in Sect. I., bed no. 14).
3. Tarannon shale.
4. Soft blue slaty shale (always found under the Tarannon shale).
5. Hard compact grits occupying the stratigraphical position of the Hirnant grits and limestone, 15 to 20 feet.
6. Shales, containing *Leptæna sericea, L. transversalis, Petraia*, a few Trilobites, &c.
7. Marine sandy bed. *Orthisina, Orthis crispa, O. flabellulum* (large, some with branching ribs), *O. elegantula, O. calligramma, O. spiriferoides* (scarce), *O. biforata, Atrypa marginalis, Strophomena grandis, St. depressa*, Lamellibranchs (several species), *Ambonychia?, Petraia, Bellerophon* (like *B. perturbatus*), *Ptilodictya explanata*, and the corals of the next bed.
8. Coral zone. *Favosites fibrosus* (branching), *Nebulipora lens, Retepora Hisingeri* (common), *Fenestella Milleri, Glauconome disticha, Cheirurus, Calymene, Illænus, Phacops, Trinucleus, Leptæna, Murchisonia, Rhaphistoma, Echinosphærites balticus, Orthis* as in bed no. 7.
9. Shale rich in Trilobites. *Calymene senaria, Trinucleus concentricus, T. seticornis, Phacops conophthalmus, Cheirurus bimucronatus, Cheirurus* sp. (but *C. bimucronatus* is most common), *Remopleurides Colbii, Orthoceras vagans, Conularia Sowerbyi, Conularia* (sp. ?= *C. lævigata*), *Favosites* (*Stenopora*), Encrinites, a few common bivalves.
10. Marine sandy shales; few fossils. About 200 feet.
11. Calcareous shales; Trilobites abundant. Equivalent of Bala Limestone. *Calymene senaria, Orthis elegantula, Leptæna sericea, O. biforata, O. calligramma* (small), *Conularia Sowerbyi, Strophomena depressa, Strophomena* sp., *Ctenodonta, Rhaphistoma* sp., Encrinites, *Favosites* (*Stenopora*) *fibrosus.*
12. Shale. *Illænus Davisii, Orthis elegantula, Leptæna sericea, Favosites fibrosus.*

of *Ptilodictya explanata* takes their place. In this bed *Orthisina* first occurs. Here we find also *Orthis crispa*, *O. flabellulum*, and *Strophomena grandis* plentifully; Trilobites, *Modiolopsis*, a species resembling an *Ambonychia*, *Bellerophon* resembling *perturbatus*, and a few well-preserved specimens of *Orthis spiriferoides* (not usually found so high in the Bala beds). In this zone also are several species of *Petraia*, and a few other undetermined fossils.

The zone No. 6 can hardly be separated from that below it. In it we find *Orthisina* and *Petraia*; but in it also we suddenly come upon great abundance of *Leptœnœ*, especially *L. transversalis*, which is common in No. 8. No. 5 consists of hard compact grits from 15 to 20 feet in thickness, of the same lithological character as the Hirnant grit, and occupying the same stratigraphical position; but as I have only found one or two small and badly preserved shells in it (except near the base, where the line between it and the underlying beds was not clear), I can give no fossil evidence; but the sections seem to prove that they are the equivalent of the Hirnant grits.

16. Description *and* Correlation *of the* Bournemouth Beds.—Part I. Upper Marine Series. By J. Starkie Gardner, Esq., F.G.S. (Read February 20, 1878.)

Descriptions of the coast-section between Highcliff and Bournemouth, with which the present paper deals, have already appeared in the publications of the Society. That by Sir Charles Lyell*, in 1826, was written when the strata included in this section were still supposed to belong to the Plastic Clay underlying the London Clay. In it the different beds forming Christchurch Head are carefully distinguished, and their superposition illustrated in a somewhat idealized section. The description of the eight miles of cliff from a mile beyond White Pits to Poole Harbour is, however, dismissed in a very few words:—The "section presented by the cliffs is continued so precisely in the line of bearing of the strata, that no new beds rise up, and it is unnecessary to describe them in detail. . . . The prevailing character of the strata throughout this extent of coast is fine white sand; but yellowish and pinkish beds of sand occur, and thinly laminated clays in great abundance, resembling in appearance many of the light-coloured argillaceous marls of Montmartre near Paris; but in none could I discover any organic remains, except vegetable impressions, and these very indistinct." The proofs of origin, whether marine or freshwater, are considered equivocal. The total thickness of the series, nowhere exposed to view, is put down at "not less than 150 feet." It is also suggested that the argillaceous strata with shells of Alum Bay "are probably concealed here at some of the interruptions of the section."

The next description of these cliffs is by Professor Prestwich† in 1848, written principally with the view of determining "the exact position which they bear with reference to the Barton Clay" (*l. c.* p. 43). He begins, however, with the assumption that Barton Clay is found to the west of Christchurch Harbour, and thence is led to place the strata of Christchurch Head higher in the section than I am inclined to do. He compares a section of the Head with that of the Barton Cliff near its western termination, and concludes that the beds with septaria common to both are upon the same horizon. A mile and a half to the west of the Head a small lens-shaped section is considered to be "a slight throwing in of an overlying stratum," and evidently presenting "in a small depression the base of the Barton clays" (p. 47). The Eocene pebble-beds taken for diluvium by Lyell are carefully separated from the overlying angular gravel by Prestwich; but it seems that he thought them to be more continuous than they now appear to me.

In 1861, the Rev. Osmond Fisher wrote ‡ defining the horizons into

* Trans. Geol. Soc. ser. 2, vol. ii. p. 279.

† Quart. Journ. Geol. Soc. vol. v. p. 43.

‡ *Ibid.* vol. xviii. p. 65.

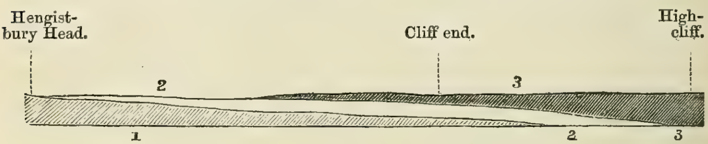
which the Bracklesham beds can be divided. His description of Highcliff stopped short E. of Christchurch Harbour; but it is of value in connexion with the present subject, since he shows that a pebble-bed at the top of the white sand at Highcliff is the equivalent of one of the higher beds of the Bracklesham series. Assuming the correctness of this determination, we have a defined horizon to start from; and as it can be shown that the sequence across the valley is uninterrupted and the dip regular, it seems to me that the position of the rest of the beds can be fixed with great accuracy.

The views I venture to put forward diverge from those of Prof. Prestwich. Although beds on the headland and on the coast almost immediately to the east of it both contain septaria, I believe them to be on different horizons, the former belonging to a separate series unrepresented elsewhere on the coast except at Alum Bay. Again, the slight throw-in of Barton Clay west of the promontory is, for me, only the most easterly of numerous and identically similar patches of the Bournemouth beds.

My views also differ slightly from those of Mr. Fisher. I think that the lower 123 feet of strata included by him in the Bracklesham series at Whitecliff may probably represent in time the *Lower Bagshot* beds. The Bracklesham beds are supposed by him to thin to only 43 feet at Alum Bay, and 35 feet at Highcliff. Even if, as he says, the 35 feet of sandy clay and the pebble-bed at Highcliff represent the whole uppermost strata of the series 130 feet thick at Whitecliff Bay, and we deduct the 123 feet placed in the Lower Bagshot, there are still some 400 feet unaccounted for. These 400 feet are, I think, not only well represented at Christchurch Head, where the strata are mapped as Bracklesham by the Survey, but also by the marine beds thence to and even beyond Boscombe, and at Alum Bay as well. I also find myself at variance with the Geological Survey, since I believe that the so-called *Upper Bagshot* beds of the London basin do not belong to that series, but are the equivalents of beds which I shall refer to as the Boscombe Sands. These Boscombe Sands and the marine Bournemouth beds are, I believe, the western equivalents or extreme shore-conditions of the Bracklesham sea.

My especial object in bringing this paper before the Society is, however, to prove that the Bournemouth leaf-beds immediately underlie

Fig. 1.—*Restored Section between Highcliff and Hengistbury Head.*



1. Hengistbury-Head beds of the Middle Bracklesham.
2. White Sands at the base of Highcliff and capping Hengistbury Head.
3. Barton and Upper Bracklesham beds.

the Bracklesham series and are, unlike those of Alum Bay, of *Middle* and *not Lower* Bagshot age, as had, I believe, been hitherto supposed. I have also ascertained that a great portion of the cliffs between the Head and Bournemouth are of marine origin and highly fossiliferous, and these I describe in detail. These marine beds are of two distinct characters; and both of them I have traced across to Alum Bay, where they are well represented.

The strata forming the promontory are higher in the series than those on the west, but below the Highcliff beds; and they can also, as divided by Lyell, be separately traced across to Alum Bay. No detailed correlation has, I believe, been previously attempted.

Highcliff Sands—At Highcliff (fig.1), nearly under Rothsay Castle, the section is substantially as given by Mr. Fisher*:—

		ft.	in.
Barton.	Coarse, green, sandy clay, with grains of quartz. "The tool gives a bright green streak."		8
	Indurated marly clay with "tabular soft septaria."		7
	Dark green, coarse, sandy clay, "giving a bright green streak with the tool."	9	0
Bracklesham.	"Pebble-bed towards the W., changing E. into soft, dark, sandy clay, with scattered pebbles and impressions of fossils"	1	6
	Sands, clayey at bottom. Very variable W. "There is a band of ironstone-septaria in these sands which is not persistent"	33	0
	Band of flint pebbles		6
	White sand; the bottom not seen	6	0

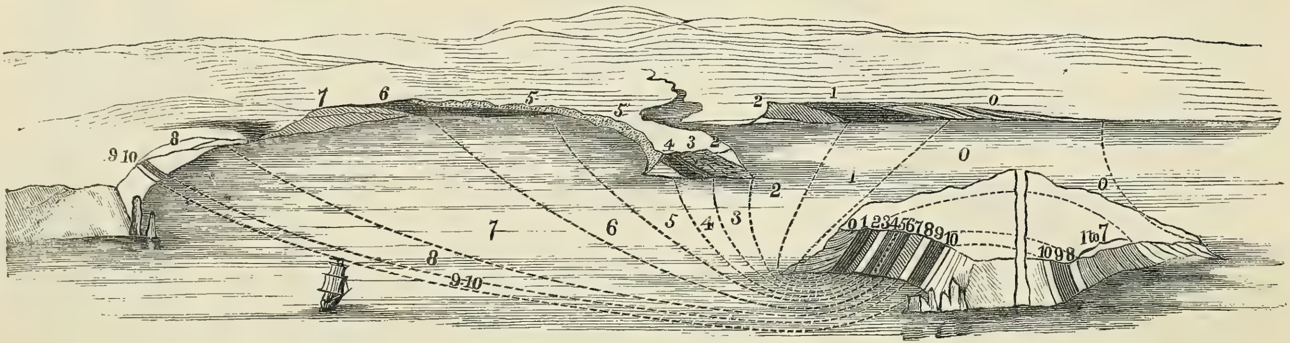
Fifty yards from the western termination of the cliffs, where they are still 50 feet high, the section has no septaria-layers; but at the base of the cliff we have coming in

	ft.	in.
Loose white sand	10	0
Hard, dark clayey sandstone with scattered pebbles at base	1	0
Hard yellow mottled sand shading to white	6	0

These sands dip conformably with the Barton and Hordwell series $1\frac{1}{2}°$ to $2°$ E. The curious turn the water flowing from Christchurch Harbour has taken within the last few years, known as the Run, has fortunately revealed the section to the very sea-level; and it is now seen that these sands rest upon another and lower series of dark sandy clay with ironstone nodules. These and the overlying sands can be almost directly traced to the headland, where they form the cliffs; for at the ferry, about midway between them, the landing-place is on hard compact clay, upon and about which are lying a few identically similar ironstone nodules. The sands themselves, however, have not resisted denudation and, like the Boscombe Sands on the other side of the Head, have been removed for the space of a mile.

* *L. c.* p. 88. The woodcut, however (p. 87), is incorrect, showing too great a dip and a sudden curve in the strata.

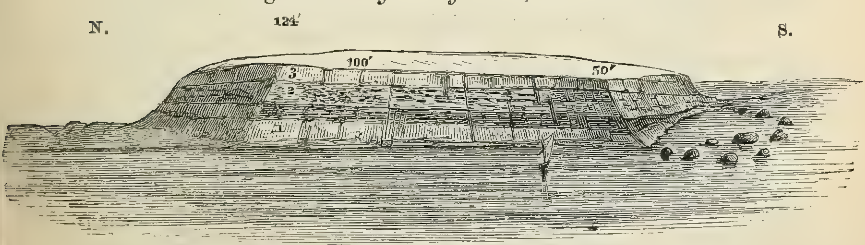
Fig. 2.—*Ideal View of the Isle of Wight and the adjacent Land, with dotted lines connecting the nearly horizontal beds of the mainland with the vertical beds of the island.*



o. Upper Eocene.
1. Barton Beds.
2. Upper Bracklesham and Highcliff white-sand beds.
3. Upper Hengistbury-Head beds, with iron-stone.
4. Lower Hengistbury beds, with green grains.
5. Boscombe Sands.
6. Bournemouth Marine Series.
7. Bournemouth Freshwater Series.
8. Lower Bagshot.
9. London Clay.
10. Woolwich and Reading beds.

Hengistbury Head.—The curious promontory of Hengistbury Head is mainly composed of strata which form the uppermost portion of a local and shore series, contemporaneous with the Bracklesham, which we may for convenience call the Bournemouth beds. It is a particularly interesting spot, as it reveals the presence of beds whose existence between the base of the Highcliff beds and the white sands of Double Dykes would probably have been otherwise unsuspected. The compact nature of the strata forming it has preserved it during the denudation of the surrounding area; and the layers of irony septaria, falling into the water, have made a reef stretching a quarter of a mile seawards, and thus saved it from being entirely swept away by the sea. The contour of these rocks, known as the Beerpan rocks, is in almost all weathers sharply defined by the smoother water within their barrier, and probably marks the original extent of the headland. The dip of the beds would take them, just beyond these rocks, out of the reach of the sea. The general shape of the promontory is a parallelogram with its northern extremity obliquely truncated; it is three quarters of a mile long, by about a quarter broad, the longer side running N.W. by S.E. The cliffs facing the sea are about 50 feet high at their S. point, increasing N. to 100 feet. N. and E. they present bold escarpments to the sea; S. and E. they rise from a plain of blown sand, which forms the banks of the harbour and stretches one mile to Mudeford. The dip and strike of the strata follow the contour of the land, and are about 3° S., 2° S.E., 3° E.

Fig. 3.—*Hengistbury Head, west side.*



1. Boscombe Sands.
2. Lower bed with green grains, and Upper bed with ironstone.
3. White Highcliff sand.

The form of the Head must have rendered it a position of great importance to an invading or beaten army in early times; and its advantages were not neglected, as the ancient walls and fosses known as Double Dykes, defending it from the mainland, prove. It should be, with its barrows and legendary name, a place of interest to the antiquary; it possesses many attractions to the artist, whilst its heather, to judge from the abundance of birds, is little disturbed by the gun.

The highest beds met with in the headland are undoubtedly, according to my thinking, the continuation of the white sands at the base of Highcliff. They extend almost all over it and at the highest point, the watch-house, are 25 feet thick. In various places sections are exposed, as at the N. corner of the Head, where under 3 feet of peat we see 12 feet brown and yellow sand; yellowish sand with four thin layers of pipeclay, 2 feet 5 inches; white sand shading to orange, 1 foot 3 inches; deep orange-mottled clayey sand, 11 inches, resting upon brownish sandy clay with septaria. At the S.E. corner we notice 6 feet whitish sand shading to orange, with 1 foot 9 inches orange sandy clay at base. The S.E. extremity presents a good section of the white sands:—

		ft.	in.
Highcliff Sands.	White sand with a few yellow bands	7	0
	Hard white sand	1	0
	Yellowish and orange clayey sand	1	4
	Hard white sand (local patch)		10
Hengistbury-Head Beds.	Dark clays and light sand in irregular layers	1	9
	Hard white sand (local patch)	3	3
	Brownish sandy clay with ironstone	44	0
	Débris concealing 12-feet bed of greensand.		

The white sands are 30 feet thick at Highcliff, having thinned out from 42 feet at Alum Bay, and are therefore probably originally even less in thickness here. At Alum Bay and at the Head the junction or base bed is strongly ochreous in colour.

Hengistbury-Head Bed.—The next stratum does not, so far as the coast-line of the mainland is concerned, extend beyond the Head itself. It is composed of brownish-drab, laminated, sandy loam, about 45 feet thick, with from 3 to 5 nearly parallel layers of large tabular ironstone * concretions. It is well exposed on the S.W. and S.E. sides, and in an extensive quarry which nearly cuts the headland in two, E. and W. These septaria are conspicuous objects in the cliffs and form a reef running out to sea. They sometimes contain sharks' teeth, of both the *Otodus* and *Lamna* type, and vertebræ. Frequently, also, compressed tree-stems of considerable size traverse them; one of these, according to Sir C. Lyell, measured $4 \times 2\frac{1}{2}$ feet with $\frac{1}{4}$ in. of bark like black shining coal; I have measured others 5 feet in length, but not so wide. All the wood is riddled with *Teredo*-borings of large size. Prof. Prestwich records the occurrence of seeds in the septaria; but I have looked in vain for them, although layers of washed and fragmentary lignitic matter are not unfrequent. It is probable that the dicotyledonous leaves in the list of fossils from Hengistbury Head on the Geological Survey map were from this stratum; since although I have failed to discover any trace of such here, I have found a tolerably perfect leaf at St. Catharine's Hill in the same beds further inland. The four bivalve shells in the same list are probably, like the *Modiola* found by Prestwich "in the lower part of the clay," from the greensand next described, in which I some years ago met with a few casts of bivalves.

Succeeding the 45 feet of ironstone-bearing sandy clay, and at about 7 feet 6 inches below the bottom line of nodules, is a distinct

* Mr. Tylor, Quart. Journ. Geol. Soc. vol. vi. p. 133, gives a brief account of these blocks.

and compact bed, 12 feet thick, of glauconitic sandy clay, with green grains and with occasional lignitic layers, very similar in appearance to some of the Highcliff beds described by Mr. Fisher*. This bed rises at the S.E. corner of the promontory, and at its N.W. end is at least 30 feet above the beach. It includes scattered, round, black flint pebbles throughout, and has a continuous layer of them at its base. This and the succeeding beds rise at an angle of 2° or 3°. Like the preceding, it does not extend along the coast beyond the Head itself. At Alum Bay the position of the two beds last described is occupied by similar sandy clays, 71 feet thick, becoming more sandy towards the base and containing five layers of lignite, and capped by a thin seam of red sandy clay, answering probably to the orange-coloured bed at the base of the Highcliff sands.

Boscombe Sands.—The next series is perfectly distinct and may be called the Boscombe Sands. It represents the principal mass, 148 feet thick, of brilliant-coloured sands at Alum Bay (numbered 25 to 26 in Prestwich's section, see fig. 6), containing thin straggling layers of flint pebbles with small rounded fragments of quartz. These beds, at Hengistbury Head, are only seen in the longest or S.W. range of cliffs, towards the centre of which they gradually rise from the beach. From the point at which they rise until a thickness of 7 feet or 8 feet is exposed, they are whitish or ash-coloured sand, containing much scattered lignitic matter, with layers of pebbles about 3 feet apart. The layers are, however, not persistent, and we find within a few yards a 3-feet bed of sand between two pebble-layers thickened to 12 feet, and including four layers of pebbles; nor are the pebbles always confined to layers. Under the white are pinkish, black, and deep chocolate-coloured sands 17 feet thick, again underlain by 7 feet of white sand. The junction between the dark coffee-coloured sands (which become black after a few minutes' exposure to the air) and the upper white sands is remarkable, the white sands having cut through and imbedded angular pieces of the darker sand of all sizes up to 4 or 5 feet diameter. The surface of the dark sand as well as some of the larger detached pieces have been bored by *Teredo* or *Pholas* before being imbedded (fig. 4, p. 216). The dark sand has basin-shaped patches of pinkish ash-coloured sand at the top, the pink sand sometimes forming a layer 1 foot 6 inches thick above the pebbles, so that the latter do not always mark the junction. Nearer the neck of the headland the bottom white beds become thicker and more compact, and contain iron layers and small concretions. The dark beds are very variable and change colour within short distances.

For half a mile the cliffs are very low, being but 17 feet high near Double Dykes, and composed of shingle, showing here and there at their base the uneven and eroded surface of the Boscombe Sands, which are now yellowish white. Here these loose sands and pebble-beds have been a prey to subsequent denudation, which, however, had not force to remove the included heavy shingle, but has left it in solid masses 12 and 15 feet thick, mixed with the

* O. Fisher, Quart. Journ. Geol. Soc. vol. xviii. p. 86.

more recent angular gravel. Both supply material to the present beach.

Fig. 4.—*Mass of Black Sand imbedded in matrix of white siliceous sand and bored by Mollusca.*

A little over 3 miles due north of the Head there is another hill or, rather, range of hills of similar contour to that of Hengistbury Head. This, St. Catharine's Hill, 160 feet high, possesses, like the headland, a flat top and abrupt escarpments on all sides, and was also chosen as a strong place in ancient British times, as the remains of a camp, fort, four watch-towers, and numerous tumuli sufficiently prove.

From the singular resemblance which the hill bears in outline to Hengistbury Head, and from its relative position, it seems certain that it must be composed of a second mass of identical strata. Although it is completely overgrown, except where a brick-pit has dug slightly into it at its northern end, the evidence there is alone almost conclusive. The following section is exposed:—

		ft.	in.
Highcliff Sand?	Orange sand and clay	3	0
Hengistbury Beds.	Ash-coloured clay	3	0
	Drab clay with iron concretions exactly as at Hengistbury Head	5	0
	Dark and very lignitic sand	2	6
	White and yellow sand with layers of light clay almost white at base	3	0

Notwithstanding that the Hengistbury-Head beds have thus perhaps thinned out, there can be but little doubt of their identity. The valley of the Avon on the east is probably scooped out of the yielding Highcliff Sands; and that of the Stour to the W. has been worn through the Boscombe Sands. The beds seen in the pits are again very variable, there being a lenticular patch of whitish sand with iron stains, 10 feet thick, on the east side of the pit. The dip is S.E. and E. about 7° and N.N.E. 6°. The laminated drab clay evidently contains well-preserved dicotyledons, but the other beds appear unfossiliferous. A pit higher in the hill-side confirms the supposition that the overlying beds are sand.

We have thus at Hengistbury Head (fig. 3), in the first place, the Highcliff Sands; white sand with a maximum thickness, under the watch-house, of 25 feet; next, the Hengistbury-Head beds, composed of 45 feet, or perhaps a little more, of clay with ironstone concretions, and 12 feet of clay with green grains; lastly, 30 or 40 feet of Boscombe Sands, whose base is not exposed. At Alum Bay, the first is represented by 42 feet of yellow and white sand, ochreous at base, like these, No. 28 in Prestwich's section*. The Hengistbury-Head beds are equivalent to No. 27 of the Alum-Bay section, 71 feet in thickness, and are confined to this Head as far as the coast of the mainland is concerned. Their position is between 150 and 200 feet down in the Bracklesham series. The Boscombe Sands extend to beyond Boscombe, and are the equivalents of beds Nos. 26 and 25 at Alum Bay, where they comprise 147 feet of sand with occasional layers of pebbles. These, although on the mainland of plain white, buff, or chocolate-colour, are the most brilliantly coloured of all the sands at Alum Bay.

A careful examination of the cliffs in the bay from this point to Bournemouth shows conclusively that there is a general sequence, and that the strata, although nearly horizontal, have a slight dip, sufficient, however, in so great a distance, to pass through two complete series of beds. The upper series is the continuation of the Boscombe Sands just noticed, and has a probable thickness of at least 100 feet, but is here entirely composed of sands shading from orange to white and enclosing heavy shingle-beds. The second series is composed of sands and dark clays of marine origin, which we may provisionally call the *Bournemouth Marine Beds*, and which contain numerous and interesting fossil remains. Both these series extend to within a third of a mile of Bournemouth pier, the lower one partly thinning out and being partly replaced by freshwater beds.

Passing over the irregular patches of white sand which are seen underlying the shingle already mentioned as forming low cliffs between Hengistbury Head and the main coast-line, we find the first regular rise of the beds at a place called the Cellars, exactly 1 mile west of the Head, and about 700 yards E. of the Coastguard flagstaff. The lowermost beds are chocolate-coloured sands and dark sandy clays with vegetable remains, belonging to the Bournemouth Marine Beds, which rise in successive layers at angles of about 5°. At a distance of 110 yards west of the Cellars they have risen but 5 feet, and are frequently obscured by heaped-up shingle. The overlying white sand beds rise with them and are here 10 feet thick. 176 yards further west we have a small patch of dark clay 25 feet across, presenting a lenticular section, underlain by shingle, a very unusual arrangement. I am particular in noticing this clay patch, as I have no doubt it was a similar patch, if not this very one, which

* Quart. Journ. Geol. Soc. vol. ii. p. 258.

Prof. Prestwich took for a "slight throw-in of an overlying stratum" of the Barton beds. The shingle is imbedded, as usual, in white sand, and underlain by yellow and grey sand in layers, and then by darker clayey sand. The cliffs are here 30 feet high with an easterly dip of 7°, and are more than half composed of gravel; 260 yards further the dip decreases to 5°, and we have in descending order ash-coloured sand and clay, a narrow seam of pink clay, white sand shading to fawn, a thin line of dark clay, lemon-coloured sand, and 23 feet white sand with laminated pale drab clays. A little westward a layer of iron sandstone appears; and 100 yards further the dip decreases again to 3° or 4°. At this point we find irony and fawn-coloured sands irregularly bedded under the gravel, then sandy laminated clay with two layers of orange-coloured clay, succeeded by three layers of black clay between lignitic sand. Under the flagstaff is an important shingle deposit comprising two nearly horizontal and parallel layers at its base, and several masses bedded obliquely at an angle of some 25° above. The whole of the shingle-beds appear to have been mistaken for diluvium by Lyell, but were recognized by Prestwich and distinguished from the surface-gravel. They consist, he says *, "uniformly and solely of perfectly rounded smaller or larger flint pebbles, mixed with more or less sand, and always, when the latter predominates, showing distinct though rough stratification." A section by Prestwich appears to have been taken from this spot, where the flints are very large and round. For 400 yards there is no change of importance; but the base-beds show clearly defined stratula, which prove, like the slope of the old shingle beaches, that they were thrown down by water advancing from the eastward. At this point occur more dark lenticular clay patches of the Bournemouth beds; and through the increased height of these more of the overlying Boscombe Sands seem to have escaped denudation. The line of separation between these latter and the beds below may be distinctly traced, as a thin but more or less persistent clay seam checks the downward percolation of water, and throws it out in numerous tiny springs, the wet uniformly darkening the beds below even where they are composed of white sand. The clay patches continue without change for 150 yards. The cliffs are then 65 feet high, 40 feet belonging to the lower series and 20 to the Boscombe Sands, with little or no gravel capping. The upper beds exhibit stratula at reversed angles, showing cross currents, or that the prevailing set of the tides was often changed. The lower beds change frequently from dark clays to buff or white sands, sometimes within 10 yards, and contain great lenticular patches scooped out of them and filled in with white sand, marking probably former channels parallel with the shore, such as we see to-day on the same spot. The damp surface of the cliffs, to which blown sand clings, obscures, however, most of these changes, and they must be bared with a spade or pick to be visible. They are most distinct after heavy rain. About 400 yards beyond a little chine in which the coastguard boats are sheltered, the junction line is temporarily lost, and the whole cliff is composed of yellow sand,

* Prestwich, Quart. Journ. Geol. Soc. vol. v. p. 46.

soon again diversified in its lower portion by a fresh series of small black lenticular patches. That these lenticular patches are cross sections of ancient channels parallel with the old shore seems probable; and that they are of considerable length may be argued from the fact that both Prof. Prestwich's sections* show an arrangement which can be identified by certain peculiarities with two existing patches, notwithstanding that, in the 30 years that have elapsed since these figures were drawn, there is reason to believe 100 yards of coast may have been washed away. One coastguardsman estimated that as much as 60 yards had gone in about 16 years, and all testimony points to a rapid waste. That this is much feared is clear from the great distance from the cliff at which the coastguard buildings are erected, and a monument on Double Dykes has had to be shifted further inland.

Wet brings down large masses of mud and sand in a few hours; wind produces continuous streams of sand; the falling pebbles compel you to give the cliffs a wide berth; and perpetual slips cause anxiety to the nevertheless fortunate proprietors of the lands bordering the sea. 250 yards to the east I detected a bean-like single-seeded pod with indistinct leaves, and other seeds in one of the lenticular patches. Here seems to be inserted a fresh series of laminated sands, 6 feet thick, with much wood and lignite; but with this exception the cliffs, 77 feet high, are all sand with only occasional darker lenticular patches, and with very few pebbles in thin small layers. The dip decreases 150 yards W. to 1°, and E.S.E. by S.E. The bottom-beds, 12 feet thick, contain distinct impressions of leaves in a liver-coloured clay; among them an ovate and a strongly serrate leaf are recognizable. 44 yards on we have several layers of black clay under the line of damp already mentioned as separating the two series of beds, then white sand, and only 10 feet dark sandy clay. The Bournemouth beds, here 40 feet thick, form, as a rule, a nearly vertical base to the cliff; whilst the Boscombe Sands, frequently nearly pure white and fit for glass-making, always slope back at a considerable angle. 130 yards W. we have another curious series of parallel shingle-beds; and in the base-beds, which are of liver-coloured clay, a large laurel-shaped leaf is abundant, associated with a pod as large as and resembling an ordinary pea-pod; 66 yards W. the cliffs again become wholly sand with a dip of 3°, the white sand showing fine examples of stratula; 154 yards further on, lenticular patches again appear, 40 feet from the beach. I will not, however, describe too minutely the details of the cliffs, and therefore pass over the changes occurring in the next quarter of a mile, and come to a concrete road constructed up the face of the cliff by Lord Portman, who has also gone to considerable expense in pile-driving at its foot, it is to be feared, unavailingly. Even the road itself, unless constantly cleared, will be filled by blown and falling sand, which forms great dunes at the top of the cliff. The cliff here shows, in descending order, gravel, ochreous sand, white sand in stratula, white sand with iron stains, iron-coloured sand, pinkish clayey sand not holding water, orange sandy clay and sand, thick black lignitic sand, mottled white

* *L. c.* p. 46. fig. 3, p. 47. fig. 4.

and yellow sand, and, finally, much twisted black clay, the latter holding the water whose mischief Lord Portman endeavours to remedy. A little eastward the pinkish clayey sand ceases, the lignitic sand passes into pure glass-sand, and there are thick shingle-beds at the top. For 200 yards further we find the lower half of the cliffs composed of white sand, the upper of orange sand; 90 yards further we meet with very regular layers of shingle and curiously twisted lignitic sand and clay at the base. The cliffs are now 100 feet high; 380 yards further on we reach the first really palæontologically interesting spot. This is an obliquely bedded lignitic sand, some 16 feet thick, containing very perfect and almost uncompressed limbs of all sizes of an American form of *Cactus* *, described by Heer from Bovey Tracey as *Palmacites dæmonorops*. Together with this, and even more abundant, are branches of a *Sequoia*-like conifer †. The upper part of the cliff is nearly pure white sand, the rest (the Bournemouth beds) being composed of greyish sand and clay in layers. It is singular that these *Cactus* and coniferous branches should have been deposited in this place in abundance, and only here, in company with fragments and branches of wood (riddled by *Teredo*) and sharks' teeth. A few yards E. or W. we may search in vain for them; and it is difficult to understand why they are so completely separated from the fruits and seeds elsewhere so abundant.

120 yards beyond this are the Honeycomb Chines, the sides of which are upwards of 100 feet high and of most picturesque appearance. The ridge separating them, deprived of its gravel capping, and formed of snow-white sand, looks quite Alpine with its sharply cut peaks and water-worn gullies, which may be magnified by imagination into chasms and crevasses. The ribbon-like and netted surface, produced by weathering, produces a singular and striking effect. Lyell represents 3 chines at about the same spot; but it is hardly conceivable that any trace of those should remain at this day, as over fifty years have since elapsed. Last spring the face of the buttress separating the two fell away like an avalanche, which will take many a rough sea to remove. The production of these chines is marvellously rapid; a week's rain sometimes goes far to produce one where a few days before not even an indentation was visible. But their picturesque aspect is not their only charm to the geologist. The beds towards the base are full of interest. A section taken on the east side of the eastern chine shows, in descending order:—

feet.	
20	Yellow sand and gravel.
38	White sand.
5	Whitish sand with lignitic matter.
1 to 3	Dark reddish ash-coloured lignitic sand crowded with *Nipadites*, but almost without other recognizable fruits.
6	Whitish and ash-coloured lignitic sand, with occasional fruits resembling *Petrophiloides*, *Cucumites*, and *Hightea* of Bowerbank.
2	White-sand matrix, black with rolled lignite.
3	White sandy clay bored by *Pholas*.
	Sand 10 or 12 feet to beach.

* Identified by Carruthers. † *Sequoia Sternbergii*?

This section varies considerably in different parts of the two chines; but the Nipadite-zone is constant in both. The thick sands of the upper series enclose no shingle here. No reliable dip inland can be obtained, as the bedding is somewhat confused; but in most of the faces running N.N.E., N.N.W., W.N.W. the beds appear horizontal, the principal dip appearing to be towards W.S.W. The horizon of the Nipadite-bed at the extremity of the chines is 42 feet above sea-level, top of lignitic sand 47 feet, top of white sand 85 feet, with a capping of about 20 feet yellow sand and gravel. At the entrance to the chine the Nipadite-bed is but 25 feet above sea, and the top of the lignitic sand 50 feet. The base of a fine palm-stem was found in sand 15 feet above sea-level, near the entrance to the second chine. The bark and woody structure are in perfect preservation, and the roots still entangle the white clay in which the tree was imbedded before it was washed, in Eocene times, from the older beds nearer to Poole.

It is singular that the *Nipadites*, which are so abundant in the chines that after rains twenty or thirty may be collected in an hour, cannot be traced either east or west of the chines. I have met with them in only one other locality nearer Bournemouth, where they are comparatively rare. No specimen has the base preserved, all exhibiting the characteristic predisposition to dissolution*.

The husks are mixed with masses of rounded and carbonized pellets of vegetable matter, occurring in layers, which have evidently been subjected to attrition by tidal water. It seems clear that they must have floated, or they would have been pulverized, like the more solid remains with which they are mingled; their deposition in layers renders it probable that they were periodically stranded by the winds and in great numbers.

Bowerbank, in his 'Fossil Fruits and Seeds from Sheppey,' gives some curious particulars respecting the *Nipadites* found at Sheppey and the recent genus *Nipa*. The principal habitat of the latter appears to be near large rivers and in watery and marshy places where the soil is black mud or clay frequently covered with water. "It is observed at the mouth of all the great and rapid rivers, and also in such places as are overflowed by the sea or by brackish water; for this tree grows best in soil impregnated with salt."

The Bournemouth species most resembles *N. crassus*, Bow. They appeared to have completed germination, and the exhausted and hollow fruit is filled with white sand with little trace of vegetable matter. The pericarp is present, and the endocarp is sometimes preserved, but equally filled with the same sand. This want of variety in the vegetable remains shows that they were deposited near to where they grew; the variety of form at Sheppey indicating, on the contrary, an assemblage brought together from a large area.

Returning to the cliffs: 220 yards to the west is Boscombe Chine, at the east corner of which is a small patch of hard greenish clay which may be designated the *Dryandra*-bed, as it is filled with tufts

* See Bowerbank, 'History of Fossil Fruits of the London Clay,' pp. 4, 7.

of leaves of a small acutely-lobed Proteacean (which differs from those of Alum Bay) and with compressed coniferous branches. Under this patch is a compact bed of hard whity-brown and ash-coloured sand with more coniferous branches and seeds. A few feet east, in 16 feet of liver-coloured clay under 8½ feet of greenish clay, we meet, for the first time, so far as I have observed, in these beds, with casts of oysters in great masses. At the corner of the chine, close to the beach, the grey sand contains branches of trees 3 or 4 feet long, with more perfect *Teredo*-borings than any met with elsewhere on this coast.

The eastern side of Boscombe Chine is overgrown; but the western side is well exposed for nearly a quarter of a mile, and shows that the beds are quite as variable in a transverse as we have seen them to be in the longitudinal section, and that they here rise inland very rapidly. The W. corner presents a curious instance of denudation by wind which has taken place within my own recollection. For 50 yards the upper beds have been swept off, the top of the lower and more compact beds now forming a plateau of that extent. Proceeding W. the lower beds for 150 yards are dark and compact, forming a perpendicular cliff 25 feet in height, the junction between these and the upper series, now of an orange-colour, being sharply defined. The masses of lignitic sand forming the upper beds of the lower series appear to enclose none of the seeds which we sometimes find sparsely scattered in the sands below. These beds dip 8°, and under them rises greensand with casts of oysters, sometimes coated with Bryozoa. 60 yards eastward a clay patch occurs as many yards in length, and of a drab and irony hue at the base, emitting a sulphurous smell when divided. It has indistinct leaf-remains, and is penetrated by fossil roots or sedges. For the next 200 yards the sections are obscured by slips, but the dark beds appear occasionally and are seen to be full of oysters.

Next to this is the iron-ladder path, where the cliffs are about 80 feet high, with the addition of a capping of nearly 30 feet of blown sand. We here find the following section:—Lower beds: base very sandy clay obliquely bedded, 3 feet; dark sandy clay getting more decidedly clayey towards the top, the last foot being very stiff black clay shading to lead-colour, 30 feet; over this are whitish-grey sands with grains of lignite and a few seeds, 8 feet; total about 40 feet. Upper beds: principally white glass-sand, but yellow towards the top and base, 40 feet. A very few yards west, however, the obliquely bedded sandy clays rise and attain a thickness of 30 feet, and are then replaced by hard white sand, unconformable to the obliquely bedded clays. At the end of 200 yards these again become first more yellow and then interlace with nearly black sands, which soon entirely replace them. Here *Nipadites* are again found, but very sparingly, together with fruits, which are rare, resembling *Hightea minima*, Bow., and *Anona*, Heer For another 250 yards dark yellow and grey sands 50 feet thick alternate, the upper beds consisting of orange or white stratulated sands of nearly equal thickness; but at this point a small patch quite at the base of the cliff deserves especial notice, as it is literally crowded with seeds and fruit, supposed of *Hightea* and *Cucumites*, and more rarely fruits of *Petrophiloides*. The patch is situated between the extremities of two unconformable sandy clay-beds. [So local, however, are these seeds that within the last year a shift of a small streamlet 2 or 3 yards to the east has caused them but rarely to be washed out.] They appear at the time of deposition to have been caught in an eddy, and are mixed with stems and leaves, the latter, although they cannot be worked out, being so perfect when weathered out by spray as to seem like freshly decayed leaves blown on to the face of the cliff*. This new base-bed soon changes to sand of a white or ash-colour, full of lignitic grains and occasional slightly bored logs of wood, without fruits, but containing in one place an included mass of jet-black clay crowded with broken pinnæ of *Osmunda*. The section of the lower series is at this spot: —black clay at base, 8 feet; then white, drab and white sand with lignite, 44 feet; capped with a thin water-holding seam of clay. The upper series is unchanged. We now approach the point of final disappearance of the marine series of beds, which within about 100 yards gives place to beds of freshwater origin. Before their disappearance, which is due partly to the rise of lower beds and partly to their passage into the freshwater beds, they become greatly disturbed, and have been much broken up and redeposited; while the changes in their composition are so rapid that the most minute and careful examination is required to understand their sequence. They are mostly highly fossiliferous and of the greatest interest. Within less than 50 yards of the last section we have the following, in ascending order:—

			ft.
Lower Series.	1	Coarse quartz grit; Light drab clay	3
	2	Liver-coloured clay with pyritized stems penetrating. Angular lumps of unfossiliferous hard dark bands redeposited in a matrix of light lignitic sand. Lignitic sand with slightly rounded blocks of a re-deposited leaf-bed	25
	3	Light grey sand	15
	4	Greenish sand with oysters, *Flustra*, &c.	4
		Pink and drab clay	1
		Lemon and ochreous clayey sand	3
Upper Series.		White sand	14
		Orange and yellow sand ....about	20
		Total about	85

* About fifteen distinct forms only are at present known from these beds, and they are mostly of small size. These fruits, although not rivalling in variety and importance those from Sheppey, are nevertheless of the highest possible interest, as should their supposed identity with the latter be sustained, the fruits of Sheppey would assist in the determination of the Bournemouth leaves in an unlooked-for manner. If these fruits, which are *above* the horizon of the leaves, are identical with or even similar to those from the London Clay *below*, we have there the strongest reason to infer that the leaves lying between them were leaves belonging to the same groups of plants to which the fruits belonged, and grew on the same land. We may thus find in the Sheppey fruits

A new bed, about 3 feet thick, of compact dark clay, next rises, containing abundant seeds and fruits*, which are compressed, not so well preserved as in the former fruit-bed, and containing, in addition, various dicotyledonous leaves, including a *Dryandra*, and also *Cactus*-spines, as well as fragments of a broad, apparently Musaceous leaf.

From a point a very few yards west of the last section, and in the marine beds numbered 4 in the preceding section, were obtained several Crustaceans. The beds here show extremely well the passage from marine to brackish and freshwater, and are as follows, descending :—

1. Dark sands with green grains, broadest and lightest at the top, containing masses of *Ostrea dorsata*? (coated with *Flustra*), an *Arca* (apparently *A. appendiculata*), a *Modiola* (probably *M. Nystii*), *Tellina tenuistriata*, and more rarely *Calyptræa trochiformis*?, *Phorus agglutinans*, *Natica labellata*, and a *Cerithium*.
2. Liver-coloured clay (turning black on exposure) with abundant remains of *Callianassa*, and, more rarely, a shore-crab. Bryozoa, first detected by Carruthers, also abound†. A *Unio*-like shell is also abundant, together with some smaller bivalves and a minute and very rare *Planorbis*? 15 feet.
   [The surface of the succeeding bed is eroded for about 6 inches, and filled in with the overlying clay, which has also formed small pipings.]
3. Stiff black clays passing into lighter liver-clays at bottom, and, after a break, into liver-clay with ferns. Very dark sandy clay. White or ash-coloured sand with lignitic bands. 30 feet.

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a great help to the correct determination of the leaves; as in cases where the form and character of a leaf would leave it doubtful to which of several genera it should be referred, the presence of fruits of any one of the genera to which the leaf might be referred would assist us to determine its genus, with a far greater approximation to certainty than if no such fruit existed.

* The likeness of these to the Bovey-Tracey seeds called *Anona* is so extraordinary that if specimens from both localities were mixed they could not again be separated with certainty.

† Mr. Waters, who has kindly examined the specimens of Bryozoa obtained here, writes to me as follows, about them :—

"The fossil Bryozoa from Bournemouth which you kindly allowed me to examine are (with the exception of one impression) all merely casts of horny species, and therefore do not permit any investigations into the shell-structure to be brought to bear.

"A few of the specimens are *Flustræ*, but, as none of the characteristic points are preserved, cannot be determined, since the only comparison that is possible is the size of the cells.

"There are, however, three specimens of great interest. These are casts of *Diachoris*, of which the lateral tubular connexions can be seen, and these are frequently broken off at the diaphragm, as is often the case in recent *Diachoris*. There are two protuberances in the cast, one on each side of the oral aperture, and these show that there were two rather large avicularia. The Bournemouth *Diachoris* has the distal and proximal ends in direct contact, as in *Flustra* and *Carbasea*, while in most *Diachoris* they are joined by a tubular connexion similar to the lateral tubes.

"This, I believe, is the first time that a fossil *Diachoris* has been found, which on that account is of much interest. There are a few species now living in the Mediterranean; but it is apparently much more common in the southern hemisphere. The *Diachoris magellanica*, Busk, is the most common in the Mediterranean. It has one or two avicularia placed slightly more laterally than those in your specimen.

"This mode of tubular connexion is not confined to *Diachoris*; for *Membra-*

The marine bed last described occurs on the east side of a slight indentation of the cliff, some 30 yards across, formed by a spring. Owing to this spring, which has of late years caused frequent landslips, the section is seldom to be seen; but it was visible after much digging during the summer, great cracks threatening all the time, however, a fresh slip. No description can render intelligible the complicated structure of this part of the series, the broad lines of which are sketched in fig. 5. On the west side of this landslip occurs the first leaf-bed which bears evidence of having been deposited in fresh water. It is made up of thin layers of a pinkish clay between films of sand, and in one place contains nothing but leaves of ferns belonging to *Polypodium*, *Chrysodium*, *Pteris*, and *Osmunda*.

Other beds contain a few dicotyledonous leaves mixed with the ferns, among them a *Eucalyptus*; whilst some of the dark beds contain branches of *Sequoia*, leguminous pods and leaves, &c. Over this, and to the east of the landslip, the last shingle-beds of the Boscombe Sands occur in lenticular, sometimes truncated patches. About 100 yards further west the marine beds finally thin out and end in a point, the cliffs being nearly all composed of white sand with short irregular patches of vegetable matter. The lowering of the cliffs and the rise of the underlying beds terminate the upper or marine series at this point.

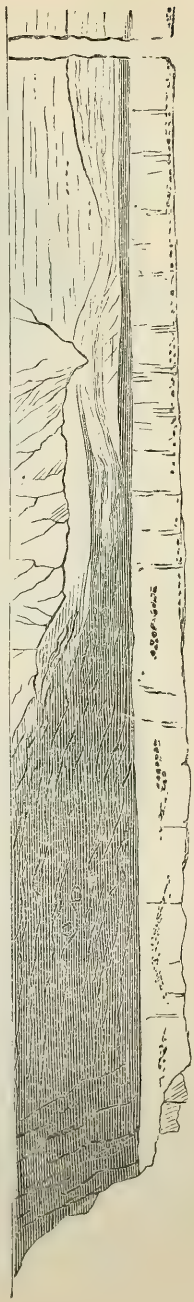

Fig. 5.—*Western termination of the Bournemouth Marine Series.*

The capping belongs to the Boscombe Sands. The dark tint indicates the Marine, and the lighter parts the Freshwater beds.

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nipora circumcincta of Heller is also connected by short tubes, which are more numerous than in *Diachoris*.

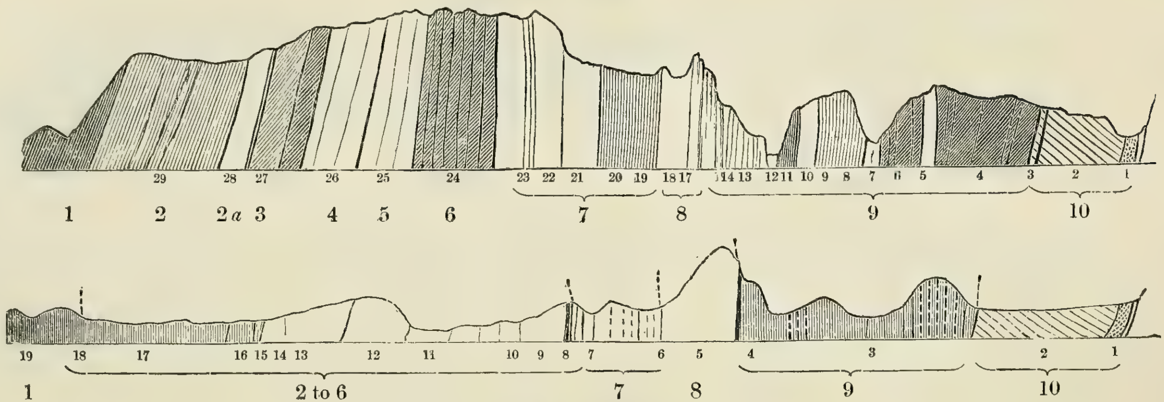
"I think your specimen might well be called *Diachoris intermedia* if it is allowed to remain with *Diachoris*.

"There is also a cast of *Membranipora*, which in shape much resembles *Membranipora pilosa*, which is common on the seaweeds all round our coast; but as there are fossils with similar-shaped cells and great variation in other points, no specific determination is possible from casts.

"There is an impression of an *Eschara* or *Lepralia*, which, I fear, cannot be determined."

Fig. 6.—*Reduced copies of Prof. Prestwich's Sections of the vertical section in Alum and Whitecliff Bays.*

Section at Alum Bay.



Section at Whitecliff Bay.

The small numbers used are according to Prestwich, the larger numbers accord with my new nomenclature. The dotted lines indicate the correlation of the beds. The large numbers correspond with those used in fig. 2. 1. The Barton beds. 2. The Upper Bracklesham and Highcliff Sand. 3. The Hengistbury-Head beds with ironstone. 4. The Hengistbury-Head beds with green grains. 5. The Boscombe Sands. 6. The Bournemouth Marine series. 7. The Bournemouth Freshwater series. 8. The Lower Bagshot beds. 9. The London Clay. 10. The Woolwich and Reading series.

The extraordinarily shifting and rapidly changing character of the beds both horizontally and vertically, the marshy character of the vegetation, as represented by ferns, *Eucalyptus*, Aroids, &c., the frequent patches of drab clay (which evidently once formed an oozy soil in which the ferns and perhaps water-plants rooted), the local patches of ironstone, the marine beds, as well as the character of the fauna, shore-crabs and *Callianassa*, mingled with Unios, clearly show that this was the actual debatable margin betwixt sea and river, beyond which, to the west, it seems clear the encroaching sea never in these ages penetrated.

With regard to the correlation of the Bournemouth Marine beds with those of the London Basin, it is clear, upon reading Prof. Prestwich's description of the Middle Bagshot series in that area, that the beds are lithologically very similar. He ascribes to it a thickness of from 40 to 60 feet, and considers it to be a division of distinct mineral character and persistent range and structure. Whitaker, in the Geological Survey Memoir*, adopts Prestwich's divisions, and quotes largely from his work. The lower part consists of laminated clays and sands; above these there is "green sand, generally very pure and of a dark bottle-green colour," 12 to 20 feet thick, succeeded by other sands and clays, with occasional layers of rolled flint pebbles. The presence of glauconite grains is a distinctive feature of the Middle Bagshot division, and the fossils that have been found are Bracklesham species. There can, I think, be no reasonable doubt that these beds represent the same stage of the Bracklesham series in the London Basin. When we come, however, to the Upper Bagshot beds in the same area, considerable doubt exists. These sands are described in the Survey memoir as "loose, generally whitish, and without signs of bedding or pipeclay, and are 250 to 300 feet thick." Considering that the Bournemouth marine beds are overlain by heavy deposits of white sand in every respect answering to this description, and that the Hengistbury-Head beds are also under a thick mass of whitish sand, and in the absence of palæontological evidence, it seems far more likely that these belong to Middle than Upper Bagshot time. On this supposition we have neither the very sudden thinning of the Middle Bagshot nor the absence of any indication of the Barton Clay to account for. I am therefore of opinion that no Eocene beds younger than the Brackleshams are met with in the London Basin. There is one other point upon which I wish to remark. The fossil plant-remains met with in the Bournemouth beds, especially those in the marine series, are so strikingly similar to the Bovey-Tracey fossils as to make it clear to my mind that the latter have been wrongly assigned to the Miocene. I believe, in fact, that they are simply an outlier of the Bournemouth series, from which they are but eighty miles distant. Whether we compare the ferns, as *Osmunda* (*Pecopteris*) *lignita*, *Lastræa Bunburyi*, the Cactus (*Palmacites dæmonorops*), the fruits, conifers, or dicotyledons, it is seen that by far the larger proportion are not only specifically identical, but occur

* Mem Geol. Surv. vol. iv. p. 329.

exactly in the same combinations and manner of preservation. The synchrony of the Bovey with the Hempstead beds has been inferred on the most slender grounds, and scarcely deserves attention now that it is opposed by strong evidence pointing in another direction.

Discussion.

Mr. Whitaker asked if the author regarded the fruits of Sheppey and those of Bournemouth as coming from the same horizon, and called attention to the thickness of strata deposited between the London Clay and the Bracklesham Series. He questioned the rejection of the older nomenclature, but admitted the great difficulty of correlating the Middle Eocene deposits of the London and Hampshire basins.

Mr. Charlesworth remarked on the interest attaching to the discovery of fossil fruits at Bournemouth, and inquired whether *Nipadites* occurred, and if the fruits were in the same state of mineralization as at Sheppey.

The Author replied that the Bournemouth fruits were generally similar to those of Sheppey, and several belonging to the latter locality also occurred at Bournemouth. He defended his correlation of the beds.

Mr. Woodward stated that he had not yet been able to study the Crustacea collected by Mr. Gardner, which were not well preserved, and he feared would prove incapable of specific determination. He had recognized among them some Spider-Crabs, apparently of the genus *Stenorhynchus*, a *Xanthopsis*, and what appeared to be a *Callianassa*.

17. *On some* Tin-deposits *of the* Malayan Peninsula. By Patrick Doyle, Esq., C.E. (Read January 8, 1879.)

[Communicated by Rev. T. Wiltshire, M.A., F.G.S.]

There is a striking resemblance in the mineral characteristics of all parts of the Malayan Peninsula, especially in regard to the mode of occurrence of the deposits of tin-ore (cassiterite).

The Malayan tin-field, including the islands of Banca and Billeton, extends over 17 degrees of latitude and 10 of longitude; but the observations of Messrs. Logan, Horsfield, and others, in different parts of this area, correspond with those which have been noted in Larnt. The peninsula consists of granitic rock overlain generally by sandstone, and frequently also by laterite or cellular clay-ironstone, and, to the north, by limestone. A granitic mountain-range extends along the whole length of the peninsula, on both sides of which, but especially on the western or Sumatran one, are extensive alluvial plains, but little above the level of the sea. Iron, tin, and gold are the principal metals. Ores of the first are found everywhere; and tin has hitherto been found in all parts where search has been made.

Perak is the second Malay State on the west side of the peninsula, counting from the north; and Larnt, its chief province, is an irregular strip of land about 70 miles long and varying from 10 to 25 miles broad, bordering the coast.

Larnt, for some ten miles inland from the sea, is a level plain; then the mountain-ranges begin and rise to a height of nearly 5000 feet, running in an almost unbroken line in a northerly direction, with detached hills at intervals at their base. All the land at the foot of these ranges is more or less stanniferous. This strip is in length above 50 miles, with an average breadth of six. Its level is even now being altered by the alluvium brought down from the hills by a rainfall which exceeds 150 inches per annum.

All the ore worked up to the present time has been found in the alluvium derived from the mountain-ranges, *i. e.*, in mining language, in stream-works. The ore has been traced up to veins in the rock, but these have not hitherto been worked.

The tin-beds are composed of the débris of granitic rocks mixed with the ore; the latter varies in size from particles like fine sand to fragments as large as a hazel-nut, the deposit becoming coarser as the mountains are approached*.

* The following specimens were presented in illustration of this paper:—(1) *Fine Tin-sand*, obtained from the alluvial flats between the coast and the mountain-range—Larnt, Perak, Malayan Peninsula. (2) *Coarse Tin-sand*, found in alluvial deposits in the interior, beyond the mountain-range and from thirty to forty miles from the coast—Kintâ, Perak. (3) *Tin-gravel*, found under boulders at varying altitudes of from 500 feet to 1500 feet above sea-level on the western slopes of the mountain-range—Larnt, Perak. (4) *Tin-ore in its matrix*, obtained from "pockets" of the hills at an elevation of 2000 feet—Larnt, Perak. (5) The *Tin-tray*, which holds the specimens, is made of the tin obtained from the smelting of the above ores, and manufactured in Larnt.

There can be no doubt that these beds have been formed by degradation of the mountains; these, as has been stated, consist of granitic rock, in which the tin-stone associated with iron-ore occurs in veins.

We still see the processes at work, though in a modified form, by which deposits have been spread over large areas during long periods of time; and the rotting trunks of trees, with other remains frequently met with in the workings, tend to prove that some of the deposits may be properly called "recent."

Sections of the mines show that the strata beneath the surface-soil consist of alternating bands of sand and dark clay of different colours, the latter sometimes being largely present. These strata appear to indicate strong current-action. The separate fragments in the lowest (or tin-bearing) layer bear clear evidence of the same.

These fragments are of quartz, felspar, mica, and schorl; and among these are occasionally found masses of clay, most of which are so friable as to crumble to pieces when touched. In some, particles of quartz yet remain projecting from the surface, so as to give it a regular striated aspect, from which felspar separates as a white powder. Many of the more solid fragments have rounded angles, and are evidently derived from veins such as still occur in different parts of the country.

Beneath the tin-bearing stratum is a peculiar white clayey substance which becomes friable on drying and is called "Kong tay" by the Chinese. This is sometimes yellow, sometimes white or somewhat bluish. It consists of kaolin, sometimes mixed with fine quartz-sand, and is a decomposition-product of felspar. The kong has been bored to a depth of 20 feet; but nothing except this "porcelain clay," mixed with more or less quartz-sand, has been found.

Opinions differ as to whether this clay invariably underlies the stanniferous deposits. In the Larnt district there is little doubt that it does generally, the only exception to the rule being where the tin-stratum rests on sandstone, which, however, some have thought to be only the same clay with a large admixture of the quartz-sand already mentioned.

The following are sections of stream-deposits in different localities and will give a very fair general idea of the district:—

I.	ft.	in.
Vegetable mould	1	3
Loam	1	0
Sand	4	0
Bluish clay	3	6
Darkish clay	3	9
Stratum with ore	6	0
	19	6

II.	ft.	in.
Mould-soil	3	0
Clay varying from dark yellow to pale grey	12	0
Light gravelly drift	3	0
Stratum with ore	6	0
	24	0

III.

	ft.	in.
Mould-soil	4	0
Sand varying from white to brown	4	0
Dark grey sand	6	0
Stratum with ore	4	0
Pipe-clay	(?)	
	18	0

IV.

	ft.	in.
Red loam	2	0
Sand drift	5	6
White grey clay	4	6
Black clay with trunks of trees	2	0
Stratum of ore	5	0
Pipe-clay	(?)	
	19	0

V.

	ft.	in.
Red loam	4	0
Sand drift	8	9
Whitish-grey clay	9	3
Stratum of ore	6	0
Sandstone	(?)	
	28	0

VI.

	ft.	in.
Red earthy loam	5	0
Whitish-grey clay	3	6
Drift sand	8	6
Stratum of ore	8	0
Sandstone	(?)	
	25	0

Some idea of the irregular stratification of the deposits in the tin-field may be obtained from the fact that in a working of less than 100 feet square the details of the sections of each of its sides differed, though, of course, there was a general similarity.

The depth at which the tin-ground is struck depends upon position and locality. There is probably no working at a greater depth than 30 feet. All the mining in Larnt is by open excavations. A mean derived from measurements of the depths of 43 mines in the Kamuntin Section gives an average of 9·91 feet, the greatest and least depths respectively being 21 feet and 4 feet. The greatest known thickness of the tin-stratum is 10 feet. The mean thickness, from measurements in the above 43 mines, is 4·87 feet, the range being from 2 to 7·5 feet. The spring-level of the country may be taken generally at a depth of 6 feet below the surface of the ground.

The workings cover an area of nearly 4 square miles of country, affording occupation for nearly 7000 labourers (Chinese), and yield an aggregate "output" of about 13,000 bharas, equivalent to 52,232 cwt. of tin per annum*. The industry is fast developing under the British rule and bids fair to eclipse, in a period far from remote, the

* The ore, when smelted (by the rude native process), yields from 60 to 62 per cent. of metal.

production of the other states of the peninsula and islands of the archipelago.

Discussion.

Mr. W. W. Smyth remarked that the details given in the paper corresponded closely with those of stream-works in other localities. Information on such subjects was important to capitalists. Large areas of alluvial deposits appeared to be rich in tin-ore in many places on the east side of the Bay of Bengal. So far as he knew, this was the first description of the region of Perak, and he trusted we should have more. He called attention to the association here, as in Queensland and elsewhere, of tin with granite. Mynheer van Groot had informed him that in the islands of Bellaton and Banka the tin was associated with slaty rocks curiously like those of Cornwall and Devon, probably, though on slight fossil evidence, of Devonian age.

Mr. J. H. Collins remarked that the similarity mentioned by Mr. W. W. Smyth extends to the associated minerals also; for wolfram and gilbertite were abundant in the specimens on the table, as in the stanniferous granites of Cornwall.

18. Note *on* Poikilopleuron Bucklandi *of* Eudes Deslongchamps (père), identifying *it with* Megalosaurus Bucklandi. By J. W. Hulke, Esq., F.R.S., F.G.S. (Read February 5, 1879.)

[Plate XII.]

One difficulty, and not the least, which besets the student beginning to study fossil reptiles is the great embarrassment occasioned by the not unfrequent description of the same reptile under different names, involving the worse than merely useless multiplication of genera and species. Wherever, then, the identification of a newer with an older genus can be established, entailing, as it should, the abandonment of the newer generic name, it is to be looked on as a positive gain. I now submit to the criticism of the Geological Society the evidence which appears to me to identify beyond reasonable doubt *Poikilopleuron Bucklandi* of Eudes Deslongchamps, père, with an older acquaintance, *Megalosaurus Bucklandi.*

The literature of *Poikilopleuron* is, fortunately, not extensive. The following list comprises all the principal papers relating to the genus which I have found, arranged according to priority of publication:—

I. "Mémoire sur le *Poikilopleuron Bucklandi*, grand Saurien fossile, intermédiaire entre les Crocodiles et les Lézards, découvert dans les carrières de la Maladrerie, près de Caen, au mois de juillet 1835." Par M. Eudes Deslongchamps. Mém. de la Soc. Linn. de Normandie, vol. vi. p. 36, pls. ii.–viii. (1838).
II. "Report on British Fossil Reptiles." By R. Owen. Brit. Assoc. Report, 1841, pp. 84–88.
III. "Contributions to the Anatomy and Taxonomy of the *Dinosauria.*" By T. H. Huxley. Quart. Journ. Geol. Soc. 1869, xxvi. pp. 28–34.
IV. *Poikilopleuron valens.* Contributions to the Extinct Vertebrate Fauna of the Western Territories. Part i. pp. 279 and 338, pl. xv. figs. 16–18. By Dr. J. Leidy. 1873.
V. *Poikilopleuron pusillus.* Supplement vii. to the Monograph on Fossil Reptilia of the Wealden and Purbeck Formations, in Pal. Soc. vol. 1876, p. 1, pl. i. By R. Owen.

The remains of the large Saurian which Deslongchamps recovered from building-materials obtained from a quarry near Caen, and reconstructed, after months of patient labour, with sufficient completeness for their skeletal determination, comprised :—a score of vertebræ in two series, all caudal ; a humerus and two bones, which he regarded as radius and ulna (but which a comparison of his excellent figures of them with metatarsals of Dinosaurs clearly shows to belong to the hind foot) ; parts of a tibia and fibula ; an astragalus and other bones of fore and hind feet; and many ribs, forming a costal apparatus of singular complexity, which suggested the generic name *Poikilopleuron.* For a long time Deslongchamps thought these remains might belong to *Megalosaurus*; but after much consideration, the weight of evidence then available appeared to him adverse to this, and he therefore gave his Saurian the distinctive generic name *Poikilopleuron*, attaching to it, as he distinctly tells us, the specific name *Bucklandi*, the same as the trivial name of *Megalosaurus*, in order that if future discoveries should identify it with this, the identification would involve only the suppression of a generic denomination.

Deslongchamps regarded his *Poikilopleuron* as holding an intermediate position between Crocodiles and Lizards. Three years after the publication of this memoir *Poikilopleuron* was adopted by Prof. Owen, and placed by him in the order Crocodilia, between *Steneosaurus* and *Streptospondylus* *; and very recently this eminent palæontologist has reaffirmed this position on the evidence of a chain of vertebræ, considered by him to indicate a small species of *Poikilopleuron*, which he names *P. pusillus*, in the collection of the Rev. W. Fox †. As this chain shows the sacrum of the animal to have consisted of two vertebræ, the same as in Crocodiles, Prof. Owen considers that it proves the *Poikilopleuron* to have been a Crocodile, and not a Dinosaur as Dr. J. Leidy suggested, in 1873, in his description of the vertebræ assigned by him to a species of *Poikilopleuron* which he named *P. valens* ‡. In 1869 it had, from the similarity of its astragalus to that of *Megalosaurus*, been placed by Prof. Huxley in the family Megalosauridæ of the order Dinosauria.

The necessary evidence for deciding the true position of Deslongchamps's *Poikilopleuron* in the class Reptilia, and also for solving the question of its individual distinctness, is fortunately to be found in the numerous and excellent figures he has left us of its remains. These, fortunately, comprise very exact and carefully executed representations, from several points of view, of some of the test-bones of Dinosauria. I refer particularly to the tibia and astragalus. Its tibia, represented in pl. vii. figs. 3, 4, is manifestly that of a typical Dinosaur; the form of its distal end is too plain to admit of any doubt on this point. The subdivision of the articular surface of this end of the shin-bone into an inner and an outer *moitié*, with their surfaces differently inclined and so adapted to the corresponding hollows in the upper surface of the astragalus as to be incompatible with motion between these bones §, the projecting angle shown on its postero-internal surface, and the entering angle depicted in its antero-external surface, for lodging the ascending process of the astragalus, are singly and collectively known

* Brit. Foss. Rept. in Brit. Assoc. Rep. 1841, pp. 84–88. R. Owen.

† 'Foss. Rept. Wealden and Purbeck,' Suppl. vii. p. 1, pl. 1 (1876), Pal. Soc. vol. R. Owen.

‡ Extinct Vertebrate Fauna, part 1, pp. 279 and 338. J. Leidy.

§ Mém. cit. pl. vi. fig. 7.

only in Dinosaurs, and have not yet been found in Crocodiles or Lizards. The form of the astragalus is so thoroughly Dinosaurian, and so unlike that of Crocodiles and Lizards, that it is unnecessary for me to do more than refer to Deslongchamps's most excellent representations of it in pl. vi. fig. 12, and pl. vii. figs. 19–22. I believe that the study of these figures of the tibia and astragalus cannot fail to convince the reader of his memoir that *Poikilopleuron* is a genuine Dinosaur. These two bones also agree in every essential feature with the same bones of *Megalosaurus Bucklandi*. Of the astralagus of *Poikilopleuron*, Prof. Huxley said, in the paper quoted in the list, " it is altogether like that of *Megalosaurus*." This statement I would confirm, and I would add that it is easily distinguishable from the astragalus of the other European Dinosaurs in which this bone has been determined. It is right to add that the complete form of the astragalus is at present known only in *Iguanodon Mantelli*, *Hypsilophodon Foxii*, and *Megalosaurus Bucklandi*. The perfect adaptation of the upper surface of the astragalus to that of the distal end of the tibia enabled us, however, to correctly infer the form of the bone in those Dinosaurs in which it is not yet known. The distal end of the tibia of *Megalosaurus Bucklandi* has strong characters which readily distinguish it from that of *Iguanodon Mantelli*, *Hypsilophodon Foxii*, *Hadrosaurus*, *Hylæosaurus*, *Polacanthus*, and *Ceteosaurus*. The peculiar prominence and sharpness of the inner lip of the astragaloid depression on the antero-external surface at once stamps it as being distinct from the tibia of all the Dinosaurs just mentioned, and this stamp is only borne also by the tibia of *Poikilopleuron*.

With respect to the vertebræ, it is unfortunate that Deslongchamps's twenty were all caudal. He writes (p. 75):—" The anterior and posterior faces of the vertebræ are slightly concave, and the concavity is deeper the nearer the vertebræ are to the end of the tail." In the vertebræ of the first series the body is nearly circular at the two ends (pl. vii. fig. 14); in the second series it more approaches an oval with the larger diameter vertical" (pl. vii. figs. 8, 9); " the border for the attachment of the outer layers of the (interarticular) fibro-cartilage is very pronounced." " The middle part of the body differs in the two series; it is compressed and rounded in the first series, so as to present not more than half the breadth of the two ends. In the narrowest part, at the junction of the body, is a wide shallow groove, the upper border of which is more prominent in proportion as the transverse process springing from it is longer." " The length of the body is to its greatest breadth as 3 : 2." " The body in the second series is rather triangular than rounded in the middle, and but slightly compressed." " In both series the body of the vertebræ is hollowed by a large medullary cavity; the spongy tissue exists only at the ends." " There is at each side in the lateral groove a hole for the passage of nutrient blood-vessels."

As regards the outward form of the vertebræ, especially in the first series, Deslongchamps's description and figures show a very close resemblance of their centrum to that of the acknowledged trunk-vertebræ of *Megalosaurus Bucklandi*, allowance being made for such modification, chiefly reduction of complexity, which in every vertebral column is observed in passing from trunk to tail; and, further, they are quite applicable to caudals of *Megalosaurus* preserved in public collections.

With its characteristic tibia and astragalus not distinguishable from those of *Megalosaurus Bucklandi*, and with the extreme similarity of the form of the vertebræ, what grounds exist for retaining the genus *Poikilopleuron*?

The distinctness of *Poikilopleuron* has been affirmed by Prof. Owen, partly on the ground of the greater simplicity of its vertebræ as compared with those of *Megalosaurus*, but mainly on the presence of a medullary cavity in the body of the vertebræ in *Poikilopleuron*, which he did not find present in a caudal of *Megalosaurus*. As regards the former of these reasons, the caudals of Deslongchamps's *Poikilopleuron* have indubitably a simpler figure than that of the trunk-vertebræ of *Megalosaurus*, but not than that of its caudal vertebræ; and as regards the second reason, unless the caudal ascribed to *Megalosaurus*, in which no medullary cavity was found, was discovered in such association with other undoubted Megalosaurian remains as to positively identify it with this Dinosaur (and this is not mentioned), I would suggest that the determination must be held to be one of probability only, since in the caudals of Crocodiles and of the carnivorous Dinosaurs a strong common likeness exists. Possibly the question is one which cannot be decided by the section of a single vertebral centrum of uncertified origin from a part of the vertebral column where generic characters are less sharply expressed. That there should be a medullary cavity in genuine Megalosaurian caudal vertebræ would not be improbable, since in the neural arch in trunk-vertebræ, and in the sacrum, medullary cavities were noticed by the late Prof. Phillips in type specimens in the Oxford University Museum *. I have myself seen, in the collection of G. B. Holmes, Esq., a fine vertebral centrum which had the characters commonly assigned to trunk-vertebræ of *Megalosaurus*, and in which, when broken across, Mr. Holmes found a large hollow space occupying nearly half the length of the centrum. It may be objected that this was actually a vertebra of *Poikilopleuron* and not of *Megalosaurus*. Conceding such a mistaken determination, it shows how extremely alike are their vertebræ when they cannot be distinguished by their figure.

The evidence adduced in favour of the generic distinctness of *Poikilopleuron* is, I venture to submit, so weak contrasted with that in favour of its identity with *Megalosaurus Bucklandi*, that I confidently expect Deslongchamps's generic name will be discontinued, and *Poikilopleuron Bucklandi* be known in future as *Megalosaurus Bucklandi*. Had Deslongchamps himself possessed the more abundant material for a comparison of the Megalosaurian skeleton with the remains of his Saurian which are now available, and had the

* Geol. of Oxford and Thames Valley, by Prof. J. Phillips, p. 206, figs. 2, 3.

order Dinosauria been then known as we now know it, I believe his sagacity would have quickly seized the order and the place to which his Saurian rightly belongs. He knew *Megalosaurus* only by the poor figure of its sacrum in Cuvier's 'Ossemens Fossiles,' and by teeth which he mentions had been found near Caen. I may add that there is in the British Museum the distal end of the tibia, probably from the same district. It once formed part of the Tesson collection.

Since the above Note was written and sent in, Mr. James Parker, of Oxford, the fortunate possessor of a magnificent collection of Megalosaurian remains, has most obligingly afforded me the opportunity of ascertaining the internal structure of the caudal vertebral centrum in this Saurian, by breaking across one in a chain of several, which by their close association with other indubitable Megalosaurian remains (teeth, limb-bones, &c.) in which they were found, as also by the close correspondence of their facies with these, are undoubtedly genuine remains of this Dinosaur. In the interior of this caudal centrum is a large medullary cavity (now filled with matrix), as in the reputed caudals of *Poikilopleuron*. With this structural agreement the last alleged skeletal fact in support of the individuality of *Poikilopleuron* disappears.

From Prof. Morris, to whom my warm thanks are due for information most kindly given, I learn that some difference of opinion exists regarding the position of the Calcaire de Caen. D'Orbigny and D'Archiac regarded it as the equivalent of the Great Oolite, Deslongchamps as representing the Fuller's Earth. The lists of fossils occurring in it, however, Prof. Morris writes, contain some which in this country and elsewhere are referred to the Inferior Oolite.

February 2, 1879.

EXPLANATION OF PLATE XII.

Fig. 1. Tibia of *Poikilopleuron*. Front view of distal end. 1*a*. Back of same.
2. Astragalus of *Poikilopleuron*. Front view. This and fig. 1 form pl. vii. f. 12 and pl. vi. fig. 3 in Deslongchamps's memoir.
3. Tibia of *Megalosaurus*. Front view. Royal College of Surgeons.
4. Tibia of *Ceteosaurus*. Phillips's 'Geol. of Oxford.'
5. Tibia of *Iguanodon Mantelli*. Front view. Brit. Mus.
6. Tibia of *Hadrosaurus*. Front view. From Leidy's 'Cretaceous Reptiles of the United States.'
7. Tibia of *Hylæosaurus*. Front view. Brit. Mus.
8. Astragalus of *Iguanodon*. In the collection of Dr. E. P. Wilkins.

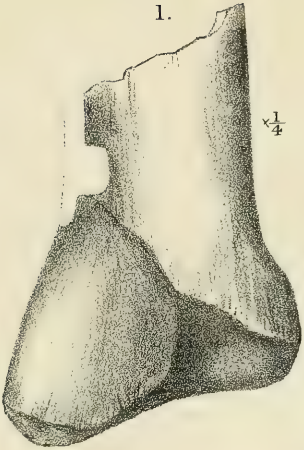
DISCUSSION.

Prof. SEELEY felt disposed to doubt from the diagram whether the species, at any rate, were identical; still, as Mr. Hulke had so many opportunities of studying the specimen, he thought the identity of the two genera might be received. The tooth figured as that of *Poikilopleuron* by Deslongchamps, he thought, belonged to *Pliosaurus*, so that difference did not militate against Mr. Hulke. Having regard to the great range of *Megalosaurus* from Lias to Wealden, he doubted whether different species had not been referred to the one *M. Bucklandi*.

Prof. MORRIS expressed his sense of the value of the paper, and said that De Blainville had expressed a similar opinion in 1852. Both De Blainville and Deslongchamps refer the long, conical teeth figured by the latter to *Poikilopleuron*. The geological position of the deposits was interesting. The Calcaire de Caen was of disputed position, some making it the base of the Great Oolite, others the equivalent of the Fuller's Earth. It, however, contains a series of fossils not found in the Fuller's Earth of this country, but characteristic of the Inferior Oolite. The Calcaire de Caen, near Bayeux, is a marly limestone, but near Caen it is a compact limestone. The Saurian bones come from a small band not much more than a yard in thickness.

Mr. HULKE said that Deslongchamps states that the tooth he figured was an isolated one; there was no proof that it was *Poikilopleuron*; and he himself quite thought it was a *Pliosaurus* tooth.

1.



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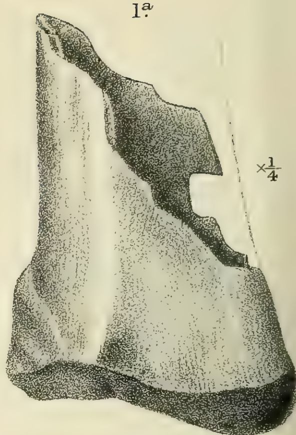
1ª.



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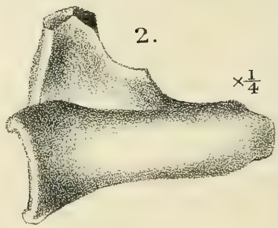

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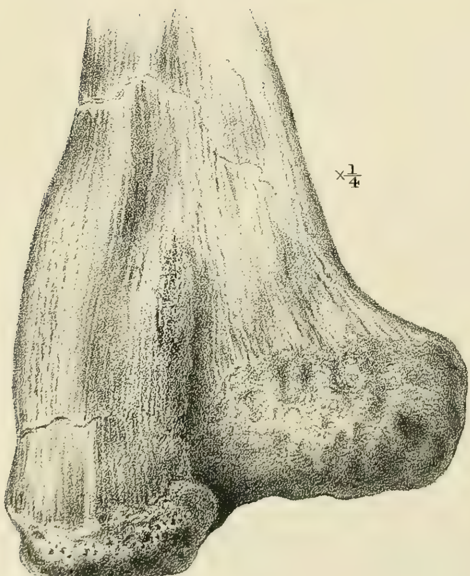

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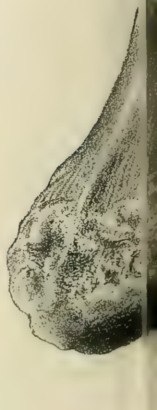

A. S. Foord del.

LIMB-BONES

6.

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4.

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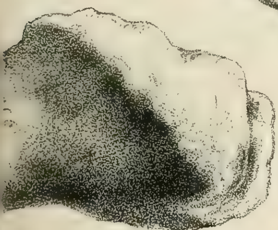

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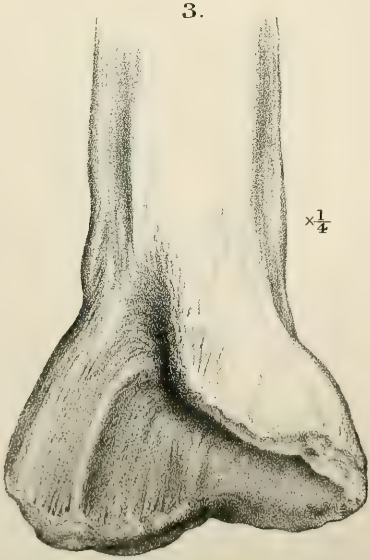

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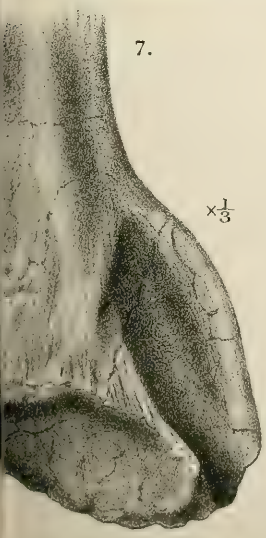

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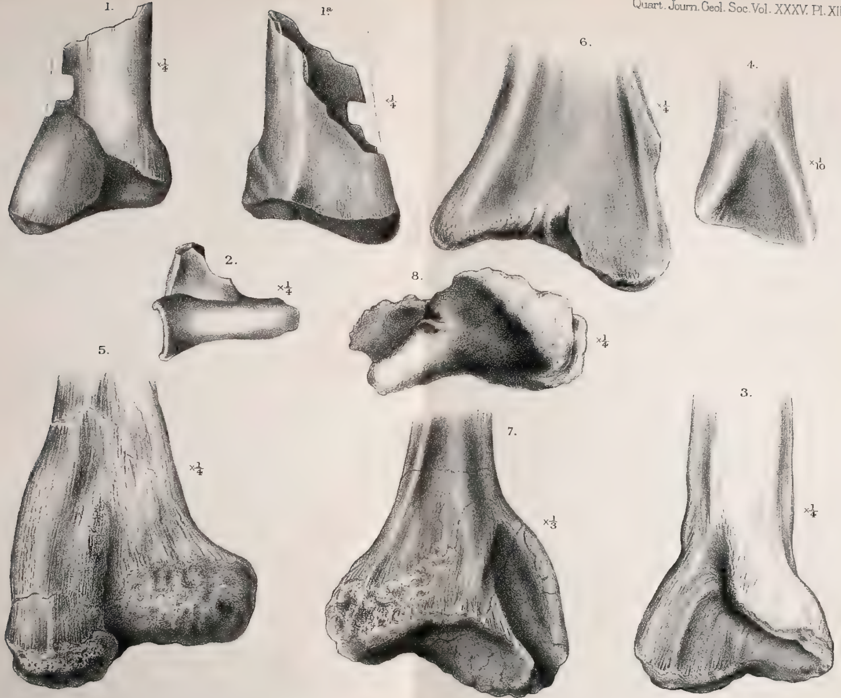
EGALOSAURS.



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LIMB-BONES OF MEGALOSAURS.

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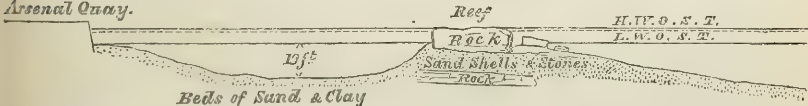
19. Notes *on the* Consolidated Beach *at* Pernambuco. By J. Clarke Hawkshaw, Esq., M.A., F.G.S. (Read January 8, 1879.)

The narrow ridge of rock which forms the seaward protection of the harbour of Pernambuco, and which appears to be the remains of a consolidated beach laid bare by the slow upheaval of the coast, has become almost as well worn a subject of discussion as the parallel roads of Glen Roy. A drawing was given of it in a Dutch work* as early as 1624, and many travellers have since described and figured it in their works. It has been called a coral reef, and has been described as consisting probably of cretaceous rocks, and it was not until after Mr. Darwin had visited it in 1836 that its true nature was pointed out by him in a short account printed in the 'London and Edinburgh Philosophical Magazine' for 1841.

The late Prof. Hartt, who has added so much to our knowledge of the coast of Brazil, confirms Mr. Darwin's view as to the nature of the reef, and describes several similar formations at various points along the coast†. At Porto Seguro there is a consolidated beach very similar to that at Pernambuco; there is also one at Santa Cruz. The stone reef shown on the chart at the mouth of the Rio Grande do Norte appears to be a consolidated beach, and patches of beach rock occur at other places; I saw some undermined by the sea along the rocky coast north of Bahia.

In 1874 I examined the beach at Pernambuco; and in the course of some investigations made for Sir John Hawkshaw in the following year for a report to the Brazilian Government on the Port of Pernambuco, a number of borings were made in the neighbourhood of the reef. Some of these passed through the reef itself, and they tend to complete our knowledge as to its extent laterally and beneath the surface.

Section opposite the Marine Arsenal, Pernambuco, at right angles to the "Reef."
(Horizontal scale, 1 inch = 500 feet. Vertical scale, 1 inch = 100 feet.)



Difference between high and low water, ordinary spring-tides, 7·3 feet (2·27 metres).

Briefly described, the consolidated beach (see fig.) consists of a ridge of sandstone from 25 to 75 yards broad, and, as shown by the borings, from 10 to 13 feet thick. The surface of the rock has a gentle slope towards the sea, the higher or landward edge being at the

* 'Reys-boeck van het Rycke Brasilien:' see 'Geology and Physical Geography of Brazil,' by C. F. Hartt p. 434.

† *Ib.* pp. 188, 189, 232.

same level as the high water of ordinary spring-tides opposite the Arsenal quay, falling from 2 to 3 feet below that level towards the lighthouse. Along the outer or sea face lie large blocks of the sandstone which have broken off as the reef has been undermined by the surf. The river flows along the inner or land face with a velocity at the ebb during spring-tides of from five to six knots an hour, and the bottom deepens rapidly from this face, there being a depth of 28 feet at low-water spring-tide at a distance of 60 feet from the rock. The rise of the tide at ordinary springs is 7 feet. Shells still preserving their colour and rounded quartz pebbles are scattered sparingly throughout the rock. The surface is in great part covered by a growth of *Serpulæ*, *Balani*, &c., and a calcareous coating described at length by Mr. Darwin. The rock is very hard, yet the pebbles which project in places unprotected by the organic covering show that it has been worn away by the action of the sea-water charged with sand. The organic covering, although softer than the rock, may be better able to resist this abrading action. A piece of lace when laid on the surface of a piece of glass will effectually protect the glass from the disintegrating action of the sand-blast machine, the result being that the pattern of the lace will be faithfully reproduced on the glass.

The surface of the rock is marked by grooves, which have been described by Mr. Darwin* as follows:—"There are also many sinuous cavities 2 or 3 inches in width and depth, and from 6 inches to 2 feet in length. The upper edges of these furrows sometimes slightly overhang their sides; they end abruptly, but in a rounded form. One of the furrows occasionally branches into two arms, but generally they are nearly parallel to each other, and placed in lines transverse to the beach sandstone ridge. I know not how to account for their origin, without they are formed by the surf, as it daily breaks over the bar, washing to and fro pebbles in depressions originally only slight. Opposed to this notion is the fact that some of them are lined with numerous small living *Actineæ*." I think the explanation suggested above as to the origin of the grooves is the true one, but that they were formed under different conditions of the reef, that is, when the surface was at a lower level than at present, so that the surface of the rock was in one plane with the surface of the foreshore. Under the present condition the pebbles, which are not abundant on the rock, would not remain long on the surface, and the action of the surf broken by the rough edge and fallen blocks on the seaward face would be very irregular. On the foreshore at Dover I have noticed grooves of a similar description in the surface of the chalk which has a regular slope from the base of the cliff to low-water mark. These may be seen below the Castle Cliff to the eastward of the last groyne in that direction. Beyond this groyne, which is a very high one, forming a jetty raised above high-water mark for a great part of its length, the foreshore pre-

* Phil. Mag. vol. xix. 1841, p. 258, and reprinted in Appendix to Darwin's 'Coral Reefs,' 2nd edit.

sents a very remarkable appearance when seen at the time of low water. The whole of the surface between high- and low-water mark is scored by a series of grooves parallel to the direction of the groyne and transverse to the shore-line. The shore is bare of shingle; but pebbles are to be found here and there along the bottom of the grooves, and there is a sprinkling of shingle about a yard in width along the side of the groyne and along the base of the cliff. The grooves on the higher part of the foreshore are from 2 to 2½ feet deep and about a foot wide; but lower down the foreshore they soon diminish in size, and do not vary much over the greater part of it, being from 4 to 5 inches wide, and from 4 to 8 inches deep. They are narrower towards the bottom, which is rounded and hollowed out more in some parts than in others. They branch into one another in places like those at Pernambuco. Though they are generally only a few inches apart, occasionally there is a greater width of chalk between them; and this is generally marked by an incipient groove a foot or two long with rounded ends, as if a piece of chalk had been irregularly scooped out with a gouge. The grooves diminish in number eastward of the groyne; and I have not noticed a similar appearance of the foreshore elsewhere, though grooves occur all along the foreshore, but at rare intervals, and are caused in many cases, I fancy, as much by the flow of land-water from the base of the cliff as by the action of the waves on the shingle. I can only attribute the presence of the grooves in such numbers at the above place to the regular action of the wash of the sea on a small supply of shingle, the groyne acting as a guide to the waves, and also intercepting the west to east drift which prevails along the coast.

It will be seen from the borings made at Pernambuco that there is another layer of rock about 8 or 9 feet vertically below the present ridge (see fig. p. 239). This rock was met with in two of the borings through the reef at depths of 13 and 16 feet below low water of spring-tides. Rock is again met with in the same line, and at a depth of from 16 to 19 feet below low-water spring-tides, at the Barra Grande, about a mile to the north of the lighthouse, which is built on the northern end of the reef. Rock was not met with elsewhere in any of the borings made in the neighbourhood of the reef*. It would therefore appear possible that there is another ridge of rock running at a lower level on the line of the existing reef. Can this be a consolidated beach of older date? The difficulty in the way of such a conclusion is that it would imply a recent depression in the level of the land, of which, I believe, there is no other evidence. On the contrary there are conclusive signs that the coast has recently risen in level, and that the southern part of the continent has been slowly rising for a long period of time. It would be remarkable,

* One other boring, made in deep water near the reef, touched on rock near the surface; but as no rock was met with in another boring made near the same place, the rock met with in the first instance was probably a block detached from the reef.

moreover, that at two periods, separated by the time required to change the level of the coast by the amount recorded in the vertical distance between the layers of rock, the conditions required to produce the consolidated beach should have obtained in the same place.

The cementing material of the Pernambuco rock is carbonate of lime. The rock is very hard, and when freshly broken it has a vitreous look. This is in a measure owing to the grains of quartz which with an occasional grain of magnetic iron ore make up the whole of the residue after the carbonate of lime has been removed by acid, being scarcely rounded, but having the original vitreous surface which they had when first liberated by the decomposition of the felspar in the gneiss from which they were derived.

On many parts of the coast of Brazil long ridges of sand occur, separated from the land by lagoons. The percolation of land-water charged with carbonic acid derived from the decayed vegetable matter in these lagoons through the sand ridges will account for the formation of the beach-rock, the water taking up and again depositing the carbonate of lime of the shells imbedded in the sand. The flood-level of the lagoon-water would determine the level of the upper surface of the beach-rock; and that of the lower surface would be determined by the cessation of the consolidating action at the level at which the sand was saturated by sea-water—that is, almost low-water level. Thus the regularity of the form of these reefs may be explained.

Consolidated beaches, however, occur in localities where there is little or no vegetation or land-water, as on the shore of the Red Sea, where I have seen beach-rock enclosing recent shells. So also on the Great Barrier reef, on the north-east coast of Australia, consolidated beaches are frequently met with. The sand is there often wholly calcareous, and when consolidated forms a very tough rock, which has been described by the late Prof. Jukes in his account of the voyage of the 'Fly'*. He attributes the formation of the rock on the coral reefs to the action of rain-water dissolving the carbonate of lime in the upper layer of coral sand and redepositing it lower down, the deposition ceasing at the level where the sand became saturated with sea-water. Prof. J. D. Dana, who describes the consolidated beaches which occur on many coral islands in the South Seas, attributes † the consolidation to the alternate wetting and drying of the sand by the rise and fall of the tide, the carbonate of lime being taken up by the sea-water and redeposited as the water evaporates. On some islands he noticed pebbles of basalt on the shore, each of which was coated with a white layer of carbonate of lime. Mr. Darwin saw somewhat similar deposits on the Island of Ascension‡. Prof. Dana also describes some drift-sand rocks on coral islands where hills of blown sand have been more or less consolidated by the agency of infiltrating water, "fresh or salt."

* 'Voyage of H.M.S. Fly,' vol. i. p. 128.

† 'Corals and Coral Islands,' p. 152.

‡ 'Voyage of the Beagle,' p. 588.

Thus it appears that beach-rocks are generally formed by the deposition of carbonate of lime; but this is not always the case. M. A. Papier has described* a rock, formed on the beach near Bona, of which the cementing material is a silicate. At that place he found sand and fragments of shells, and also a shingle of quartz pebbles, consolidated into a hard rock. The sand-rock effervesced slightly with acid, owing to the presence of fragments of shells; but the shingle-rock, which was exceedingly hard, showed no signs of effervescence whatever, and neither the one nor the other was disintegrated by the strongest acids.

The beach-rock at Pernambuco has probably not been exposed for a long period of time, there being unmistakable signs elsewhere of a recent elevation of the coast. Nevertheless it is remarkable that it should have resisted the sea for so long a time as it is known to have done. The port of Pernambuco owes its existence entirely to the presence of this narrow bar of sandstone.

Is it possible that these beaches mark periods of repose in the slow vertical movements which have occurred within recent times in the northern part of South America, as the successive lines of inland cliffs which divide the sloping shingle plains of Patagonia in almost unbroken lines for hundreds of miles have been shown by Mr. Darwin to mark, on a much grander scale, the periods of repose during the slow elevation of the southern part of the continent?

Discussion.

Prof. Duncan said that he thought geologists, as a rule, agreed that Prof. Dana's explanation of the formation of coral-rock was correct, though there might be exceptional cases. The amount of carbonate of lime introduced into these beaches was remarkable. The marine vegetation found at the bases of these rocks seemed to show that there was a considerable quantity of carbonate of lime in the sea-water. He thought, from the specimens on the table, that the author was right in assuming an upheaval. With regard to the grooves in the Chalk of the Kentish shore, noticed by the author, he had observed that waves meeting made lines of greater pressure, which seemed to correspond with these grooves. The case of the cementation by a silicate mentioned by the author was very interesting.

Sir John Hawkshaw had examined the reef, and, from its appearance, had conjectured it to be thin, which on boring proved to be the case. There are along the Brazilian coast, in some places, parallel ridges of sand at much the same distance from the shore as the reef. These did not appear to be yet solidified; but, under favourable circumstances, they might be. Behind some of these ridges were pools of water, in which are found shrimps which are different from those found in the adjoining sea, their antennæ

* Bull. de la Soc. Géol. de France, 3e sér. vol. iii. pp. 46–48.

being enormously long and their eyes much larger than in those found in the sea. The water in these pools was opaque, which might have led to the above singular differences.

The PRESIDENT asked if the author had ascertained the amount of carbonate of lime in the consolidated rocks.

The AUTHOR stated that he could not give the amount; but the cementing material in the specimens examined was wholly calcareous. Liais states that the cementing material in some of the beaches is partly calcareous and partly siliceous.

20. *On the* Triassic Rocks *of* Normandy *and their* Environments.

By W. A. E. Ussher, Esq., F.G.S. (Read May 22, 1878.)

Introduction.

Mr. Vicary's indefatigable zeal in the collection of specimens has attracted much attention to the lithological characters and fossil contents of the Budleigh pebbles. Being so different from those exhibited by Devonshire rocks (within the present limits of the country), the attention of geologists was divided between certain quartzites on the south coast of Cornwall, at the instigation of Mr. Peach, and the Grès de May, advocated by Mr. Salter, as the probable source of the pebbles. Mr. Davidson, however, subsequently pointed out the preponderance of Devonian forms in the pebbles; with his arguments and the inferences therefrom deduced I have dealt elsewhere*. It suffices here merely to state that the settlement of this vexed question induced me to spend part of my vacation in Normandy, after a careful perusal of M. Bonissent's excellent and exhaustive memoir on the Geology of La Manche†; and that, from a footnote to Mr. Salter's paper citing Mr. Godwin-Austen as to the occurrence of a similar Triassic quartzite gravel in Normandy, and from the personal observations of my friend Mr. Linford to the same effect, I was under the impression that the Norman area not only formed the south-eastern margin of our Devonshire Triassic basin, but that it would also furnish a sequence of deposits equivalent to the Upper and Lower Keuper of Devon, and, owing to the proximity of quartzite rocks, would probably afford a much greater development of the quartzite gravels which heralded the formation of the Keuper in South Devon.

M. Bonissent is dead, as I learned on my arrival at Carentan, so that I was unable to obtain any assistance in the investigation; and this was the more distressing as I am compelled on general grounds to dispute a very material observation made by him as to the occurrence of Grès bigarré (Bunter) at Montebourg. Limited time made my own observations so imperfect that I should have hesitated to question any assertion made by M. Bonissent, were it not that in this instance the absence of any corroborative statement renders the matter an open question for solution.

In the following pages I shall have occasion frequently to quote M. Bonissent's work, which remains a marvel of persevering energy, close observation, and exhaustive detail. Nor is it extraordinary that amidst so vast a field of labour, the fragmentary exposures of the Triassic rocks of La Manche should be relegated to so small a space as six pages (pp. 267–272). What I shall endeavour to prove

* Trans. Dev. Assoc. for 1877, p. 224.

† "Essai Géologique sur le Département de La Manche." Extrait des Mémoires de la Société des Sciences Naturelles de Cherbourg et d'Avranches.

in this paper may be succinctly stated in the four following propositions:—

1. That the Triassic rocks of Normandy are a south-easterly prolongation of the Devon and West-Somerset area, and bear somewhat the same relation to it as the Marls and Dolomitic Conglomerate of the Mendip area.

2. That Keuper deposits alone are represented in Normandy, and apparently only the upper stage of that division.

3. That from the foregoing considerations &c. there are strong grounds for concluding that fragments of the Norman palæozoic rocks were never incorporated in the Triassic strata of Devonshire.

4. That the constitution of the coasts of Normandy, Devon, and Cornwall is such as to justify the belief that varieties of Cambrian, Silurian, Devonian, and granitic rocks formed the bed of the Triassic waters in the area now occupied by the English Channel, and that to these sources fragments in the Trias of Devon, foreign to its soil, are to be attributed.

The grounds on which I venture to propound these statements being, in many instances, common to more than one of them, it is not possible in every case to deal with the evidence for the propositions seriatim, without including under one head arguments applicable to others.

First Proposition.

The first proposition does not admit of positive proof, but is put forth on the strength of certain considerations and analogies, as follows:—First. The thickness of the Trias, with few local exceptions, steadily increases from the Mendip area southward till its maximum, so far as can be observed, is attained on the South-Devon coast; so that it is likely that the prolongation of the formation would exhibit a still greater development in the area of the English Channel.

Secondly. Fragments derived from sources foreign to Devon and Somerset appear in the gravelly beds of the Trias near the southern shores of the former county, preponderating at the expense of local materials from about twenty miles inland, till, on reaching the seaboard, a maximum increase is exhibited. This seems to favour the idea that Triassic sediments not only extended far into the Channel area, but were there to a great extent formed from rocks different in character from those met with in Devon, and, in some cases, of older date than any to be found in the south-western counties. As, from the Budleigh-Salterton pebbles, we must conclude that Silurian and Devonian quartzites (and, not improbably, Cambrian strata) furnished material, either directly or, in part, in the form of palæozoic conglomerates *, one not unnaturally turns in the direction of the nearest land where similar rocks occur, not necessarily in the hope of finding a direct source, but of obtaining indices of the proximity of similar sources in the bed of the intervening Channel. Hence,

* Mr. H. B. Woodward suggests that a conglomerate of Devonian age would furnish the requisite material.

finding some rocks in Normandy identical in lithological characters, and accompanied by beds of Triassic age, I am led to infer that the Triassic strata of France and England were connected, and that the French Palæozoic rocks stretched far into the Channel from the Norman coast.

Thirdly. As the Mendip area acted as a barrier between the midland and south-western counties until the Upper Keuper waters of both were united, there is no reason for supposing that a similar extension may not have caused the union of the Trias of England and France, even though a barrier existed in Normandy representing the extreme south-eastern margin of the English Trias. Points of analogy are furnished by the local variations of the attenuated sediments in both areas, namely, in the Dolomitic Conglomerate of the Mendips and the small quartzite gravels of Normandy.

Second Proposition.

The second proposition brings me to the facts of this paper, namely, the actual nature of the Norman Trias and its environments. I shall only deal at length with the department of La Manche, as the major part of the Trias is contained within its limits, and as the same rocks in Calvados, directly subjacent to the *Infralias*, and dotted by its outliers, would furnish very little additional evidence.

La Manche is divided into two distinct physical regions:—The Bocage, a plateau between Granville and Villedieu, from 490 to 650 feet above the sea, formed of granitoid rocks, grits, and diverse schists, stretching to the north of the peninsula; and the Cotentin, only from 80 to 100 feet above the sea, which includes the rich country between Valognes and Le Petit Vey, called "the Gulf of Cotentin," where formations from the Coal-measures up to Recent beds are found resting on more ancient rocks whose summits may be seen here and there*.

"The secondary area is bounded on the east by the sea, on the north by Cambrian and Devonian rocks, on the west by Devonian, Silurian, and (in one place) Carboniferous strata, and on the south by Cambrian rocks;" "it is composed of Triassic, Liassic, Cretaceous, Tertiary, and Recent formations†," to which we may add the Oolites of Calvados. In La Manche the Secondary area may be roughly estimated at 380 square miles; of this, however, a considerable portion consists of alluvial flats; and the Triassic rocks, where uncovered by the Infralias, are seldom visible, owing to the thickness and extent of the diluvium; the Triassic districts lie towards the north, west, and south of the Secondary area, and extend nearly as far as Bayeux in the department of Calvados. The Trias is composed of quartzite gravels and conglomerates, sandstones, rock-sand, and marls. The distribution of these components seems to have been much influenced by proximity to local and variable sources of supply. The absence of any detailed section of the deposits from top to base renders even the assignment of a general order of suc-

* Bonissent, *op. cit.* p. 6.

† *Ibid.* p. 264.

cession doubtful. In La Manche gravels and sandstones seem to be generally uppermost.

Commencing in the north of the district with Valognes as a starting-point, the succeeding sections will show how inconsiderable is the thickness of the Trias in that part of the area.

Section I. (fig. 1). From Valognes by Huberville and St. Martin d'Audouville to Crasville.—The town of Valognes is situated on Infralias limestones, exposed in quarries in some places to a depth of 40 feet. The first valley, crossing the road along which the section is taken, exposes whitish sand under greenish marl, mottled with red, overlain by Infralias, which appears to be the subsoil nearly as far as the turning to St. Germain-de-Tournebut. In quarries near Huberville the *Pecten-valoniensis* beds are present; the rock presents a somewhat concretionary structure and rubbly bedding; it is overlain by diluvium 10 feet thick, consisting of drab and brown sandy clay, with occasional quartzite pebbles and fragments of the subjacent rock. Another set of quarries, further east, show 5 feet of similar diluvium on 8 feet of Infralias, composed of:—

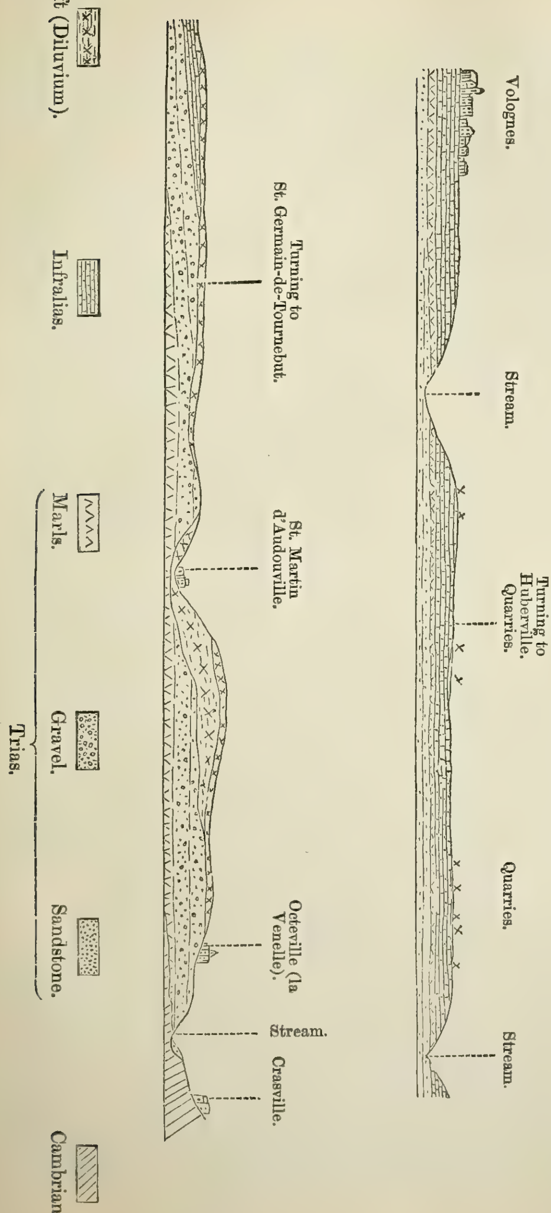
1. Thin rubbly limestones overlain by diluvium.
2. Whitish and grey limestones.
3. Grey shaly clay and tough impure yellowish and grey limestones.

The beds appear to be horizontal. *Pecten valoniensis* is present. The next valley toward St. Germain-de-Tournebut may have been cut through to the Trias, if traces of greenish and bluish-grey clay can be taken as evidence of the proximity of that formation. Near the turning to St. Germain-de-Tournebut, gravel of quartzite and grit pebbles in coarse yellowish-brown sand, apparently in part composed of flint, covers the surface; toward St. Martin d'Audouville this gravel gives place to gravel of irregular quartzite and quartz pebbles, generally small, but occasionally of fair size, in coarse yellowish-brown sand, in parts of which the pebbles are very sparsely disseminated. The distribution of these materials is as perfect an index of bedding as that exhibited by many of the pebble-bed sections in Devonshire.

I regard the bedded gravel as Triassic, and that previously mentioned as composed of redistributed material, for the following reasons:—First. Silurian quartzites are exposed at the surface not far to the southward, and pebbles of quartzite occur in the drifts covering the Infralias, which are probably represented by the first-mentioned gravel near St. Germain-de-Tournebut. Secondly. The bedded gravel occurs in a place where Trias might be expected; for, had the Infralias continued beyond the turning to St. Germain-de-Tournebut, one would expect to find less quartzite and more local fragments in the overlying drifts. Thirdly. From the proximity of Silurian quartzites the Triassic beds might naturally be expected to take the form of gravels, and the drift upon them to be largely composed of their redistributed materials, as if directly derived from the Silurian the pebbles would be less worn.

By the Chemin Vicinal, south of St. Martin d'Audouville, gravel

Fig. 1.—*Section from Valognes by Huberville and St. Martin d'Audouville to Crasville.*
(Horizontal scale, 1 inch = 1025 metres = 1121 yards. Relative sketch contours, 1 inch = 400 feet vertical.)



(apparently a redistribution of the Trias) is overlain by coarse buff quartzose sand, with patches of bluish lead-coloured clay in places. The whole seems to attain a thickness little short of 100 feet. The clay may have resulted from the destruction of Infraliassic outliers.

On ascending the hill from St. Martin d'Audouville toward Octeville a similar dark-coloured clay is irregularly associated with sand and gravel, the whole being overlain by brownish earthy diluvium covering the high ground. These deposits appear to me to represent the *Diluvium gris* and *rouge* respectively.

Toward Octeville, with the descent of the ground, a yellowish-brown quartzite gravel makes its appearance, being exposed near the village to a depth of 10 feet. Proceeding from Octeville (la Venelle) to Crasville, similar quartzite gravel associated with sand is exposed to a depth of 15 feet; on the further side of the valley the gravel is associated with buff sand, and seems to rest on the Palæozoic rocks which are exposed in quarries at Crasville and at about a quarter of a mile to the north of it. From the presence of an Infraliassic outlier at Octeville*, I regard these gravels, as well as those near St. Martin d'Audouville, as the uppermost beds of the Trias.

By the road leading south-east from Octeville, within a quarter of a mile of the village, brown gravel, either Trias *in situ* or redeposited, overlies red and grey marl resting on whitish rock-sand, overlying, and apparently passing into, quartzite gravel in buff sand exposed in a pit to the depth of 10 feet.

Quitting this road and following a by-lane leading southward, parallel to the stream (towards Lestre), Triassic rocks appear to be subjacent, faint indications of quartzite gravels and marl being sometimes met with in the loamy drift-soil. By the road to Lestre, which crosses this stream, and at a point about 500 yards from the village, the Trias appears to be represented by coarse whitish sand-rock with occasional small pebbles and quartzite gravel.

On the south-east of the village, by a semicircular by-lane, a quarry, 6 feet in depth, exposes irregular rubbly beds of greyish marlstone with carbonate of lime disseminated throughout; the rock seems to be quite devoid of fossils, and weathers in rugged corrugations.

This variety of the Trias appears to be very local, and not much to exceed the exposed 6 feet in thickness.

It is mentioned by M. Bonissent, who described the Lias of Lestre†, as follows:—"Here calcareous greyish quartzose sandstones appear under the Diluvium; they are often red or amaranthine in colour, micaceous, and more or less solid, sometimes friable: they rest on a compact limestone of violet, reddish, and yellowish hues. In some of these rocks, particularly where the calcareous element predominates, little geodes lined with white crystals of carbonate of lime occur; the rocks are often full of cavities giving them the aspect of

* "Les petits ilots de Videcosville, Octeville la Venelle et St. Germain-de-Tournebut voisins du massif de Valognes." Bonissent, *op. cit.* p. 275.

† Bonissent, *loc. cit.* p. 267.

a cavernous millstone." From this it appears that the Lestre marlstone underlies the sand-rock and gravel previously noticed.

Speaking of the Infralias of Valognes and Yvetot, M. Bonissent says*, "The last bed, called 'marlière' by the quarrymen, is composed of greyish limestone feebly cellular, unfossiliferous, and of crystalline texture." I quote this, as it appears from the description to present much analogy to the rock just described at Lestre.

Section II. (fig. 2).—Returning to Valognes and following the highroad thence to Pont-à-la-Vieille (in the direction of Cherbourg), the Trias crops out from beneath the Infralias at about 1100 yards from Valognes. The scanty surface-evidence seemed to indicate marls under the brown diluvial soil, but so feebly that it may be only a bed in or on sandstone. Approaching Pont-à-la-Vieille, the base of the Trias resting on Devonian schists appears to consist of whitish sands. M. Bonissent mentions † the occurrence of white (*polygénique*) calcareous sandstones resting on compact, violet, reddish, greyish, and yellowish limestone at Pont-à-la-Vieille, Fosse Prémesnil, and Croix Morville; the latter localities I was unable to find. This shows, however, that in the north of the area marlstones were not unfrequently amongst the earliest Triassic sediments deposited, probably owing to the local development of Palæozoic limestones.

Proceeding from Valognes westward to the viaduct of Pont-de-Six, north of Négreville, hard whitish calcareous sandstones are shown in a pit near the railway-station. M. Bonissent ‡ says that fine-grained very solid calcareous sandstones mottled with various tints are shown at Valognes. As Infralias is extensively quarried near Valognes Station, the beds immediately underlying it would appear to be arenaceous, possibly separated from it by a thin stratum of marl: on the whole, however, I am inclined to regard the lithological varieties of the Trias of the Valognes district as interchangeable.

Section III. (fig. 3).—By the road to Pont-de-Six, at about a mile and a quarter from its junction with the Infralias of Valognes, the Trias consists of gravel and sand exposed in an extensive, though shallow, pit on the south side of the road. Subjoined (fig. 4) is a section of one part of the pit where it is 4½ feet in depth. In other parts of the pit the gravel is false-bedded, containing incipient bedding-courses of sand or pebbles; it appears to rest on sand, and in parts to be replaced by it. Taking all parts of the pit together, about 15 feet of gravel and sand are exposed. The character of the whole forcibly reminded me of sections of the Devon pebble-beds near Aylesbeare, Tallaton, and Kentisbere, where the larger pebbles are absent, the irregular association of sand, incipient indications of bedding, occasional false-bedding, and in many cases similar light tints being common to both; but the analogy ceases here, as the Devon beds occupy a much lower horizon than those of Normandy.

Although very unsatisfactory, the evidence obtained in proceeding from the gravel-pits towards Pont-de-Six leads me to regard the subjacent rock as marl upon which traces of gravel, Triassic or derivative, seem to rest in one or two places.

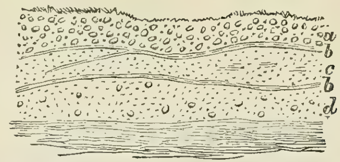
* *Op. cit.* p. 276. † P. 267. ‡ P. 267.

Fig. 2.—*Section from Valognes to Pont-à-la-Vieille.* (Scale as in fig. 1.)

For explanation, see fig. 1.

Devonian.

Fig. 4.—*Gravel-and-sand Pit west of Valognes, north of Yvetot.* (Scale, 1 inch = 8 feet.)

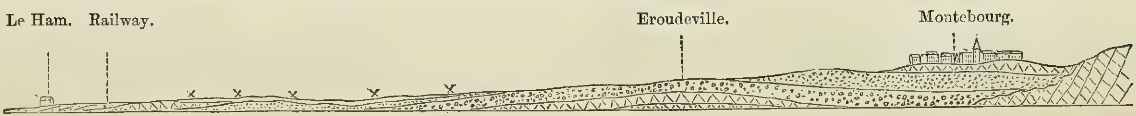


a. Coarse buff-brown sand, full of small quartzite, grit, and quartz pebbles.
b, b. Irregular seams of light greenish clay.
c. Light buff-brown sand, with occasional incipient laminæ.
d. Olive sand, with occasional small pebbles.

Fig. 3.—*Section from Valognes towards Pont-de-Six.* (Scale as in fig. 1.)

Explanation as in figs. 1 & 2.

Fig. 5.—*Section from Montebourg to Le Ham.* (Scale as in figs. 1, 2, and 3.)



For explanation, see fig. 1.

Silurian.

In the railway-cutting at Pont-de-Six about 15 feet of whitish sandstone forms the base of the Trias upon the older rocks. M. Bonissent* mentions the occurrence of a limestone, sometimes fragmentary, sometimes solid, at Pont-de-Six exhibiting very vivid and various tints, and regarded by him as identical with the limestone of Fosse Prémesnil. Consequently limestone or marlstone seems to occur in the Trias near its western margin, from Pont-à-la-Vieille to Pont-de-Six; and still further, if La Croix Morville (where a similar bed has been noticed) lies within Morville (an adjacent commune to Négreville on the south-east), or is a synonym for La Croix des Auneys of the same neighbourhood in the commune of Magneville. Southward from Valognes to Lieusaint, where an inlier of Silurian rock occurs, the Trias near its junction with the Infralias, judging from indications by the railway, appears to consist of marls and whitish sandstone, the latter probably uppermost.

By the highroad from Valognes to Montebourg drifts conceal the subjacent rock. Between St. Cyr and Montebourg Silurian quartzite is exposed in a quarry by the highroad, forming the corner of a large inlier extending thence to Quinnéville on the east coast. Near its junction with the Silurian on the north of Montebourg the Trias appears to consist of marl. Near Montebourg, by the highroad to Carentan, yellowish-brown sandy soil with quartzite pebbles covers the surface, being probably to a great extent a redeposit of Triassic sands and gravels which may be concealed by it.

Section IV. (fig. 4).—By the road from Montebourg to Le Ham Station, near the former, beds of coarse light brownish sand-rock dip to the north at a small angle. At Eroudeville a pit by the road shows 8 feet of coarse yellowish-brown sand with small irregular quartzite pebbles exhibiting traces of bedding. A similar gravel, as I was informed, is worked near St. Cyr; indications of it were noticed at about 1100 yards to the south of Eroudeville: from this point to Le Ham Station no evidence is obtainable, owing to the covering of drift-soil. At Le Ham Station, however, red marl is exposed very near the Infraliassic junction. Proceeding along the railway from Le Ham toward Flottemanville, whitish sand-rock, apparently Triassic, is exposed in one or two places. From these observations I am inclined to regard the Trias of Montebourg and Valognes as occurring in the following descending order:—

1. Thin deposit of red marl under Infralias.
2. Whitish sands passing into, or replaced by, pebble-gravels.
3. Red marls, possibly alternating with, and resting on, sandstones.

M. Bonissent, however, who had much more ample opportunities of studying the district, states† "that the grès bigarré rests on inclined Silurian rocks at Montebourg, and disappears in other directions beneath the Keuper and Lias." He describes it as composed of very fine and medium-grained *métaxites* (an untranslatable term likewise applied to a variety of Cambrian rocks, p. 136; a species of sand or sandstone is meant) alternating with thin beds of whitish

* *Op. cit.* pp. 267, 268. † P. 266.

and greenish clay. In the upper part the rock sometimes passes into a quartzose puddingstone. Its structure is often massive in the lower beds, sometimes becoming shaly toward the surface. The sandstones (*métaxites*) are slightly micaceous, of a dirty white colour, very rarely exhibiting rose-coloured or bluish tints. No traces of animal remains were obtained; but fragments of petrified trees were found lying horizontally in the middle of the sandstones (*métaxites*) in the commune of Eroudeville near Montebourg; they measured from about 6 to 10 metres* in length by 20 centimetres to 6 decimetres † in diameter: the species were indeterminable.

If these beds are really Bunter, a very great unconformity, eliminating not only the Muschelkalk (*calcaire coquillière*) or its equivalent, but also the whole of the lower and much of the upper Keuper series, could alone account for its occurrence. I think, however, that the correlation can be successfully disputed upon the following grounds:—

First. The thinness of the Trias at Montebourg, as the distance from the Infraliassic margin on the south to bare Silurian rocks on the north does not exceed 3 kilometres (3300 yards).

Secondly. The similarity of the deposits to those already described in the neighbourhood of Valognes, and hereafter to be noticed in the environs of Carentan.

Thirdly. The impossibility of drawing hard lithological boundaries in a district where the constitution of the beds is so variable from local derivation, as M. Bonissent's observations prove the Keuper deposits to be.

Fourthly. The absence of all mention of unconformability in M. Bonissent's account.

Fifthly. The excessive improbability of the existence of unconformity in the attenuated Triassic rocks of Normandy, and the absence of any circumstances favourable to its occurrence in the neighbourhood of Montebourg.

At Mont Busnon in St. Cyr branches of trees were discovered in diluvium covering "New Red Sandstone (Keuper)"‡. It is a curious coincidence that arboreal remains should occur in the same district both in diluvium and Trias. I did not visit the Triassic districts on the west of the railway between Négreville and Carentan. The fragmentary nature of the exposures of the Trias of that neighbourhood may be gleaned from the following.

Between Urville and Orglandes, at Cauquigny, Picauville, and from Cretteville to Baupte, the Trias is covered by Infralias §. At Gourbesville, Orglandes, Hauteville, Biniville, and Reigneville Cretaceou deposits occur, and rest directly on Palæozoic rocks at Néhou, Golleville, La Bonneville, and Crosville ||. Eocene beds are spread over the communes of Gourbesville, Hauteville, St. Colombe, Néhou, Reigneville, Crosville, and La Bonneville: Lower Miocene is represented at Rauville-la-Place, and Upper Miocene in the communes of

* Roughly speaking, from 20 to 33 feet.

† Roughly speaking, from 8 inches to 2 feet.

‡ Bonissent, *op. cit.* pp. 393, 394. § *Ib.* p. 275. || *Ib.* p. 310, &c.

Gorges, Gomfreville, Nay, St. Germain le Vicomte, Bohons, St. Eny, and Auxais. Pliocene marls occur at Marchesieux, Feugères, and St. Martin d'Aubigny*. Diluvium is developed at Raids and St. Sauveur (Le Vicomte) sur Douve†; it covers all the communes on the west bank of the river Elle, Beuzeville les Veys, and Brevands; and occurs at Dézert and St. Jean de Daie‡. On the south and west of Carentan, the plateau of Anvers, Méautis, the Bohons, and St. Eny is covered by diluvium which descends the slopes to the marshes (alluvium) of the river Taute. In this district it is said§ to be from 330 to 1640 feet thick (100 to 500 metres).

As diluvium also occurs at St. Jores, Vindefontaine, Etienville, Picauville, Rauville-la-Place, and other localities, the evidence of Trias in this part of the area must be very meagre indeed.

I will now proceed to quote all the facts mentioned in M. Bonissent's work with reference to the occurrence of the Trias in this complicated area.

Approaching l'Étang-Bertrand the Devonian is visible here and there beneath the rolled stones of the Keuper; from this hamlet it follows both banks of the river Douve, returning by the right bank towards the farm of Banoville, &c., after having previously traversed Rouge Bouillon and Loraille in Bricquebec and Négreville, but in this course it is often hidden under the Marnes irisées ||.

The next notice¶ of Triassic deposits is at a considerable distance to the south of the above. Going from Périers to Pont Labbé reddish or lilac clays of the Trias, alternating with clays of a whitish or greyish hue, have been observed at St. Germain le Campagne (le Petit) south of Plessis. At Nay, on the road to Périers, and near a windmill and watermill, a reddish-brown quartziferous and calcareous rock, belonging to the Trias, covered by pebbles and red marls (redeposits of the same formation), was discovered under the Pliocene formation**.

Raids Church is on Diluvium; but in following a small tributary of the river Sève for some distance from it Trias was met with, represented by sandstones alternating with shaly marls, both being mottled red and greenish.

From these observations it would appear that the Trias of this part of the area is composed of the same general sediments as elsewhere, but varying a little in character and mode of arrangement from local causes.

District South of Carentan.—Near the church of St. Eny††, in the commune of St. Georges de Bohon, and at the farm of La Joubardière‡‡, near Carentan, the diluvium does not appear to have been penetrated in wells sunk to a depth of nearly 33 feet; but in these localities§§ it descends from the hill-top to the marshes of the rivers Taute, Douve, Sève, and their tributaries. Nevertheless whitish and greyish sandstones, sometimes calcareous, were noticed by M. Bonissent to the south of Carentan||||, and considered by him to

* Bonissent, *op. cit.* p. 323, &c. † *Ib.* p. 383. ‡ *Ib.* p. 387.
§ *Ib.* pp. 389, 390. || *Ib.* p. 243. ¶ *Ib.* p. 260. ** *Ib.* p. 268.
†† *Ib.* p. 391. ‡‡ *Ib.* p. 390. §§ *Ib.* p. 389. |||| *Ib.* p. 269.

be continuous with similar beds in Carentan canal, and analogous to those under the Diluvium in the commune of Lestre*.

Carentan is built for the most part on diluvial débris, which nearly everywhere covers the Keuper; some houses are, however, situated on Keuper rocks, which in places stain the soil. Reddish and grey, or whitish and calcareous, sandstones are frequently visible in some spots. They contain mica and débris of rose-tinted felspar, and are for the most part stained by red marls. Under these lies a conglomerate, composed of a calcareous sandy clay paste enclosing fragments of red or greenish marls, quartz, quartzite, and various other rocks. This conglomerate sometimes assumes a slightly honeycombed (lit. rotten) appearance, where the marl fragments have been dissolved out of their cavities. These different rocks constitute the bottom and sides of the canal which leads from the port to the sea†.

In walling Carentan quay basin in 1845 a hard white rock was encountered under about 26 feet of alluvial and estuarine deposits associated with peat‡; though not further commented on, it appears as if the Trias had been reached.

I was unable to find the locality of the quarries of l'Eau Parti; it is probably somewhere near the confluence of the streams on the south and east of Carentan. The following section of the quarries is given by Bonissent§:—

1. Gravel and clays, old alluvia.
2. Quartzo-calcareous (polygénique) puddingstone with feeble traces of manganese.
3. Hard red marl mottled white.
   Under the puddingstone a greyish sandstone, sometimes slightly calcareous, is visible.
4. Calcareous (polygénique) sandstone.
5. Very solid, hard red marl.

To the east of Carentan the Keuper is well developed in the communes of St. Hilaire, Catz, Beuzeville-les-Veys, &c. It is represented to a depth varying from about 3 to 65 feet by very compact greyish (polygénique) calcareous sandstone and conglomerate quarried for building-purposes‖. In the quarries of Chapelle St. Nicholas (Beuzeville-les-Veys) very compact variegated Keuper marls, sometimes shaly, are overlain by grey diluvium of pebbles and sand¶. At a place called Le Cavé, to the east of the church of the commune of Catz the same compact greyish calcareous sandstone above mentioned occurs.

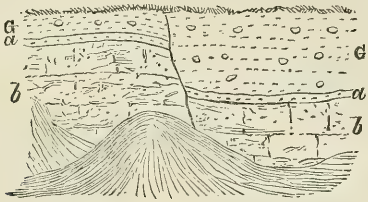
M. Bonissent remarks** that of all the localities he had visited the succession of the Keuper beds can be inferred only from the quarries of Montmartin en Graignes, worked for building-purposes from time immemorial. At Carentan, judging from inquiries made on the spot, these quarries appear to be almost unknown. I only succeeded in finding a few shallow pits by repeated inquiries at the houses *en route*. I cannot believe that M. Bonissent's section was

* Bonissent, *op. cit.* p. 267. † *Ib.* p. 268. ‡ *Ib.* p. 412. § *Ib.* p. 269.
‖ *Ib.* p. 269. ¶ *Ib.* p. 387. ** *Ib.* p. 269.

taken from these pits, but think that the quarries have been disused, and may be situated at or near the village of Montmartin-en-Graignes, whilst those I visited are more than two miles to the westward of it, near the hamlet of Le Cap.

Of the four pits noticed in the last-named locality, one gives the following section (fig. 6):—

Fig. 6.—*Sand-pit near Le Cap in Montmartin-en-Graignes.* (Scale, 1 inch = 20 feet.)



G G. Brown loam with irregular pebbles of quartzite and grit dispersed throughout.
a a. Greenish sand-bed.
b b. Tough, coarse-grained, whitish sandstone, with occasional pebbles often of clayey material.

The beds are displaced by a fault with a downthrow of about 6 feet, also affecting the diluvium.

Another pit shows:—

2 feet of red and grey clay, with sandy concretions, on light greenish sandstones of unequal durability, the harder portions exhibiting more even bedding; exposed to a depth of 8 feet.

Of the two remaining pits, one exhibits the following section, about 20 feet in depth:—

1. Soil with pebbles.
2. Ochre and grey-coloured sand with concretions of a conglomeratic character.
3. Light greenish-grey, coarse, tough sandstones, containing a marly seam near the base of the section.

Not far to the westward of the above pits, a well in course of construction in a farmyard, at the hamlet of Le Cap, showed red marls by its sides as far as visible, and the stuff thrown out and piled round its mouth was of the same character. The surface soil was sandy. The workmen informed me that 60 feet had been sunk through the marls without bottoming them. In a field adjoining, about 3 feet of loose surface sand of a greyish colour was observed, probably the redistributed relics of sand-beds on the marls, and formerly continuous with those exposed in the pits; so that the latter appear to rest directly on marls or to pass into them through dovetailing or intercalation.

In the lane to Deville, a hamlet near Le Cap, reddish and brown sand-rock is exposed; its junction with the marls of Le Cap is not shown, but it appears to rest upon them at Deville.

To the north of Deville 14 feet of gravel are exposed in a pit; it consists of irregular quartzite pebbles, mostly small, exhibiting in places a rough indication of bedding, in the arrangement of the stones in lenticular seams with regard to gravity. In one part of the pit an irregular seam of grey sand is shown. The matrix of the gravel is a reddish-brown loam, earthy, and with fewer stones in the upper part. I cannot tell whether this gravel is of Triassic age or a redeposit of subjacent or preexistent Triassic gravels. In either case it seems to show that in this, as in other parts of the area, gravel formed part of the latest Triassic deposits.

At Clist Williams Farm and the Blue Anchor Inn, north of Talaton, in Devon, gravels with argillaceous matrices rest on the lower marls (or Middle Trias). In general character the pit sections are very similar to that at Deville, and the same uncertainty prevails as to whether they are redeposited Trias or *in situ*.

The following is M. Bonissent's section* of the general succession of beds in the quarries of Montmartin-en-Graignes (the first seven beds are referred to the diluvium):—

1. Yellowish or whitish fine-grained sand, alternating with rolled stones of various sizes.
2. Conglomerate with siliceous matrix.
3. Reddish, greenish, or white-and-yellow mottled clays, with or without rolled stones.
4. Compact marls of various colours with occasional veins of yellowish-white sand.
5. Whitish micaceous sands.
6. Fragmentary Magnesian Limestone of various colours.
7. Sands and clays.

Below this, divesting the section of all minutiæ, the general succession would be:—

8. Conglomerates, occasionally very calcareous in the upper parts.
9. Grey calcareous sandstones.
10. Light-coloured sandstones, partly calcareous, occasionally conglomeratic.
11. Hard marls, red, or banded with other tints, containing in the lower part impure limestones.

The thickness of the whole section is about from 77 to 80 metres (roughly 250 to 260 feet).

Although cumbered with minute description, this section is very unsatisfactory in essential points. We are not told how much of the 77 to 80 metres is taken up by the diluvial deposits; and judging from their thickness on the south of Carentan, no more than 60 feet of Trias may be described.

The relative thicknesses of the conglomerates, sandstones, and marls, particularly of the latter, have been unfortunately omitted.

Department of Calvados.—Judging from Knipe's geological map, the Trias does not extend more than five miles into Calvados from Littry—that is, for about fourteen miles eastward of the confines

* Bonissent, *op. cit.* pp. 269–271.

of La Manche, near Beuzeville-les-Veys and Montmartin-en-Graignes. In this extension it is bounded on the north by Liassic districts, and on the south by the Palæozoic area. Knipe's map gives its breadth, south from Isigny, as nearly six miles, and north of Littry as nearly three miles; on the west of Littry two (Infra) Liassic outliers are shown; and three, apparently Carboniferous, inliers are indicated between the same village and Trévières to the north of it (some miles off).

I drove out from Bayeux for fourteen kilometres along the road to St. Lo, stopping to examine all the sections visible *en route*; then turning northward, returned to Bayeux by a road nearly parallel to the railway on the north side, having almost crossed the Triassic area from south to north. The following are the observations made in this circuit:—On the road to St. Lo, near Sables, a large quarry exposed (Infralias) limestones, whitish and arenaceous in the upper, bluish and even-bedded in the lower part of the quarry, and alternating with thick beds of dark bluish clay.

In a small pit near the hamlet of Agy red marly clay mottled with grey, apparently the soil of Triassic marls, seemed to be faulted against Lias.

By the road from Bayeux to St. Jean de Daie, on the north side of the road, at a point to the north of Campigny, 12 feet of soft buff sand with small quartzite pebbles was noticed; chalk or decomposed flint appeared to be amongst the ingredients. Near this a pit by the road displayed about 15 feet of buff and yellowish sand, stained reddish by ferruginous infiltration in irregular bands; no pebbles or coarse materials were present. The section strongly reminded me of some Upper-Greensand exposures on the Blackdown Hills. This sand may possibly be of Triassic age, or a redeposit of Triassic sands, though both sections might be referred to the grey diluvium of La Manche in the absence of corroborative evidence.

In an extensive brick- and tile-yard to the south of the railway, near La Mine, I recognized a large pit of marls, red, with greenish mottling, and passing upwards into a sandy clay used for the manufacture the bricks and tiles, and just the same in character as the upper marls of Somerset in the brick-pits of Taunton and Wellington. This marl seemed to rest on the Palæozoic rocks of the valley of the river Merdillon, which are Carboniferous, according to Knipe.

From this point northward the ground descends to extensive flattish alluvial tracts concealing much of the Triassic area to the north of the railway.

The road to Bayeux, to the north of Saon, appears to be covered by diluvium, apparently in part resulting from the redeposit of Triassic gravels and marls, and containing fragments of flint towards Bayeux.

Mr. Linford, of Exeter, to whom I am much indebted for verbal information, copied out and sent me all the extracts bearing on my subject from a correspondence he had kept up with a friend at Caen. From these I select the following notes:—

"Deposit of May gravel near Evrecy, where it is capped by Lias."

"This gravel resembles in every particular the beds between Tamworth and Lichfield (Warwick) laid down by Murchison as Dolomitic Conglomerate." "We have no gravel-beds near Caen, nor even near May."

"M. de Caumont says the Evrecy beds belong to the upper part of the New Red Sandstone, and have great development in the Cotentin."

I have traversed the country on foot from Caen to Evrecy, thence to May, and back to Caen without finding any indication of Trias. Evrecy is on the Oolites.

The locality specified as "near" it may be some miles off, Knipe's map being worthless, except as a general index of the lie of the rocks. The note is important as bearing on the probable termination of the Trias eastward, and as confirmatory of the idea that the sands to the north of Campigny were derived from Triassic sands underlying pebble gravels near Evrecy, and overlying marls towards La Mine.

The foregoing quotations and observations lead to the following inferences:—

First. That the Trias of Normandy is much more variable than its equivalent in Devon and Somerset, owing to the greater variety of Palæozoic rocks furnishing its materials. For instance, Silurian and Cambrian quartzites would afford material for gravels and conglomerates; the further comminution of the same strata with their associated slates and schists and Devonian grits &c. would produce the sandstones and sands, becoming more or less calcareous, and locally exhibiting the characters of a limestone, according to the local prevalence of Palæozoic limestones, as, for instance, the Cambrian limestones of St. Clair, St. Jean de Daie, Meauffe, Bahais, Cavigny, Airel, &c., all lying to the south of Carentan. The further comminution of schists, slates, shales, and limestones would favour the deposition of marls.

Secondly. The general sequence of deposits appears to be pebble-beds and conglomerates, passing into and resting on sandstones, generally overlying marls, the latter being locally developed on different horizons, or, in other words, the constituents of the Trias being interchangeable.

Thirdly. The relations of the deposits bear some analogy to the marls and dolomitic conglomerates of the Mendip area on the one hand, and to the feeble traces of Upper Keuper Sandstone in the vale of Taunton and elsewhere on the other; but they exhibit more successional arrangement than the former, and an excess of the conditions which led to the deposition of the latter.

I have hitherto confined myself to the descriptive portion of the second proposition; it now remains to show the additional grounds which justify the statement that only part of the Upper Keuper division is represented in Normandy. These are based on the thickness of the deposits, not shown in actual figures, but proved by the nature of the district; thus:—

First. The Norman Secondary area, as far as embraced in this paper, does not exceed, as a rule, 100 feet above the sea *.

Secondly. Infraliassic outliers occur at Videcosville, Octeville la Venelle, and St. Germain-de-Tournebut, in the north part of the area, and at Dézert, Brévands, and near Littry in the south; so that were Trias everywhere at the surface between these outliers and the Liassic districts, owing to the gently undulating character of the surface in some cases and its plateau-like contour in others, and to the slight dip of the Secondary rocks, the uppermost beds of the formation (Upper Keuper) would alone be represented at and near the surface.

Thirdly. M. Bonissent, commenting on the presence of a quartz rock of Cambrian age on the boundary of the communes of Gourbesville and Amfreville, says, "Its presence in these places leads us to think that the Gulf of the Cotentin, in which the Keuper deposits were laid down, is of no very great thickness in all points where it is visible." This remark applies to the whole area, as "the ancient formations which formed the base of the newer sediments present little insulated patches, which the more recent formations have not entirely covered, for example, in the environs of Montebourg, Valognes, Lieusaint, Rauville la Place, Magneville" †; add to these the quartz-porphyry of St. Colombe, the Cambrian limestones of Cavigny and La Meauffe, the Silurian inliers of Colomby and Flottemanville ‡, and the palæozoic patches near Littry.

Making, therefore, due allowance for depressions in their bed, the Triassic rocks of Normandy can scarcely exceed 200 feet in maximum thickness, whilst their mean thickness is probably less than 100 feet. I am therefore forced to regard them as a part only of the Upper Keuper, which in the Devon and Somerset area south of the Mendips appears to present a mean thickness of about 700 feet; so that even if the rocks of Normandy attained 300 feet, that thickness would not represent the whole of the Upper Keuper division.

Third Proposition.

If this reasoning is conclusive, it follows that the present extent of Normandy was not submerged until after the deposition of the earlier sediments of the Upper Keuper, and in no case could it have been under water during the formation of the pebble-beds of Devon which constitute the base of the Lower Keuper sandstones; so that there are strong grounds for entertaining the conclusion set forth in my third proposition, "that fragments from the Palæozoic rocks of Normandy (in its present extent) were never incorporated in the Triassic sediments of Devon."

Fourth Proposition.

I now come to the concluding proposition, that the foreign fragments in the South-Devon Trias were derived from rocks in the Channel area, the existence of which is proved by the nature of the Palæozoic areas of Normandy, Devon, and Cornwall. I shall first mention briefly the varieties of Palæozoic and igneous rocks of

* Bonissent, *op. cit.* p. 6. † *Ib.* p. 264. ‡ *Ib.* p. 192.

La Manche, commencing with the igneous. According to M. Bonissent *, granite and associated granitoid rocks (syenite, diorite, pegmatite, amphibolite, fraïdonite, harmophonite, petrosilex, protogine, protogenic, syenitic, dioritic, and petrosiliceous porphyries, syenitic granite, and serpentine) form a great part of the coast from Sciotot (near Pieux) on the west to St. Vaast on the east.

The patches of porphyry in the tract limited on the south by Coutances and St. Lo, and on the north by a line from Vasteville by Thiel to St. Vaast and Morsalines, are cited † as examples of M. Dufresnoy's opinion, that they represent " the vents of a great interior mass of porphyry, whose eruptive force had been sufficient to disturb and fissure the rocks of older date, but too feeble to open a large outlet for widespread ejection."

Speaking of the granitic and porphyritic rocks of La Manche, M. Bonissent ‡ says:—" These different groups are but very small portions of the great mass of which they ought to form part, judging from the different isolated veins with no apparent connexion with the principal groups. As also the islands and rocks between the Channel Islands and the most westerly point of England are formed of granite, and as the same rocks almost exclusively form the coast from Brest to St. Malo, and, in England, have in several places pierced the primitive formation, it is easy to conceive that all these veins, rocks, and groups are connected with one and the same granitic formation, in part hidden beneath the sea."

Talcite.

The north coast bounding Cherbourg Bay, from Bretteville to Omonville, a distance of nearly twenty miles, is composed of talcites. At Airel, in the district of St. Lo, talcites were recognized at a depth of nearly 33 feet beneath the Cambrian from the surface.

Mica-schists occur in the neighbourhood of Coutances, also gneiss, which is likewise found near Cherbourg, Pieux, &c.§

Cambrian.

The Cambrian rocks of La Manche are divided into two stages—the Upper consisting of anagenites, conglomerates, and various grits (arkoses), the Lower of phyllades and grauwackes ||.

Arkoses and anagenites are well developed in the north of the Cotentin, from Morsalines, on the north-eastern confines of the Secondary area, to Cape la Hogue¶. In the latter locality phyllades and grauwackes are but sparingly distributed. In one spot in the commune of Eculleville they are accompanied by a reddish-brown crystalline limestone **.

The schistose character of the talcose rocks nearly always disappears in the arkoses and anagenites ††.

By the road to St. Vaast, at the entry of Valognes, phyllades and

* *Op. cit.* p. 31 &c. † P. 47. ‡ P. 12.
§ *Ib.* pp. 103, 104. || P. 122. ¶ P. 138. ** P. 124.
†† P. 136.

grauwackes much altered were noticed under redeposited Keuper clays; they underlie the arkoses of Montaign la Brisette *.

The Cambrian rocks almost entirely environ the Secondary area on the north, south-west, and south.

Silurian.

The Silurian grits of the north of La Manche do not all belong to the same horizon; thus the grits of Cherbourg, which rest unconformably on talcite at Mont Roule, of Tollevast, Sottevast, Lieusaint, Montebourg, &c., which contain *Scolithus linearis*, are regarded as equivalent to the English Stiper Stones. Those of Moitiers d'Allonne (south of Pieux) are considered as contemporaneous with slaty schists with *Calymene Tristani*, equivalent to the Llandeilo Flags. The grits of Val de Cie, Vrétot, and Besneville, being of the same age as the Grès de May, are equivalent to the Caradoc †.

The succession in ascending order is as follows ‡:—

	Localities.
1. *Scolithus-linearis* grits, sometimes azoic, sometimes with *Lingula*	Montebourg, Cherbourg, &c.
2. Slaty schists and grits with *Calymene Tristani*	Cherbourg, Siouville, &c.
3. Graptolite schists without *Cardiola*	Vrétot, Val de Cie, Siouville, Besneville, &c.
4. Grits with May fauna	St. Sauveur le Vicomte.
5. Schists with *Graptolites colonus* and *Cardiola interrupta*	Varenguebec, Vrétot, St. Sauveur le Vicomte, Siouville, &c.

At Rufosse, nearly seven miles to the west of the east coast at St. Vaast, Silurian grits rest unconformably upon the Cambrian, as also on the hillock of Blémond in Octeville la Venelle, where the Silurian is represented by very compact dark-brown quartzite §. At Crasville I noticed a quarry of quartzite splitting up in small pieces.

The Silurian rocks of Montebourg ‖ occupy a tract of greater elevation than the Liassic and Triassic district surrounding them. It comprises the communes of Huberville, Tourville, Lestre, St. Floxel Quinéville, and Octeville la Venelle. At Tourville the rock is often schistose, and in places constitutes great beds dipping in a south-westerly direction. It occupies a part of the commune of Quinéville, and is prolonged thence to the isles of St. Marcouf, passing by the rock of Bavesknie, where it assumes an excessively compact and crystalline texture, exhibiting a kind of semifusion from the injection of a vein of quartz chalcedony. At Montebourg the rock is sometimes conglomeratic in the lower portion, containing pebbles of quartzite and decomposed felspathic rocks as well as fragments of talcite. Fossils are very rare in this locality. Indeterminable species of *Orthis* have been recognized on the north-eastern limits of the mass.

Near the cross-roads to Aumeville, Ozeville, Quinéville, and Montebourg, I observed a quarry of pale grey and whitish Silurian

* P. 127. † P. 185. ‡ Pp. 205, 206. § P. 196. ‖ P. 197.

quartzite, capped by a drift containing boulders and occasional pebbles of the same rock. Near St. Cyr, by the highroad from Valognes to Montebourg, I visited a quarry of violet, red, and grey Silurian quartzite, capped in part by drift.

In the grits of St. Sauveur le Vicomte, Rauville le Place, Besneville and Etanclin, fossils of the May type have been recognized. At Besneville, *Homalonotus*, *Orthis redux*, *Cœlaster*, *Palæaster*, and *Avicula matutina*; at St. Sauveur le Vicomte, *Homalonotus* and *Orthis redux*; at Varenguebec, *Cleidophorus*; at Etanclin, *Orthis redux* *. These rocks bound the Trias south of Valognes.

Traces of the same formation have been recognized in the commune of Moon †, on the southern borders of the Triassic area, near the limits of Calvados and La Manche.

I visited the quarries of May (south of Caen), on the west side of the village. The quartzite varies in colour from reddish and pale greenish to white. Here and there vertical red markings in the grey quartzite show a perfect resemblance to many of the characteristic Budleigh pebbles.

The beds dip towards north 30° east. Some of them are very thick, one being observed of from 7 to 8 feet. A sandy bomb about 6 feet in diameter was noticed in one part of the quarry face. During a couple of hours' search I procured some specimens of *Orthis redux* and thoracic plates of Trilobites.

Devonian.

The lower part of the Devonian only is represented in La Manche‡; its constituents occur in the following descending order:—

1. Schists with thin beds of soft grit containing much mica, sometimes alternating with limestones.
2. Greyish or blackish limestones, with alternating blackish schists, often micaceous.
3. Grits of various colours, especially greenish, alternating with schists of the same hues §.

This triad grouping reminds one of the Devonian flanking the South-Devon Trias as given by Mr. H. B. Woodward ||:—1. Thin band of shales on limestones; 2. Slates; 3. Red Sandstones: in descending order.

The Lower Devonian grits of La Manche are not so pure as those of the Silurian formation. It happens, however, that some of these grits, through the effects of metamorphism, have acquired a very close texture, and thus present the appearance of quartzites. The Devonian area lies between Pieux and Valognes on the north, and Lessay and Le Plessis on the south; it is bounded by the sea on the west, and by the Triassic districts on the east. Beyond these limits

* Bonissent, *op. cit.* p. 200.

† P. 209. A band of Silurian is shown on Knipe's map bounding the Secondary area from Moon to Campigny.

‡ P. 224.

§ Pp. 226, 227.

|| Geol. Mag. for Oct. 1877, No. 160.

only one small outlier has been found; it occurs at Siouville (north of Pieux) at about ten miles from the main mass; from which M. Bonissent inferred* "that the Devonian rocks occupy elsewhere a great part of the space between the Anglo-Norman Isles and the west coast of La Manche."

From the neighbourhood of Valognes to Golleville the Devonian does not extend far beyond the limits of the sea of the Marnes Irisées†. Approaching the town of Valognes, grey grit alternates with schists, and contains *Orthis*, little Spirifers, and *Leptæna Murchisoni*. On the north-west of Cape Rozel a greyish quartzose grit containing *Orthis, Spirifer*, and *Productus* has been separated from the main mass of the Devonian by fraidonite and red porphyry, which have been injected into the Cambrian and Devonian rocks‡. In the commune of Surtainville brownish, greenish, and grey grits, sometimes banded with red and yellow, contain *Orthis* and little Spirifers. At Surtainville whitish grit mottled yellowish, containing *Leptæna Murchisoni*, rests on the greenish variety§.

The following list of fossils obtained from the Devonian rocks of La Manche is given by M. Bonissent ‖ :—

Fish-bone?
Dalmania callitelis, *Gren.*
—— sublaciniata, *Vern.*
Homalonotus Gervillei, *Vern.*
—— Forbesii, *Rou.*
—— Hausmanni, *Rou.*
—— Brongniarti, *Rou.*
—— Buchii, *Vern.*
Proetus Cuvieri, *Stein.*
Bronteus flabelliformis, *Barr.*
Leperditia britannica, *Rou.*
Orthoceratites calamiteus, *Münst.*
—— Buchii, *Vern.*
Cyrtoceras, sp.
Murchisonia intermedia, *D'Arch.*
Loxonema, sp.
Pleurotomaria Bachalieri.
Turbo, sp.
Macrocheilus Murchisoni, *Bon.*
Natica cotentina, *D'Orb.*
Bellerophon Sæmanni, *Rou.*
—— Gervillii, *Vern.*
Capulus scalaris, *Rou.*
—— Lorierei, *Vern.*
—— cassideus, *Vern.*
Pileopsis, sp.
Euomphalus, sp.
Conularia Gervillii, *Vern.*
Serpularia, sp.
Pterinea spinosa, *Phill.*
—— lævis, *Goldf.*
Avicula spinosa, *Phill.* (and indeterminable species).
Modiola, sp.
Nucula, sp. n.
Sanguinolaria soleniformis, *Goldf.*
Leda, sp. n.
Redonia (allied to *R. Deshayesiana*).
Grammysia hamiltonensis, *Vern.*
Conocardium clathratum, *D'Orb.*
Orbicula, sp.
Terebratula concentrica, *Buch.*
—— Ezquerra, *Vern.*
—— hispanica, *Vern.*
—— undata, *Def.*
—— Archiaci, *Vern.*
—— reticularis, *Linn.*
—— eucharis, *Barr.*
—— Wilsoni, *Rou.*
—— subwilsoni, *D'Orb.*
—— prominula, *Röm.*
—— Guerangeri, *Vern.*
—— Pareti, *Vern.*
—— upsilon, *Bon.*
—— porrecta, *Bon.*
—— Blackii, *Rou.*
—— strigiceps, *Röm.*
Pentamerus galeatus, *Dalm.*
Spirifer Rousseau, *Rou.*
—— subspeciosus, *Vern.*
—— heteroclitus, *Defr.*
—— Davousti, *Vern.*
—— Pellico, *Vern.*
—— Bellouini, *Rou.*
—— Dutemplei, *Rou.*
—— macropterus, *Goldf.*

* Bonissent, p. 255. † Ib. p. 245. ‡ P. 227.
§ Bonissent, p. 227. ‖ Ib. pp. 251–253.

Orthis Beaumontii, *Vern.*
—— striatula, *Schloth.*
—— orbicularis, *Vern.*
—— Gervillii, *Barr.*
—— Trigeri, *Vern.*
—— hipparionyx, *Schn.*
—— eifelensis, *Vern.*
—— Monieri, *Rou.*
Chonetes Boulangeri, *Rou.*
Rhynchonella, sp.
Strophomena, sp.
Productus, sp.
Atrypa, sp.
Leptæna Murchisoni, *Vern.*
—— subplana, *Vern.*
—— laticosta, *Conrad.*
—— Sedgwickii, *Vern.*
—— Phillipsii, *Barr.*
—— depressa, *Sow.*
—— Bouei, *Barr.*
Calceola (sandalina).
Pentremites.
Encrinites.
Pradocrinus Baylii, *Vern.*
Tentaculites, sp.
Caryophyllites, sp.
Heliolites interstincta, *M.-Edw.*
Alveolites, sp.
Favosites Goldfussi, *D'Orb.*
—— polymorphus, *Goldf.*
Calamopora, sp.
Cyathophyllum celticum, *D'Orb.*
—— Bouchardi, *M.-Edw.*
—— cæspitosum, *Goldf.*
—— turbinatum, *Goldf.*
Madrepora, sp.
Aulopora cucullina, *Mich.*
Retepora, sp.
Fenestella, sp.
Pleurodictyum problematicum, *Goldf.*
—— (with round calices).
—— (with sharp serpuliform calices).
—— constantinopolitanum, *Röm.*

Carboniferous.

The representative of the Carboniferous Limestone occurs in a small space, not five miles in length by about two thirds of a mile in breadth, on the south-west coast, at nearly twenty miles distance from the unproductive Coal-measure strata of the little basins of Le Plessis and Littry, bounding the Triassic districts on the south *. With them my brief notice of the Norman Palæozoic rocks closes.

Returning to our own side of the Channel, we find the Cornish peninsula composed of a granitic backbone, represented superficially by four principal masses, surrounded, except in the case of the Lands-End mass, on all sides by Devonian rocks more or less metamorphosed, and constantly intersected by greenstones and elvans. We find the Lizard district mainly composed of serpentine and diallage rocks partially flanked by hornblendic slates; whilst between Chapel Head and Nare Point, in the districts of Veryan and Gorran, a rock of pre-Devonian age occurs.

Again, in South Devon we have the same granitic centre, and from it southwards pass from Culm-measure rocks to Devonian, locally intersected by numerous patches of greenstone; whilst the remarkable metamorphosis of the rocks forming the most southerly part of Devon, from Start Point to Bolt Head, seems to indicate the proximity of extensive igneous districts now hidden beneath the sea.

Taking both countries together, we have in their most southerly projections the indications of conditions approaching those exhibited in La Manche. Would not the area occupied by the English Channel be expected to furnish the transition between these extreme points? Would not such a transitional area display great centres of ancient igneous activity—the extension of the Silurian and older formations

* Bonissent, p. 260.

towards Devon, the superposition upon them of Devonian rocks prolonged from the coasts of Devon and Cornwall, and their partial conversion into quartzites (which has been already described as locally effected by extreme metamorphism in the Devonian grits of La Manche)? To these I might add the probability of an extension of the Devonian rocks of La Manche towards Devon, on the eastern flank of the granitic mass of which Jersey, Guernsey, &c. are the highest summits. Applying these inferences to the solution of my fourth and concluding proposition, I feel justified in ascribing: first, such granitic, porphyritic, and stratified rock fragments of the Lower Trias of South Devon as cannot be reasonably referred to rocks within the limits of the south-western counties (whether exposed or concealed by Secondary strata) to the many varieties of igneous rocks and Palæozoic formations doubtless occurring in the area now occupied by the English Channel; secondly, the Budleigh-Salterton pebbles to Devonian and Silurian quartzites, and in some cases perhaps to igneous and Palæozoic sources formerly existing in the Channel area.

In conclusion, I have to acknowledge the kind offices of Messrs. Linford and Vicary in furnishing me with information bearing on the subject, and in putting their libraries at my disposal.

Discussion.

Prof. Ramsay remarked that the fossils in the Budleigh-Salterton pebbles are of Silurian as well as of Devonian species. He supported the view that the pebbles were derived from rocks now destroyed by denudation, and existing in what is now the Channel area. He supported the views of Mr. Godwin-Austen on the grouping of the Triassic beds and on their origin in a great lake.

21. *On the* Occurrence *of* Pebbles *with* Upper Ludlow Fossils *in the* Lower Carboniferous Conglomerates *of* North Wales.

By Aubrey Strahan, Esq., M.A., F.G.S., H.M. Geological Survey, and Alfred O. Walker, Esq., F.L.S. (Read February 5, 1879.)

[By permission of the Director-General of the Geological Survey of Great Britain.]

Nearly forty years ago Mr. Bowman drew attention to "a small patch of Silurians west of Abergele." in which he described the following subdivisions in descending order*:—

f. A conglomerate of pebbles of greenish micaceous sandstone in a light loamy earth resting on a similar sandstone.
e. Thick red marl with numerous pebbles of red sandstone, micaceous, with many bivalves.
d. A hard compact conglomerate of green sandstone and quartzose rock.
c. Compact red limestone.
b. Fine blue loamy clay.
a. Clay-slate.

He makes the observation that the red-sandstone pebbles in bed *e* resemble Ludlow rock, and names four Ludlow species as occurring in them.

Our attention was directed to these beds by numerous excavations made in them at the time of the recent activity in the iron trade. The only good exposure is in Ffernant Dingle, a deep ravine running from the Pen-y-Cefn lane southward past Cefn-y-Fran, about one mile south of Llysfaen.

The southern or lower end of this dingle is occupied by Wenlock shale, a pale blue slaty clay, with occasional sandy beds. The beds are much jointed, and sometimes cleaved so as to weather into pencil-like fragments. At the south end of the dingle they are nearly horizontal, but dip gently to the north higher up, near Cefn-y-Fran.

At this point the Wenlock shale is unconformably overlain by hard, mottled, red and green brecciated limestone, containing beds of green sandstone pebbles in a sandy matrix. The limestone and the conglomerates dip to the N.N.E. at 28°.

This limestone constitutes bed *c* of Mr. Bowman's section. It is exceedingly hard, with a hackly fracture, of a green colour mottled with red. It contains perfectly angular fragments of Wenlock shale, and rounded pebbles of a greenish sandstone; there is also so large a proportion of quartzose and argillaceous impurity in it as to give

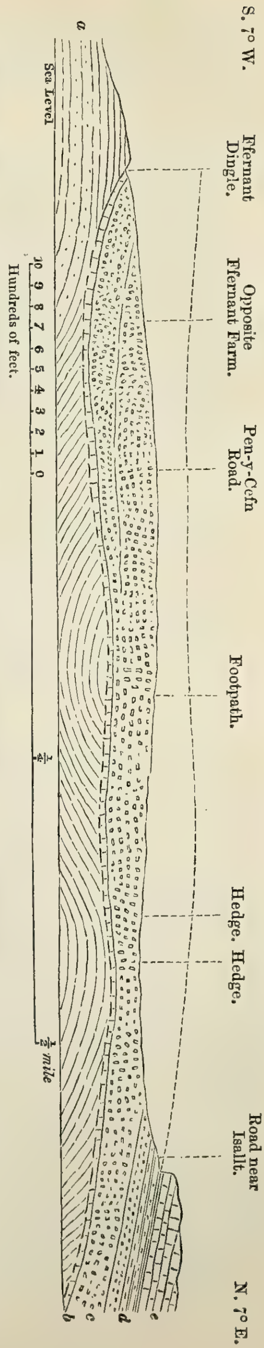
* Geological Transactions, vol. vi. part 1.

rise to a porous sandy mass when the lime is removed by weathering. We have been unable to detect any organic remains in it, even with the aid of the microscope. In all these respects it contrasts with the Carboniferous Limestone proper, which is free from grit, and is almost entirely made up of fragments of Corals, Encrinites, and Foraminifera. This brecciated limestone is locally known as the Bastard Limestone.

The unconformable position of the Bastard Limestone on the Wenlock shale is shown in a quarry on the west side of the dingle, and in a pit 150 yards further to the west. The shale dips to the north at from 6° to 7°. Its bedding planes are cut off towards the north by the Bastard Limestone, which dips to the N.N.E. at from 26° to 27°. A little local breccia, consisting of small fragments of Wenlock shale in a red clay or brown earth, about from 8 to 12 inches thick, separates the limestone from the surface of the Wenlock shale. The limestone is also exposed south-east of Twynan-uchaf and near Tyn-y-Pistyll, and has been proved in hæmatite trials near Orsedd, and in the slope of the hill below Cefn-uchaf and Cefn-y-Castell. It is represented at the Pile House, near Colwyn, by a porous sandy bed, slightly calcareous, but in a much weathered condition. The Bastard Limestone occupies a position at the base of the beds about to be described over a considerable area.

A great thickness of shales, sandstones, and conglomerates overlies the limestone. The following details of the lower portion of these beds were obtained in Ffernant Dingle, in ascending order:—

Section from Ffernant Dingle to the Carboniferous Limestone near Isallt. (Scale 6 inches to one mile.)



a. Wenlock shale. *b.* Bastard Limestone. *c.* Shales, sandstones, and conglomerates. *d.* Conglomerates and shales. *e.* Carboniferous Limestone.

	ft.	in.
Bastard Limestone, containing two beds of green sandstone pebbles in a sandy matrix	10	0
Conglomerate of red and green sandstone pebbles in a mottled red and green sandy matrix, the pebbles varying in size from that of a walnut to that of a flattened cricket-ball	12	0
Bastard Limestone	1	6
Fine gravel	0	8
Red shale	3	0
Bastard Limestone	1	0
Hard red sandstone crammed with green and red sandstone pebbles	3	0
Bastard Limestone	1	0
Soft, red, micaceous sandstone with pebbles	6	0
Thick deep-red clay, crammed with liver-coloured sandstone pebbles, micaceous, flattish, and fissile, the largest 1 foot across by 2 or 3 inches thick	20	0
Soft red sandstone with green blotches	3	0
Deep-red marl, weathering into cubes or rhombs (resembling some beds at the base of the Keuper marls of Cheshire)	3	0
Coarse conglomerate of purple sandstone pebbles	6	0
Soft bright-red sandstone	10	0
Thick deep-red clay, crammed with pebbles (bed *e* of Mr. Bowman)		

The last-named bed, with a few sandstones, occupies the remainder of the dingle, and continues over Pen-y-Cefn and down the slope to the north to near the foot of the limestone escarpment, a distance of more than 1000 yards; its thickness must therefore be very great. It is everywhere crowded with pebbles of red and purple sandstone, liver-coloured when fine-grained, and purple and very micaceous when coarse-grained. They are all fissile, and when split open disclose casts of numerous fossils. They vary in size from 14 inches $\times$ 8 inches $\times$ $3\frac{1}{2}$ inches to an average of 4 inches $\times$ $2\frac{1}{2}$ inches $\times$ $1\frac{1}{2}$ inch. They are dissimilar to any rock known *in situ* in the district, and are invariably waterworn, generally to a flattened oval shape, but occasionally subangular. The whole deposit is well stratified and pervaded by current-bedding, without any appearance of ice-action. Throughout this vast mass of pebbles there is no other rock than the fine and coarse-grained red sandstone.

Overlying this thick bed, and occupying the slopes immediately under the Carboniferous Limestone, are some conglomerates of green and yellow sandstone pebbles in a red and green matrix, and associated with mottled red and green shales. Some of the pebbles differ slightly from the last described in being tougher and less fissile, but the majority are similar except in colour; they also contain the same fossils. No hard and fast line can be drawn separating the red conglomerates of Ffernant from these mottled beds; and the difference is probably due partly to their having been derived from a variegated rock, partly to subsequent alteration. Some of the pebbles in the upper beds are partly green and partly red.

The red and green shales and conglomerates are succeeded by the Carboniferous Limestone, the lowest beds of which contain Encrinites, *Producti*, *Athyris*, and Foraminifera in abundance. The junction is visible in a farmyard near Bryniau Cochion, where red-stained limestone, rather impure, rests on green and purple shales, with a sharp line of demarcation, but without signs of erosion or unconformity. Occasionally the lower beds of the limestone are interstratified with shales so as to form a passage*. There is always a perfect conformity in dip.

Distribution and Thickness.—The accompanying section (p. 269) is drawn to a true scale of 6 inches to the mile, the horizontal distances and heights taken from the Ordnance 25-inch maps, supplemented by aneroid measurements. The dip of the Bastard Limestone in the dingle is 28°; this diminishes towards the top of the dingle to 12°. No dip is then to be got till we reach the Carboniferous Limestone, which dips at 9° to 10°. From these data we get an apparent thickness of a thousand feet for the conglomerates. It is probable that this far exceeds the reality, through the inequality of the surface of Wenlock shale and through the possibility of a roll in the limestone. Making allowance for this, their thickness cannot be much less than 500 feet. At Penlwys (Pile House), where we have been able to make a direct measurement in the hill-side, we find the thickness to be 130 feet, and west of Colwyn Bay they have thinned out to nothing, the rate of attenuation being about 1 in 34. Eastwards the conglomerates thin out equally rapidly, and finally are overlapped by the Carboniferous Limestone at a distance of three miles from Ffernant. The conglomerates become finer as the beds become thinner, and tend to pass into shales and sandstones, affording evidence that the thinning and thickening of the beds is due to their original unequal distribution, rather than to their partial removal by denudation before the deposition of the Carboniferous Limestone.

The position and appearance of the beds in Ffernant Dingle favour the idea of their having been deposited against a bank or sloping surface of Wenlock shale, probably one side of a broad hollow cut out by denudation in the surface of these rocks. The irregular distribution of the conglomerates is probably due to such inequalities in the surface on which they were deposited.

It may be mentioned that a fine section is exposed in the valley of the Clwydog, near Ruthin, showing Carboniferous Limestone resting conformably on red micaceous shales with thin sandy beds, and thrown against similar beds by a fault ranging north and south through Berth. In the bed of the river at Berth brecciated and conglomeratic limestone, dipping N.E. at 5°, forms the base of the deposit; it rests on Wenlock shale dipping S.W. at 30°. Conglomeratic beds occur in the series in the side of the highroad to Ruthin, half a mile west of Llantwrog. The pebbles are similar to those of Ffernant.

Origin of the Pebbles.—In the Bastard Limestone there occur a few fragments of Wenlock shale, all angular and evidently of local origin. With the exception of these, the pebbles are all waterworn and generally completely rounded. A few of the less fissile and

* Mr. G. H. Morton states that beds of limestone and conglomerate are interstratified near Denbigh.

finest-grained green pebbles from the upper part of the conglomerates resemble the sandy beds in the Wenlock shale, but the vast majority are totally dissimilar to any rock known *in situ* in the district. On the other hand, they closely resemble the Upper Ludlow beds of Kendal and Central Wales, both the red and green varieties being referable to these beds*.

Mr. R. Etheridge has kindly examined some of the pebbles, and has named the following genera and species of fossils occurring in them:—

Orthis filosa, *Sow.*, *Sil.* xx. 21. Wenlock and Ludlow.
—— lunata, *Sow.*, *Sil.* xx. 11. Ludlow.
—— elegantula, *Dalm.* Llandeilo to Ludlow.
—— crispa, *M'Coy*, *Sil. Foss.* p. 29. Llandeilo to Ludlow.
Chonetes striatella=lata, *Dalm.*, *Sil. Syst.* iii. Ludlow. Four specimens.
Spirifer crispus, *His.*, *Sil.* xxi. 4. Llandovery to Ludlow. Five specimens.
—— elevatus, *Dalm.*, *Sil.* xxi. 5, 6. Llandovery to Ludlow.
Rhynchonella Stricklandii, *Sow.*?, or borealis, *Schl.* Wenlock.
—— ——: fragments.
Pterinea retroflexa, *Wahl*, or lineata, *Goldf.*, *Sil.* ix. 26. Ludlow. Three specimens.
Orthonotus.
Arca (or Pterinea ?).
Theca (?).
Tentaculites ornatus, *Sow.*, *Sil.* xxvi. 11. Caradoc to Wenlock.
Holopella.

He remarks that they are undoubtedly Upper Silurian and 90 per cent. Ludlow, and that the pebbles in their flaggy nature and micaceous condition resemble beds of this age in Westmoreland.

In considering from what direction the pebbles have been transported it is necessary to bear in mind that, excepting only the angular fragments in the Bastard Limestone at the base, not a single fragment occurs that is referable to the Wenlock, or any Silurian rock older than the Wenlock. It is therefore certain that the denudation in that area from which the conglomerates were derived had not been sufficient to remove the whole of the Ludlow beds and expose the underlying Wenlock shales, fragments of which must otherwise have occurred in the conglomerates. We must therefore look for the source of the pebbles in an area in which the Silurian series remained perfect, at least so far as the Lower Ludlow beds, when the pre-Carboniferous denudation of these rocks ceased.

This condition is fulfilled at Ludlow, at a distance of more than fifty miles to the south. But over this intervening space the Carboniferous Limestone is resting on Wenlock shale, which was therefore undergoing denudation and contributing débris. Had the drift been from this direction, this Wenlock débris must have been intermingled. Similarly to the west, near Snowdon and Anglesey, and to the north-west, in the Isle of Man, the Carboniferous rest on Wenlock or older beds, so that these directions need not be discussed. There remains only to be considered the possibility of a source in a north or north-easterly direction.

The removal of the Ludlow beds from the areas of North Wales

* On this point we had the valuable opinion of Mr. W. T. Aveline, F.G.S.

and the Lake-district was due to the elevation of these tracts, and consequent denudation, in a period preceding the Carboniferous. The comparative depression of the intermediate area of South Westmoreland, and probably Lancashire, and of South Wales preserved these beds or a portion of them, or even led to further deposition, so that 10,000 feet of red beds are found in Herefordshire which are missing in Denbighshire. While in the areas of elevation the unconformity at the base of the Carboniferous is immense, in the areas of depression the gap is *apparently* filled up through the comparatively slight denudation to which the beds were exposed.

Neglecting minor undulations, the general tendency of the Wenlock shale of North Wales is to dip in a north-east direction off the Bala beds of Conway and Bala. If this dip is continued under the Carboniferous strata it must bring on in natural succession the missing Silurian beds in the direction of Liverpool and Lancashire. On the southern side of the Lake-district, where the Silurians reemerge, the series is actually complete as far as the Kendal Flags (Tilestones) before it is overlapped by the Carboniferous.

It is therefore probable that in the old synclinal between Wales and the Lake-district, Silurian beds higher than any existing in North Wales underlie the Carboniferous strata. The resemblance of the Ffernant pebbles to the Westmoreland beds has been remarked by Mr. Etheridge; but from the large size, incomplete rounding, and friable nature of some of the pebbles, it is not probable that they have travelled so far as from the Lake-district to Wales. We therefore suggest the probable extension of the Ludlow beds under Lancashire as the most likely source from which they can have been derived.

Mr. Goodchild has been kind enough to furnish us with the following notes on conglomerates occupying a similar position on the borders of the Lake-district. They rest with an extreme unconformity upon all the older rocks. On the other hand, they pass up into the limestone, or are sometimes rather sharply divided from it. They are also interstratified with beds of sandstone and even shale, which occasionally form the mass of the deposit. There is evidence in the conglomerates of their having been drifted from a north-west direction.

In the Isle of Man, near Castletown, the conglomerate rests on the smashed edges of nearly vertical Silurian strata. It is interstratified with discontinuous beds of sandstone and grit. In the upper part it is interbedded with Carboniferous Limestone. The Peel Sandstones are described by Mr. Horne* as containing occasional bands of breccia and thin cornstones, and as passing conformably under the limestone. In all cases the conglomerates are highly charged with iron.

Over a large area in the north and west of England and Wales these red conglomerate sandstones and shales are conformable to the Carboniferous Limestone, and occasionally interstratified with

* Trans. Edinburgh Geol. Soc. 1874.

it, while they invariably show the most complete unconformity with the Silurian beds below.

Discussion.

Mr. De Rance expressed his agreement with the paper after having walked over the ground. He also thought that the source of the pebbles had probably been the Lake-district or old destroyed lands under the Irish Sea. He had been informed by Mr. Morton that, in examining the caves in the Carboniferous Limestone near Abergele, east of the direction of the author's section, a number of these fragments had been found, showing underground drainage from the outcrop of the basement beds to the sea.

Prof. Hughes bore testimony to the accuracy of the observations of the authors, but thought caution was needed in accepting some of their conclusions. A bed might be stained in a conglomerate of a colour which it never bore *in situ.* Pebbles from grey rocks in the red basement conglomerates of the Carboniferous rocks in the Eden valley were stained red. He also thought that the general character of the pebbles did not agree with the Ludlow of the Lake-district. All the fossils were Ludlow, but also occurred low down in the Denbigh Flags.

Mr. A. O. Walker said that the conglomerates above these beds were of greenish or whitish pebbles, and so not in the least stained themselves. He thought that the pebbles in the caves mentioned by Mr. De Rance occurred in the drift.

Mr. Rutley said that an exposure of Upper Ludlow rock in the Long Sleddale valley of the Lake-district had a lithological character identical with that of the specimens brought by the authors.

The President asked if there was any physical evidence as to the direction whence the pebbles had drifted.

Mr. Strahan said that probably the hardest portions of the rock survived in the existing pebbles, which, however, were softer than the Wenlock shale. There was no other rock of similar character in the district. He also thought the general position of the beds favoured the idea of denudation they had suggested ; but there was no certain physical evidence as to the direction whence the fragments had proceeded.

22. *A* Review *of the* British Carboniferous Fenestellidæ.

By George Wm. Shrubsole, Esq., F.G.S. (Read February 26, 1879.)

The following are some of the results obtained in working out the fossil Polyzoa found in the upper beds of the Carboniferous Limestone on Halkin Mountain in Flintshire.

In some of the bands of calcareous black shale and chert the Fenestellidæ occur in considerable abundance, and generally in a good state of preservation. During the last few years some thousands of specimens, mainly of *Fenestella*, from this locality have come under my notice. The condition of many of these has been such as, I conceive, to throw considerable light upon their true form and mode of growth, and so to add largely to the information we possess respecting this interesting group of the Polyzoa, and render possible what has been long felt to be a desideratum by all who have studied the subject, namely, a revision of the several species of *Fenestella*.

Twenty-six so-called species of *Fenestella* have been described from the Carboniferous series. Of these I have carefully examined twenty, and find that they can be reduced to five species.

The following is a complete list of the British Carboniferous *Fenestellæ*:—

Fenestella antiqua, *Lonsd.*, M'Coy, Syn. Carb. Foss. Ireland, p. 200.
—— arctica, *var.* scotica, *Eth. jun.*, Ann. & Mag. Nat. Hist. ser. 4, vol. xx. p. 31.
—— bicellulata, *Eth. jun.*, Mem. Geol. Surv. Scotland, sheet 23, p. 101.
—— carinata, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 28. fig. 12.
—— crassa, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 29. fig. 1.
—— ejuncida, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 28. fig. 11.
—— flabellata, *Phill.*, Geology of Yorkshire, pl. 1. figs. 7–10.
—— flustriformis, *Phill.*, Geology of Yorkshire, pl. 1. figs. 11, 12.
—— frutex, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 28. fig. 10.
—— formosa, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 29. fig. 2.
—— hemispherica, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 29. fig. 4.
—— intertexta, *Portl.*, Geology of Londonderry, p. 324, pl. 22. fig. 3.
—— irregularis, *Phill.*, Geology of Yorkshire, pl. 1. figs. 21, 22.
—— laxa, *Phill.*, Geology of Yorkshire, pl. 1. figs. 26–30.
—— membranacea, *Phill.*, Geology of Yorkshire, pl. 1. figs. 1–6.
—— Morrisii, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 28. fig. 14.
—— multiporata, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 28. fig. 9.
—— nodulosa, *Phill.*, Geology of Yorkshire, pl. 1. figs. 31, 32, 33.
—— oculata, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 28. fig. 15.
—— plebeia, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 29. fig. 3.
—— polyporata, *Phill.*, Geology of Yorkshire, pl. 1. figs. 19, 20.
—— quadradecimalis, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 28. fig. 13.
—— tenuifila, *Phill.*, Geology of Yorkshire, pl. 1. figs. 23, 24, 25.
—— tuberculo-carinata, *Eth. jun.*, Mem. Geol. Surv. Scotland, sheet 23, p. 101.
—— undulata, *Phill.*, Geology of Yorkshire, pl. 1. figs. 16, 17, 18.
—— varicosa, *M'Coy*, Syn. Carb. Foss. Ireland, pl. 28. fig. 8.

The causes which have contributed the most to the present confusion in the group have been:—(1) a very imperfect acquaintance with the true size of the polyzoarium, which, as a rule, is much greater than previous writers have suspected; (2) not allowing for the natural difference in the structure, both at various periods and parts of its growth; (3) the uncertainty as to the typical form.

With regard to size I have traced the folded-up expansion of *Fenestella plebeia*, M'Coy, along lines of bedding, which showed that it attained a circumference of at least two feet, and probably more. It will be convenient to describe the growth as having three clearly marked stages, viz. the young, the mature, and the aged form, each of which differs much from the others in outward appearance. The young or early condition of the polyzoon was foliaceous in shape, often cordate, some, as *Fenestella nodulosa*, Phill., having a distinct stem.

The mature form was a circular or oval expansion, more or less depressed in the centre, the extremities terminating in semicircular lobes, slightly folded or plaited. The flabelliform shape, so often mentioned by writers on the subject, is not a true or perfect form, but a segment taken from the outer expansion of the polyzoarium. In the aged stage (and in this we may take *Fenestella plebeia*, M'Coy, as the type) the interstices and dissepiments become so much thickened as to resemble *Polypora* in size and character, the latest phase being from the straight interstice to zigzag, caused by an increased growth between the angle of the interstice and dissepiment. The fenestrules in consequence became hexagonal. I have little doubt that this last stage of *Fenestella plebeia*, M'Coy, is the *Fenestella arctica*, Salter *, from the Carboniferous Limestone of the Arctic regions.

It is to be noted that these successive stages of growth were each marked by peculiar features in the polyzoarium which deserve mention.

The basal portion at all times differed considerably from the upper portion. In the early growth the fenestrules were large and irregular; in the later both smaller and regular. The thickening at the base was a gradual and continuous process, which went on until the pore-cells became obliterated and the real base became a solid calcareous mass.

Now in bringing this information to bear upon the drawings and description of *Fenestella* given by Phillips and Prof. M'Coy, and particularly the Polyzoa named by the latter, and now in the Woodwardian Museum, which I have been permitted to examine by the courtesy of Prof. M'Kenny Hughes, I find, as a matter of fact, that in some instances the young, the mature, and aged condition of the same polyzoon have been described as distinct species, a similar distinction being sometimes conferred upon the base and the upper growth of the polyzoary.

These variations in fossil polyzoal growth have not been unnoticed by careful observers. Writing recently of an allied form, *Polypora biarmica*, Keys., R. Etheridge, jun., says of it that "it is a most interesting one, from the peculiar change the polyzoarium appears to undergo with age and increased growth. The obverse and re-

* Belcher's 'Arctic Voyage,' 1855, vol. ii. p. 385, t. 36. f. 8.

verse differ so materially in appearance that they might easily be mistaken for distinct species, were it not for their constant occurrence together in close proximity, and also that some of the fragments are so fractured as to show the gradual passage from the broad flat interstice of the obverse to the narrower and more convex stems of the reverse"*.

What is here said to hold good respecting *Polypora biarmica* I find to be true, not only of the Fenestellidæ in particular, but of the reticulated forms of Polyzoa in general. Unfortunately for the cause of palæontology these facts have not been allowed to have their due weight in the description of the various species; and the result has been a needless multiplication of ill-defined and uncertain forms, very perplexing to the student and of doubtful benefit to the science.

Bearing in mind the differences which I have pointed out in the character of the individual polyzoon, it is no wonder that the early describers fell into this error when the determination was often made from fragments only, and these imperfect.

More important even than this was that they failed to see the true character of the genus. M'Coy believed that it would be found in *Hemitrypa*†. Although some species of *Fenestella* pointed in the true direction it was not discerned. At this time the character of the genus was a poriferous face, bare and smooth, the cell-pores level with the interstice and the latter having a faint keel. In 1874 Messrs. Young and Young announced the discovery of a new Carboniferous polyzoon‡ having the outline of a *Fenestella*, but with so many new features that they felt themselves justified in creating for it a new genus, *Actinostoma*, calling the species, to mark its specific character, *fenestratum*.

In this species the true cell-pore stood well up above the interstice, a rounded nipple-shaped projection terminating in an opening or mouth furnished with eight denticles set around the margin. Below this was a smaller and more superficial opening, which may have been the base of some polyzoal appendage. On the prominent keel were elongated prominences with smaller ones at regular intervals: apparently they had been hollow, and may have been spines. This highly ornamental variety, presenting a strange contrast to the majority of the Fenestellidæ, was really the more perfect form of *Fenestella nodulosa*, Phill. §, although not recognized as such at the time by the original discoverers. Still it is due to Messrs. Young to state that to them we are indebted for the first insight into the true type of the genus *Fenestella*. Since then it has been ascertained that when *Actinostoma fenestratum*, Young, has been worn down by attrition or the action of water it becomes what we know as *Fenestella nodulosa*, Phill. It is a common occurrence for a frond to have upon it the characters of both *Fene-*

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 622.
† M'Coy's Syn. Carb. Foss. Ireland, p. 200.
‡ Quart. Journ. Geol. Soc. vol. xxx. p. 681.
§ Geol. Yorks. pl. 1. figs. 31, 32, 33.

stella nodulosa, Phill., and *Actinostoma fenestratum*, Young, the difference being due to preservation and to no other cause.

An important question next arises, Is *Fenestella nodulosa*, Phill., peculiar in respect to these details, or are the features observable in *Actinostoma* common to all the *Fenestellæ*? I think we have evidence in favour of the latter view. In several species I have noticed the prominent cell-pores; and in one instance I have traced the rayed cell-mouth as in *Actinostoma* as belonging to *Fenestella plebeia*, M'Coy, also as having the prominences on the keel.

In another species, *Fenestella polyporata*, which Phillips figures without a keel, I have found it having a prominent keel with strong spear-shaped projections upon it.

It is evident, therefore, that *Fenestella nodulosa*, Phill., is not alone in possessing the characters given to *Actinostoma*.

There is an additional reason for thinking that this ornamentation was common to all the Fenestellidæ, since the worn-down form of *Fenestella nodulosa*, Phill., in no respects differs from the other members of the family in a similar condition. It seems only fair, then, to believe that the bare and smoothed condition of most of the Fenestellidæ is due to attrition in the Carboniferous sea, which has destroyed all the prominences and delicate surface-markings, and that only in rare and exceptional cases have they escaped this treatment.

It may be interesting here to notice that in an enlarged drawing of the poriferous face of *Fenestella tenuiceps*, Hall *, the interior of the cell-mouth, instead of being blank, is filled with a circular arrangement of fine points, evidently intended for organic structure. If so, then it may be that we have here a foreshadowing of the denticulate cell-aperture of *Actinostoma*.

I propose to arrange the various described forms of *Fenestella* under the following species.

FENESTELLA PLEBEIA, M'Coy.

Fenestella antiqua, Lonsd., M'Coy's Syn. Carb. Foss. Ireland, p. 200

F. carinata, M'Coy, Syn. Carb. Foss. Ireland, pl. 28. fig. 12.

F. flustriformis, Phill., Geol. Yorks. pl. 1. figs. 11, 12.

F. irregularis, Phill., Geol. Yorks. pl. 1. figs. 21, 22.

F. formosa, M'Coy, Syn. Carb. Foss. Ireland, pl. 29. fig. 2.

F. tuberculo-carinata, R. Ether., jun., Mem. Geol. Surv. Scotl. sheet 23, p. 101.

F. undulata, Phill., Geol. Yorks. pl. 1. figs. 16, 17, 18.

This, which is the common species of the group, is individually more numerous than any other. In size of structure it occupies a position between *Fenestella nodulosa*, Phill., and *Fenestella polyporata*, Phill. Its polyzoarium, in adult specimens, was from 18 inches to 2 feet in circumference. Phillips found and figured

* Hall's Palæont. N. York. 1852, pl. 40 D. fig. 2.

various parts of the growth, which he describes as distinct species. Prof. M'Coy subsequently, finding it only doubtfully described, gave a very full and accurate account of the polyzoon as usually seen. In *Fenestella irregularis*, Phillips partly describes the base; *Fenestella flustriformis*, Phill., is the cast only of the reverse face; *Fenestella undulata*, Phill., has the cell-pores partly exposed, possibly by the removal of the outer cortical layer. In *Fenestella antiqua*, M'Coy, the specific distinction is the "inosculation" of the cell-pores. The specimen in the Woodwardian Museum is a weathered reverse from which all the substance of the polyzoon has been removed, leaving the base of the filled-up cell-pores exposed and apparently in junction. The distinction is founded upon the error of mistaking the reverse for the obverse face. The cell-pores are set obliquely in the interstice; the median keel causes them to spread out on the obverse but not on the reverse face.

The aged form of the polyzoon we have in the *Fenestella carinata*, M'Coy *, in the Woodwardian Museum. The *dissepiments* at this stage are quite as thick as the *interstices*, and the appearance on the reverse that of a *Polypora*. The last stage is marked by an additional thickening, more particularly of the dissepiment at its junction with the interstice, giving the hitherto straight interstice a series of sharp angular turns or zigzags. This, I have no doubt, is the *Fenestella arctica*, Salter †. Examples of both of these later conditions are found on Halkin Mountain, and frequently on the same frond.

As yet I have referred only to the bare and denuded forms of *Fenestella plebeia*, M'Coy. Quite recently I have met with what I have no doubt is a very near approach to the life-form of the species. There is no doubt about its true character, as in size, number, and distance of pore-cells it agrees in all respects with *Fenestella plebeia*. As such I prefer to regard it rather than to make it into a new species. In it the cell-mouth is rayed as in *Actinostoma fenestratum*, Young ‡, and the number of denticles is the same. The pore-cell is rounded and projected well above the interstice. The keel is prominent, slightly waved, and studded at regular intervals with spiny processes of varying size. Between this, which is probably the nearly perfect form, and the bare one previously described we have the several stages of the obliteration process represented by such forms as *Fenestella formosa*, M'Coy §, and *Fenestella tuberculo-carinata*, R. Eth., jun. ‖ As Prof. M'Coy was the first to describe this species, it is better that it should still be known as *Fenestella plebeia*, M'Coy. By some authorities this species is regarded as identical with *Fenestella* (*Gorgonia*) *antiqua*, Goldf.; and perhaps with good reason. For the present I prefer to confine my attention to the British varieties.

* Syn. Carb. Foss. Ireland, pl. 28. f. 12.
† Belcher's Arctic Voy. 1855, vol. ii. p. 385, t. 36. f. 8.
‡ Quart. Journ. Geol. Soc. vol. xxx. p. 681.
§ Syn. Carb. Foss. Ireland, pl. 29. fig. 2.
‖ Mem. Geol. Surv. Scotland, sheet 23, p. 101.

FENESTELLA CRASSA, M'Coy, Syn. Carb. Foss. Ireland, pl. 29. fig. 1.

Fenestella laxa, Phill., Geol. Yorks. pl. 1. figs. 26–30.

In point of size of interstice &c. this is the largest of the British species. Both Phillips and Prof. M'Coy have described it, the former imperfectly, the latter with care and accuracy. Prof. M'Coy says that his species is allied to that of Phillips, but possesses distinct features; in other words, his specimen was not so much worn down as that of Phillips. Prof. M'Coy's is by far the fullest and best description of this species, and I propose to retain the name given to it by him.

FENESTELLA POLYPORATA, Phill., Geol. Yorks. pl. 1. figs. 19, 20.

Fenestella multiporata, M'Coy, Syn. Carb. Foss. Ireland, pl. 28. fig. 9.

This species in size is intermediate between *Fenestella crassa*, M'Coy, and *Fenestella plebeia*, M'Coy. Both Phillips and M'Coy describe the denuded form of the species. M'Coy based the difference between the two species upon the absence of keel in *Fenestella polyporata*, Phill., and its presence in *Fenestella multiporata*, M'Coy, which means that *F. polyporata* had been rather more denuded than *F. multiporata*. The almost perfect remains of an individual of this species which I have recently discovered have the cell-pores prominent and projecting, and the keel with spiny processes at intervals. As Phillips has fairly drawn the denuded form, it is only right that the name which he gave to it should be retained.

FENESTELLA NODULOSA, Phill., Geol. Yorks. pl. 1. figs. 31, 32, 33.

Fenestella frutex, M'Coy, Syn. Carb. Foss. Ireland, pl. 28. fig. 10.
F. bicellulata, R. Eth., jun., Mem. Geol. Surv. Scotland, sheet 23, p. 101.
Actinostoma fenestratum, Young, Q. J. G. S. vol. xxx. p. 681.

In size of interstice this interesting species occupies a midway position between *Fenestella membranacea*, Phill., and *Fenestella plebeia*, M'Coy. It is not so common as the latter. It is very regular in its mode of growth, and is altogether an object of considerable beauty. Its early growth much resembles a tiny shrub, as mentioned by Prof. M'Coy. In this stage it has a distinct stem or footstalk with parallel interstices having dissepiments describing a series of semicircles around the base. This is the *Fenestella frutex*, M'Coy. The mature but worn-down form is the *Fenestella nodulosa*, Phill. As we approach the more perfect condition of the polyzoon we have the *Fenestella bicellulata*, R. Eth., jun., with spiny projections on the keel. In *Actinostoma fenestratum*, Young, as before remarked, we have possibly its full development and the true type of the species. It is characterized by round and prominent pore-cells with circular mouths set with eight denticles, and a keel studded with spiny processes. Examples of this variety I have found in all stages of mutilation; step by step have the various details been removed until it is plainly the *Fenestella nodulosa*, Phill. The connexion between the two forms can scarcely be more closely established, every link in the chain is complete.

It is quite true that the early workers among the Polyzoa failed to see the true generic form of *Fenestella*. The circumstance that we have it now clearly established in these ornate forms of the Fenestellidæ scarcely warrants the creation of a new genus for their reception. It is admitted that the group has hitherto been only imperfectly described, and that the genus needs revision. This I hope to accomplish shortly. When this is done, the retention of *Actinostoma* will be unnecessary. I see no objection to the retention of Phillips's name for this species, *Fenestella nodulosa*, even with the additional details to be given to it.

FENESTELLA MEMBRANACEA, Phill.

Fenestella tenuifila, Phill., Geol. Yorks. pl. 1. figs. 23, 24, 25.
F. hemispherica, M'Coy, Syn. Carb. Foss. Irel. pl. 29. fig. 4.
F. flabellata, Phill., Geol. Yorks. pl. 1. figs. 7–10.
Hemitrypa hibernica, M'Coy, Syn. Carb. Foss. Ireland, p. 205, pl. 29. fig. 7.

The above are the most minute and delicate of the British forms. In size and specific characters they are all, within reasonable limits, identical.

Fenestella membranacea, Phill., differs in shape from all the other Carboniferous varieties. The commencement of its growth was a hollow cone with anchoring rootlets; the cone rapidly widened and expanded outwards, forming folded and lobed fronds around the original cone. The cone is *Fenestella membranacea*, Phill.; the upper and expanded part of the polyzoarium is known as *Fenestella flabellata*, Phill., and *Fenestella tenuifila*, Phill. Sometimes the conical base commenced its outward extension somewhat earlier, causing it to assume a somewhat globose shape; in this state it is the *Fenestella hemispherica*, M'Coy. It is only right that I should state that W. H. Baily regards *Fenestella membranacea*, Phill., as identical with *F. hemispherica*, M'Coy *.

Now as to these synonyms: looking to the complete agreement which exists as to pore-cells, interstices, and dissepiments between *Fenestella membranacea*, *F. tenuifila*, and *F. flabellata* there need be no doubt or hesitation in allowing the "spreading corallum" in Prof. M'Coy's description of *Fenestella flabellata* to resume its right place on the "elongate conical polyzoarium" of Phillips's *Fenestella membranacea*. In so doing we not only make it a "thing of beauty," but, what is still more important, restore it to its true life-form.

I will now allude to the genus *Hemitrypa*, M'Coy. As such its claims are not now for the first time called in question. It is described as having "an internal network covered with an external sheath," while of *Hemitrypa hibernica* † we are told that "the in-

* Baily's Palæozoic Foss. p. 107.
† M'Coy's Syn. Carb. Foss. Ireland, p. 205.

ternal network is keeled and poriferous, as in *Fenestella*, indeed resembles *Fenestella membranacea*." To complete the evidence as to the connexion of *Hemitrypa* with *Fenestella*, W. H. Baily says of *Fenestella membranacea*, Phill., that "it exhibits impressions corresponding with the condition of the fossil named *Hemitrypa hibernica*, M'Coy." Lonsdale, an early worker among the Polyzoa, has something to the point. Writing, in 1844, of *Hemitrypa sexangula**, from Van Diemen's Land, he says of it "that it is not merely 'like some *Fenestella*,' but it possesses all the essential characters of that genus, and is believed to be a fragment of *Fenestella fossula*, Lonsd."†. Then he goes on to say, "Of the true nature of the external network no opinion is ventured. That it was a parasite, little doubt is entertained; and the interesting agreement between the space occupied by the double row of meshes and that of the parallel branches of the *Fenestella* arises apparently from the latter having afforded suitable base-lines for attachment." There can be no doubt that the interior portion of *Hemitrypa hibernica* is a true *Fenestella*; nor need we be in any doubt as to the species. Only one, *Fenestella membranacea*, Phill., has a conical base. The difficulty has always been the external sheath. It is important to mention that the same form is parasitic on brachiopods and crinoids, as well as *Fenestella*. Its connexion therefore with *Fenestella* is accidental and not structural. It is without doubt a small coral common to the limestone, very similar to *Flustra palmata*, M'Coy ‡, the empty calices of which cover over and conceal the *Fenestella* beneath. *Hemitrypa*, as we have seen, has *Fenestella membranacea*, Phill., for the groundwork and a microscopic coral or polyzoon for the superstructure.

Prof. M'Coy has a note to the effect that "*Hemitrypa hibernica*, M'Coy, is possibly only the perfect state of *Fenestella*" §. We have seen that *Actinostoma*, and not *Hemitrypa*, furnishes the true type of the genus *Fenestella*.

It is perhaps best to retain the name of *Fenestella membranacea* given to this species by Phillips; otherwise, from its unique form, it might well be distinguished as *Fenestella carbonaria*.

The remainder of the Carboniferous species of *Fenestella* (six in number) are of doubtful character. Of *Fenestella intertexta*, Portl.‖, it is enough to say that it has none of the characteristic marks of the genus. It is not a *Fenestella*. On the other hand, *Gorgonia regularis*, Portl.¶, from the Silurian, is a true *Fenestella*; and the description, which is exceedingly true of *Fenestella* growth, is as follows:—"Grows from a central attachment into a circular flattened expansion. The stems are slightly branched, wiry, rather distant, and united by regular dissepiments."

* Darwin's 2nd Voy. Beagle, pt. 2, p. 167.
† Darwin's 2nd. Voy. Beagle, pt. 2, p. 168.
‡ M'Coy's Syn. Carb. Foss. Ireland, pl. 26. fig. 14.
§ M'Coy's Syn. Carb. Foss. Ireland, p. 205.
‖ Geol. Londonderry, p. 324, pl. xxii A. fig. 3.
¶ Ibid, p. 323, pl. xx. fig. 6.

Fenestella arctica, var. *scotica*, Ether., jun., is a recent addition to the list *. It is unfortunate that in neither the species nor variety was the poriferous face in a condition to admit of description. In the absence of all reliable specific details they must be regarded as doubtful. I have previously given my reasons for believing that *Fenestella arctica*, Salt.†, is the last stage of *Fenestella plebeia*, M'Coy. In this view I am confirmed by the examination of some specimens from the shales of High Blantyre.

Here occurs a species which on the reverse answers fully the description of *Fenestella arctica*, Salt. On lifting this reverse from the shale by the process made known by Mr. John Young, F.G.S., the obverse is seen to have the true characters of *Fenestella plebeia*, M'Coy, and with scarcely a trace of the zigzag markings which on the reverse serve the purpose of a bracket under the dissepiment to support the increase of growth in the polyzoarium.

Fenestella Morrisii, M'Coy ‡, in the Woodwardian Museum, is in a condition that defies specific definition. It is often found in the Carboniferous strata that water has removed the whole or part of the organic remains. In the case of *Fenestella* the first portions to disappear are the thin dissepiments, leaving an irregular number of pores between the remaining dissepiments. Both *Fenestella Morrisii*, M'Coy, and *Fenestella quadradecimalis*, M'Coy §, I believe, have originated in this way. This is partly borne out by what Prof. M'Coy says of *Fenestella Morrisii*, "dissepiments thin, often disappeared."

The interstices and dissepiments of *Fenestella quadradecimalis*, M'Coy, are also described as thin, evidently water-worn. The explanation of these forms probably is that *Fenestella Morrisii*, M'Coy, is a fragment of *Fenestella plebeia*, M'Coy, from which alternate dissepiments have been removed. In *Fenestella quadradecimalis*, M'Coy, the same thing has occurred to *Fenestella polyporata*, Phill., giving twice the usual number of pores between the dissepiments. This loss of dissepiments in *Fenestella* is a very ordinary occurrence, and, in the case of fragments, likely to mislead, as the means of correction are not to hand. Hall figures a *Fenestella* (*prisca*) with the dissepiments absent ||. There still remain unnoticed *Fenestella oculata*, M'Coy, *Fenestella ejuncida*, M'Coy, and *Fenestella varicosa*, M'Coy. They are mostly unknown to the most diligent workers among the Polyzoa. Small pieces may be found having more or less divergent features; but it is a question whether these are distinct species or mere variations in growth, such as often occur on large fronds, and in so marked a manner that, by the same rule, two, three, or even four supposed species might be made out of a portion only of the polyzoarium. It is significantly said of *Fenestella oculata* by Prof. M'Coy that it "occurs only in fragments."

* Ann. & Mag. Nat. Hist. ser. 4, vol. xx. p. 31.
† Belcher's Arctic Voyage, 1855, vol. ii. p. 385, t. 36. fig. 8.
‡ Syn. Carb. Foss. Ireland, pl. 28. fig. 14.
§ Ibid. pl. 28. fig. 13.
|| Hall's Palæont. New York, vol. ii. pl. xix. fig. 4*b*.

Fragments of *Fenestella* are not always to be relied upon for the purposes of classification. It is clear from what has been said that if fragments of Polyzoa had been less relied upon by describers, much of what has been written in this paper would have been unnecessary.

Discussion.

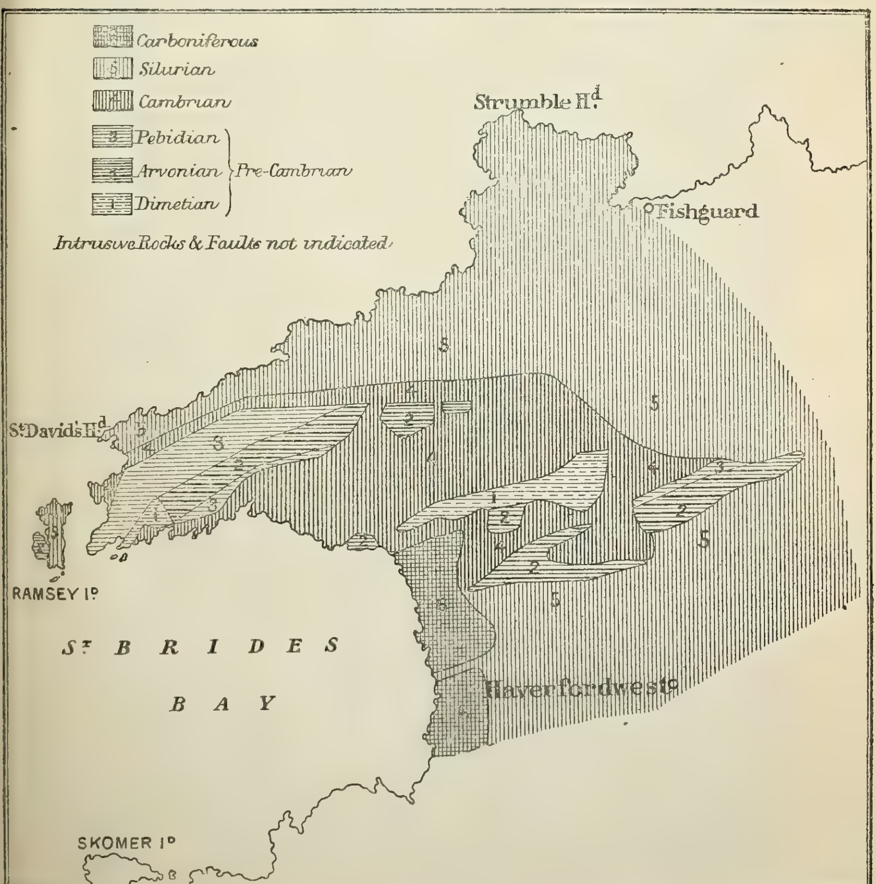
Mr. De Rance bore witness to the great industry of the author in working out this question, and to the value and excellence of preservation of the specimens derived from the Halkin-Mountain quarries.

23. *On a new* GROUP *of* PRE-CAMBRIAN ROCKS (*the* ARVONIAN) *in* PEMBROKESHIRE. By HENRY HICKS, M.D., F.G.S. *With an* APPENDIX, by T. DAVIES, Esq., F.G.S. (Read February 5, 1879.)

DURING my researches in Pembrokeshire last year, I was fortunate enough to discover some new areas of Pre-Cambrian rocks, and, moreover, to make out that the rocks which chiefly occupied those areas were generally unlike those which I had previously described under the names Dimetian and Pebidian.

Indeed it soon became evident that the majority were of a kind such as had not previously been recognized, at least to any extent, in the

Fig. 1.—*Sketch Map of St. David's Head and the neighbouring parts of Pembrokeshire.* (Scale about 6 miles to 1 inch.)



British Isles. They were marked on the Geological Survey Maps as intrusive felstones; but a very cursory examination proved that they were not of that nature, and that they were in reality bedded sedimentary rocks which had undergone metamorphic change. The first area which I propose to describe lies about five miles to the N.W. of Haverfordwest. It has a general E.N.E. strike, is narrow towards the west, and widens out eastward and there throws out two arms which at their extremities are distant about two miles. The actual width exposed at its greatest breadth is rather over a mile; and as the beds appear everywhere nearly vertical and not repeated, we have probably a vertical thickness of strata shown of not much less than a mile in extent. The ridge formed by these rocks is for the most part barren and wild-looking, and the highest point, called Plumstone mountain, attains to a height of nearly 600 feet. Lower Cambrian rocks rest upon it along the N.W. edge for about two thirds of the distance, and faulted Lingula-flags along the remainder. The southern and eastern sides are also in contact with faulted Lingula-flags for the most part, though at some places Lower Silurian rocks have been brought down against it. Roch Castle, an old fortress, and a very conspicuous object on the road-side between Haverfordwest and St. David's, stands almost on the western extremity of the ridge; and as the rocks are very well exposed at this point, the spot is a very favourable one for their examination. In colour they are mostly of a dull yellowish-grey tint, though some of the beds are light and very quartzose in appearance, others dark and cherty-looking. The lighter ones also are frequently banded in deeper tints. Some, again, appear at first sight as if porphyritic from grains of quartz; but these, it will be seen, are identical in character with the others when examined under the microscope. The texture usually is hard and flinty, and they break frequently with an imperfect conchoidal fracture. Others have a more horny fracture. I have had several microscopical sections made of these rocks; and Mr. T. Davies, F.G.S., of the British Museum, has kindly given descriptions of these in the Appendix (Nos. 1, 2, & 3). Speaking generally, the rock may be described as a "microcrystalline mass of quartz-grains with some interstitial light-grey substance, having but little action on polarized light." But the chief peculiarity consists in the manner in which the quartz is separated away into nests, so as to give that curious porphyritic appearance already mentioned. The mode of behaviour of the quartz also here is particularly interesting and instructive in regard to the changes which many crystalline rocks have undergone, especially the gneisses. In some cases the quartz is seen in distinct fragments, but yet coalescing, as if attracted together by some natural affinity from the surrounding material. In the next place the grains are so compressed together (and yet distinctly fragmentary) that all other material is removed, and nests of pure quartz grains only are seen, having a very crystalline appearance. By this selective process also the darker material is brought together and made to fold round the nests, so that a banded or imperfect flow-structure is given to the rock. All this looks as if an incipient gneiss was being formed, the metamorphic action being incomplete, a kind of semi-metamorphism and softening having taken place sufficient only to allow the particles to arrange themselves according to their natural affinities. In general, as well as in microscopical appearance, this rock is so like the "Hälleflinta" of the Swedish geologists, that we propose for the present, in the absence of a satisfactory English term, to give that name to all the rocks of this type in our descriptions. Though the group may be said to be chiefly characterized by these hälleflintas, we yet find associated with them true quartz-felsites, evidently old lava-flows, and some volcanic breccias. It is a highly acid group on the whole; and much of the material which has entered into the composition of the hälleflintas was probably derived either directly as fine dust from volcanos, or from the breaking up and denudation of acid volcanic lavas, combined, of course, with a certain proportion of ordinary marine sediment.

The next area to be described is in a line with the former, though separated from it by a considerable thickness of Lingula-flags and other Cambrian beds, which have been dropped between by faults. This has a length of about five miles, with an average width throughout of over a mile. Along its north-western edge the Lower Cambrian beds occur as in the former case, and between these and the true hälleflintas are altered schistose beds probably of Pebidian age. Its eastern edge is a line of fault, with Silurian rocks abutting against it. The southern line has in parts also some overlying Pre-Cambrian rocks (Pebidian) resting upon it, and in other places Silurian rocks brought against it by faults. The evidence here is conclusive as to the position which the group must occupy in the Pre-Cambrian formations, especially when combined with the information subsequently obtained from other areas. We see at once that it is Pre-Cambrian from the way in which Cambrian rocks are everywhere brought down against and upon it. We also see that it is Pre-Pebidian, as these last lie upon it, and fragments of the hälleflinta are frequently found in the Pebidian conglomerates. The evidence to be brought forward will also show that it is not of Dimetian age, but subsequent to that formation. It is clear, therefore, that it holds an intermediate position between the Dimetian and Pebidian formations, and is not of the age of either. For this reason I proposed at the last meeting of the British Association in Dublin to give to the group a new name; and it was then thought that, as these rocks were also found by us to occupy some areas in Caernarvonshire, the name "Arvonian," derived from the ancient name for Caernarvon, would be an appropriate one. The general character shown by the rocks in the area now described is similar to that found at Roch Castle. They are for the most part true hälleflintas, and excellent sections may be seen in the gorge through which the western Cleddau river flows, and the road from Haverfordwest to Fishguard passes. The "Treffgarn Rocks," very prominent weathered masses of these rocks, are seen for a considerable distance along this road, and vertical cliffs of considerable height occur close

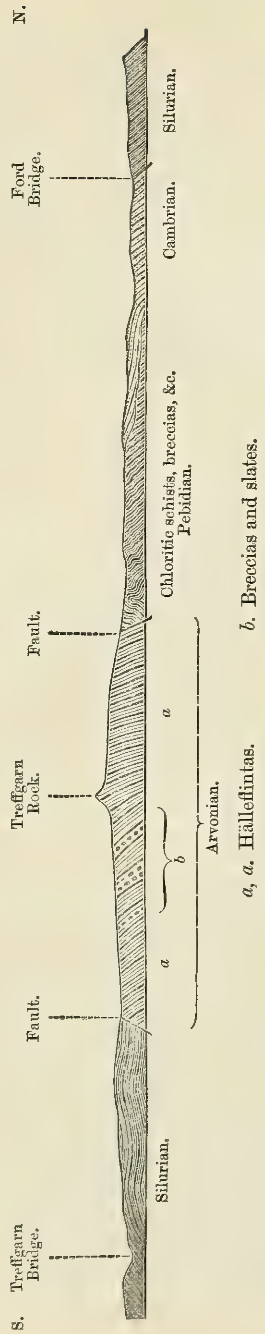


Fig. 2.—*Section from near Treffgarn Bridge to the north of Ford Bridge on the Road from Haverfordwest to Fishguard.* (Scale, 6 inches to 1 mile.)

a, a. Hälleflintas. *b.* Breccias and slates.

to the road-side, and offer very favourable opportunities for their examination and for the collection of specimens.

Another area of these rocks occurs to the N.W. of those just described, here also running in a direction from N.E. to S.W., and parallel to and apparently flanking towards the S.E. the Dimetian axis of Brawdy and Hayscastle. The detached mass on the coast, in a line with this ridge, is also more of the nature of these rocks than of the Pebidian or Dimetian.

It will be seen also that they form a considerable proportion of the so-called Dimetian axis at St. David's.

In my last paper on the Dimetian and Pebidian rocks of St. David's *, I called attention to the fact that the series 1 and 2 in the general section there described were lithologically very unlike the series 4, 5, 6, and 7, which I stated formed the bulk and typical portions of the Dimetian. The series 1 and 2 were called generally quartz-porphyries and quartz-felsites, and were then supposed to have either a volcanic or intrusive origin. They were also excluded in the calculation of the thickness of the Dimetian on account of their doubtful character and dissimilarity to the rocks of that group. But as at that time there was no evidence to show that these were distinct from the Dimetian in any other way than in their mode of origin, and as, moreover, it was clearly seen they could not be allied to the Pebidian (since the latter everywhere rested upon them unconformably), I felt justified in keeping them with the Dimetian.

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 153.

The discovery of new areas, however, has now made it clear that these quartz-felsites are more characteristic of the Arvonian group, and usually in association with the hälleflintas; and that at St. David's, as elsewhere, they are for the most part old rhyolitic lavas interstratifying rocks of the true hälleflinta type.

Much of the ground to the N.E. of St. David's is obscured by drift, bogs, and mossy ground, and hence some difficulty has been experienced in unravelling it satisfactorily. I have, however, by carefully tracing all lines of streams, the materials derived from deep wells, as well as all quarries that could be found, now proved conclusively that at least two thirds of the central axis will have to be associated with the Arvonian—or, in other words, that nearly all of the red patch, coloured as syenite and felstone in the Geological Survey Map, to the N.E. of St. David's will have to be assigned to that formation, the lower portion only, that of which I have already given sections, being Dimetian.

The discovery of the new areas already referred to, viz. of Roch and Treffgarn, and of a new type or group of rocks there, has cleared up much of the difficulty which we had to deal with in the rocks of St. David's and in North Wales; and I venture to hope that it has given us the clue by which many other areas hitherto doubtful may be unravelled.

The junction of the Arvonian with the Dimetian may be seen at St. David's, about a quarter of a mile to the south of the Cathedral and near Rock House. The Dimetian is well exposed at Bryn-y-garn, where it stands out as a prominent ridge. A little to the north of this there is a slight depression in the surface of the ground; and this I consider to mark a line of fault, for immediately beyond this the Arvonian rocks are seen striking up towards the ridge. The lowest beds, as seen on the road-side near the Deanery, show somewhat of a brecciated appearance; but when the rock is submitted to microscopical examination this character is less evident, and it may possibly be a form of brecciation *in situ*. Both this rock and the immediately succeeding one, according to Mr. Davies's descriptions (Nos. 4 and 5), come sufficiently near the hälleflinta type to associate them together. The difference in any case between them and the Dimetian is most marked; and the abrupt junction between the one and the other at this point has led me to place here the line of demarcation. Succeeding these, as we trace the line to the N.E., are the quartz-felsites and porphyries mentioned in my former paper, and which are well exposed near the church and board-schools. No. 6 in Appendix also comes from this point. Nearly opposite this, on the east side of the ridge, between Trepewet and Clegyr, true hälleflintas are found, in some cases showing a brecciated appearance, but in others the compact variety found at Roch and Treffgarn. These show, under the microscope, the characteristic nests of quartz, and one of the brecciated ones is described by Mr. Davies in No. 7. In association with these are found the quartz-porphyries of the Church-school quarry type; and resting unconformably upon the whole are the great agglomerates of Clegyr

Hill, the base beds of the Pebidian, which are made up chiefly of masses of Dimetian rocks, of quartz-felsites, spherulitic felstones, and hälleflintas, and all in the condition in which they are now found composing the underlying ridges. From this evidence it is tolerably clear that the position of the Arvonian or hälleflinta group is intermediate between the Dimetian and the Pebidian, and that there is, at least in this area, very clear proof of unconformity, and hence of a lapse of time having intervened.

From this point to near Llanhowell there are but few exposures; but it is clear from the rocks that I have been able to examine that they are much of the same character as those nearer St. David's, an alternating series of true hälleflintas, breccias, and quartz-felsites usually striking across the axis. Near Caervoriog Bridge, the Pebidian agglomerate is made up in some cases almost entirely of masses of hälleflintas. At and about Llanhowell the rock is of a lighter appearance than further south, and a section has been examined (No. 8, Appendix).

Beyond this, and extending as far as the great E. and W. fault, hälleflintas and breccias, with some quartz-felsites, are again the prevailing rocks (*vide* No. 9, Appendix).

All along the flanks of this axis on either side and dipping away from it are found either Pebidian or Lower Cambrian rocks, the former everywhere along the N.W. and nearly along the whole of the S.E. side. The N. end is cut off by the E. and W. fault, and Upper Cambrian and Lower Silurian rocks have here been brought against it. Two other masses of Arvonian rocks are found in a line to the east of the north end of the ridge; and these in their lithological characters are almost identical with those described from the axis.

The prevailing characters in the three formations of Pre-Cambrian rocks now made out in Pembrokeshire may be briefly defined as under:—

Pebidian ...	*a.* Micaceous, talcose, and chloritic schists, with slaty and massive green bands containing epidote, serpentine, &c.
	b. Tuffs, indurated ashy shales, breccias, silvery schists, porcellanites, conglomerates, and agglomerates.
Arvonian...	Breccias, hälleflintas, and quartz-felsites.
Dimetian...	Quartzose rocks, granitoid gneiss, and compact granitoid rocks with bands of crystalline limestone.

Speaking generally, it may be said that the state of alteration or metamorphism exhibited by the rocks in each of these formations is in proportion to their age, the Dimetian being the most highly altered, and the Pebidian the least so.

This, however, will not apply to every member in each group; for some materials, as is well known, tend to change more readily than others. For instance, deposits which are of chemical origin, or even partially so, naturally assume a more crystalline appearance than those entirely made up of detrital materials. Again, sediments largely made up of volcanic materials readily put on a metamorphic aspect; and this is increased also by the frequent presence of crystals or fragments of crystals derived directly from volcanos, and sometimes also from the denudation of igneous rocks. Then, again, rocks made up of large fragments and rough materials are, on the whole, less easily attacked than those of a more homogeneous nature.

Each of these formations, however, by the majority of the rocks composing them, show a state of alteration peculiarly characteristic; and from this fact, as well probably as from the original nature of the materials out of which they were formed, the rocks of each group are easily recognized after a very slight acquaintance with them. Indeed so curiously marked is this in the various areas examined, that by lithological characters alone one was frequently instinctively lead to recognize their presence where they were previously quite unsuspected. It is evident also that these are not local peculiarities only, but of very wide application, since the descriptions given by some Swedish geologists of similar rocks in their own country indicate that they are, approximately at least, of the age of these rocks. Again, rocks of a like nature have been described in America by Professors Hunt, Hitchcock, and others; and these, again, appear to hold a somewhat equivalent position in geological succession.

APPENDIX *on the* MICROSCOPICAL STRUCTURE *of some* ARVONIAN ROCKS *from* PEMBROKESHIRE. By THOMAS DAVIES, Esq., F.G.S.

1. *Roch Castle, Pembrokeshire* (p. 286).—This rock, which presents the external aspect of a hornstone, when examined in a prepared section under the microscope is seen to consist mainly of a cryptocrystalline ground-mass which, in numerous nests and fissure-like groups, is developed into a microcrystalline structure. Examined with a high objective, this cryptocrystalline mass is resolved into grains which exhibit, both in ordinary and in polarized light, the characteristic aspect of quartz, and is found to contain as an interstitial ingredient a light-grey, somewhat indefinable constituent, having but little action on polarized light, and which, from its great resemblance to the known felsitic substance of many of the quartz-felsites, constitutes the felsitic portion of the rock. The nests and fissures (resembling groups of coarser structure) present a rude parallelism suggestive either of an incipient foliation or of a stratification.

The whole mass is traversed by numerous well-defined fissures (quite distinct from the fissure-like groups), which are filled with a clear crystalline quartz, probably of subsequent origin. Very numerous acicular crystals and spots of an undeterminable substance (which, with a high power, are found to depolarize light and to assume a rich brown colour) are disseminated through the whole, accompanied by an opaque black mineral resembling magnetite.

2. *Roch Castle* (p. 286).—The compactness and dull splintery fracture of this rock recall still more than the preceding the characteristics of a hornstone. Its structure likewise, as exhibited under the microscope, bears a marked resemblance, but is characterized by some well-defined differences. In places an exceedingly fine dust in the

cryptocrystalline base is enclosed in wavy bands, which appear to have been disturbed in their parallelism by the subsequent development of the microcrystalline nests. These nests and also the fissure-like groupings are distributed throughout, and are encircled by bands of a fibrous chalcedony, the structure of which is well exhibited with polarized light, the foliation or stratification being more markedly illustrated than in No. 1. In one part of the section of this rock undoubted angular fragments, distinct in size and shape from the mass, are enclosed, affording further evidence of its probable original sedimentary origin. Similar minute needles and spots of the opaque and sometimes translucent brown mineral are present here as in No. 1.

3. *Treffgarn Rocks on Fishguard Road* (p. 287).—Another rock of the same type as the two preceding, its structural peculiarities being almost identical with No. 2. The nests of quartz are, however, somewhat coarser-grained, while the indications of foliation or stratification are not so distinct. Exceedingly minute needles are distributed throughout, here and there aggregated into dense groups. Under a high objective these are resolved into very distinct transparent crystals, which depolarize light. I have not yet been able to satisfy myself as to their mineral nature, but believe them to be related to hornblende. With these are associated numerous opaque or semitranslucent crystals, occasionally presenting a hexagonal section, and which are probably magnetite.

The macroscopical and microscopical characters of these rocks are so remarkably like those of the hälleflintas from Sweden, that they are not to be differentiated by means of the microscope. The same variations in texture, the indefinite character of the interstitial felsitic constituent, the presence of the numerous acicular crystals (only seen to be such by the use of high objectives), are also characteristic of their Swedish prototypes, to which I propose to refer them; and so far as their present structure (as determined by the microscope) can indicate their origin, it would appear to have been a sedimentary one.

4. *Road south of the Deanery, St. David's* (p. 289).—This is a greenish-grey rock with blackish-grey spots, and exceedingly fissured; this and its spotted character give it the aspect of a breccia. Examined in thin sections it presents a microcrystalline ground-mass of quartz and felsitic matter with a thickly distributed undeterminable dark grey dust-like substance, much resembling that found in many of the so-called "volcanic ashes," mingled with grains of a black opaque mineral with the habit of magnetite. The spotted appearance of the rock is due to the denser aggregation of this substance in patches, associated with viridite. Crystals or parts of crystals of felspar, mostly orthoclase, are occasionally discernible, while indistinct columnar crystals of a grey colour, becoming black between crossed Nicols, are thickly distributed in parts of the ground-mass.

5. *Road south of Deanery, St. David's* (p. 289).—Apparently the same rock as No. 4, but the brecciated aspect is here not apparent.

A thin section discloses a coarser microcrystalline ground-mass with more numerous crystals and fragments of orthoclase felspar. In places the felsitic matter has assumed a spherular structure, indistinctly radial, and without a peripheral definition, but passing into the microcrystalline ground-mass; this is best observed between crossed Nicols.

This absence of definition of the spherular limits of the felsitic radii observable here, and also in some other Arvonian rocks*, though not unknown in some trachytic examples, I am disposed to regard as evidence of a subsequent rearrangement of part of the felsitic constituent.

6. *Near Church Schools, St. David's* (p. 289).—Consists of an intimate microcrystalline association of felspathic substance with quartz-grains. The felspathic ingredient constitutes by far the larger proportion of the ground-mass, and has a great tendency to develop into small columnar crystals, which, though possessing an indefinite outline, are yet distinctly discernible. Here and there appear a crystal or group of crystals of orthoclase (as evidenced by the Carlsbad twins) distributed porphyritically. A similar radial-spherular arrangement of part of the felsitic substance to that in No. 5 is shown, but, though more distinctly developed, is much less frequent. Viridite in patches pervades the whole rock.

7. *Road east of Trepewet, St. David's* (p. 289).—A compact rock with a very splintery fracture, and resembling hornstone.

Under an inch objective the ground-mass of this rock is seen to be exceedingly fine-grained, much of it having no action on polarized light, but it is variegated by patches having a microcrystalline structure and a strongly depolarizing action. Numerous angular and subangular grains of quartz are dispersed throughout.

This rock has a considerable resemblance to the hälleflintas; and I am inclined to refer it to that type, but I have not yet met with a Swedish example presenting so decided an illustration of detrital origin.

8. *Llanhowel Quarry, in field north of Church* (p. 290).—A light yellowish-grey rock, very compact, with some disseminated mica.

Microscopical examination reveals that it consists almost exclusively of felspar and quartz. The felspar constituent of the ground-mass is largely in the form of minute slender prisms, its orthoclase affinity being here and there evidenced by the Carlsbad twinning; whilst that of the larger porphyritic crystals is a plagioclase, as indicated by the faintly coloured striæ observable between crossed Nicols; this felspar appears to be much altered. The remainder of the felspathic constituent is more indefinite, and with the slender prisms and the quartz-grains forms the fine-grained ground-mass. Some of the quartz appears as large, more or less rounded crystalline grains, similar to those familiar to us in the quartz-felsites. Numerous crevices are occupied by a colourless, diverging, fibrous mineral, which is probably an epidote.

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 164. These are Nos. 1 & 2 described under and then supposed to belong to the Dimetian, but now associated with the Arvonian on the grounds mentioned in the present paper.—H. H.

9. *Near Bryn, S.E. of Treglemais* (p. 290).—Appears macroscopically to be a quartz-felsite of a greenish-grey colour; it is much fissured.

Exhibits in thin section numerous fragments of preexisting rocks which have been caught up in a quartz-felsite, the confused fluxion structure of which characterizes a certain type of these rocks. Among the fragments thus enclosed are those of a rock like No. 8, of some hälleflintas like Nos. 1 & 3, with numerous crystals and fragments of orthoclase and plagioclase, also angular quartz and grains of magnetite. Crystalline quartz occupies numerous fissures and nests in the mass.

(For Discussion on this paper, see p. 325.)

24. *On the* Pre-Cambrian (Dimetian, Arvonian, *and* Pebidian) Rocks *in* Caernarvonshire *and* Anglesey. By Henry Hicks, M.D., F.G.S. *With an* Appendix, by Prof. T. G. Bonney, M.A., F.R.S., Sec.G.S. (Read February 5, 1879.)

Introduction.

When exploring the districts in North Wales described in my paper communicated to the Geological Society in December 1877 *, I visited several other areas, and observed, in some of these, facts tending to show that the Pre-Cambrian rocks had a far wider distribution there than was then supposed; and in a note to one of my papers † I ventured to suggest the position which some of these, viz. those in Anglesey and South-west Caernarvonshire, were likely to occupy. With the hope of being able to arrive at a satisfactory conclusion as to the age and position of these, and also as to the true nature of some of the other great masses which were marked on the Geological Survey maps as intrusive in Silurian rocks, but which I had previously suspected to be of Pre-Cambrian age, I visited North Wales again last August, and was fortunate in being accompanied during most of the time by such experienced geologists as Professor Torell of Stockholm, Mr. Tawney, F.G.S., of Cambridge, Professor T. M'Kenny Hughes, of Cambridge, and Dr. Sterry Hunt, of Montreal. Some of the facts to be brought forward in this paper were communicated to the British Association at the late meeting in Dublin; but as the results at that time had not been fully worked up, and some even were obtained subsequent to that meeting, I have thought it advisable to bring this paper before the Society, as embodying not only the results then given, but many additional facts and observations. As I propose also to commence the description with the immediately adjoining area to that treated of in my paper last year, it will appropriately appear as a continuation of that paper.

Glynllifon and Craig-y-Dinas.

Along the west side of the areas of Moel Tryfaen and Pen-y-Groes described in my former paper, there is in the Geological Survey map an extensive area coloured as altered Cambrian. It extends westward as far as Glynllifon, and the line to the south is marked as occurring at Craig-y-Dinas. On examining these rocks at various points, I could see nothing to indicate that they were altered Cambrian beds; and on carefully tracing the line of junction between them and the unaltered Cambrian rocks, I found distinct evidence that the latter rested unconformably upon them, and hence the

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 147. † *Op. cit.* p. 163.

altered beds were undoubtedly Pre-Cambrian. The majority of the rocks in this area are breccias and felspathic schistose rocks; but there are also some porcellanitic and compact and schistose chloritic rocks. I look upon them as belonging to the Pebidian formation and probably unconformable to the central ridge previously described. In my description of that ridge * I associated the rocks composing it with the Pebidians also, as we were then unaware of a third group as distinct from the others. It seems likely now, however, that the more central or highly altered portion will have to be associated with the Arvonian, and that only the least-altered beds along the flanks can be grouped with the Pebidians. On the accompanying map (p. 297) the three Pre-Cambrian groups are indicated; and places where each may be examined will be mentioned in the description given of the separate areas.

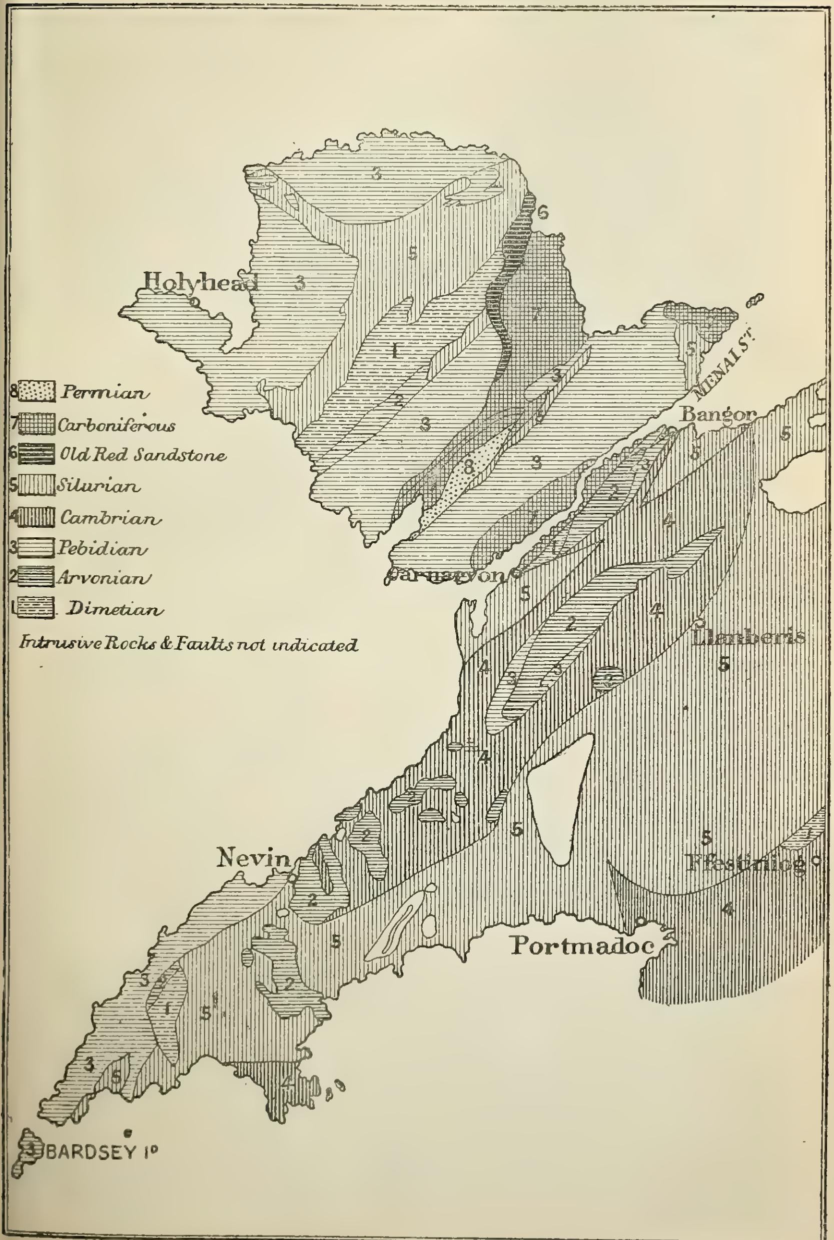
Caernarvon to Bangor.

I propose to refer very briefly to this area, as it was partially described by Professor Hughes in his paper † read before the Society in December 1877; and it has subsequently been examined by Professor Bonney, in whose paper it will be fully referred to. As the results, however, obtained by me when examining the rocks in this area in August last seem to bear out the interpretation which I had previously given to it, I feel it necessary to lay a few of the facts before the Society. In the former paper I stated that "representatives of the two great unconformable series, Dimetian and Pebidian," occurred in Caernarvonshire. "With the former of these I would associate the so-called syenitic ridge (granitoid rocks) of Caernarvon; and with the latter the altered beds which rest directly on the syenite ridge towards Bangor." These expressions were used after a careful examination of portions of the area in 1877; but I felt it necessary to devote more time to the district before venturing to express myself more strongly on these points. The results obtained in our explorations last year have fully borne out my previous views; and it is also a great source of satisfaction to find that the careful labours of Professor Bonney, both in the field and with the microscope, tend also in every way to confirm those views.

The new facts which I need to refer to chiefly bear upon the varying character of the rocks as we proceed from Caernarvon to Bangor. At Caernarvon the true Dimetian type is found. About four miles to the north of this, on the road to Menai Bridge, a sudden change takes place, and a greenish-grey compact rock is seen having more of the character of some of the Arvonian or hälleflinta rocks of St. David's than of the Dimetian. The microscopical examination of this rock is given by Professor Bonney in the Appendix, No. I. I believe it will be found that a stratigraphical break on a fault occurs near here, and that rocks belonging to two distinct formations, Dimetian and Arvonian, are thereby brought into contact. These

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 147. † Ibid. p. 137.

Sketch Map showing the Pre-Cambrian Rocks in Anglesey and Caernarvonshire. (Scale about 6 miles to 1 inch.)



are succeeded by quartz-felsites of the true Arvonian type (with probably some bands of hälleflintas), which may be traced continuously to near Bangor, where the Pebidian beds, I believe, rest upon them unconformably.

According to this view the three formations made out in Pembrokeshire are found closely associated also in Caernarvonshire; and the evidence, as there, seems to point to their being unconformable here also to one another.

How far these unconformities may be considered as evidence of important changes or simply as local accidents, it is of course impossible to say; but it seems as if a considerable lapse of time was indicated, and that other formations may possibly have even intervened, from the different state of metamorphism in which they are found, and the different direction usually of the strike in the beds in each formation, which, if constant, would certainly mean different periods of upheaval.

Lleyn Promontory.

In the Lleyn Promontory, or that part of Caernarvonshire which gradually tapers towards the S.W., with an imaginary base-line drawn from Clynnog-fawr on the one side to Criccieth on the other, numerous masses of so-called intrusive rocks are marked on the Geological Survey maps. That some of these are, as supposed, intrusive masses, which have altered to some extent the surrounding rocks, there can be no doubt; but that by far the larger proportion are not so, and do not in any way alter the beds in contact with them is equally certain. That many of these also are of Pre-Cambrian age I think I shall be able to prove, though, in the absence generally of true Lower Cambrian rocks in this area, the evidence has to be based frequently on the general character of the rocks themselves and the behaviour of the beds in contact with them. I may say also that as no contemporaneous lavas of Lower Cambrian or even Upper Cambrian age have been recognized in Caernarvonshire, this fact will be considered as of importance in attempting the correlation of the rocks, though not as absolute proof alone. In the term Upper Cambrian I include the rocks now generally recognized as Lingula-flags and Tremadoc rocks only.

The rock of Mynydd-y-Cennin is described by Professor Ramsay as "a quartz-porphyry similar to that of Llyn Padarn near Llanberis, and probably having a like origin;" this is therefore undoubtedly an exposed portion in continuation of the Llyn-Padarn and Moel-Tryfaen ridge, and, like it, of Pre-Cambrian age. The Lower Cambrian rocks have here been faulted down; but they are still surrounded, partially at least, by beds of Upper Cambrian age, and which are not in the slightest degree altered at the junction. The mass to the north of Clynnog-fawr is of the same character, and also surrounded by Upper Cambrian rocks, and on the one side by even Lower Cambrian beds also unaltered in contact. The masses further south, and forming the mountains of Bwlch-mawr, Gryn-goch, Pen-llecLog, and the beautiful and very conspicuous Eifl (or Rivals) range of mountains, are in some respects unlike the rocks already described, but yet clearly of that type and age, with the exception of some dykes which have been intruded amongst them. The main masses are of a highly felspathic type, chiefly old rhyolitic lavas and breccias, which have undergone subsequent change. The rocks No. II., described by Professor Bonney in the Appendix, are from the Eifl range. In the spur of the Eifl to the south-east felspathic breccias and schistose felspathic rocks occur. Near the centre horny-looking quartz-felsites of the Llyn-Padarn and Moel-Tryfaen type, showing a bedded appearance (perhaps only a parallelism of jointing), are seen interbedded with rocks of the hälleflinta type. Further westward quartz-felsites again prevail. The detached mass on the coast is a kind of fine-grained granite, and is supposed by Professor Bonney (Appendix, No. III.) to be of igneous origin. Upper Cambrian rocks, chiefly of Tremadoc age, are faulted against these masses, and are in no cases altered except near the dykes of intrusive rocks (gabbros, &c.). Lower Tremadoc fossils (*Neseuretus*, &c.) were found in beds at Pont-rhyd-Goch, a mile north of Four Crosses.

The rocks forming Nevin and Boduan mountains, as well as some masses near Pwllheli, and to the north and south of Llanfihangel Bachellaeth, are of the same type as those described from the Eifl range (*vide* Appendix, No. IV., from Boduan mountain). They are in the main lava-flows, breccias, or hälleflintas, and show no characters indicative of intrusive rocks. They are highly metamorphosed, and are traversed by many intrusive dykes; but the flow-structure is frequently quite apparent in the field, and a bedded appearance commonly shown. The surrounding sedimentary rocks are also quite unaltered in contact with them. These, therefore, we may I think, without fear, also place with the Pre-Cambrian rocks, and in their general characters they seem allied to the Arvonian. Some few of the less altered brecciated rocks found here and there in near association with the quartz-felsites may belong to the Pebidian group. The rocks, No. V. in the Appendix, are from the mass to the east of Nanhoron; and though in the field they look almost as if bedded and intermediate in character between Dimetian and Arvonian rocks, yet on microscopical examination this view does not seem to be borne out, and Professor Bonney thinks they are of intrusive types.

It is satisfactory to find, however, that undoubted Dimetian rocks occur not far south of this point, and that the great mass, called on the Geological Survey maps Rhos Hirwain syenite, is of this nature. Both in the field and under the microscope the Dimetian character of this rock is undoubted; and there can be no difficulty in recognizing at once that we have here an old ridge of these rocks such as is found at Caernarvon to the north and St. David's to the south. Its position here also is most instructive, as bearing out our views expressed with regard to some of the other areas.

In crossing the ridge from east to west, starting from Sarn Meyllteyrn, after passing some masses of intrusive gabbros with

Silurian beds altered in contact, the true Dimetian type is seen near Ty-mawr and for some distance across (*vide* Appendix, No. VI.). Eastward of this, and as we approach the so-called altered Cambrians, rocks of a more felsitic character come in abruptly, and it is probable that these are of Arvonian age. Both groups are largely penetrated by intrusive gabbros, but not to the extent marked in the Survey maps, especially not so much so to the north of the main road across. The Dimetian axis here seems to run in a direction almost due N. and S. Its eastern edge is a line of fault or faults, and along its western edge newer Pre-Cambrian rocks rest upon it. This condition of faulting along one side of these old rocks, with the entire loss of the succeeding groups, is such a frequent occurrence that it seems necessary to refer specially to the physical conditions or probable causes which produced this effect. One thing which has become particularly evident during our researches is the fact that all bits of Pre-Cambrian rocks which have been included in succeeding sediments must have been not only in an indurated condition when broken off from the parent rocks, but, moreover, that they had even then undergone metamorphism, and the more slaty ones a species of cleavage. The lowest Cambrian rocks found are made up of bits and pebbles of these rocks; and so like are they frequently to the solid rocks below, that there can be no doubt that they were the beach-pebbles when those old rocks formed coast-lines. Now these old rocks must have undergone gradual depression to receive the subsequent sediments; and as this depression could not take place in rigid or metamorphosed rocks without producing fractures, we have at once one cause for some of the faults, and reasons for coast-lines continuing for a considerable period in some cases, whilst the surrounding areas were becoming depressed to a great depth. The greatest faults, however, and those which we have most frequently to deal with, are those which occurred after the succeeding Cambrian and Silurian sediments were deposited. During the great contractions of the crust in Palæozoic time, especially towards its close, the rigid Pre-Cambrian crust could not fold, enormous fractures would take place instead, and the overlying rocks would be thrown down. In some cases, as found here and at other places, the Pre-Cambrian would be brought to the surface along one edge of the fracture, and its other edge would be depressed to a great depth. The fault in Ramsey Island, at St. David's, has a downthrow of over 16,000 feet; and I think the one here can hardly be less—that is, if the usual sediments found in other areas in Caernarvonshire were ever deposited here, and there seems no reason to suppose that they were not.

According to this view beds belonging to many different horizons in geological succession would now appear on the surface faulted against the Pre-Cambrian rocks; and this it is that occurs wherever they can be examined. I have found beds occupying every position from the Lowest Cambrian to the Bala beds in direct contact with the Pre-Cambrian rocks as the result of faults. The constant recognition of these facts has been of great value in attempting to unravel so difficult a region as the Lleyn Promontory has proved to be.

Nearly the whole of the area to the west of the Rhos-Hirwain ridge is occupied by so-called altered Cambrian rocks. These, it will be seen, are all of Pre-Cambrian age, chiefly belonging to the Pebidian formation.

They are described generally by Mr. Selwyn, in Professor Ramsay's memoir, as "a series of green, grey, and purple schists, often very hard and siliceous, sometimes arenaceous and gritty, with large and small veins, beds and masses of quartz rock, also bands and patches of calcareous rocks, and grey and pink siliceous crystalline limestone occasionally burnt for lime," and to be pierced "by numerous greenstone dykes, and contain patches of serpentine, and veins and nodules of red jasper. These beds are much contorted on a small scale, but their general dip is north-westerly from 25° to 50°." In this concise and clear description by Mr. Selwyn we see nothing to indicate that these are in any way like the Cambrian rocks in other areas in Caernarvonshire; but his description at once calls to mind the Pebidian rocks of St. David's, Bangor, and other places. Our personal examination of these rocks was still more conclusive; and I have not the slightest hesitation, after the evidence obtained, in associating these rocks with those of Pre-Cambrian age, and more immediately with those in the Pebidian formation.

They occupy an extensive area and "form a band (exclusive of Bardsey Island) 14 miles long from Bardsey Sound to Nevin, and generally from a mile to 2 miles wide. A long spur also proceeds southward from the main mass to the east coast of Aberdaron Bay," where they are described as "green chloritic siliceous schists." Bardsey Island also consists of similar rocks. Though frequently much contorted, and hence repeated in folds, it is perfectly clear that they, on the whole, dip away from and follow the outline of the axis to the east formed of Dimetian and Arvonian rocks. We have therefore a succession here almost identical with the one in the next promontory to the south, viz. the St. David's one. On the whole also the rocks representing the three formations in both promontories are exceedingly alike; but it is probable that in Caernarvonshire a greater thickness is shown, and hence that some bands occur which are but imperfectly represented at St. David's, as, for instance, the calcareous and serpentinous ones. The unravelling of this district, occurring, as it does, intermediate between St. David's on the one hand and the great metamorphic areas in Anglesey on the other, seemed to me of the utmost importance, as any interpretation which it might offer could not fail to have an important bearing on several other districts in North Wales, and especially in Anglesey.

Anglesey.

Some previous excursions which I had made into Anglesey had not enabled me to arrive at any thing like a satisfactory conclusion with regard to some of its rocks. Fortified, therefore, with this new evidence, we this year again carried our investigations there; and this time with much success. It seemed but natural now also, after what we had seen in the other areas, that we should, in the first place, attempt to discover some base-line or axis from which to start; and we were fortunate in discovering such a line near Ty-Croes, a railway-station on the Holyhead line. A little to the west of this point, in the Geological Survey maps, a large patch is coloured as granite running in a direction nearly N.E. and S.W., and with a width in some places of between two and three miles. On examining this we soon found that we had here an almost identical rock with that found at Twt Hill, Caernarvon, at Rhos Hirwain, and at St. David's, and that we had in reality come upon what would in all likelihood prove to be another Dimetian axis. This was very satisfactory; and the microscopical examination of the rocks forming this ridge subsequently made has fully borne out the conclusions then arrived at in the field (*vide* Appendix, No. VII.).

We were fortunate also in finding on the roadside, and in a quarry near some cottages about half a mile W.N.W. of Ty-Croes, the actual junction between the Dimetian (or granitoid) rocks and the adjoining ones. These last appeared brecciated at this point and seemed to contain fragments of the granitoid rocks. Tracing these backwards towards Ty-Croes, this brecciated character was soon lost, and compact greenish-grey rocks of the hälleflinta type appeared to rest upon them in natural succession. To the east of Ty-Croes micaceous and chloritic schists again lie upon the hälleflinta group, and dip away from the latter towards the S.E. So that in this neighbourhood, and within a small compass, we meet with rocks belonging to three distinct formations, and in the order of succession indicated already in other areas. The granitoid gneiss and more compact granitoid rocks compose the Dimetian axis. Flanking this along the eastern edge are found the breccias and hälleflintas of the Arvonian; and beyond and resting probably unconformably upon these the micaceous and chloritic schists of the Pebidian. Professor Bonney, who subsequently examined this neighbourhood, has kindly furnished me with notes upon it, which are of great importance as confirmatory of our conclusions, and also as adding new and valuable supplementary information. They refer chiefly to the area west and south of the point indicated above, where I consider the junction of the Dimetian with the Arvonian occurs, and are important in showing the presence of bands of chloritic schistose rocks associated with the granitoid rocks here, similar in a marked degree to those described by me in the Dimetian at St. David's. The following are the notes by Professor Bonney:—

"In a shallow cutting just south of Ty-Croes station (on railway) is a hard greyish bedded rock, like a fine felspathic grit or mudstone much altered. Walked along highroad towards Llanfaelog, passing over schist. At Felinbont the rock is a greenish grey, rather calcareous, micaceous schist, of the general type so common in Anglesey, the foliation-planes striking N.E. and S.W. with dip to S.E. Came on to the first of the two 'granite' promontories of map. The rock not a granite, but a granitoid rock like that of Twt Hill (Appendix, No. VII.) A little north of Penbryn is a quarry on road (to which we were directed as the "hardest rock in these parts") in a dull greenish-grey schistose rock (*vide* Appendix, No. VIII.). This rock has, in parts, a peculiar brecciated or fragmental aspect, the fragments in one or two places becoming quite distinct by weathering and being angular. It is the sort of rock I should expect would be produced by the metamorphism of a rather basic volcanic ash. Crossing the creek we found, in a pit between the main and cross-road near the church (nearest to the cross-road), another schist with indications of included fragments and some appearance of a fault. In the road-cutting a few yards off the granitoid group of the former type appeared. We then followed the main road (running N.N.W. of Llanfaelog church) over a second 'granite' promontory; the 'granite' here is rather darker, having more of some green mineral (*vide* Appendix, No. IX.). It is obviously not true granite, and at times has an appearance as if it were made up of rolled fragments, such as we might suppose a coarse quartz-felspar grit, highly altered, would assume.

"Towards the middle of the mass it is distinctly a porphyritic gneiss with pink felspar crystals. Just beyond 'Siop' is a shallow valley with stream running through it. Turned into field. On the slope we have pale-coloured gneissose rock, and near the bed of the valley a coarse purplish quartzose grit, with a well-bedded finer grit above; dip 30° W.N.W., the nearest exposures of grit and gneiss being fifty yards apart. Walked along valley to railway, then turned back along it, entering a cutting. Here we find a dull bluish or greenish schist (*vide* Appendix, No. X.), overlying a porphyritic gneiss with pink felspar crystals (Appendix, No. XI.), like that mentioned above. The gneiss begins about twenty yards from the opening of cutting, and there seems to be a slight fault at junction; but as there are gneissose bands on the one side and schistose bands on the other, it is clear the fault is unimportant (if it exist) and there is a true sequence. We walked rapidly back along the railway, passing mostly through granitoid gneiss, and noting the schistose band that separates the two 'granite' promontories."

The western edge of this axis seems to be a line of fault; for Silurian beds are brought down against it almost continuously along this side. Beyond the Silurian area the metamorphic rocks again occur, here chiefly in the character of micaceous, quartzose, and chloritic schists with bosses of serpentine. The beds here generally lie at rather low angles, and are frequently much contorted. The whole of these rocks are so well described, and their behaviour illustrated, by Professor Ramsay in his excellent memoir *, that it seems quite unnecessary here to do more than refer the reader for any further information required to that work. It would be quite beyond the scope of the present paper to attempt to describe minutely these rocks in the various districts in Anglesey. My wish only is to point out certain places where characteristic beds in each group may be found. The rocks in the last district referred to, as well as

* Mem. Geol. Survey, vol. iii.

most of those in the neighbourhood of Holyhead and along the north-west coast, seem to me closely allied to rocks of the Pebidian formation in other areas; and I propose, therefore, to associate them with that group, though possibly some, such as the rocks of Holyhead mountain, may prove to be of different age and probably older (Dimetian?). The remaining area is described as "a belt of metamorphic rocks, from two to four miles wide, that strikes north-east from Newborough Sands across the island to Beaumaris and Llandona." The prevailing rocks in this area, as seen, at least, on the road from Menai Bridge to Beaumaris, may be described as green or greenish grey, with a schistose foliation. Interstratified with these are also some hard green bands frequently containing veins of epidote. Some micaceous schists and purplish rocks are also described as occurring in this area.

The rocks collectively, as seen here, are peculiarly like those in the Pebidian group at St. David's, and there can, I think, be little doubt of their position. *Vide* Appendix, No. XII.

Ffestiniog and Dolgelly.

In addition to the Pre-Cambrian rocks now described, there are in North Wales at least two other areas in which they are found; but as these are in the county of Merioneth, and not intimately associated with the districts under consideration, I hope to be able to describe them more fully in a future communication. One of these is in the neighbourhood of Ffestiniog and partly shown in Map, the so-called Moel-tan-y-Grisiau syenite, and was examined by me some years since, but has been more recently explored by Mr. Tawney, who has, I think, most satisfactorily proved that it is mainly of Dimetian age. The other is in the neighbourhood of Dolgelly, and was recently mentioned, in my paper to the British Association, as being chiefly of Pebidian age.

Conclusions.

Collectively, these additions to the Pre-Cambrian areas hitherto known are large and important, and many of them were not in the slightest degree suspected until we commenced our researches amongst them a few years since. Of others, especially some of the rocks in Anglesey, Professors Sedgwick and Phillips many years ago expressed the opinion that they were older than the Cambrian rocks. These views, however, did not receive much support from geologists, but were for the time crushed by the combined weight of authority vested in the Geological Survey as represented by its chiefs, who all declared that these must be altered Cambrian and Silurian rocks only. Consequently they were so marked on the geological maps, nd still remain so.

APPENDIX.

Notes *on the* Microscopic Structure *of some* Rocks *from* Caernarvonshire *and* Anglesey. By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

I. *Road-side near Port Dinorwig, Caernarvonshire* (p. 296).

This rock has an ill-defined granular structure, not unlike that of a microcrystalline quartz-felsite; but after careful study I am of opinion that it is an altered rock, probably once a fine felspathic mud. A good many minute grains of quartz can be distinguished. There is a fair quantity of opacite in parts, rather earthy-looking, and a pale yellowish mineral in filmy microliths, perhaps allied to vermiculite.

II. *From the Eifl Range* (p. 299).

(*a*) From the Eifl range, south-east side.—Structure cryptocrystalline, the felspathic component being rather decomposed and containing many microliths, probably of secondary origin. Some opacite, a few larger grains of quartz and (probably) of decomposed felspar. I believe the rock to be a quartz-felsite.

(*b*) Eifl range, east side.—Structure cryptocrystalline; possibly a little glass even yet remains; indications of flow-structure; several grains of quartz and one or two of felspar. General character similar to the quartz-felsites described on p. 317, and like them an old rhyolite. As happens sometimes with them, the rock has been considerably crushed; the fractures are filled in by a minutely crystalline mineral, showing rather bright colours with crossed Nicols.

III. *On coast north-west of Eifl range* (p. 299).

Structure crystalline, but rather finely so, sometimes inclining to porphyritic. Chiefly consists of felspar and quartz, much of the latter interstitial with the former rather than in separate grains; also mica, iron peroxide (possibly some ilmenite), and a few microliths, possibly apatite. The felspar is rather decomposed; but a plagioclase as well as orthoclase can be recognized. Part of the mica exhibits the characteristics of biotite; but much of it is replaced by a green dichroic mineral not unlike chlorite, which, indeed, it possibly is; but I think most is only one of the green magnesia-iron silicates which often replace biotite. I have no doubt the rock is igneous, but in its present condition, and without chemical analysis, hesitate whether to class it with the quartziferous mica-syenites or mica-diorites, or the fine-grained granites (the granite-porphyry of many petrologists).

IV. *Boduan mountain, south side* (p. 299).

Structure rather microcrystalline than crystalline; but as the felspar, its chief constituent, is much decomposed, and some of the quartz seems of secondary formation, it is difficult to pronounce. The general form of the felspar suggests that a plagioclase predominates over orthoclase. A fair amount of opacite is present, and one or two scales which may be an iron mica. I have no doubt the rock is an igneous one, but hesitate whether to call it a quartz-felsite or quartz-porphyrite.

V. *Nanhoron quarries* (p. 299).

(*a*) Structure generally rather like III., except that a microscopic graphic, sometimes almost dendritic*, structure is common. Felspar decomposed, but some Carlsbad twins still recognizable, so probably mostly orthoclase. The dark finely granular mineral visible in the hand specimen is seen, under the microscope, to be chiefly a pale yellowish mineral, sometimes rhomboidal in outline, having a rather granular structure and fairly distinct cleavage, associated with and often rather clouded by opacite. I believe it to be titanite, and do not find either mica or hornblende. The rock is igneous, and is thus a kind of aplite.

(*b*) The hand specimen of this rock has a general resemblance to the last, except that it is more compact, and the dark specks are blacker and more sharply defined; under the microscope the structure is seen to be microcrystalline, consisting of quartz and felspar with a fair amount of iron peroxide (hæmatite in part) in clustered granules. The "dendritic" structure more abundant here than in the last specimen; no titanite is certainly recognizable, but neither mica nor hornblende are present. One or two larger crystals of felspar are orthoclase. The rock is a quartz-felsite.

VI. *Near Ty-mawr, Rhos Hirwain* (p. 300).

This rock exhibits the peculiar structure characterizing the granitoid rocks as distinguished from the true granites†. It chiefly consists of quartz, felspar, and mica; the first is so full of minute enclosures as to look quite 'grimy.' The felspar also, besides being rather decomposed, often does not appear to be clear. Orthoclase is present, some cross-hatched, as described by Mr. Rutley‡; also some very closely twinned plagioclase. There is a fair quantity of

* See description of this structure, Geol. Mag. dec. 2, vol. iv. p. 508.

† The distinction of structure between the granites and granitoid rocks (that is, between those of igneous origin and metamorphic clastic rocks) is a subject to which I have paid much attention, and on which I hope in course of time to communicate some notes to the Society. In the latter, for example, the quartz differs from that in true granite, sometimes by showing a more subangular and fragment-like outline, sometimes by a much more irregular boundary. The grains also vary more in size and are more irregularly distributed; the felspar also differs in form, exhibiting corresponding irregularity. In parts of the slide a little of an indefinite felsitic matrix may be seen. Other differences, which cannot be briefly described, exist; but for the present it may be enough to say that my microscopic studies have strengthened my scepticism as to the existence of "metamorphic granite."

‡ Quart. Journ. Geol. Soc. vol. xxxi. p. 479.

mica, which is nearly colourless with ordinary light, but shows bright colours and rather 'satiny' texture with crossed Nicols, and is so remarkably like my specimens of paragonite, that I think it probably this mineral. The correspondence between this rock and specimens from Twt Hill and Anglesey is very close.

VII. *West of Ty-Croes, Anglesey* (p. 302).

Structure similar to last, but very little mica, and that a fibrous mineral associated with opacite, probably replacing some other species. The quartz rather clearer, many minute acicular microliths and a few of larger size, bordered with opacite (? titanite or epidote). A specimen of similar rock in my own collection exhibits a structure yet more irregular and unlike a true granite, and contains a fair quantity of paragonite with some minute zeolitic products.

VIII. *Penbryn, near Llanfaelog, Anglesey* (p. 303).

(*a*) This rock, in the hand specimens, shows traces of a brecciated structure. This is yet more distinct under the microscope; but the individual fragments seem to be at most varieties of one and the same species of rock, and there appears very little matrix or dust among them; their structure varies from rather granular to fibrous schistose; there are many patches of a green mineral, probably chlorite, and grains or rods of iron peroxide; also a few of quartz, to which mineral many very minute clear specks probably belong. With crossed Nicols, the rock is seen to be largely composed of a minute, rather fibrous, fairly bright-coloured mineral, possibly allied to sericite; it seems to be a chloritic mica-schist. The foliation of the different fragments is not parallel, so that the brecciation seems subsequent to the metamorphism.

(*b*) West of Ty-Croes, on road to Llanfaelog.—A specimen collected by Dr. Hicks from same neighbourhood. Similar structure; varietal difference is that the fragments are rather less schistose and contain a little more quartz, and there is a good deal of chlorite, not generally in patches in the fragments, but filling veins and cracks between them. A part of a quartz-vein occupies a corner of the slide.

IX. *North-north-west of Llanfaelog church* (p. 303).

The chief difference between this and VI. is that the micaceous constituent is now represented by a green slightly dichroic mineral, probably allied to chlorite, associated with many small grains of iron peroxide. In the felspar are many specks and films of some secondary product, not unlike prehnite; some, however, look more like a mica.

X. *Railway-cutting near Ty-Croes* (p. 303).

This rock mainly consists of felspar, chlorite, an iron peroxide, and calcite. The structure is more granular than one would have expected from the external aspect, the first mineral occurring in forms which suggest that when found deposited they were slightly rounded grains. It is much decomposed, in many places full of minute microliths and earthy dust, but the striation of the plagioclase group can here and there be distinguished. The chlorite occurs in filmy or fibrous-looking scales, of no very definite shape, but more like mica than any thing else. The third mineral is in angular and club-like grains; from the outline, ilmenite or hæmatite seem most likely. It is difficult to say what the rock has formerly been, but it is such a rock as I should expect would be formed from the coarse detritus of a dolerite, subsequently metamorphosed.

XI. *Railway-cutting near Ty-Croes* (p. 303).

A very characteristic gneiss consisting of quartz, felspar as in VI., one or two grains much resembling microcline, and associated chlorite, opacite, and a colourless mica (probably replacing biotite); in the felspar are a good many irregular microliths of secondary formation (? some of them epidote), and a few others, perhaps apatite.

XII. *Quarry near the Anglesey Column* (p. 304).

A foliated dense felted mass of a dull greenish, rather decidedly dichroic mineral (probably a species of chlorite), and of small greenish-yellow epidote crystals, with a few angular fragments of quartz (?) and two or three scales of mica (? paragonite).

(For Discussion, see page 325.)

25. *On the* Quartz-felsite *and* Associated Rocks *at the base of the* Cambrian Series *in* North-western Caernarvonshire.

By Rev. T. G. Bonney, M.A., F.R.S., Sec. G.S., Professor of Geology at University College, London, and Fellow of St. John's College, Cambridge. (Read February 5, 1879.)

[Plate XIII.]

This subject has already been brought to the notice of the Society by communications from Prof. Hughes and Dr. Hicks, published in the last volume of the Quarterly Journal*. These vigorous and valuable sketches still leave many details, especially with regard to the great masses of quartz-felsite (or quartz-porphyry) in the vicinity of Bangor, Caernarvon, and Llyn Padarn, to be filled in by future observers, so that I venture to hope the following notes may be useful as a small contribution to the subject. I spent several days in September 1878 in working carefully over parts of the district†, and the conclusions formed in the field have been tested by subsequent study of a series of slides, prepared for me, as usual, by Mr. F. G. Cuttell. The result has been that I differ in several respects from the views recorded on the maps of the Geological Survey, and in the Memoir on the Geology of North Wales.

But, while expressing a very decided difference of opinion on certain points, I gladly bear testimony to the general excellence of the maps and the value of that Memoir. It needs but a few days' work in North Wales to show how arduous a task the survey must have been. It should also be remembered that this was executed before the microscope was generally applied to lithological study. That has rendered clear much which was previously uncertain, and has given to the student a firm basis of ascertained facts wherefrom to educate his eye and his perceptions. It is therefore not surprising that the officers of the Survey should have been occasionally misled by the superficial aspect of the rocks, when no more searching tests could be applied.

As may be seen by a glance at the Survey Map, the Cambrian strata between the base of the mountains of North Wales and the Menai Straits appear to rest upon, or be cut off by, a great lenticular mass of quartz-felsite‡, which extends in a north-east direction across the lower end of Llyn Padarn. A second and smaller *massif* is represented as extending from the town of Caernarvon to near

* Vol. xxxiv. pp. 137 & 147.

† I was accompanied by several members of my geological classes, past and present, some of whom, especially Dr. R. D. Roberts, Mr. Houghton, and Mr. Marr, rendered me very valuable assistance; and on one occasion we had the advantage of being conducted by Prof. Hughes. Since the reading of the paper I have briefly revisited the district.

‡ Called quartz-porphyry in the memoir. Notwithstanding the weighty authority in favour of this term, I think the objections to the word porphyry (on account of its vagueness) are so strong that I prefer to use quartz-felsite.

Bangor. If I rightly understand the Map, these are coloured as intrusive; but in the Memoir (pp. 140, 141) we read:—"Below [the purple slates] are other thinner bands of slate, grit, and conglomerate, the lowest of which, by Llyn Padarn and elsewhere, *passes into* the quartz-porphyry that for thirteen miles stretches along the midst of the Cambrian strata. . . . . So closely does the matrix of the altered rock resemble the adjoining typical porphyry, in colour, texture, and even in porphyritic character, and by such insensible gradations do they melt into each other, that the suspicion, or rather the conviction, constantly occurs to the mind that the porphyry itself is nothing but the result of the alteration of the stratified masses. . . . This conclusion is further aided by the capricious variation of the strata adjoining the porphyry. . . . This I can only account for by the supposition that these beds have, as it were, been partly eaten into by heat and themselves converted into porphyry."

The points which I hope to establish are:—

(1) That the former and a part of the latter *massifs* are neither intrusive nor metamorphic, in the ordinary sense of the word, but are parts of ancient lava-flows, which, were they of modern date, we should probably not hesitate to call rhyolites.

(2) That the southern portion of the second *massif* is quite disconnected from the northern, and is a group of metamorphic rocks of earlier date.

The former of these propositions is the subject of the present paper. The latter is treated in a separate communication. The proofs can, I think, be given most conveniently by describing the sections which I was able to examine.

Moel-Tryfaen District.

The section at the adit in Moel Tryfaen has been described by Dr. Hicks*. As our party was no better provided with lights than his, I did not think it worth while to examine the adit, but collected specimens carefully from the spoilbank outside. The following (besides the usual Cambrian slates) are the principal varieties:—(1) rather gritty greenish slate banded with rounded grains of a pinkish or purplish felsite and light-coloured felspar; (2) a rock of mottled and streaky aspect containing larger fragments of the same felsite; (3) a conglomerate of the same; (4) a number of greenish slates and grits. The first three closely resemble members of the Cambrian conglomerate; and the last group (4) resembles some of the rocks which, in the Bangor sections, lie at no great distance beneath the Cambrian conglomerate.

Dr. Hicks says†, "we did not succeed in touching the conglomerate in the tunnel." I have, however, no doubt that the "more porphyritic-looking rock, mostly dark-coloured with spots of highly vitreous quartz in a base of felsitic matter," &c. was really the conglomerate, which, owing to the imperfect light and other causes, to be mentioned hereafter, he failed to recognize. The outcropping

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 147.

† *Loc. cit.* p. 148.

mass of the conglomerate, which he describes, on the summit of the hill, contains pebbles of the same purplish quartz-felsite, generally from about 2 to 4 inches diameter, but sometimes a foot or more, together with angular fragments of purple slate. On the western side about one fourth of the fragments are felsite; the remainder slate, green and purple, and a dull-green grit resembling one in the underlying series. The fragments of purple slate are rather more numerous on the eastern side. The strike of the conglomerate appeared to be about E.N.E. and W.S.W. The cleavage dipped at a high angle to S.S.W., and the bedding, as it seemed to us, dipped to the N.N.W., also at a high angle; but as many of the smaller pebbles had been twisted so as to have their longer axes to the planes of cleavage, it was difficult to be sure of this. I have examined microscopically two specimens from the adit; but it will save time to describe them with the specimens from Llyn Padarn. The quartz-felsite was abundant in the loose blocks below Rhos Tryfaen; but as I did not meet with a good exposure of live rock, I have not examined it microscopically. In general character, however, it is identical with those described hereafter.

We crossed the *massif* again by the road from Bethgelert to Caernarvon. The felsite is well exposed left of the road north of Bettws Garmon. Here it is rather pale in colour, and shows traces of cleavage. Subangular patches of a darker colour suggest at first sight included fragments; but a closer examination shows that they are merely due to slight variations in structure. This somewhat streaky or mottled aspect is not uncommon in modern trachytic lavas*. Microscopic examination shows that the rock has a cryptocrystalline ground-mass of rather variable character, the structure being sometimes exceedingly minute, containing crystalline grains of quartz and felspar—part is orthoclase, closely resembling sanidine, part plagioclase. Microlithic enclosures are common in the felspar, some looking as if they had once been glassy. There are a few grains of iron peroxide and some disseminated opacite. A portion of the slide shows flow-structure very clearly. The rock seems to have been crushed; a very minute gold-coloured mineral appears in the cracks, and is disseminated about the slide.

Llyn-Padarn District.

We examined the quartz-felsite on both sides of the lake, on the western along the highroad, as well as by the railway. The lithological details are given below, and with them, in order to save time, I have included a description of specimens from the northern end of the second massif. The following facts, however, noted in the field, of themselves, I think, are hard to reconcile with any theory of metamorphism or intrusion.

(1) The streaky structure so characteristic of lavas (especially of an acid type), as well as the platy jointing common in igneous rocks, may be seen not seldom in the quartz-felsite about Llyn Padarn. The most striking example is in a quarry by the roadside north of

* The "piperno" of the Phlegræan Fields is a marked example.

Cwm-y-Glo village. Here the streaky structure is as distinct as in a modern rhyolite, and the platy jointing is hardly less so. In parts of the quarry it is a true "fissile structure"*, cutting the fluidal lines at various angles, sometimes as much as 70°.

(2) On the western side of Llyn Padarn there is a band of slate intercalated in the felsite. This is a rather soft black slate, not conspicuously altered. We found exposures (probably of the same band) both by the roadside and in the railway-cutting. The former is only about 3 feet wide, and from its appearance might be claimed as an included fragment; but I have elsewhere seen soft rocks similarly "nipped" by interbedded harder strata †. Microscopic examination shows the structure of the slate to resemble that of the ground-mass of some of the chiastolite slates: the junction with the felsite suggests that the one rock has been deposited on the other; for the material of the slate can be traced filling a crack in the felsite, the surface of which seems as if it had been denuded.

(3) Near Llys Dinorwig, north-east of Llyn Padarn (lower end), the felsite is associated with an agglomerate. This was shown to me by Prof. Hughes, who at the time was not quite satisfied as to its true significance. On that point, however, there is no reason for doubt. It is as characteristic as any that are seen in Charnwood, containing fragments of all sizes, from mere lapilli to blocks full 2 feet in diameter. One or two, indeed, may possibly be the ends of small "strings" of lava. Here and there a band of finer material is interstratified, as in recent volcanic cones. I have also examined this under the microscope, and find it made up of rhyolitic lapilli, some showing flow-structure very well, with fragments of quartz and felspar imbedded in an altered felspathic dust—in short, the usual structure of the matrix of such an agglomerate. The mass appears to be intercalated in the felsite near to its northern edge; but time did not allow me to trace out its boundary with any minuteness.

Proceeding, then, to the examination of a series of specimens, we find that the rock in the neighbourhood of Llyn Padarn is a compact felsite of a dull grey colour, sometimes with a reddish tinge, porphyritic with numerous quartz grains and small whitish crystals of felspar. As a rule, there is nothing abnormal in its appearance; some fragments could hardly be distinguished from rhyolites from Hungary or the Euganean hills. I have had a series of six slides prepared to exhibit the principal varieties.

(1) *Quarry North of Cwm-y-Glo.*—This rock, as already stated, shows flow-structure remarkably well. Under the microscope it resembles a glass of slightly granular structure, with wavy light-brown bands, occasional clear rather granulated interspaces, and clouds of disseminated opacite ‡. With crossing Nicols the granular part is seen to consist of minute crystals. With a high power these are shown to be partly extremely minute colourless belonites, partly

* See my paper, Quart. Journ. Geol. Soc. vol. xxxii. p. 142. A glance shows it is not a true cleavage, as it frequently changes its direction.

† For example, in thin bands of soft schists intercalated in the granitoid gneiss of the St. Gothard.

‡ Plate XIII. fig. 1.

of irregular outline, as though either imperfectly formed or distorted by tension. I am not able to assert positively that any truly glassy base still remains, but think this is the case, and feel certain that it was once present. Subangular grains of quartz, with occasional partial inclusion of the base, and small cavities are frequent, also felspar crystals rather decomposed, not seldom including microliths: these are orthoclase with a little plagioclase.

(2) *From near a Tunnel south of Cwm-y-Glo Station.*—Colour a dull grey; example of the ordinary type. This rock has a general similarity to the last, except that the fluidal structure is less markedly parallel and less distinct. Microliths are more numerous and larger, and the rock generally has a less glassy aspect, part of the slide showing a distinctly cryptocrystalline structure. The rock is traversed by cracks, which have been again cemented; they were doubtless caused by the pressure which produced the cleavage of the district.

(3) *Railway-cutting near the top of the Mass.*—A pale pinkish rock showing a rude cleavage. A general similarity to the last, but the fluidal structure still less distinct, and the rock yet more crushed, so that parts of the slide resemble a breccia cemented by a filmy pale greenish-yellow mineral. The crystals of quartz* and felspar are occasionally crushed *in situ* and cemented again. This might easily be mistaken for a clastic rock, but with crossing Nicols its homogeneous character is readily discovered.

(4) *Highest Felsite seen on west side of Llyn Padarn.*—This rock is roughly cleaved, and has quite a schistose aspect. Closer examination, however, shows that in about ten yards it passes by insensible changes into the last. This also accords with its aspect under the microscope, where a sort of banded structure and numerous subangular grains of quartz and felspar suggest a stratified origin. But a closer examination with higher powers shows that it is really an igneous rock, which has evidently been greatly crushed *in situ*. The fibrous cementing mineral (with crossed Nicols) shows rather brilliant golden and blue colours.

(5) *Two specimens from near Brithdir*† (one from the cliff overlooking the Caernarvon road, the other from a quarry west of the farm). These, from the northern *massif*, are of a purple-red colour, like the rock near Rhos Tryfaen. The slides differ but little one from another, and only as varieties from (2). There is a little more opacite, and the imbedded crystals are rather more numerous. One or two are probably altered biotite, and some microliths are possibly apatite.

(6) *A specimen from the Roadside above the 'Antelope' Inn, near the Menai Bridge.*—The general character of this is similar to that of the last, but the slide is rather more stained by ferrite. The structure

* The cavities in the quartz are a little larger in this specimen. It also contains two or three crystals of an altered mica, and there seems to be a little calcite in a crack.

† A specimen from the same district is described by me, vol. xxxiv. p. 145. The description may also serve for these specimens.

of the ground-mass is more glassy, and there are some indications of flow-brecciation. I may also refer to a specimen from Llanddeiniolen, described by me in an appendix to Prof. Hughes's paper *, which belongs to the same series. I was then wholly ignorant of the relations of the rock to the others in the district, and had formed no opinion about them, as I had never examined the felsite *in situ*, and so venture to quote the remark which I made on the appearance of the slide;—"The rock is probably from an old flow of rhyolitic lava."

Thus, although in one place the top of the quartz-felsite, where it is most affected by subsequent pressure, does bear something of a schistose and fragmentary character †, and though doubtless old compact felsites are sometimes very difficult to distinguish from certain rocks of similar chemical composition, but of sedimentary origin, I think we are justified in saying that the evidence against the theory of metamorphism is too strong to be resisted ‡. If, however, further proof be needed we shall find it in the overlying series of slaty and conglomeratic rocks.

These then we proceed to examine, commencing with the south-western side of Llyn Padarn. Beyond the cutting in quartz-felsite (No. 4), the railway crosses a small bay of the lake, and then passes into fine green grits or "bastard slate," beyond which we find a thick mass of interbedded conglomerate and similar grit, then another band of the grit, followed by a band of small rolled fragments of felsite about as large as hemp-seed. As, however, this section has been carefully drawn by Mr. Maw §, and more than once described ||, I will confine myself to microscopic details, merely stating that we endeavoured to trace the junction of the felsite and overlying rocks near the highroad. It is, however, much masked by débris and vegetation; but there is little doubt there is a fault, through which a greenstone dyke has subsequently forced its way, and which has cut out some of the grits visible by the shore of the lake. Near the road the felsite and conglomerate are seen on

* Vol. xxxiv. p. 145. I have recently visited this locality and examined the felsite, which is rather pale in colour, but not otherwise remarkable. I also visited several other felsite exposures in the district, which present differences only varietal, though in some cases possibly interesting.

† I should perhaps mention that, to my mind, there is nothing to connect this local crushing with any theory of volcanic activity. I have observed in Wales several cases of this crushing of the exterior portion of a compact igneous rock, so that it assumes a sedimentary or schistose aspect.

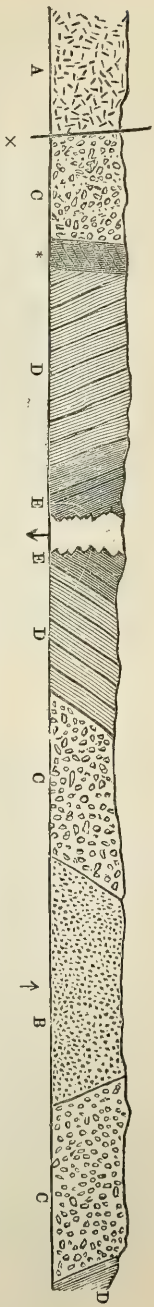
‡ These rocks have a certain resemblance to some of the lavas from the Wrekin district described by Mr. Allport (Quart. Journ. Geol. Soc. vol. xxxiii. p. 449), also, to a less extent, to some of the fragments in the Charnwood agglomerates. They differ considerably from the felsites in the Bala series of Northern Caernarvonshire.

§ Geol. Mag. vol. v. pl. 6.

|| Geol. Mag. vol v. p. 121, where some analyses of neighbouring rocks are given; also Quart. Journ. Geol. Soc. vol. xxxiv. pp. 143, 150, 764; Mem. Geol. Survey, vol. iii. p. 142. I may state that I carefully examined the "unconformity" asserted by Mr. Maw to occur in the railway-cutting higher up, and have no hesitation in agreeing with Prof. Hughes, and so differing from Mr. Maw, in his interpretation of the phenomena.

opposite sides of the dyke; but higher up the hill, where the dyke thins, some felsitic-looking grit appears below the conglomerate.

By the tramway on the north-eastern side of the lake, we pass in going from Llanberis three masses of the conglomerate; but there is little doubt that it is only one and the same group of bands repeated by folding, and that the section is as annexed*, an anticlinal and a synclinal repeating the conglomerate and overlying slates, so that the green grit beneath it is only visible once. On this supposition the conglomerate varies considerably in thickness in a short distance; but a sort of "rain-spot" rock at the base of the middle mass might very well represent part of the southern and thicker. The actual junction of the northern mass of conglomerate and the felsite is masked, but the one can be seen within about a yard of the other. This last conglomerate has, no doubt, a rather "melted down" aspect; but, as Dr. Hicks has pointed out†, here as elsewhere, this quite disappears when the rock is weathered. Its superficial character is also evident on microscopic examination. I have had slides prepared from different parts of the section described above, from the finer variety noted in the railway-cutting on the opposite shore and, as already mentioned, from Moel Tryfaen. With considerable variety of detail the general character of these is similar, so that a minute description of each slide is hardly needed. They consist of fragments of quartz-felsite, often very characteristic of that which we have been describing, slaty and gritty rock‡, subangular and rounded quartz grains, and broken felspar crystals, among which, though rather decomposed, both orthoclase and plagioclase may be recog-



A. Quartz-felsite. B. Green slaty grit. C. Conglomerate. D. Green slate. E. Purple slate.
* Greenstone Dyke. × Fault. Anticlinal. Synclinal.

Diagrammatic Section on N.E. side of Llyn Padarn.

* This, I find, is Prof. Ramsay's opinion, Mem. Geol. Survey, vol. iii. p. 144.

† Quart. Journ. Geol. Soc. vol. xxxiv. p. 151.

‡ Varieties of flinty argillite and fine quartzite are common among the larger pebbles, together with the quartz-felsite pebbles and fragments.

nized. Besides these are fragments, generally rather irregular in form, of a slaggy aspect like a glass (devitrified), rendered more or less opaque by opacite, which I have no doubt are of volcanic origin. The matrix in which the above are imbedded is sometimes rather streaky, composed probably of minute fragments of felspar crystals and felspathic mud, now considerably altered, and sometimes interspersed with opacite and filmy patches of viridite. The quartz grains are sometimes crushed by the pressure which the rock has undergone, and the fragments of included rock are often rather flattened and distorted. Some, however, are distinctly rounded; and all have probably been transported by water, though many are still fairly angular.

In one of the specimens from the thickest part of the conglomerate, on the east side of the lake, I observed a part of a pebble which struck me as bearing a great resemblance to the peculiar rock of Twt Hill, Caernarvon*. This I have examined microscopically, and feel no doubt of the identity. This identification is of great interest, as it shows that some area of this granitoid rock was undergoing denudation, and was approximately in its present mineral condition, when the Cambrian conglomerate was being formed.

The matrix and some of the included fragments of the slides from the conglomerate between the greenstone dyke and the quartz-felsite are rather more altered than the rest; but the changes are more of the nature of those brought about by water and pressure at moderate temperatures than any thing like "melting down." At any rate the clastic character of the rock is still perfectly distinct.

Bangor District.

Proceeding now to the eastern edge of the northern mass of quartz-felsite, and commencing near Brithdir Farm†, we find exposed in the road and elsewhere a grit composed of well-worn fragments of quartz-felspar and quartz-felsite. It is generally of a mottled purplish-red colour (very like the neighbouring quartz-felsite) with grains about $\frac{1}{10}$ inch in diameter, but becomes in places conglomeratic, with subangular pebbles up to 1 inch diameter. It weathers a reddish-buff colour, and one knoll in a field close to the road has a certain superficial resemblance to the rock of Twt Hill. The rock clearly derived its materials from the adjoining quartz-felsite. We find a similar, but rather finer and more quartzose grit exposed above the quartz-felsite on the northern side of the Bangor-Caernarvon road in the adjoining valley, and again, to the north, behind Tafn-Newydd Farm, and another adjoining the felsite exposed in the road about half a mile to the N.E. by "Beulah chapel"‡. The last I have examined microscopically, and found it confirm the opinion stated above as to the source of its material, as it made up of

* See next paper. Prof. Hughes also found a similar pebble in the vicinity of Llanddeiniolen, *loc. cit.* p. 140.

† Just south of the first letter "r" in that name on the map.

‡ A similar pale grit also overlies the felsite near Llanddeiniolen.

grains (angular and rounded) of quartz, felspar (some plagioclase), and a rock resembling the quartz-felsite with much interspersed ferrite.

Descending from Brithdir in a north-east direction towards the Bangor road, we pass a greenish slaty rock, and on reaching the bed of the valley find shallow excavations in a similar rock in the angle between the main and the by-road. This latter is much crushed and jointed, as if some intrusive rock were near; but the dip (which varies) seems to be E.N.E., or a little to the east of that, at a high angle *. Bearing to the east we find a quarry among woods at Tair-ffynnon. The rock here varies from a slaty grit to an agglomerate or conglomerate of fragments of quartz-felsite and slate in a green matrix. I have examined slides of each variety. They consist of lapilli or fragments of igneous rock, broken crystals of felspar and quartz, and bits of slaty rock. Some fragments †, especially in the coarser variety, have a general resemblance to the quartz-felsite of the adjoining *massif*, but most of the igneous constituents are rather different. There are of these three well-marked varieties:—(*a*) glassy or nearly glassy, the base often opaque from abundant opacite, with many acicular felspar microliths and spots of viridite, probably replacing augite or hornblende ‡; (*b*) a more glassy and transparent rock, with acicular microliths and larger felspar crystals, up to 0·03 in. diameter, sometimes certainly plagioclase §; (*c*) a fairly clear rock, with glassy aspect and partial cryptocrystalline structure; iron peroxide in larger, but less frequent, grains. Most of these are probably lapilli. The finer rock is chiefly composed of fragments; the coarser has a good deal of matrix, cemented by viridite and a very pale green mineral, which, with crossed Nicols, shows fibrous structure and bright golden-green and orange-red colours. The materials of this rock are largely derived from volcanic ejecta, and some apparently have not come from far; but I do not think it bears decisive evidence of contemporaneous volcanic action.

Further to the east, by ascending a hill on the northern side of the road, we find both inside and outside the wood a great quantity of a similar rock. Its microscopic structure also corresponds, some of the included fragments showing a very distinct flow-structure. A little more to the east, and nearer Perfyddgoed House, the rock becomes so compact that it might be easily mistaken for a quartz-felsite (greenish grey). Microscopic examination, however, shows it to be beyond doubt a clastic rock, with many small subangular quartz grains, and minute rolled fragments of various compact rocks, some of which are certainly of igneous origin. One is almost a mass of opacite.

To the north-east we find other fine felsitic grits and ashy-looking rocks, and at Cae Seri a coarse conglomeratic rock, somewhat resembling that of Tair-ffynnon, but with more slaty fragments of a dull

* On the opposite side of the fault a purplish slate seems to succeed the grit by the Caernarvon Road, and a prominent knoll to the N.E. consists of slaty rock dipping a little N. of E.N.E. at an angle of 50°.

† Plate XIII. fig. 2. ‡ Plate XIII. fig. 4. § Plate XIII. fig. 5.

red colour. Microscopic examination confirms this, grains of a gritty slate and lapilli being abundant. One or two, however, differ from those already described, being full of felspar microliths, partly grouped so as to have a feathery or tufted aspect, and in one or two cases indicating an approach to spherulitic structure. Following the road to the north, we come to a quarry at the back of some white cottages (? west of Minffordd), and find a felspathic grit of a dull greenish colour speckled with white. Under the microscope it is seen to consist of rather decomposed felspar crystals (both orthoclase and plagioclase recognized), varying generally from about 0″·01 to 0″·03 in diameter, mingled with finer dust and a few small lapilli and quartz grains. There is a considerable quantity of viridite in filmy patches, looking sometimes as if it had replaced a pyroxenic constituent. Many fragments are little, if at all, waterworn.

The dip over this district is often not easy to obtain with accuracy, but it appears to be generally not far from N.E. to E.N.E., and high.

Returning now to the main road from Caernarvon to Bangor, which runs near a line of fault*, and following it towards the latter place, we find, after about half a mile, a quarry at the back of a cottage. Here we find the following ascending succession:—(1) conglomerate rather like that of Tair-ffynnon, with rolled fragments of red quartz-felsite, sometimes 4″ diameter, angular fragments of purple slate, and a few green-coloured 2 or 3 inches diameter; (2) a fine grit, in the upper part not unlike one of those low down in the Llanberis Cambrian series; (3) conglomerate, more slaty; (4) a green slaty rock, near to which were one or two large slaty masses looking like included fragments. The section is rather irregular, and is disturbed by a fault; but I believe the above to be correct, and the dip to be about 50° a little east of north-east. Microscopic examination of the conglomerate confirms the above description and the general correspondence with the Tair-ffynnon rock. The fragments of the quartz-felsite are very characteristic †.

About a furlong further, behind another cottage, are ashy-looking fine grits; and some four hundred yards from these, in a rock exposed behind the "poor-house," are greenish-grey slaty grits with a band or so containing felsite fragments about as large as peas. Dip nearly as above, but a little steeper. Microscopic examination of this shows various slaty and gritty fragments, lapilli, some almost wholly black with opacite, and the quartz-felsite, quartz grains, &c. as usual ‡. There is one fragment of the peculiar rock observed at Cae Seri.

We then approach the town of Bangor and the district which has been fully described by Prof. Hughes, so that for the slaty beds and green breccias which here form the upper part of the series and underlie the Cambrian conglomerate (in which the characteristic quartz-felsite may frequently be recognized, as asserted by him and Dr. Hicks) I refer to his paper and my note on the microscopic structure of two of the rocks appended thereto.

* The displacement hereabouts does not seem large.

† Across the valley on the opposite side of the fault are beds more of the Minffordd type.

‡ Plate XIII. fig. 3.

Conclusions.

We see, then, that the rock in the quartz-felsite *massif* exhibits every characteristic of an igneous origin; we see also that fragments closely corresponding with it occur again and again in the overlying rocks, and that these rocks, as a rule, are comparatively little changed—the evidence of alteration being illusory, and quite ordinary slates or grits in some cases interposing between the quartz-felsite and the supposed highly metamorphosed rocks. We must then refuse to these Caernarvonshire "porphyries" an origin different from that of other igneous rocks of similar composition, and cease to quote them as examples of what extreme metamorphism can effect.

I may repeat again that, allowing for slight mineral changes brought about by the agencies to which all rocks have been exposed in the long lapse of ages (such as devitrification, the formation of viridite, &c.), there is no difference of any importance, so far as I can see, between these quartz-felsites and comparatively modern rhyolites; and if I could prove that a base still remained undevitrified, I would give them the latter name. That they were rhyolites in pre-Cambrian times I have no doubt.

Further examination will probably discover more agglomerates, and perhaps further subdivide the lava-flows, which certainly seem at present of exceptional thickness and extent*. Whether volcanic action continued during the time when the conglomerates of Tair-ffynnon &c. were formed is uncertain. The lapilli in them are in some cases not waterworn; but then they may have been derived from the destruction of cones of scoria, which, no doubt, rose among and even upon the neighbouring lava-flows. Their lightness might cause them to float for a while, and so escape the rounding which has befallen some of the other materials. The uppermost beds at Bangor (and to these, perhaps, we may add the Minffordd rock) certainly seem to indicate volcanic action†; but the ejecta are very different, and the outbursts were probably very local.

The evidence which has been brought forward warrants, I think, our proposing the following general ascending order for the group near Bangor between the quartz-felsite and the Cambrian conglomerate:—(1) felsitic grit and fine conglomerate; (2) green slates‡; (3) conglomerates with interbanded green grits passing into slaty grits—Tair-ffynnon to Perfyddgoed; (4) another group of gritty and conglomeratic beds ending with the conglomerate of Cae Seri; (5) Mynffordd rock and upper green breccias, grits, and slates. Doubtless there are gaps in this grouping, and changes may hereafter

* The larger *massif* is about thirteen miles long and two at greatest breadth. The smaller on the map appears not quite two thirds the above dimensions, but, as will be seen hereafter, is really much less. Examples of very extensive lava-flows, so far as I remember, are much more common in basic than in acid rocks.

† Quart. Journ. Geol. Soc. vol. xxxiv. p. 146.

‡ It is almost impossible to give precise names to these bedded rocks. One finds almost every variety from fine grit to fine, but imperfectly cleaved, slates. Our petrological nomenclature always seems to me a little too restricted in regard to this group of rocks.

be made; but still, comparing the two sections described above, where the first quarry on the Bangor road in conglomerate is probably near the horizon of the Tair-ffynnon group, and the Poor-house rock not very far away from some part of the Cae Seri, there seems a strong probability that we are not far wrong. The thickness of the series must be very great, unless there is considerable repetition by faults (and of this I have seen no evidence); it can hardly be less than 3000 feet, and is probably more.

It is probable that the thickness of the sedimentary beds about Llyn Padarn and Moel Tryfaen (where the quartz-felsite must be very thick) is much less. The little which we now see of the beds between the felsite and the Cambrian conglomerate reminds us rather of the upper part of the Bangor group; and though doubtless some beds are cut out by the boundary fault, the impression which I formed on the ground was that the thickness of these was not very great*. If a volcanic district, such as Jorullo, for example, were slowly subsiding, the accumulating sediments would form so as to take a sort of cast of the igneous features, and be thickest where they were least prominent (and so thinnest).

The quartz-felsite rocks, however, did not wholly disappear below water till after the formation of the Cambrian conglomerate†. Appearances suggest that there is a marked physical break between this and the subjacent sedimentary series (Pebidian of Dr. Hicks); but though I believe there is very great unconformity between the latter and the quartz-felsite in certain places, I think it quite possible that the subsidence may have begun, as would be natural, after the last volcanic outburst, and so the whole, notwithstanding the break, may really belong to one and the same series—the Pebidian.

(For the Discussion on this paper, see p. 325.)

EXPLANATION OF PLATE XIII.

Fig. 1. Quartz-felsite from quarry near Cwm-y-Glo, showing flow-structure and quartz grains.

Fig. 2. Part of a fragment of quartz-felsite, showing irregular fluidal structure &c., from the coarser conglomeratic rock of Tair-ffynnon (the blank part is a crack in the slice).

Fig. 3. Fragment of quartz-felsite (*a*), showing fluidal structure, with quartz, slaty rock, and decomposed felspar, from rock at the back of the Poor-house near Bangor.

Figs. 4 & 5. Portions of the finer conglomeratic rock of Tair-ffynnon, showing fragments of igneous rock (*a, b, c*), quartz (*d*), &c.

All these are magnified 50 diameters.

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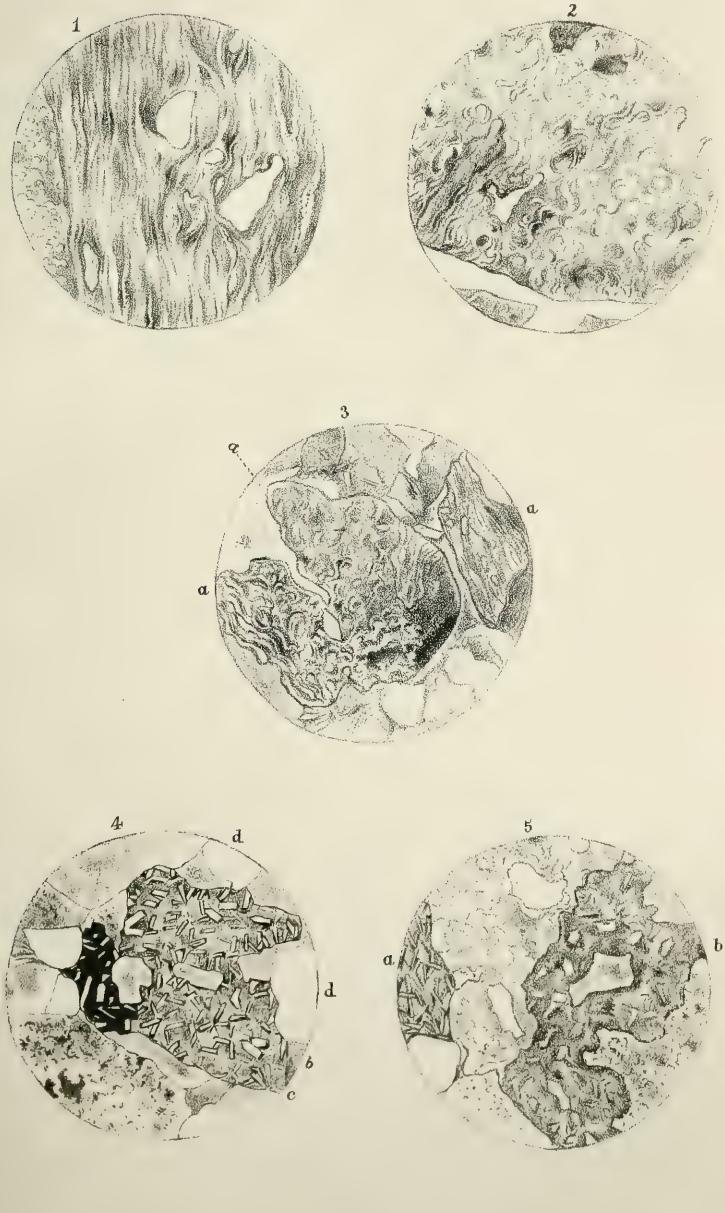
* Since the above was written, I have visited Llanddeiniolen and there seen, near Fachell, quartz-felsite, felsitic grit, green slaty rock (slight exposure only, but apparently *in situ*) and Cambrian conglomerate in close sequence.

† I have not at present identified them with certainty at any higher level.



A. Foord lith.
Hanhart imp.

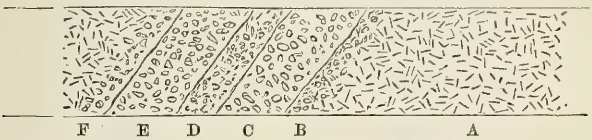
QUARTZ-FELSITES &c. OF CAERNARVONSHIRE.

26. *On the* Metamorphic Series *between* Twt Hill (Caernarvon) *and* Port Dinorwig. By Rev. T. G. Bonney, M.A., F.R.S., Sec. G.S., Professor of Geology at University College, London, and Fellow of St. John's College, Cambridge, and F. T. S. Houghton, Esq., B.A., Scholar of St. John's College. (Read February 5, 1879.)

This interesting group, which on the map of the Geological Survey is not divided from the "quartz-porphyry," has already been briefly noticed by Prof. Hughes and Dr. Hicks *. They assert that the rock is not igneous, and lithologically much resembles the Dimetian of St. David's. That view is fully borne out by our observations, which, we venture to think, prove conclusively that there is here a series of metamorphic rocks much older than the quartz-felsites and conglomerates described in the last paper †.

The rock exposed on the summit of Twt Hill is at first sight very like a coarse granite, which, however, is almost without a

Diagrammatic Section (reduced to one plane) of Pit to N.E. of summit of Twt Hill.



A. Granitoid rock.
B. Same, becoming pebbly.
C. Coarse conglomerate.
D. Fine conglomerate.
E. Coarse conglomerate.
F. Finer conglomerate, in parts more like B and A.

micaceous constituent. We saw nothing absolutely irreconcilable with an igneous origin; but still there was in the aspect of the rock a something, hard to define, which suggested a metamorphic origin. This is particularly noticeable by the wall on the southern side of the ridge. Under the microscope it is seen to consist of quartz, felspar (rather decomposed), a few granules and grains of iron peroxide, and a very small quantity of a micaceous mineral. The quartz is so full of minute enclosures as to have a rather "dirty" aspect. A very closely twinned plagioclase felspar is

* Quart. Journ. Geol. Soc. vol. xxxiv. pp. 142–152.

† Accompanied by the party named in the last paper, I examined the vicinity of Twt Hill last September, and discovered the conglomerates described below. Mr. Houghton, who remained at Bangor for some time afterwards, was able to return and traverse the ground between Caernarvon and Port Dinorwig, and to trace the boundary for some distance from that place between the quartz-felsite and the older rock, forwarding to me the specimens which he had collected. Since the reading of this paper, we have separately traversed again most of the ground described in it, revising the work, and making a few additional notes.—T. G. B.

present as well as orthoclase. The structure of the rock, as explained below, suggests that it belongs to the granitoid gneiss group rather than to the true granite *.

The next exposure of rock which we visited set our doubts at rest. It is in a pasture-field, where, on the S.E. side of the ridge, and perhaps a furlong to the N.E. of Twt Hill, is an old quarry. This affords the section shown in the sketch (p. 321). The lowest rock exposed is of the same type as that of Twt Hill. Above it comes a bed with a similar matrix, containing pebbles in the upper part; then a band of coarser conglomerate, the pebbles being often full an inch in length. To this succeeds a band of finer conglomerates, then of coarser, and, lastly, another of finer, passing up into a rock which has some resemblance to the bottom rock. The pebbles are almost all vein-quartz, and are rather flattened; one or two look like an impure jasper. The strike of the conglomerate is about E.N.E., and the dip about 60° on the southern side. In the finer bands the pebbles appeared more rolled than in the coarser, varying from the size of hemp-seeds to that of peas. The matrix of the most conglomeratic part is a kind of quartzose grit. Microscopic examination, as will be presently shown, fully confirms the above evidence as to the clastic origin of this rock.

On the N.W. side of Twt Hill are quarries showing a rock more distinctly gneissose than it is at the summit, the component minerals having often rather a banded arrangment. One block, observed by Mr. Houghton, showed very well an alternate banding of coarser and finer varieties of the rock. The rock also in the higher part of the quarry became finer in texture †, and contained considerable quantities of a decomposed green mineral like epidote ‡; some quarried blocks in a field showed bands of grey grit interbedded with the normal Twt-Hill type of rock.

On the right-hand side of the new road leading to Llysmeirion is a rock of the same general character, but paler in colour and more metamorphic in aspect. It seems to lie a little below the conglomerate, and to overlie those exposed in the last pit, which are part of the general mass of Twt Hill. The rock from the pit near Llysmeirion has already been noticed §.

Specimens from some of the above beds have been examined microscopically. Commencing with a section ‖ cut from the finer part of one of the conglomerates (which is more granitoid in aspect than some of the other bands), we find the rock obviously (as we should

* A name appears to be needed for these granitoid rocks, which in general aspect much resemble a granite poor in mica, are metamorphic clastic rocks, but differ from ordinary gneiss in being scarcely, if at all, foliated, as well as in the small amount of mica. I venture to propose the name "Granitoidite." —T. G. B.

† A fine gritty-looking rock may also be seen on some waste ground higher up the hill, near a white cottage.

‡ Specimens from these quarries exhibit considerable variety in the relative amounts of quartz, of felspar, and of the green constituent, some of which is more like a kind of chlorite.

§ Quart. Journ. Geol. Soc. vol. xxxiv. p. 145.

‖ Kindly lent to me by J. E. Marr, Esq.—T. G. B.

suppose) of clastic origin, consisting of subangular grains of quartz, often rather full of very minute cavities (? empty) and specks of opacite, and of a quartzite varying from rather fine to moderately coarse, which are imbedded in a minutely crystalline matrix. This, when highly magnified, exhibits a felted fibrous structure, brightly coloured with crossing Nicols, probably formed by the alteration of a rather siliceous mud into microlithic products of more than one mineral; there are also two rather angular fragments of a fine-grained quartz-schist, and two or three more of doubtful origin, in part, perhaps, decomposed felspar. There are also some patches of a green chloritic mineral and, in parts of the slide, fair quantities of opacite.

The rock from the quarry by the road to Llysmeirion is also certainly clastic, and has some similarity to the last; but it is more difficult to determine the amount of alteration. Some of the quartz grains (showing cavities * and included opacite) have a distinctly fragmental aspect; but here and there one is seen irregularly "fused" at the edge with the matrix, as if formed by segregation from it. The matrix is earthy in aspect, and more granular in structure than the last, and occupies the major part of the slide; in it, however, there seem indications of fragments, suggesting that it may be composed chiefly of grains of decomposed felspar. The aspect of this rock suggests that it was once very probably a coarse quartz-felspar grit †. The rock on the southern side of the Twt-Hill ridge has some resemblance to this variety.

A compact "greenstone" dyke, probably a diabase (to which my attention was called by Dr. Hicks), is exposed in the narrow lane leading from the street to Twt Hill. It is about four yards wide, and strikes rather S. of S.E.

About half a mile from the quarry on the N.E. face of Twt Hill, in a field (used for football), is another quarry ‡. Here we find an interesting section exposed, which has been examined by Mr. Houghton. The face of the quarry is apparently formed by a bedding-plane; the highest stratum seen is a rather coarse conglomerate, consisting of pebbles $\frac{3}{4}''$ to $2''$ long, mostly round and quartzose. There are not a few subangular fragments of quartz, quartzite, red jasper, &c., and a few flat little-worn fragments of schistose rock, not unlike some of the Anglesey schists. Total thickness 4 feet. Below this is a band about the same thickness, pink-coloured at the top, grey below, consisting of similar material in a finer state of division. Parts of this are a very fine altered grit or quartzite. Beneath this is 8 feet of conglomerate, the pebbles being more angular than in the upper bed. A considerable thickness of finer beds succeeds. Dip 45° to 50° S.S.E.

About 200 yards S. of Cae-Gwyn farmhouse is another quarry, showing a conglomerate consisting of well-rounded pebbles (quartz,

* Some at least of these are nearly full, as minute bubbles can be seen.

† See Appendix to Dr. Hicks's paper, *suprà*, p. 306.

‡ Position on map a little S. of the "u" in "Bathing House." The quarry is just on the crest of the ridge; I have recently visited it myself.—T. G. B.

with a few of jasper), the matrix being a purplish-brown quartzose grit, apparently not more highly altered than those at the base of the Cambrian series. Strike difficult to obtain, but probably W.S.W. About a mile beyond this, along the road, is a quarry * on the left hand, showing rock of the normal Twt-Hill type, but rather fine in texture ; and further on, in a farmyard, " Parciau Isa," a similar rock. The same may also be seen off the main road, halfway between Griffith's Crossing (Llanfair-is-gaer of map) and Port Dinorwig.

Rock of the same general type, granitoid, and consisting mainly of quartz and felspar, with sometimes a slight approach to a foliated structure, extends to " Elim Chappel," a little beyond Port Dinorwig. In this place, where the railway crosses the main road, is a good exposure of the above rock. Mr. Houghton, by following a footpath leading from the Bangor road and crossing the railway †, found some decomposed rock, probably of the same character ; and then behind the northernmost buildings of " Pen-r-allt " a felsite, and on the hill above that a purplish quartz-felsite of the normal aspect (*e.g.* like that of Brithdir). He traced the felsite along this ridge ; but after crossing a slight valley, and ascending another ridge overlooking the Straits, found again the Twt-Hill rock ‡.

He observed in a quarry by the road running up from " Ferry House " a rather compact grey variety of the metamorphic rock, and at the N.W. end of it a green rock. A little green rock intercalated in the metamorphic occurs on Pen-r-allt on the northern side. The normal quartz-felsite occurs at the corner, " Pant yr fallan fach;" and to the N., behind Pant yr fallan, is a very pretty variety.

Granitoid or gneissoid rock may be traced for some distance on the left-hand side of the main road to Caernarvon, where it runs parallel with the railway. This is here faulted against dark shaly Carboniferous rock. It may also be seen at the top of the steps behind the Arvon inn, between a school and chapel (felsite is exposed on the hill-side about a furlong to N.E. along the road) ; and rock of a gneissoid type occurs where the road (joined by that coming from the Ferry House) turns sharp to S.E., and by the side of a ravine in this latter direction. On the left bank of the same ravine it is again exposed, near Tan-y-maes ; but on crossing the stream we find a rotten felsite exposed near Tan-y-perthi, and a little further on, by a farmhouse, we are on a knoll of the characteristic quartz-felsite. To the S. of Tan-y-maes, in a field, is a fine greyish bedded grit (sometimes brownish) ; some four yards or more in thickness are exposed, and the dip is about 30° to S.E. This rock seems hardly more altered than many Cambrian grits ; still, as it can be nearly matched from bands intercalated in some of the conglomerates, and rock of the granitoid type is exposed in the

* On map $\frac{3}{10}$" N. of first "1" in Pengelli.

† Running between words " bush " and " inn " on map.

‡ The specimen is a gneissose rock, consisting of quartz, felspar, and a dark-green mineral, seen also at Twt Hill, and on close examination shows indications of a fragmental structure.

next field, it seems more probable that this belongs to the oldest series, and is not some faulted Cambrian.

Mr. Houghton has traced the grit for some distance towards the S., beginning with this hill between Gareg goch and Tyddyn bach. It occurs at the S.E. end of the slight knoll on which stand the Tan-y-maes cottages, and when traced round this in a N.W. direction becomes felspathic, till it assumes the usual type mentioned above *. On the E. slope of a hill N. of a lane leading towards Griffith's Crossing from Pen-Rhos farm, the quartzite occurs interbedded with a felspathic rock; and on the S.W. slope of the same hill is the granitoid rock, which also occurs in other places nearer to that railway station.

It results, therefore, that this northern strip of "quartz-porphyry" consists of two very different groups of rocks, divided roughly by a line drawn on the map from the left side of the "C" in Elim Chapel, between the two "n"'s in Bush Inn, between the "r" and "alt" in Pen-r-alt, and the "y" and "g" in Tan-y-grisrau, and probably continued across the patch in the same (S.W.) direction †. To the N.E. of this division we have the quartz-felsite already described; to the S.W. a group of metamorphic rocks, which vary in character from quartzose conglomerates to granitoid rocks poor in mica, some of which have considerable resemblance to the so-called granite of Ty-Croes, Anglesey, and are probably very much older than the quartz-felsite. If there is no faulting, the Twt-Hill group is the highest of the metamorphic series, the dip, where observed, being approximately S.S.E. As the length of the strip is about $4\frac{1}{3}$ miles, $\frac{2}{5}$ of the whole area, coloured red on the map, belongs to the Pre-Cambrian (Dimetian) rocks; and the thickness of the series, if we may suppose there is no repetition by faults, can hardly be much less than 5000 feet.

Discussion.

The President had made microscopical sections thirty years ago of the rocks of Caernarvonshire, in illustration of the question of the origin of slaty cleavage. When he commenced his work, ridicule was thrown on the application of the microscope to the study of rocks; but the papers of the evening had fully shown that this mode of study was now regarded in a very different light.

Prof. Hughes asked for better proof than had been given by Dr. Hicks that his three series are unconformable with one another. He thought that Dr. Hicks's identification of some of the patches

* The exact boundary will require re-examination at Tan-y-Maes, for I find that a specimen which, in the field, I had regarded as a variety of the granitoid group is really a spherulitic quartz-felsite, quite unlike, however, any that I have yet seen in this district. It is remarkable how similar the rocks of these two groups now and then are in the field, though under the microscope it would hardly be possible to imagine any two things more different.—T. G. B.

† Outcrops and pits appear to be wanting in the remaining part of this. A rock resembling rotten felsitic grit is just exposed on the road between Bethel and Llanddeiniolen rectory, and beyond Gors bach is true quartz-felsite.

of rock as Pre-Cambrian was premature. He thought that there was evidence that the three series (the granitoid, the felsitic, and the volcanic) passed into one another. The sequence of these beds it is often very difficult to discover, on account of the difficulty of making out which of the divisional planes are due to original bedding and which to joints, as well as because of the numerous faults which traverse the district, which did not seem to have been taken into account. He criticised the views of Prof. Bonney as to the direction of the dip of the beds seen near Caernarvon.

Mr. Rutley thought that the presence of fluidal structure might, in some cases, fail to afford decisive evidence as to the rocks having flowed as lavas, since he thought it possible that such a structure might also be formed by a kind of convective action in the throats of volcanos. He expressed some doubt as to the sedimentary origin of hälleflintas. He thought that the cryptocrystalline character of such rocks might be of secondary origin, and due to the passage through them of alkaline waters, as suggested by Mr. John Arthur Phillips.

Mr. Davies regarded the hälleflintas as quite distinct from the felstones, as the former contained a larger proportion of silica and are of very different physical character.

Mr. Rutley, in reply, insisted on the widely variable characters displayed by the rocks classed together as felstone.

Mr. Tawney doubted the advisability of coining a new formation to include the quartzites near Haverfordwest, and the quartz-felsites and grits near Bangor, until their relations had been worked out more in detail; the proofs of unconformity to rocks above and below he also regarded as dubious.

Dr. Hicks had proposed the names of the three series for convenience' sake. He could vouch for their being unconformable in many places, as was proved by the test of included fragments; but at other points they might be conformable with one another. He pointed out, in opposition to Mr. Rutley's view, that both Mr. Davies and Prof. Bonney agreed as to the distinction of the hälleflintas from the felstones. In reply to Mr. Tawney, he stated that the Arvonians were separated from the Dimetians below and the Pebidians above by great masses of breccias.

Prof. Bonney replied to the remarks of Prof. Hughes that the rocks of the granitoid and felsitic series were very distinct from one another. He maintained the accuracy of the section at Twt Hill. He thought that the occurrence of derived fragments of the rocks in question in the overlying beds placed both the intrusive and metamorphic theories of the origin of the felsite series out of question. In reply to Mr. Rutley, while admitting that a kind of flow-structure might be found in sedimentary rocks, he thought that the rocks in question were certainly lavas. He thought that hälleflintas are usually of sedimentary origin.

27. *On* Community *of* Structure *in* Rocks *of* Dissimilar Origin. By Frank Rutley, Esq., F.G.S., H.M. Geological Survey. (Read January 22, 1879.)

Speculations upon the origin of rocks have always been fraught with more or less grave difficulties; and although much has from time to time been written upon the subject, those writings are in very many instances open to the objection that they are merely speculations, and that the data from which they have been educed are often by no means of a comprehensive nature. Within the last few years the microscope has afforded a large amount of information respecting peculiarities which were previously unknown in the structure of rocks—*microscopic* peculiarities it is true, but still amply sufficient to demonstrate that the cubic inch and the cubic mile of rock are often identical in mineral constitution, and built up in the same manner.

Given a patent community of origin, and often a coexisting community in the mineral constitution of rocks, we then see little or no reason to doubt the truth of many of the deductions which have been made; and the geological literature of twenty years ago then appears to be often quite as satisfactory as that of to-day.

It is, however, very common to find that the origin of certain rocks is by no means so evident, and the darkness which veils their past history, and the conditions under which they were formed, is not always to be dissipated even by the most patient and unbiassed research.

So far as the nomenclature of rocks is concerned, it was a wise practice on the part of the older geologists to avoid entering too much into detail in the separation of rocks which were more or less closely allied in mineral constitution; and, instead of blaming, we should rather thank them for the employment of such generally comprehensive terms as greenstone, aphanite, &c., which roughly indicate the facies of certain rocks without implying too definitely a knowledge reserved for the students of a later date.

That this knowledge is still very imperfect there is no doubt; and it behoves modern petrologists to exercise a like cautiousness, and to beware lest, in discarding some of the useful terms employed by their predecessors, they institute a more complex classification, hemmed in by definitions sharper than any which nature warrants—definitions which a future generation may bring in evidence against them.

Sharp definitions are, however, to a certain extent a necessary evil. Without them no satisfactory classification can exist, and without classification no student can work systematically.

It may be well to consider a few petrological terms and definitions, and to endeavour to ascertain how far they tend to elucidate the structure, the mineral constitution, and the origin of certain rocks.

For example, the terms dolerite, anamesite, and basalt are accepted as indicative of variation in the texture of certain rocks which are identical in mineral constitution. We may apply any of these terms to such a rock, but we do not imply any difference either in the nature or in the relative amounts of its mineral constituents.

These names simply indicate varieties of texture or crystalline development; and they probably only denote differences in the temperature at which the rock was erupted, or differences in the rate of cooling during the solidification of any such mass of rock.

Be these differences great or small, the origin of these rocks has been approximately the same. The temperature during eruption and the rapidity of cooling are simply subordinate and relative questions: they are mere questions of degree; and dolerite, anamesite, and basalt are mere phases of one and the same rock.

Very fine-grained or cryptocrystalline rocks of the basalt group, the diorite group, &c. are designated aphanite, a good and useful term under which to cloak ignorance; and aphanite, in part, may be regarded as a still lower grade in the crystalline development of a basalt.

The same may be said, structurally, of the granitic rocks, which range from the coarsely porphyritic granites to the fine-grained elvans.

Between the extremes of development of the constituents in such rocks there lies much the same difference as that which exists between a dwarf and a giant. The principle which governs the development of the large crystals is also evident in the structure of the smaller ones.

If, then, in our classification of rocks such questions of relative magnitude in the development of crystals may be ignored, how much more justly may they be set aside when we come to consider the structure of clastic rocks? The differences between shingle, scree-material, gravel, and fine sand merely represent the differences which we find in their cemented and consolidated representatives, conglomerates, breccias, grits, and sandstones. The finest-grained sandstone or grit is but a conglomerate or breccia in miniature. The terms lapilli and ash, as applied to volcanic ejectamenta, also merely indicate *degrees* of comminution.

Certain substances, however, are more easily susceptible of fine division than others; and in the mud which, on consolidating, forms shales and slates, and in the more finely pulverized volcanic dust which on levigation gives rise to mud streams, such as the *moja* of the Andes, we find probably the extreme limits of mechanical power as applied to the natural disintegration of rock matter.

Before quitting the subject of relative dimensions in the constituents of rock masses, it may be worthy of remark that the term porphyritic is one which is conveniently, though unjustly, limited. Rocks which, to the naked eye, present no porphyritic appearance whatever are often seen, under the microscope, to be perfectly deserving of the title, the magnified image exhibiting all the characters which distinguish coarsely porphyritic rocks. Macroporphyritic and microporphyritic are convenient terms by which to indicate such differences.

The next question which seems worthy of consideration is the importance which should be attached to the rounded contours of the fragments and crystals which enter into the constitution of many rocks, attaching importance to the question mainly because a just solution of the various cases which present themselves may serve to throw considerable light on the origin of the rocks in which such rounded fragments and crystals occur, and because we may thus be enabled in time to distinguish the different causes which have been instrumental in obliterating angularity.

We find fragments and crystals which have unquestionably been rounded by attrition. The attrition has in some instances been produced by the motion imparted to these bodies either by running water or by the action of waves on coasts. In other instances it is due to the ejection of fragments and crystals from volcanic vents, operating both during their upward journey and their descent.

Again, we find rounded crystals occurring in volcanic rocks, notably in those of a vitreous character, and we also meet with them occasionally in rocks of a totally different origin (*e.g.* the coccolith grains in certain limestones and the glauconite grains in some sedimentary rocks; the latter are, however, often the internal casts of Foraminifera).

In some cases crystals present rounded forms, due to aborted development, as instanced by Prof. Renard in the orthoclase crystals of the porphyroids of Mairus and Laifour in the Ardennes. These crystals have, externally, the aspect of water-worn pebbles; but when broken open they are all seen to be twinned on the Carlsbad type. This is probably a much more frequent cause of the rounded appearance of crystals than is generally supposed.

The roundish amygdaloidal kernels of calcspar which occur in vesicular rocks sufficiently demonstrate their secondary origin by their polysynthetic character; but in the case of other minerals which sometimes occupy such cavities, it is not always so easy to *demonstrate* that they have been subsequently infiltered, although there can, as a rule, be little doubt on the subject. The difficulty in such demonstration lies chiefly in showing that their origin is not concretionary, since in radial crystallization and in concentric zonal structure they often simulate concretions and spherulitic bodies. It appears, indeed, an open question at times whether the amygdaloidal character of some rocks is not rather due to concretionary developments than to the filling in of vesicles.

If the amygdaloids in such rocks consist of calcareous or other readily soluble matter, the rocks, when weathered or when treated with acids, present the character of true vesicular rocks, and, without due precaution, very erroneous conclusions may be formed concerning their real nature and origin. Some of the vesicular schalsteins afford good examples of this kind; and a highly vesicular character is sometimes imparted to certain micaceous eruptive rocks by the weathering out of the crystals and scales of mica, which, at first, leave definitely shaped cavities or moulds of the departed crystals; but these in time become further weathered into more or less spherical cavities, so that at length the rock resembles a scoriaceous lava. The rock at Washfield, near Nether Stowey, is a good example of this.

We must not, indeed, always impute an eruptive origin to every rock which exhibits traces of vesicular structure, since vesicles may even be met with in sediments. They are, however, very rarely seen. The marsh-gas derived from decaying animal and vegetable matter may account for their presence in the mud of ponds, brooks, &c.; for, if we stir such mud gently with a stick, bubbles of gas are freely disengaged, and it is consequently evident that they must exist, pent up within the mud.

If the decomposing matter lie beneath merely a thin covering of mud the gas-bubbles, as they become naturally disengaged, will probably pass completely through it; but, in other cases, where the superstratum of mud is thick, the bubbles may only pass some little distance into the mud; and if such a deposit became quickly dry (as it might do on a muddy shore or in an estuary when the tide went out), it is quite possible that the gas-bubbles would form permanent spherical cavities. Under similar conditions raindrops, worm-tracks, and footprints have formed permanent records, and like conditions ought to suffice for the preservation of a vesicular structure in fine muddy sediments in which organisms have decomposed.

That records of this kind are of rare occurrence is doubtless due to the obliterating disturbance produced by the returning tide.

That they are so seldom observed is also due, in part, to the infiltration of mineral matter in solution after the consolidation of the deposits.

In rocks of this kind which have undergone little or no compression such cavities would be spherical; but in all old deposits which have undergone the pressure of a considerable thickness of superincumbent strata, we should naturally expect to find them ovate or lenticular. The irregular form of the vesicles so common in eruptive rocks must be attributed to forcible injection of gas or vapour, compression, or the irregular motion of surrounding matter in a viscid condition or sometimes even in a state of ebullition. A pisolitic structure is occasionally met with in fine pumice tuffs, and is stated by Cotta* to be due to the action of raindrops, being a phenomenon similar to that which is produced at the present day when showers of rain accompany showers of volcanic ashes. The spherical form of volcanic bombs is due to the rotation of masses of molten matter during their projection and fall through the air. We have now reviewed the principal causes which account for the rounding of crystals and fragments of mineral matter and for the spherical or spheroidal cavities and kernels which occur in rocks; but there are other spherical and spheroidal forms which have yet to be considered, and which are also of considerable petrological interest. In many

* Rocks Classified and Described (London, 1866), p. 309.

vitreous rocks, such as pitchstones and obsidians, spherules are often developed in great profusion. These appear to represent devitrification around certain points; and similar bodies may sometimes be observed in window-glass. Spherules in vitreous rocks usually have a radiately fibrous or incipient crystalline structure, often accompanied by a concentric zonal banding which is generally peripheral, or is, at all events, more strongly perceptible towards the margin. What starts the devitrification in these spots, and what constitutes their nuclei, are questions which yet remain to be worked out; but in some instances minute crystals or grains of magnetite &c. may be seen to occupy the centres of these bodies. They are not related to amygdaloidal, concretionary, or perlitic structures, and, if they have any representatives, they are probably crystallites, or rudimentary phases of aborted crystals, such as those already alluded to. In some rocks they are seen to run in regular planes or bands, and occasionally coalesce and form continuous belts.

Then, again, there is perlitie structure, upon which Prof. Bonney and Mr. Allport have already written able papers, demonstrating its relation to spheroidal structure. Then there is the coarse spheroidal structure which is at times associated with columnar structure, while occasionally it seems to occur in an independant manner; and, in the latter instances, it might not be an altogether unprofitable inquiry to attempt to ascertain the relation which ordinary conchoidal fractures bear to these spheroidal surfaces. The microscopic cavities filled with gas or vapour, which are frequently spherical, and the little cavities containing fluids and sometimes vitreous matter, and which are seldom spherical, do not materially influence the broader questions which I now wish to raise, although, when present, they should never be ignored.

Finally we have concretionary structure, commonly giving rise to spherical, spheroidal, or lenticular forms of most variable dimensions, ranging from minute oolitic bodies up to the large balls which are met with in slate-quarries and the ironstone nodules which occur in the Coal-measures.

I have by no means enumerated all the varieties of structure which come under these different heads, since in this paper I am anxious to deal with minutiæ only when they affect principles.

The following table is an attempt to classify the component parts of rocks:—

Crystallizations ...	definite ...	megascopic.	
		microscopic.	
	indefinite...	macrocrystalline	Ground-masses and interstitial residues.
		microcrystalline	
		cryptocrystalline	
Microfelsitic matter			
Amorphous matter			
Infiltrations	interstitial (cements in clastic rocks).		
	venous.		
	amygdaloidal.		
	internal casts of fossils.		
	metasomatic.		

Pseudomorphs ...	by infiltration.	
	by replacement.	
	by alteration......	chemical.
		physical.
Clastic matter......	psephitic (breccias and conglomerates).	
	psammitic (sands).	
	pelitic (muds).	
Organic remains...	animal.	
	vegetable.	

After this short *résumé* of the leading structural characters which rocks present, it may be well to follow it up by a consideration of certain rocks, or groups of rocks, in which structural peculiarities may be regarded as indicative of their origin, and others in which structural characters are of no value in elucidating the conditions of their genesis.

Rock-forming materials.

Common to Eruptive and Clastic rocks.	*Crystals* with sharp angles.
	,, with rounded angles.
	,, with no angles (aborted crystallization).
	Fragments of crystals with sharp angles.
	,, ,, with rounded angles.
	Crystalline grains of irregular and angular form, as in granites.
	Crystallites.
	Fragments of Rocks with sharp angles.
	,, ,, with rounded angles.
	Segregations, Concretions, &c.
	Solids, fluids, vapours or gases filling, or partially filling, cavities in minerals and rocks (amygdaloids, fluid-cavities, steam-pores, &c.).
Peculiar to Clastic rocks.	*Solids* precipitated from infiltered solutions and constituting cements.
	Solids precipitated from solution, constituting rock masses entirely or partly.
	Solids secreted from solution and from other sources by organic agency, forming the tests of Foraminifera, Mollusks, &c., and the bones of vertebrate animals.
Peculiar to Eruptive rocks.	*Amorphous glassy matter,* resulting from the rapid cooling of fused mineral matter.
Peculiar to Clastic rocks.	*Débris* water-worn / ,, unwater-worn } cemented and uncemented.

In the preceding table I have treated all rocks under two heads, the Eruptive and the Clastic.

The latter may be divided into:—

Ordinary Clastic rocks or ordinary detrital sediments, and Pyroclastic rocks or volcanic ejectamenta.

As examples of *eruptive rocks* containing *crystals with sharp angles* may be cited:—*Basalts,* in which the augite, felspars, nepheline, magnetite, &c. occur in well-developed crystals; *Phonolites,* in which the nepheline and other constituents are commonly well crystallized; *Granites,* in which the felspars, apatite, and often the micas are met with in well-formed crystals.

As instances of *eruptive rocks* containing *crystals with rounded angles* we may quote:—*Basalts,* in which the olivine crystals very commonly present rounded angles or occur merely in rounded pellets or grains; *Leucitophyrs*, in which the leucite crystals sometimes give almost or quite circular sections; *Granites*, in which the felspar crystals are sometimes rounded; *Quartz-porphyries*, in which the quartz frequently occurs in rounded grains; *Porphyrites*, in which quartz sometimes occurs in rounded grains similar to those in quartz-porphyries; *Porphyritic pitchstones* and other vitreous rocks, in which the felspars and other porphyritic crystals often present rounded angles; *Volcanic ejectamenta*, in which rounded crystals are of common occurrence.

Among *Sedimentary rocks*, *Grits and Sandstones* commonly consist in great part of crystals of quartz and felspar with rounded angles; but these minerals are more often completely rounded, so that they frequently show no trace of crystalline faces.

The porphyroids sometimes contain crystals which present perfectly rounded contours; but it has been shown, as already mentioned, that, in some cases at all events, their rounded contours are due to aborted crystallization. The Tirce limestone contains coccolite, rounded grains of augite.

The Folkestone beds of the Lower Greensand contain rounded grains of glauconite; but, as already mentioned, the form of these grains is, at all events in some instances, due to the glauconite having been deposited in the interior of Foraminiferal tests &c.

Among the metamorphosed rocks, garnets frequently occur in rounded forms which evince no external trace of crystallization. The minerals chondrodite and pargasite also occur in roundish grains in granular limestones.

Whether a connexion exists between any of these rounded forms (excluding, of course, those rounded by attrition) and the curvature of the faces of certain crystals, is a problem which may possibly deserve attention.

In the Cubic system we have examples of	
Curvature in	Rounding in
Diamond.	Garnet.
	Leucite.
In the Rhombic system,	
Curvature (?) in	Rounding in
Olivine.	Olivine.
	Chondrodite.
In the Hexagonal system,	
Curvature in	Rounding in
Dolomite,	Quartz.
Chalybite,	
Corundum.	
In the Monoclinic system,	
Curvature in	Rounding in
Selenite.	Augite,
	Orthoclase.

Note. In this table the word curvature is used to signify the curvature of definitely developed faces of crystals, accompanied, of course, by curvature of the edges formed by the junction of such faces; while the word rounding denotes abrasion of the surfaces of a crystal, which tends to obliterate edges and angles and to reduce the crystal to a spherical or spheroidal form.

These are only a few examples, and a comparison of them does not certainly *seem* to promise any useful results.

The occurrence of *fragments of crystals with sharp angles* may be due either to the fracture and comparatively slight displacement of crystals developed in a rock, such as the fractured and faulted crystals sometimes met with in eruptive rocks of various kinds, especially in lavas; or to the fracture and wide dispersion of the resulting fragments of crystals, such as one meets with in volcanic ejectamenta and in sedimentary rocks. The one case differs from the other only in the fact that, in the case of imbedded crystals, the dispersion of the fragments could not take place to any great extent; while in the other instance the crystals have been entirely or partially isolated prior to fracture, and the fragments were consequently free and capable of performing long journeys. Such fragments would naturally lose more of their angularity in proportion to the distance over which they travelled, unless transported under conditions in which attrition was impossible.

That microcrystalline felsitic matter and cryptocrystalline felsitic matter, or ordinary felstones, felspathic sandstones and grits, arkose, granulite, and devitrified hyaline rhyolites, are closely allied is a point which I shall now endeavour to demonstrate.

The terms microcrystalline and cryptocrystalline, as used by Prof. Rosenbusch, are here purposely employed to designate the conditions of felsitic matter known as felstone, because they have, or are assumed to have, a more or less definite mineral constitution, as implied by the term ortho-felsite of Dr. Sterry Hunt, consisting of crystalline grains of felspar (typically orthoclase) and quartz. These grains do not always show definite boundaries, but often appear under the microscope, in polarized light, to shade off one into another, representing what Zirkel describes as "unindividualized granules."

When the grains are individualized it then becomes a matter of considerable difficulty to distinguish between such felstones and certain granitoid rocks such as haplite and perhaps granulite, and also between such felstones and certain sedimentary rocks in which little or no perceptible cementing matter occurs, as in some examples of felspathic grit, sandstone, and arkose; and I believe that to this similarity is due much of the confusion in the statements concerning the origin of some of our bedded felstones, some observers maintaining that they are contemporaneous sediments in which crystallization from aqueous solution has supervened, while others contend that they are true eruptive rocks which have crystallized on cooling. Be their origin, however, what it may, the point which I now wish to establish is their community in mineral constitution and their approximate or, possibly, in some cases absolute community of structure.

Felsitic matter, however, as Zirkel observes, must not always be confounded with the idea of felstone. Felsitic matter is a very comprehensive term, and, in spite of all that has been written about it, a very ill-defined term for matter possessing very ill-defined structure. It is commonly stated that in its most typical development it is almost totally amorphous, frequently exhibiting little or no double refraction. Now I wish this point to be specially borne in mind, because we often find that more or less clear and translucent amorphous matter, glass in fact, both artificial and natural (as obsidian, pitchstone, &c.), has undergone change of such a nature that what was glass is no longer glass, what was once amorphous is now crystalline in structure, and that this change has resulted in the production of felsitic matter.

Many of these hyaline rhyolites have approximately the chemical composition of felspars; and we find not merely such amorphous rocks, but at times we also meet with individual crystals of felspar converted into a similar felsitic substance.

It is common to find that in proportion to the age of such rhyolitic rocks so is the change which they have undergone, and, in extreme phases of devitrification, it often becomes most difficult to speak with any thing like certainty about their origin or to distinguish them from sedimentary rocks, such as felspathic grits and sandstones.

Evidence, indeed, is not wanting, especially in North Wales and in the Lake-district, to show that rocks which are commonly regarded as volcanic ashes, and which certainly have a fragmentary constitution, pass by almost insensible degrees into true felstones or hälleflintas.

Here, then, we find that we have at times scarcely any means of distinguishing between lava-streams which have represented the most extreme phase of igneous fusion, clastic rocks, possibly representing volcanic ejectamenta, and detrital rocks which have been deposited as sediments in water. The rocks of all these classes have once formed superficial layers and may consequently occur interbedded with stratified rocks.

It may at once be said, "Look for alteration of beds subjacent to lava-flows!" A good and wise precaution! but alteration is not always to be found. Where this test fails, how shall we manage to assign a definite origin to such rocks with any certainty? This is best answered by an examination of recent vitreous rocks, which very frequently present distinctive characters. One of the most marked is the phenomenon of fluxion-structure; yet even this is to a certain extent simulated in detrital deposits.

It is not, for instance, uncommon to find large stones imbedded in laminated sediments; and where this is the case the laminæ which overlie the stone, and often those below it, are deflected from the general planes of lamination and sweep round the unyielding mass in curves which approximately correspond with its outline. We find the same thing reproduced on a small, often on a microscopic, scale in schistose volcanic ashes and tuffs; and the appearances thus produced are frequently very suggestive of fluxion-structure and are extremely deceptive to those who have had but little experience in the microscopic diagnosis of rocks.

Let us now consider the characters by which we may or may not safely distinguish volcanic ejectamenta from other rocks.

(1) Volcanic ejectamenta (ashes, dust, sand, and lapilli) consist of fragments of minerals and fragments of rocks. These fragments are sometimes angular, at other times they exhibit rounded contours. Besides these fragments they often consist to a greater or less extent of entire crystals, which may also have their angles and edges either perfectly sharp or else rounded. In all cases the rounding is due either to attrition or fusion, or to both of these causes.

(2) Sedimentary rocks (especially grits, sandstones, and tuffs) consist of fragments of minerals, and sometimes fragments of rocks. These fragments may be either angular or rounded. Sedimentary rocks also frequently contain entire crystals, which may also have their angles and edges either perfectly sharp or else rounded. In all cases the rounding is due to attrition, except in crystals whose development has been aborted, or unless actually fused volcanic ejectamenta have become incorporated with the sediments. It is possible that in some cases sandstones may result from actual crystallization from solution; and the formation of flint may be regarded as due to a similar origin. A felspathic grit formed under such conditions may not be distinguishable from a felstone either structurally or mineralogically. From these considerations we may assume that, structurally and mineralogically, as flint is to sandstone so is felstone to felspathic sandstone; and since flint appears to be an intimate admixture of crystalline and amorphous matter, the polarization-picture of flint closely resembles that of some forms of petrosilex or felstone.

(3) The minerals which constitute volcanic ejectamenta are the same as those which enter into the constitution of lavas or other eruptive rocks, the former being usually derived either in great part or entirely from the latter.

These minerals are principally felspars, augite, hornblende, olivine, micas, and quartz.

(4) The minerals which constitute sedimentary rocks are chiefly quartz, felspars, micas (in rocks of the grit, sandstone and tuff types), clays partly resulting from decomposition of felspars, serpentinous matter, chlorite, &c. resulting from the decomposition of augite, steatite, talc, hornblende, olivine, &c.

(5) The minerals occurring in the two classes of rocks may therefore be classed as follows:—

Volcanic ejectamenta and other eruptive rocks.	Sedimentary rocks, Grits, Sandstones, Tuffs, &c.
Felspars.	Felspars and decomposition-products from felspars.
Augite.	Decomposition-products from augite.
Hornblende.	" " " hornblende.
Olivine.	" " " olivine.
Micas.	Micas.
Quartz.	Quartz.
	Clays, shales, and slates may consist of materials derived from the decomposition of felspars, usually with admixture of more or less quartz, and sometimes mica or talc, &c.

Carbonate of lime may occur in either eruptive or sedimentary rocks—in the former as cements or other infiltrations; in the latter case either constituting entire rock masses or forming cements, &c.

From this tabulation we see that felspars and quartz are the principal minerals common both to pyroclastic and clastic rocks, while it is quite possible for any of the other minerals, or alteration-products from them, to be also common to the rocks of both classes.

(6) The nature of the changes which the foregoing minerals suffer from the action of heat are somewhat variable.

The felspars may become fused superficially, or reduced to a complete state of fusion throughout. Microscopic examination of perfectly fused felspar shows it to be a thoroughly amorphous substance, possessing the optical character of homogeneous glass.

Lacunæ of glass are common in many of the minerals constituting volcanic ejectamenta, and it is not uncommon to find fused surfaces on these crystals. Moreover the minerals in many lavas also contain glass lacunæ, so that frequently no distinction can be made between the minerals occurring in lavas and those met with in volcanic ejectamenta. This is not to be wondered at, since ashes, lapilli, &c. are derived at times from the disintegration of lava, or possibly more often from the bursting-up by volcanic explosions of viscid magmas similar to those from which the lavas are derived.

(7) An examination of recent lavas, erupted both beneath the sea and on land-surfaces, shows that no appreciable difference exists between them.

(8) Both lavas, intrusive sheets of molten rock, and volcanic ejectamenta may occur interbedded with ordinary sedimentary rocks; and except from alteration of the adjacent sediments at the contact of the lavas at their lower surfaces, and at the upper and lower surfaces of the intrusive sheets, there is no evidence to be procured in the field to show whether a certain bed represents a volcanic ash, a tuff, or an ordinary detrital sediment such as a felspathic grit.

The intercalation of clastic rocks with lava-flows lends considerable probability to the assumption that such rocks may be of pyroclastic origin; but it does not afford conclusive evidence, since we occasionally meet with ordinary sedimentary deposits occupying similar positions.

(9) In view of the foregoing considerations, I think we may assume that:—Neither the angularity of fragments and crystals, the rounding of fragments and crystals, the mineralogical or lithological character of fragments and crystals (except perhaps the fusion of surfaces of crystals, their envelopment in glass, or the presence of separately fused fragments of glass), the inclusions in crystals, the presence or absence of cementing matter, the petrological associations, nor the mode of occurrence afford any *certain* clue to the origin of fragmentary rocks, and that assertions hitherto made regarding their pyroclastic origin are incapable of *demonstration*, except in instances where it is known that no submergence of land has taken place in particular areas since certain periods of volcanic activity, or in instances in historical times in which showers of ashes have

actually been seen to fall. We may admit that in many cases such assertions are backed by great probability and are very likely correct; but, in the present state of knowledge, we should often accept them rather as theories than as facts.

The writings of Zirkel, Vogelsang, Von Lasaulx, Rosenbusch, and Penck have to some extent helped us to a right understanding of the relative points of resemblance and difference between volcanic ejectamenta and other rocks which may assimilate to them either in mineral constitution or in structure ; but apparently there is much more to be learned before we can safely speculate on the pyroclastic origin of many of our older rocks.

Having now considered some of the elements of doubt which frequently perplex us, let us look for a few of the phenomena which may serve to dispel this uncertainty, first with regard to clastic and pyroclastic rocks, and next in the case of grits, felstones, and once-vitreous lavas.

(i) A pyroclastic rock may sometimes be distinguished from an ordinary clastic rock by the presence of crystals which are more especially characteristic of lavas and which, as a rule, would become decomposed prior to the atmospheric disintegration of the lavas which contain them. This, however, is not always a trustworthy character, since it is often difficult to distinguish between tuffs and consolidated ashes. A safer means of discriminating between pyroclastic rocks and ordinary clastic rocks lies in the occurrence in the former of crystals with fused surfaces or with vitreous envelopes, and of isolated shreds of vitreous matter. These are the best evidence ; while in the next place a paucity or absence of quartz may also be regarded as in favour of pyroclastic origin so long as the quartz does not appear to have been derived from its dissociation from silicates, in which latter case felsitic matter would probably be the result.

In many cases it appears quite impossible to distinguish a consolidated ash from a volcanic tuff. Indeed atmospheric degradation and volcanic eruption going on synchronously, it is quite possible to find rocks of a mixed character—rocks, in fact, which are partly tufaceous and partly ashy; and these, again, are sometimes mixed with ordinary sediments.

(ii) A felspathic grit may be distinguished from a felstone dyke by its mode of occurrence, and from an interbedded felstone by the occasional fragmentary character of the felspar crystals &c. and by the presence of a cement, which often is of a friable nature, rendering the fracture or disintegration of the rock an easy matter.

(iii) The characters which may serve to distinguish a devitrified or felsitized pitchstone, obsidian, perlite, or rhyolite from a felstone are:—Fluxion structure, especially when indicated by bands or the remains of bands of unaltered glass, or when indicated by devitrified bands which differ from the surrounding matter in microcrystalline or cryptocrystalline development or texture, or, again, as indicated by streams of microlites following definite directions.

The presence of perlitic structure.

The presence of spherules lying in bands.

The occurrence of bands formed by the coalescence of spherules.

The presence of glassy matter in strings or bands is, however, one of the safest tests.

The rounded contours of porphyritically imbedded crystals also serve to distinguish a once-vitreous lava from a felstone.

There is a close relation in chemical composition between hyaline rhyolites, felsites, &c.

The devitrification of hyaline rhyolites may also result in hälleflinta or felsite without any marked change in the chemical composition of the rock; and this indicates that devitrification is rather to be regarded as a physical change.

Deductions.

In this paper I have endeavoured to show:—(1) That many rocks to which different names have been applied are identical, sometimes in mineral constitution, sometimes in structure, and that they merely differ in the relative dimensions of their constituent crystals, grains, or fragments.

(2) That the rounded forms of crystals and fragments may be due to various causes already specified.

(3) That vesicular and amygdaloidal structure may be due to various causes already specified.

(4) That other spherical or spheroidal structures occurring in certain rocks are due to various causes already specified.

(5) That in view of the foregoing considerations it may be well to roughly classify all rocks as eruptive and clastic, and to subdivide them according to certain structural peculiarities, as indicated in the classification proposed in this paper.

(6) That both angular and rounded fragments frequently occur in the same rock, and consequently that sedimentary rocks cannot be characterized as consisting exclusively or especially of rounded grains.

(7) That the microscopic characters of felsitic matter in some cases may, in others may not, afford a clue to the origin of certain rocks; and that, since, in many cases, lavas and volcanic ejectamenta are often bedded, just like sediments, no distinction can be found, either by observation in the field, by pyrognostic deportment, or by microscopic examination, between certain devitrified lavas, felstones, and arenaceous sediments, when they all present felsitic characters, and between certain grits, breccias, tuffs and volcanic ashes.

Let us for a few minutes consider what are the bearings which recent petrological investigations have with regard to past geological work. With every modern appliance it is often difficult or impossible to pronounce more definite opinions upon the character or origin of certain rocks than those which were enunciated years ago. The more we learn about some rocks the less are we disposed to assign them definitely to any particular origin; and we are not unfrequently compelled to fall back upon the vague terms of our predecessors as harbours of refuge in which to shelter until more knowledge is acquired, and we can again sail out into the sea of legitimate speculation. For this reason I would strongly deprecate the abolition of the terms greenstone and aphanite. To uphold the old statements with regard to volcanic ash is a much more delicate question, since we can, in many cases, prove that these so-called ashes *may be* other rocks, although we are not always in a position to prove definitely that they *are not* ashes. In such instances I would earnestly suggest that the terms tuff or breccia be employed, as signifying a clastic rock which is not necessarily of pyroclastic origin.

The older observers deserve all honour for the skill with which they frequently detected lithological differences; under similar circumstances few petrologists of the present day could do better; and even when the latter have recourse to methods of investigation, formerly unknown, they are often compelled to admit the ability with which the old work was done, and in many cases the surprisingly acute perception of small lithological differences which it evinces. By patient study we shall, year by year, get nearer and nearer the truth; but in the present state of our knowledge such an object would be considerably retarded if previous experiences were ignored and old ideas and old terms ruthlessly abolished.

It is not quite easy to realize how much we owe to the labours of those who have gone before us; and the least we can do is to recognize those labours when the results prove to be correct, and to deal leniently with errors into which any men might have fallen under similar circumstances. The old work ought not to be set aside until all facts have been carefully sifted out and preserved; and it is to be hoped that in time some of our pioneers will modify their opinions, and thus help their successors in breaking down a few of the old-established barriers which for years past have obstructed progress, and in building up a stronger and a better belief, commended by a simplicity of theory and based upon a multiplicity of facts.

Discussion.

The President confined his remarks to the question of the rounding of grains in stratified rocks. His own experience showed that while the larger particles in sandstone rocks are rounded, those of smaller size are quite angular.

Prof. Bonney, though agreeing with the author as to the great difficulty of distinguishing rocks of different modes of origin, was, however, inclined to take a more sanguine view, and to hope that the experience gained by long and careful study will enable the microscopist to discriminate between clastic and pyroclastic rocks. He also took exception to the views of the author concerning the formation of amygdaloids.

Dr. Hicks remarked on the suggestiveness of the paper to those engaged in the study of the older rocks. He demurred to the author's views as to the deep-sea origin of the Coniston grits.

The PRESIDENT remarked that many rounded grains of glauconite were not formed by the infilling of Foraminiferal cavities.

The AUTHOR, in reply to the President's remarks, stated that he had not studied the relation between the size of the grains of sand and their degree of rounding. He agreed with the President as to his views on the subject of glauconite grains. In reply to Professor Bonney, he stated that some of the cases to which he had directed attention were rather exceptional, and that in the majority of instances no such difficulties as those to which he had alluded are met with. He considered that many of the rocks hitherto regarded as pyroclastic really consist of volcanic ejectamenta, but that there was often great difficulty in demonstrating this assumption. In reply to Dr. Hicks, he expressed a belief that the fossils of the Coniston series indicate former deep-sea conditions.

28. *On the* Occurrence *of* Branchipus (*or* Chirocephalus) *in a* Fossil State, *associated with* Eosphæroma *and with numerous* Insect-remains, *in the* Eocene Freshwater (Bembridge) Limestone *of* Gurnet Bay, Isle of Wight. By Henry Woodward, LL.D., F.R.S., F.G.S. (Read December 19, 1877.)

[Plate XIV.]

There is hardly a spot in the British Islands so well known to geologists at large as the Isle of Wight.

Exhibiting, as it does, so many fine and varied natural sections in its cliffs, from the Wealden up to the Quaternary, it has attracted the attention of observers from the days of Sir H. Englefield, Bart. (1816), and since that date of Captain L. L. Boscawen Ibbetson (1849), of Dr. Mantell, Prof. Prestwich, Prof. Edward Forbes, Mr. H. W. Bristow, and quite recently of Dr. C. Barrois, of Lille, who has added considerably to the geological literature of the island.

The sections and map of the Isle of Wight published by the Geological Survey of Great Britain, and accompanying Mr. Bristow's valuable memoir, leave apparently little to be desired; but much has yet to be done in order to complete our knowledge of the vast series of fossil remains which are constantly being discovered, especially the large collections yielded by the fluvio-marine series.

The Hempstead and Bembridge * beds have long been known and studied by the late Prof. E. Forbes and others, and have yielded a rich series of fossils to the labours of Henry Keeping, many of which have already been described in Frederick Edwards's monograph and elsewhere. The plant-beds at the base of the Eocene series in Alum Bay, already partially examined by De la Harpe and Salter, are now likely to be thoroughly worked out by the energetic labours of Mr. J. Starkie Gardner, F.G.S., aided in the determination of the plant-remains by Mr. W. Carruthers, F.R.S., F.G.S., and the Baron von Ettingshausen, who have both promised their cooperation.

The fossils of the Eocene marine series have been studied by many able geologists—Lyell, Forbes, Edwards, Owen, Bowerbank, Mantell, and others.

But between the Bagshot beds (Middle Eocene) and the Hempstead and Bembridge beds (Upper Eocene) one meets with the Headon and the Osborne or St. Helen's beds, forming the *lower* part of the fluvio-marine series of the Isle of Wight.

This series consists of an aggregation of beds of freshwater, estuarine, and marine origin, the Headon beds being computed by Mr. Bristow at from 133 to 175 feet in thickness at Headon Hill and Whitecliff Bay, whilst the Osborne series attains a total thickness of 79 feet.

Chara Lyellii, *C. medicaginula*, *C. Wrightii*, and *Carpolithes ovulum* and *C. thalictroides* are the only plants recorded.

* Lyell's earliest papers related to these beds.

Of Crustacea there have been found:—*Candona Forbesii*, *Cytherideis unisulcata* and *C. Colwellensis*, *Cytheridea debilis*, *Mülleri*, and *perforata*, *Cythereis cornuta*, *Cytherella Münsteri*, *Cythere plicata*, *C. angulatopora*, and *C. Wetherelli*; also two Cirripedes, *Balanus unguiformis* and *Pollicipes reflexus*.

These, with about 42 genera of Mollusca (many of which are estuarine and freshwater, and some land species), make up the known fauna of these beds at the time of the Geological Survey Memoir.

To Mr. E. J. A'Court Smith is due the credit of the discovery of a thin but very richly fossiliferous band in this series of deposits at Thorness and Gurnet Bays, near Cowes, which has largely increased the interest of these beds, especially by a very important addition to the known terrestrial forms of life belonging to the Eocene period.

The section is as follows:—

General Section at Thorness and Gurnet Bays.

		Thickness. ft.	in.
	Surface soil.		
I.	*Grey* Clays with occasional bones of *Emys* or *Trionyx*	10	0
II.	Lighter (*Yellow*) Clays with broken shells	2	0
III.	*Limnæa* Limestone with *Planorbis* and bones of *Emys*, also hard concretions (*Hard limestone* bed)	3	0
IV.	Variegated fossiliferous Clays	8	0
V.	Upper Limestone beds with *Limnæa* and small oblong Oyster (*Ostrea* sp?)	3	0
VI.	Band of loose shells with *Ostreæ* and Sharks' teeth	0	6
VII.	Blue Clays with *Cyrena*	3	0
VIII.	Fossil Plant and Insect-bed	1	0
	Base of cliff.		
		30	6

"The Limestone at Hempstead Ledge" (5 miles S.W. of Gurnet Bay), writes Mr. Bristow *, "consists of three beds with other softer beds between, and contains numerous *Limnæa longiscata*, *Planorbis*, *Chara*, &c. There, as well as in Gurnet Bay and at West Cowes, it appears to be about 15 or 16 ft. thick. It presents very uniform characters in all these localities, where it is highly fossiliferous, and marked by the presence of occasional *Planorbis*, and *Paludina orbicularis*, together with (as usual) numerous *Gyrogonites* and casts of *Limnæa longiscata*. At the point between Gurnet and Thorney Bays it stretches out at sea towards Hempstead Ledge, in a direction 30° S. of W., with a dip 35° S. of E. On either side of Gurnet Bay it forms a conspicuous curve, and determines the form of the slope on which Cowes is built, although on the surface it is not seen, being concealed by the superincumbent marls and, eventually, by the gravel. On the quay, at West Cowes, it serves for the foundations of some houses built on the northern part of the Parade, opposite to which it forms a ledge dipping 10° S. of E. and skirting the shore as far as Egypt."

* "Memoir on the Geology of the Isle of Wight," by H. W. Bristow. Mem. Geol. Survey Gt. Britain, 1862, 8vo, p. 77.

There can be little doubt that the beds exposed in the cliff-sections at Gurnet and Thorness Bays belong to the Bembridge series, and that the hard band, from which the insect-remains and Crustacea have been obtained, belongs to the lowest part of that series.

The beds dip to the S.W., so that in about half a mile the lower bed of limestone is just on the line of high water; and about 200 yards further west it forms a reef known as "Stuckler's Ledge," which is the eastern point of Thorness Bay.

Within Thorness Bay the beds dip more rapidly to the south, till at 400 yards distance from the ledge the shale with fossils dips down to the beach and forms a small reef.

As no fossils, save those already recorded, had been noticed by Messrs. Forbes and Bristow, great was my delight to find in Mr. A'Court-Smith's collection, the result of 20 years' patient collecting in his leisure hours, abundant remains of insects evidencing the presence of more than twenty genera, representing Coleoptera, Hymenoptera, Lepidoptera, Diptera, Neuroptera, Orthoptera, and Hemiptera, and one representative of the Arachnida.

Mr. A'Court-Smith accounts for the abundance of remains of insects in particular blocks by the theory that they were (after being drowned) left by eddies in pockets, much in the same way as we find organic remains in streams, lakes, and along the coast at the present day.

For the determination of the insect-remains, so far, I am indebted to my experienced friend and colleague, the late Frederick Smith, Esq., Assistant-Keeper of the Zoological Department, British Museum. Possibly some more adventurous palæo-entomologist may make a more rigorous study of them, and give to some at least of the more perfect remains generic and specific determinations.

List of Insect-remains from Gurnet Bay, near Cowes, Isle of Wight, determined by the late Frederick Smith, Esq., Assistant-Keeper, Zoological Department, British Museum.

	Number of specimens.
I. Coleoptera.	
1. Staphylinus	1
2. Dorcus (Lucanidæ)	1
3. Anobium	1
4. Curculio	7
II. Hymenoptera.	
5. Wings of	2
6. Formica	19
7. Myrmica	7
8. Camponotus	7
III. Lepidoptera.	
9. Lithosia	2
IV. Diptera.	
10. Wings of	43
11. Tipulidæ	6

	Number of specimens.
V. Neuroptera.	
12. Phryganea	8
13. Termes?	1
14. Hemerobius	1
15. Perla	2
16. Agrion	2
17. Wings of Libellula	9
VI. Orthoptera.	
18. Gryllotalpa	1
19. Acridiidæ	2
VII. Hemiptera.	
20. Wing of?	1
21. Triecphora sanguinolenta	1
Arachnida.	
1 Spider	1

Mr. A'Court-Smith has likewise been fortunate in discovering numerous fragmentary remains of plants, such as leaves of palm (*Flabellaria*), seeds of water-lily (*Nelumbium*), leaves of rushes and other aquatic plants. With these plant-remains and insects were also found two forms of Crustacea belonging to the Edriophthalmia and the section Isopoda, also abundant remains of a minute Phyllopod Crustacean allied to *Branchipus* or *Artemia*.

Bivalved Entomostraca, as already stated, had been noticed and described by Prof. T. Rupert Jones from these beds to the number of some 14 species and six genera (*Candona*, *Cythere*, *Cythereis*, *Cytherella*, *Cytheridea*, *Cytherideis*); but these, it must be borne in mind, are represented by their calcareous bivalved carapaces, not by the remains of appendages, no limbs (save in a single instance*) having been met with.

Even the Isopoda have a tolerably firm though thin crust; and the paper-like valves of *Estheria* have sufficient chitine in them to give them consistence, and enable them, like the elytra of insects, to be preserved in a fossil state. But that a Crustacean like *Branchipus*, destitute of shelly covering, having a long slender diaphanous many-segmented body and 13 pairs of laminar branchial feet, should undergo the process of fossilization, and leave any trace behind, is truly remarkable.

The preservation of these delicate little Phyllopods is, no doubt, due to the admirable nature of the fine argillaceo-calcareous mud-rock in which they have been entombed in such numbers, the iron having collected around them and stained the outline of the delicate gill-feet and appendages upon the stone, as if painted by some photographic process.

In the first Heft of his 'Fauna Saræpontana Fossilis,' 1873 (Die Fossilen Thiere aus der Steinkohlenformation von Saarbrücken), Dr. Friedrich Goldenberg has described and figured, on Taf. 1. fig. 15 (16), six somewhat doubtful-looking segments which he attributes to *Branchipus*, and names *Branchipusites anthracinus*. Without a careful examination it would be imprudent to pronounce a judgment upon this specimen; I annex a translation of Dr. F. Goldenberg's remarks upon it.

"Of this animal," he says, "eight segments are to be seen in the side view; but of these, the first and last are very imperfect. The middle segments are also very imperfectly preserved, so that one can only find indications of their segmentation. The lateral appendages (side-pieces), of which six are present pretty perfect, in their natural connexion, have much resemblance to the lamellar branchial feet of a *Branchipus*. Their anterior margin is somewhat incurved; the hinder margin, which is parallel to the anterior, bends at about two thirds of its course at an obtuse angle towards the apex of the anterior margin. In the middle of this oblique inferior margin oval thickenings make their appearance, which I regard as remains of vesicular branchiæ, which were seated here at the base of the lobe, unjointed swimming- (or fin-) feet. The substance of these swimming-feet

* *Palæocypris Edwardsii*, from the Coal-measures, Saint-Etienne, France, discovered by M. Ch. Brongniart (see Ann. des Sci. Géolog. 1876, art. no. 3, pl. 7).

seems to have been very thinly membranous and of a blackish-brown colour."

I know of no other recorded example in a fossil state.

It is interesting to mention that both the males with large clasping antennæ, and the females with small antennæ and egg-pouches with large and very distinct disk-like bodies (the compressed eggs), can be made out upon the slabs.

I propose to name this interesting fossil Phyllopod *Branchipodites vectensis* (Pl. XIV. figs. 6–9).

Dimensions:—Length of fossil 6 millims., breadth 2 millims.

The two forms of Isopods discovered by Mr. A'Court-Smith differ considerably both in form and relative size; and as they are, moreover, derived from different horizons in the Bembridge beds, I feel justified in treating them as distinct species.

The smaller species (Pl. XIV. fig. 1) was found in one of the hard blocks met with upon the beach which have yielded the fossil *Branchipus* and the insect-remains; whilst the larger species (Pl. XIV. fig. 2) was obtained from a yellow marly bed charged with the roots of aquatic plants, which occurs somewhat higher up in the series.

The former of these (fig. 1) occupies the surface of a small, grey, and very compact slab, in which about twenty-five specimens may be counted in the space of a few inches.

The largest individuals measure 8½ millims. in length by 4½ or 5 millims. in breadth, the smallest being 7 millims. long by 3½ millims. broad.

The head is small, measuring only half the breadth of the thorax (pereion); the eyes are reniform, marginal, and prominent.

The thorax (pereion) is composed of seven somites; the first of these is greatly produced laterally and deeply emarginated anteriorly, for the insertion of the head, as is the case in several living species of Sphæromidæ and Oniscidæ. The six succeeding somites are well developed, their tergal portion nearly straight and the epimera somewhat strongly recurved.

The abdomen (pleon) is composed of a single caudal shield, nearly circular in outline, and forming one third of the length of the entire animal. Two lamellar caudal appendages or uropoda, which are articulated to the anterior margin of the caudal shield, are seen, one on either side. These, with a trace of antennæ, are the only appendages observed in the fossil.

There can be little doubt of the propriety of referring this species to a position near to, if not actually in, the family of the Sphæromidæ; and it is satisfactory to find that a closely allied fossil form, also from the Eocene, has already been so referred by Prof. H. Milne-Edwards.

I propose to place all these Tertiary forms of Isopoda Normalia in a distinct genus, under the name of *Eosphæroma*, to which I shall refer again subsequently. I designate this small species *Eosphæroma fluviatile*.

The second and larger species (Pl. XIV. fig. 2) occurs on the surface of a fine yellow marl or pipe-clay, full of the rootlets of aquatic plants, and is represented by a group of ten individuals.

The specimen measures $16\frac{1}{2}$ millims. in length and $10\frac{1}{2}$ millims. in breadth. In outline this species is much more oval than fig. 1. The head is less deep, but broader, and the eyes less conspicuous and placed more in front. The head is 4 millims. broad and 2 millims. deep.

The segments of the thorax (pereion), seven in number, are considerably arched, the three median segments being not only broader but deeper than the rest. As in fig. 1, the anterior thoracic somite is developed laterally, so as to enclose the sides of the head. The length of the thorax is 8 millims., breadth 10 millims.

The caudal shield (pleon) is large and nearly semicircular, being 6 millims. long by 8 millims. broad.

Two lamelliform appendages (uropoda), articulated to and arising from the sides of the abdomen, closely encircle the caudal shield. A small ramus is given off from the second (third?) articulation of the uropodite, as in recent Sphæromidæ. Traces of antennæ can also be detected on the slab, but no other appendages are preserved.

I have designated this form *Eosphæroma Smithii*, after its discoverer, Mr. E. J. A'Court-Smith.

It must not be supposed that these remains occur throughout the bed described. The bed itself is at most 12 inches thick, but more often only 2 inches. Thousands of blocks of this fine hard-grained limestone have been broken up, in the course of the last twenty years, by Mr. A'Court-Smith to obtain specimens.

I subjoin a short description of the French Eocene form described by Prof. H. Milne-Edwards*, which I propose to refer to the same genus with those from the Isle of Wight (see Pl. XIV. fig. 3):—

"This Isopod was found in the neighbourhood of Paris, in digging the fortifications at the hill of Chaumont; it was met with in a bed of marl, immediately below the green marl containing *Cythere*†. It is so abundant that sometimes in the space of a square foot one can count the impressions of more than a hundred individuals.

"The form of these little Crustaceans is pretty regularly oval; the largest individuals measure only about 12 centims. [*sic*]‡ long by 7 or 8 broad.

"The body appears to have been depressed, as in *Ancinus*, for the impressions left do not exceed half a centimetre [*sic*] [*read* "millimetre"] in thickness, and present no appearance of deformation.

"The head is of medium size, and gives insertion to the antennæ by a slight frontal flattening; the eyes are small and placed laterally.

"The thorax (pereion) is composed of seven rings, and presents

* See 'Annales des Sciences Naturelles,' 2e série, 1843, tome xx. Zoologie, p. 329.

† [Lower Tertiary.]

‡ [For "centimetres" read "millimetres." This is evidently an uncorrected printer's error, as the specimens, with Prof. Milne-Edwards's label, are now before me, and do not exceed about 12 millims.]

on each side a border formed by the epimeral pieces, which overlap one another and are of a quadrilateral form.

"The abdomen is composed of two segments, the first of which resembles the thoracic rings and presents traces of a transverse suture; the second is scutiform and semioval. Lastly, on each side of this terminal plate, one detects lamellar subfalciform natatory appendages, placed as in *Sphæroma*.

"From these peculiarities of structure, I am induced to believe that this fossil ought to be placed in the family of Sphæromidæ; but it does not sufficiently closely resemble any of the existing species in this group, and in the Museum I have classed it between *Sphæroma* and *Ancinus*, and I have named it *Palæoniscus Brongniartii*."

If to this we add *Palæoniscus obtusus*, Meyer*, from the Miocene of Bonn, which is, no doubt, closely related to the foregoing species, we have all the Tertiary forms hitherto described.

The name *Palæoniscus*, unfortunately, cannot stand, having been preoccupied by Blainville for a genus of Fishes since 1818 (*Palæoniscum*), and by Agassiz since 1833 (*Palæoniscus*). I would have suggested the substitution of *Archæoniscus*, Milne-Edw., the name given to a fossil Isopod from the Purbeck of the Vale of Wardour; but a reference to the figure (Pl. XIV. fig. 4), and to the subjoined description, will show at once that the relations of the four forms above enumerated are with the Sphæromidæ, whereas the presence of several free and movable abdominal somites in *Archæoniscus* connects it with the Ægidæ and other errant Cymothoidæ.

I would venture therefore to propose for these Tertiary forms the generic appellation of *Eosphæroma*.

The known list of Isopod fossils will be then as follows:—

Armadillo molassicus, *Heer*, '*Primæval World of Switzerland*,' vol. ii. p. 5, fig. 210. Miocene, Œningen.
Eosphæroma (Palæoniscus) obtusum, *Meyer*. Miocene, Bonn.
—— (——) Brongniartii, *Milne-Edwards*. Lower Eocene, near Paris.
—— fluviatile, *H. Woodw*. Upper Eocene, Gurnet Bay, Isle of Wight.
—— Smithii, *H. Woodw*. " " "
Palæga Gastaldi, *Sismonda*. Miocene, Turin.
—— Carteri, *H. Woodw*. Grey Chalk, Dover.
—— sp. (*Ferd. Roemer*). White Chalk, with flints, Aalborg, Jutland, Denmark.
Bopyrus (under carapace of *Palæocorystes*). Greensand, Cambridge.
Archæoniscus Brodiei, *Milne-Edwards*. Lower Purbeck, Vale of Wardour, Wiltshire.
—— Edwardsii †, *Westwood*. Lower Purbeck, Durdlestone Bay, Dorset.
Præarcturus gigas, *H. Woodw*. Old Red Sandstone, Rowlestone, Herefordshire.

Among the Sphæromidæ common to our coast at the present day, and also to that of France and Ireland, is *Sphæroma serratum*, Fabr., sp. (see Pl. XIV. fig. 5).

* Palæontographica, Dunker und Meyer, 1858, Band v. pp. 111–113, t. 23. f. 3, 7, 8.

† See Quart. Journ. Geol. Soc. 1854, vol. x. p. 393. I regret to say I had overlooked the fact that Prof. J. O. Westwood had given a specific name to the specimen of *Archæoniscus* figured by him on pl. 14. fig. 12.

This form resembles our fossil in the small size of the cephalon and the broadly-expanded recurved character of the margin of the anterior segment, in the form of the eyes, the antennæ, and the posterior pair of limbs; but the abdominal shield is larger in the fossil.

Dr. Kinahan obtained *Sph. serratum* in the River Logan, Belfast, and in the River Dodder, Dublin *; so that the fossil species occurring in this fluvio-marine bed is quite in accord with the habits of its modern congener.

I subjoin a brief notice of *Archæoniscus Brodiei* by Prof. Milne-Edwards, who writes†:—

"The specimens which I have received from Mr. Brodie (discovered in the Wealden [*sic*] [Purbeck] formation, in the Vale of Wardour, Wiltshire) are 12 centimetres ‡ in length and 9 in breadth; but this geologist has found some whose dimensions are much greater." [I subjoin the measurements of several specimens presented by the Rev. P. B. Brodie to the British Museum—

Length.		Breadth.
12 millims.	....	8 millims.
14 ,,	....	9 ,,
19 ,,	....	11 ,,
20 ,,	....	13 ,, .]

"The body is very smooth, and composed of a series of rings terminated posteriorly by a rounded shield. Unfortunately the head is not well preserved in those specimens which I have examined. I have not been able to discover any traces of the legs; but Mr. Brodie has detected them in some of his specimens. I have been able to make out traces of the antennæ. The fossil is evidently an Isopod, and from its general form should be arranged in the family of Cymothoidæ, but it cannot be referred to any known genus. It appears to be intermediate between *Serolis* and the errant Cymothoidæ. It resembles the former in the greater development of its body-segments, especially of the epimeral portion of the segments as compared with the tergal portion, and also in the expansion of the epimera and the position of the terminal shield of the body.

"It differs from *Serolis* by the greater development and mobility of the anterior rings of the abdomen—characters which ally it to *Æga* and other errant Cymothoidæ. The several rings between the head and the caudal shield scarcely differ from one another, so that there is no visible limit between the thorax and the abdomen; but one can count as many as twelve; and as the number of thoracic rings never exceeds seven in the Edriophthalmia, we must conclude that the remaining five most posterior ones belong to the abdomen, which would consequently be composed of six movable segments, as

* Bate and Westwood, Hist. Brit. Sess.-eyed Crustacea, 1868, vol. ii pp. 405–407.

† 'Annales des Sciences Naturelles,' 2e série, 1843, tome xx. Zoologie, p. 327.

‡ [For "centimetres" read "millimetres." This error occurs throughout Milne-Edwards's paper. I have the specimens of both *Archæoniscus Brodiei* and *Palæoniscus Brongniartii* before me; it is evidently a clerical error.]

in *Æga*, *Nelocira*, &c. The sixth abdominal ring, which constitutes the terminal shield, is nearly semicircular, and presents on its median and anterior portion a tubercular swelling nearly analogous to that observed in the caudal shield of several Sphæromidæ. Lastly, the structure of the head appears to be intermediate between that of these last-named Crustacea and that of which *Serolis* offers us an example; for the cephalic ring is enlarged, as in the Sphæromidæ, while the eyes approach the median line, as in *Serolis*.

"From these facts one sees that this fossil Crustacean is perfectly distinct from all living Isopods, and ought therefore to be placed in a separate genus. I would propose to designate it *Archæoniscus Brodiei*."

I have given an outline figure of this old Isopod in my plate (Pl. XIV. fig. 4).

EXPLANATION OF PLATE XIV.

Fig. 1. *Eosphæroma fluviatile*, H. Woodw., 3 times nat. size. Upper Eocene, Bembridge series, Gurnet Bay, I. of Wight. *u*, uropoda.

Fig. 2. *Eosphæroma Smithii*, H. Woodw., twice nat. size. Ditto. *u*, uropoda.

Fig. 3. *Eosphæroma* (*Palæoniscus*) *Brongniartii*, H. Milne-Edw. sp., "Couche de Marne à *Cytherées*, sous les Marnes vertes." U. Eocene, Butte de Chaumont, près Paris. 3 times nat. size. *u*, uropoda.

Fig. 4. *Archæoniscus Brodiei*, Milne-Edw. Lower Purbeck beds, Vale of Wardour, Wilts. 3 times nat. size. (The mesial line dividing the posterior somites in this figure appears to be due to the decortication of these segments, which has laid bare the cast of the straight alimentary canal.)

Fig. 5. *Sphæroma serratum*, Fabr., sp. Recent British Marine and Estuarine.

Fig. 6. Part of a slab of Bembridge stone, drawn of the natural size, covered with impressions of *Branchipodites vectensis*, H. Woodw.

Figs. 7, 8, & 9. Portions of individual specimens, drawn with the camera and 1-inch objective, showing—*br*, *br*, branchial feet; *e*, *e*, the eyes; *o*, *o*, the ovaries, with contained ova; *c*, *c*, the caudal somites.

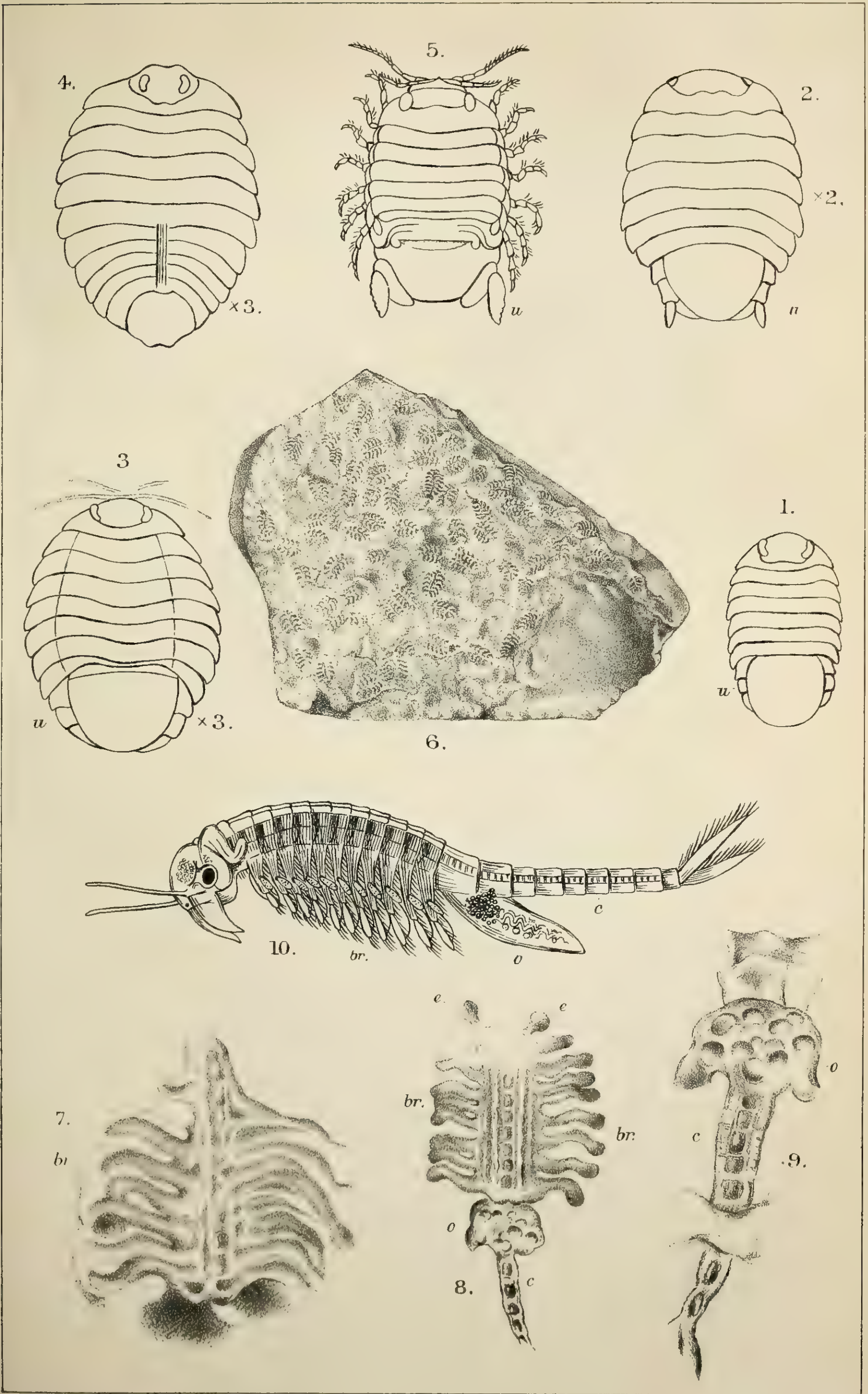
Fig. 10. *Branchipus* (*Chirocephalus*) *diaphanus*, Prevost. Recent freshwater. British.

(Figs. 1–4 and Fig. 6 drawn from specimens in the Geological Collection of the British Museum.)

Discussion.

Prof. Wood-Mason stated that he was acquainted with three or four genera of Isopoda, members of which can live indifferently in salt and fresh water, one of them being the parasitic *Bopyrus*—facts that seemed to indicate the process by which, in the course of ages, our fresh waters and, eventually, the land had gradually become stocked with mollusks and crustaceans, littoral and estuarine representatives of these two classes of animals, which were ametabolous, having sufficient plasticity of their organism to enable them to withstand a gradual change from salt- to freshwater conditions.

Mr. J. S. Gardner said that the beds belonged to the Bembridge formation, and that he had diligently examined the corresponding beds in the eastern corner of Whitecliff Bay, but had found them quite barren. No insects had been found in Alum Bay, and comparatively few at Studland and Bournemouth. The Eocene insects found in England everywhere indicate a temperate climate.



A. S. Foord del.

Mintern Bros imp.

EOCENE CRUSTACEA FROM THE ISLE OF WIGHT ETC.

29. *On* Conodonts *from the* Chazy *and* Cincinnati Group *of the* Cambro-Silurian, *and from the* Hamilton *and* Genesee-Shale Divisions *of the* Devonian, *in* Canada *and the* United States. By George Jennings Hinde, Esq., F.G.S. (Read March 12, 1879.)

[Plates XV.–XVII.]

Soon after the publication by Dr. Pander, in 1856, of his well-known monograph, in which he announced the discovery, in the lowest fossiliferous rocks of Russia, of small "teeth" named Conodonts, and referred by him to fishes, several discussions arose as to the character of these minute bodies, and various opinions were expressed as to their near relations, without, however, any satisfactory conclusion being arrived at. Since that date Conodonts have been found in several other places; and in this communication I propose to describe a great variety of forms which I have collected within the last two years from several different formations in North America. Though my specimens may not suffice to determine the true position of the organisms to which they were attached, they will at least add something to our previous knowledge, and thus assist in reaching a decision on the subject.

The next account, after Dr. Pander's, of the *discovery* of Conodonts is by Dr. J. Harley, in an article on the Ludlow bone-bed and its crustacean remains *. Only two of the specimens described by this gentleman have any resemblance to the Conodonts of Pander; but a comparison of these with other very differently formed bodies in the same beds led him to express the opinion that all the forms were of crustacean origin, and that Conodonts were probably only spines similar to those attached to the margins of the carapace of *Limulus* and the caudal segment of *Squilla*. He therefore included all together under the provisional genus *Astacoderma*.

In 1869 Mr. Charles Moore, F.G.S., discovered undoubted Conodonts in the Carboniferous Limestone of this country †; and in a late communication from that gentleman he informs me that he has them from the Silurian probably up to the Permian.

Within this last year these small bodies have been found in great variety and most beautiful preservation in Lower Carboniferous strata in Scotland by Mr. C. J. Smith, of the Eglinton Iron-works, Kilwinning, and some notes on them have been laid before the Natural-History Society of Glasgow by Mr. John Young, F.G.S. I am indebted to Mr. Young for the opportunity of looking over his specimens, and at once recognized that many of them were identical with those from the Devonian and Carboniferous formations of North America, as also with those from the same formations in Russia, figured by Pander.

* Quart. Journ. Geol. Soc. vol. xvii. p. 542 (1861).

† Report of British Association, 1869, p. 375.

Conodonts were first noticed on the American continent by Dr. Newberry, who, in the second volume of the 'Palæontology of Ohio' (1875), figured several forms and discussed their probable relations, which he believed to be rather with fishes similar to Myxinoids than with invertebrates. All Dr. Newberry's specimens were from the Lower Carboniferous at Bedford in the State of Ohio.

The oldest strata in which I have met with Conodonts are thin layers of a dark limestone belonging to the Chazy formation of the Cambro-Silurian, which, if not the equivalents, are not far separate in relative age from the green sands and black shales of Russia, the lowest beds in which these bodies have been found there. These Chazy beds are exposed on the banks of the Ottawa River at Grenville, in the province of Quebec, and are largely composed of the small tests of bivalve Crustaceans belonging to the genus *Leperditia*, associated with a few small Trilobites and Gasteropods. There are no indications of any of the larger Crustacea or Mollusca to which these Conodonts could be referred; and they are altogether too large, even if they could be referred to either of these classes of animals, to have belonged to those whose tests are here preserved. Though the Conodonts are not unfrequent in these limestones, it is somewhat remarkable that they are all of one species, and this is one of the largest of the known compound forms.

In the strata of the Cincinnati group exposed near Toronto, in which a few Conodonts appear, the rocks are principally micaceous flags and shales, and contain a great variety of fossils, Graptolites, Corals, Annelids, Brachiopods, Gasteropods, and Cephalopods of the genus *Orthoceras*, all well-known forms. No crustacean remains beyond scattered fragments of small Trilobites of the genus *Calymene* have been noticed. Whilst most of these fossils are in thin lenticular beds of limestone intervening between the flags and shales, the Conodonts are generally imbedded in the latter. In addition to a few compound teeth, there are also the simple spine-like forms of Conodonts; and it is worthy of notice that these simple forms are much more restricted in their distribution than the compound; for whilst the latter appear from the Cambro-Silurian to the Lower Carboniferous, the simple teeth are only met with, both in America and in Russia, in the Cambro-Silurian.

I have not as yet found any Conodonts in the Trenton and Utica shale rocks, which come betweeen the Chazy and the Cincinnati group, nor in any strata of the Silurian proper and the lower division of the Devonian; but in the middle Devonian they reappear in great abundance. In strata of this age belonging to the upper beds of the Hamilton group of limestone and shales, exposed near the village of North Evans, on the south shore of Lake Erie, New York State, they are very numerous; and one particular band of limestone, which I propose to designate the Conodont-bed, is filled with fragments of these small teeth. This limestone band varies from half an inch to three inches in thickness, and may be traced for some distance. On fracture it presents a dark subcrystalline aspect, with occasional particles of a green colour, and also crystals of iron-pyrites. In addition to the Conodonts, there are in this same bed numerous fragments of Crinoid stems, bones and plates of undetermined fishes, and teeth closely resembling, if not identical with, those of *Ptyctodus* *, Pander, also from Devonian strata in Russia; but there are no remains of Crustaceans or Gasteropods. It is only on the weathered surface of the rock that Conodont teeth are visible, and then only with the assistance of a good lens.

There are also a few Conodonts associated with plates and teeth of fishes in a thin band of limestone of the Hamilton group at Arkona, Lambton County, Ontario.

Immediately succeeding the Hamilton group are beds of black bituminous shale, known as the Genesee Shale in New York and Canada, and as the Huron Shale in Ohio; and the Conodonts are distributed in these shales, in places widely apart. I have found them in exposures of these strata at Kettle Point, on the shores of Lake Huron, and at Bear Creek, both in Lambton County, Ontario, as well as in small boulders derived from these beds in the cliff-sections on the north shore of Lake Erie: at North Evans, New York, where there is a splendid section of these shales, Conodonts are also abundant; and I have also fragments from the same shales near Louisville, in Kentucky. At all these localities these shales are but sparsely fossiliferous, and the fossils are limited to spores of Lycopods and portions of other plants, a few Brachiopods of the genera *Lingula* and *Discina*, *Aviculæ*, and the scales, mostly detached, of *Palæoniscus*. There are no organic fragments to give any clue to the animal to which these numerous Conodont teeth belonged.

Though my paper does not include the Lower Carboniferous Conodonts of Ohio, treated by Dr. Newberry, I may mention, from my own examination of the beds in which they occur, that the strata are black shales not dissimilar in appearance to the Genesee shales, but less bituminous; and, like these latter also, have scarcely any other organisms in addition to the Conodonts but plants and scales of Ganoid fishes.

My object in mentioning somewhat in detail the fossils occurring with the Conodonts in the different formations has been to point out that they cannot be attributed to these associated organisms, and to show the probability, so far as negative evidence extends, that these minute teeth and plates are the only portions of the animals capable of preservation in a fossil condition.

The appearance of the American Conodonts is so similar to those from Russia that Pander's description will almost equally apply to both. They occur as very minute, shining bodies, sometimes consisting of a single more or less curved conical tooth with an expanded base; but more frequently they possess an elongated basal portion in which there is generally a large tooth with rows of similar but smaller denticles on one or both sides of the larger tooth, according as this is central or at one end of the base. In some forms the

* 'Ueber die Ctenodipterinen des devonischen Systems,' St. Petersburg, 1858, p. 49, table 8.

large tooth is continued below the level of the base, forming one or more small blunted extensions; and in one of the Devonian forms this extension is greatly prolonged and also supported denticles. In other examples there is no prominent central tooth; but a series of more or less similar teeth are carried on a straight or curved base. There are also forms with a wide basal plate denticulated on the upper edge, to which, in two instances, there is an appendage attached at right angles, and apparently of different structure from the toothed basal portion. Besides these more typical examples there are other structures, not hitherto noticed, which, from their intimate connexion with the teeth, evidently belonged to the same organisms. These are minute plates of various forms, with a longitudinal ridge which, in certain cases, is extended beyond the plate and has its upper border denticulated. The plate itself is ornamented on one surface with small tubercles, whilst the other is smooth.

All these forms, though imbedded in strata of very different mechanical and chemical character, as flagstones, shales, and limestones, appear to have experienced but little alteration; they still retain their bright shining lustre, and the smooth and undisturbed outline of their bases plainly indicates that they have not been broken from the edges of the carapace of any crustacean.

The very perfect condition of the extremely minute teeth in many of the specimens also shows that they could not have been exposed to any injuries from transportation. They are all very brittle and are slowly dissolved by nitric acid. Most of the specimens are of a reddish horn-colour and translucent; very rarely do they occur of a milky white, though this white tint is the usual condition of the Ohio Carboniferous specimens, and appears to have been common in the Russian examples. Pander regarded the white specimens as belonging to older individuals; but there can be little doubt, from the occurrence of examples of both kinds of the same dimensions, that the white tint is due to some change in the chemical composition. I find the white specimens more frequently in rocks near the surface, which have been more exposed to atmospheric influences. In many specimens, particularly those occurring in the black shales, while the flat base of the compound tooth is of a reddish horn-colour and transparent, the large tooth is nearly of an ivory-white, a difference which, on microscopic examination, is seen to be due to a different structure of the tooth and base. The Conodonts from the Conodont-bed at North Evans are, as a rule, more robust and opaque and of a different lustre from those in the bituminous shales; whilst those from the Chazy limestone differ from all the rest in possessing a bright, glossy black tint.

As regards the structure of the American Conodonts, an examination of microscopic sections corroborates the result obtained by Pander from the Russian examples. I can detect the same delicate conical lamellar structure both in the specimens from the Chazy and in some of those from the Devonian; in other Devonian specimens, however, the basal portion appears to be homogeneous and without structure, whilst the teeth imbedded in this base have either a clouded fibrous appearance, or seem to be composed of minute nuclei, as represented by Pander (Monogr. tab. 2A. figs. 11, 12).

Hitherto the Conodonts have only been found as detached specimens, scattered irregularly throughout the rock; but I have one example, from the Genesee bituminous shale, in which a group of various forms of teeth and plates have been compressed together in such a manner as to show that they must have belonged to the same animal. Unfortunately the teeth in this specimen are so crushed that nothing can be ascertained as to their natural arrangement; at the same time their numbers and variety of form show no resemblance to those of any existing animal, so that very little fresh knowledge can be gained from this specimen beyond the fact that, whatever may have been the zoological relations of the animal, it possessed a complicated and varied apparatus of teeth and plates.

I submitted my specimens to Professor Huxley, who expressed the opinion that some of them so closely resemble the teeth of the Hag-fish (*Myxine*) that it would be difficult to prove that they did not belong to fishes of this order; at the same time no living fish exhibited an assemblage of teeth and plates at all similar to those shown in the fossil example (Plate XVI. figs. 6–18).

From a microscopical examination of original specimens of Conodonts from Russia, Professor Owen states, in the first edition of his 'Palæontology,' 1870, that only those referred by Pander to the genera *Ctenognathus*, *Cordylodus*, and *Gnathodus* had any probable claims to vertebrate rank, but they might also be only remains of the dentated claws of Crustacea. In the second edition of the same work, however, Professor Owen concludes that they have most analogy with the spines, or hooklets, or denticles of naked Mollusks or Annelids.

Whilst the discovery of these American Conodonts, of which some are identical with, and all generally resemble, those from corresponding rock-formations in Russia, proves the very wide distribution of these bodies, the conditions under which they appear and the fossils associated with them in America assist but little in solving the question as to their relations. In the Cambro-Silurian rocks the fossils of marine invertebrates are very varied and abundant; but there are no large Gasteropods whose lingual teeth could be supposed to be similar to Conodonts, nor the carapaces or segments of any Crustaceans to which they could have been attached as defensive spines. In the Devonian strata, where the Conodonts are much more numerous and diversified in form than in the lower rocks, the only invertebrate fossils accompanying them are Crinoids and Brachiopods; but there are here plenty of fragments of undisputed fish-teeth and bones. There is thus the same ground as in Russia for the supposition that the Conodonts were the only parts of the organism to which they were attached capable of fossilization, and that the body of the animal might have been composed of nothing more durable than the cartilaginous structures of the lower orders of fishes, or the soft tissues of Annelids and naked Mollusks. That, however, the Conodonts cannot be referred to the horny jaws of Annelids may be conclusively shown by the discovery, by the writer, of these Annelidan structures in the same strata with Conodonts, from which the former can readily be distinguished by their chemical composition and their resemblance to the jaws of existing Annelids. Against the probability of the Conodonts having been the teeth of naked Mollusks, it may be noted that the former are principally composed of carbonate of lime, and that it is highly improbable that naked Mollusks should have abounded without any of their shell-bearing relatives having been also present (and of these in the Conodont-bearing beds of the Devonian there are no traces); nor can it be supposed that their shells can have been removed by solution when the most delicate structures of carbonate of lime have remained intact.

It has been shown that whilst Conodont teeth do not correspond in minute structure with, and are far more varied in form than, the teeth of any known fish, they yet approach closest to those of the Myxinoids. As it is not at all improbable that there was in Palæozoic times as great a development of the Cyclostome Fishes as of the Ganoids and Elasmobranchs, with a consequent great amount of variation in their structural development, we could hardly judge, from their pauperized descendants of the present day, how far this variation may have extended in former times. We should not, therefore, on account of the imperfect analogy of the Conodonts with the teeth of existing Myxinoids, reject altogether the probability that they may have belonged to a similar low type of Fishes. At present, however, the facts at hand appear insufficient to decide the question.

Owing to the uncertainty respecting the animals to which the Conodonts belonged, any arrangement of the teeth themselves must almost entirely rest on an artificial basis, and consequently possess little zoological value; detailed descriptions and figures, however, such as those given by Dr. Pander, are of great importance and service for palæontological reference; and for this purpose I have attempted to give a similar detailed account of the American forms, commencing with those from the earliest formation in which I have met with them.

1. *Conodonts from the Chazy Formation.*

Genus Prioniodus, Pander, 1856.

Prioniodus radicans, Hinde. (Pl. XV. figs. 1–6.)

The central tooth relatively very long and robust, and gradually tapering to a point, either straight or with a more or less dextral or sinistral curvature. The lower portion is produced below the position of the lateral denticulate extensions, to form a single blunted termination or two or three small fang-like projections. The front portion is strongly convex in section, but nearly flat at the back, and a deep longitudinal groove extends at the back of the tooth from near the tip to the base. The lateral extensions, springing more or less obliquely from both sides of the main tooth, are narrow, straight, or slightly curved, strongly convex in front and with a groove like that of the main tooth at the back. They are frequently unequal in length and in the number of denticulations in the same specimen. These vary from 4 to 11, and are either short and blunt, or long, pointed, and slightly curved, in some cases of equal length on the same base, but frequently the central denticulations are the longest.

The teeth are smooth, black, and, where not much weathered, of a brilliant polish. The length of the central tooth varies from $\frac{1}{2}$ line to $1\frac{5}{8}$ line, the greater number are about $1\frac{1}{4}$ line. The lateral extensions vary between one third and two thirds the length of the main tooth. Though there is a great difference in form and size in these teeth, the extremes are connected by so many intermediate forms as plainly to indicate that all belong to a single species, and no other form but this appears to be present in these rocks.

This species is closely allied to *P. Volborthii*, Pander (Monogr. p. 30, tab. i. fig. 1), from which it may readily be distinguished by the basal termination and the deep longitudinal groove of the main tooth, and the proportionately less development of the lateral extensions. I am unable to make any comparison of the relative dimensions of this and Pander's species, as unfortunately no reference is made by him either to the actual size of the specimen or to the scale to which the figure is drawn.

The species is abundant and well preserved, and occurs in beds of dark limestone, principally composed of the tests of *Leperditia*.

Loc. Grenville on the Ottawa River, province of Quebec.

2. *Conodonts from the Cincinnati Group.*

Genus Drepanodus, Pander, 1856.

Drepanodus arcuatus, Pander. (Pl. XV. figs. 7, 8.)

Drepanodus arcuatus, Pander, Monographie der fossilen Fische, 1856, p. 20, tab. i. figs. 2, 4, 5.

Tooth simple, resembling a more or less curved spine, nearly circular in section, the basal portion expanded and with a slight contraction between it and the shaft of the tooth. The teeth are all translucent and of a reddish horn-colour; they vary in length from $\frac{3}{4}$ line to $1\frac{1}{8}$ line, and in width at the base from $\frac{1}{4}$ line to $\frac{3}{8}$ line.

Loc. Garrison Common, near Toronto, Ontario. Abundant.

Genus Distacodus*.

Machairodus, Pander, 1856.

Distacodus incurvus, Pander. (Pl. XV. fig. 9.)

Machairodus incurvus, Pander, Monographie der fossilen Fische, p. 23, tab. i. fig. 22.

Base of tooth expanded, the shaft slightly curved, the point com-

* I propose to substitute this name for Pander's *Machairodus*, the latter having been long preoccupied by Kaup.

pressed and acute; a very strongly marked broad and sharp edge on the outer curve, and a similarly sharp but narrower edge on the inner curve of the tooth; the central portion convex in section. Length $1\frac{1}{4}$ line, width of base $\frac{1}{2}$ line.

Loc. Garrison Common, near Toronto, Ontario.

PRIONIODUS ELEGANS, Pander. (Pl. XV. fig. 10.)

Prioniodus elegans, Pander, Monographie, p. 29, tab. ii. figs. 22, 23.

Basal portion straight and narrow; at the anterior extremity is an elongated tapering main tooth, the lower portion of which appears to extend below the front part of the base. On the base are thirteen straight, delicate, pointed denticles nearly uniform in size. Both main tooth and denticles convex in section. Length of main tooth $\frac{5}{8}$ line, of the horizontal base $\frac{5}{8}$ line.

My example has not the exterior denticle or the sharp edges of the main tooth of Pander's example, but in other respects it is similar. I have found but a single specimen.

Loc. Garrison Common, near Toronto, Ontario.

PRIONIODUS? POLITUS, Hinde. (Pl. XV. figs. 11, 12.)

Basal portion of tooth compressed, uneven in width, straight or slightly curved; at or near the central part a short robust main tooth with a series of short compressed denticles, varying from five to eight in number, on either side of it. Length of base from $\frac{1}{2}$ line to $\frac{3}{4}$ line. The specimens have a bright polished appearance and a light horny tint.

Loc. Garrison Common and Don valley, near Toronto, Ontario.

PRIONIODUS FURCATUS, Hinde. (Pl. XV. fig. 13.)

Base narrow and strongly arched, at the centre of the arch a prominent robust main tooth, slightly curved, depressed convex, and with sharp edges, the lower extremity blunted and produced beyond the base. On one side of the central tooth the base carries six flattened denticles inclined to the centre; on the other side are eight similar denticles, but vertical to the base. Length of main tooth $\frac{3}{8}$ line; distance between the extremities of the base $\frac{5}{8}$ line.

The strongly arched form, the prominence of the main tooth, and its extension below the base distinguish this from the foregoing species.

Loc. Garrison Common, near Toronto, Ontario.

Remarks on the Cambro-Silurian Conodonts.

It is worthy of notice that of the six species above described no fewer than three should be identical with, and the other three should have a close general resemblance to, the forms discovered by Pander near St. Petersburg. At the same time there is by no means the same proportion in respect to the number of the species of the simple and compound teeth found in the two countries; for whilst there is nearly an equal number of the compound forms in the Cambro-Silurian of Canada as of Russia, only two species of the simple teeth have as yet been found in Canada; but in Russia these simple teeth abound in such great variety that Pander divided them into no fewer than seven genera, including thirty-eight species. It is also remarkable that neither in Canada nor in Russia do these *simple* teeth appear to extend to a higher geological horizon, though the *compound* ones in the lower rocks have a generic resemblance to those from the Devonian and Carboniferous. There is the still further coincidence that in Russia only traces, and in Canada none, of these bodies have as yet been met with in strata between the Cambro-Silurian and the Devonian; but a further special search may lead to their discovery in the intermediate rocks.

3. *Conodonts from the Hamilton and Genesee-Shale divisions of the Devonian.*

In certain beds of these Devonian rocks the Conodonts appear in such profusion and variety of form as far to surpass those already described from the Siluro-Cambrian; and, judging from Pander's description, they are more numerous and better-preserved than those in the Devonian and Carboniferous rocks of Russia. The work of classifying these various forms has to some extent been simplified by the discovery of the specimen, already mentioned, in which a number of diversely shaped teeth, together with small plates, are shown to have appertained to the same individual, which I describe below under the generic name of *Polygnathus*. A good proportion of the other detached teeth in the same rocks are related to those of *Polygnathus*, and, for the sake of reference, will have to be described separately, though, judging from the remarkable combination of various forms in this individual, all these teeth may have belonged to two or three species only. There are, however, in this type specimen of *Polygnathus* none of the more typical forms of *Prioniodus* with a very prominent elongated central or terminal main tooth, so that I purpose to retain this genus for similar forms. As an indication of the uncertainty attending the classification of these teeth from detached specimens, I may mention that in the individual example of *Polygnathus* there are teeth which Pander has placed under different genera.

PRIONIODUS ERRATICUS, Hinde. (Pl. XV. fig. 14.)

Tooth with a short, narrow, slightly arched base, at one extremity of which a relatively large, cylindrical, slightly curved main tooth projects obliquely outwards, forming an obtuse angle with the base. On the base are five stout, nearly upright, smaller teeth or denticles, which in some specimens are more elongated than in the one figured.

Locality and Formations. North Evans, New York State: from the "Conodont-bed" of the Hamilton group. Also from Bedford, Ohio: in the Cleveland Shales of the Lower Carboniferous.

PRIONIODUS ABBREVIATUS, Hinde. (Pl. XV. fig. 15.)

Base of tooth very short and stout, at one end a comparatively long, nearly straight, cylindrical, blunted, main tooth, on one side of which are two blunted denticles with small knobs at their summits. Length of main tooth $\frac{5}{8}$ line, of the base $\frac{1}{4}$ line.

Loc. North Evans, New York: from the "Conodont-bed" of the Hamilton group.

PRIONIODUS CLAVATUS, Hinde. (Pl. XV. fig. 16.)

Basal portion arched, narrow, stout and convex in section; the central tooth straight, cylindrical, and blunted; on one side of this there are four, and on the other two stout teeth similar to the central tooth and but little inferior in size.

Length of base $\frac{5}{8}$ line, of the central tooth $\frac{1}{2}$ line.

Loc. North Evans, New York: from the "Conodont-bed" of the Hamilton group.

PRIONIODUS ANGULATUS, Hinde. (Pl. XV. fig. 17.)

Base thin, narrow, and arched, so that the two sides meet at an acute angle; from the apex there rises a long, straight, compressed, needle-shaped main tooth with a median longitudinal groove; on either side of the base are four slightly curved slender denticles. Distance between extremities of the base $\frac{1}{2}$ line; length of main tooth $\frac{1}{2}$ line. This species is very delicate and brittle, and perfect examples are rare. The missing portions, however, leave their impressions in the shale, so that the entire form can be readily distinguished.

Loc. North Evans, New York: from Genesee Shale. Also at Bedford, Ohio: in Cleveland Shales, Lower Carboniferous.

PRIONIODUS ACICULARIS, Hinde. (Pl. XV. figs. 18, 19.)

Basal portion straight or slightly arched, generally wide, very thin, polished and transparent; near one extremity a relatively large, slightly curved, compressed main tooth, with two denticles on one side, and on the other a series of from eleven to thirteen delicate, slightly curved, acutely pointed denticles, slightly inclined to the base in which they are imbedded. The main tooth and the denticles have a polished aspect and tint like ivory, whilst the base is of a brownish horn-colour. In fig. 18 the length of the base is $\frac{7}{8}$ line, and of the main tooth $\frac{5}{8}$ line; in fig. 19 the base is 1 line and the main tooth $\frac{7}{8}$ line in length.

The base is very variable in width in different examples, and in some forms the two denticles preceding the main tooth are not present.

Loc. Kettle Point and Bear Creek, Lambton County, Ontario; North Evans, New York: Genesee Shale.

PRIONIODUS ARMATUS, Hinde. (Pl. XV. figs. 20, 21.)

Basal portion very narrow and slightly curved; at one extremity a relatively large, triangular, depressed convex main tooth, the exterior basal angle of which is produced downwards into a short spur. There are from five to eleven straight compressed denticles. Length of base from $\frac{1}{2}$ line to $\frac{3}{4}$ line, of the main tooth $\frac{5}{8}$ line.

Loc. Near Port Stanley, Lake Erie, Ontario: in erratic boulders of Genesee Shale. Also from North Evans, New York, in Genesee Shale.

PRIONIODUS SPICATUS, Hinde. (Pl. XVI. figs. 1, 2, 3.)

Basal portion straight, narrow, and convex; at one extremity a straight or slightly curved main tooth which is produced below the horizontal base to a pointed projection. A variable number of straight slender denticles are present on the base, and between these are intercalated still smaller denticles. Length of base $\frac{3}{4}$ line, of main tooth $\frac{1}{2}$ line to $\frac{5}{8}$ line.

Loc. Bear Creek, Ontario; North Evans, New York: Genesee Shale.

PRIONIODUS PANDERI, Hinde. (Pl. XVI. fig. 4.)

A relatively very large, slightly curved, depressed convex main tooth springs from one extremity of the narrow horizontal base; attached to the base of the main tooth, and extending downwards, is a prominent spike-like projection, which has on its upper surface the bases of what appear to have been four stout denticles; on the horizontal base are the lower portions of six denticles. Length of the large tooth $1\frac{1}{8}$ line, of the projection $\frac{1}{2}$ line, and of the base $\frac{7}{8}$ line.

This species is allied to *P. tulensis*, Pander (Monograph. p. 30, tab. 2A. fig. 19) which has also a somewhat similar produced spike below the main tooth, with a single denticle on it. *P. tulensis* is from the Carboniferous Limestone in the province of Tula, Russia.

I have named this species in memory of Dr. Pander, the first discoverer of Conodonts.

Loc. Kettle Point, Ontario: Genesee Shale. Also from North Evans, New York: in the "Conodont-bed" of the Hamilton group.

PRIONIODUS? ALATUS, Hinde. (Pl. XVI. fig. 5.)

A comparatively large, triangular, depressed convex main tooth with a narrow arched base, one arm of which is produced obliquely downwards and carries five, short, blunted denticulations on the exterior edge. This tooth varies greatly from the more typical forms of *Prioniodus*, in its triangular form and in having the basal portion but very indistinctly marked off from the tooth itself; the smaller denticulations have also the appearance of being only prolongations of the thin border of the main tooth. Length $1\frac{7}{8}$ line, greatest width $\frac{3}{4}$ line.

Loc. North Evans, New York: in the "Conodont-bed" of the Hamilton group.

Genus POLYGNATHUS, Hinde, nov. gen.

I propose this genus for an animal possessing numerous minute and variously formed Conodont teeth and similarly minute tuberculated plates grouped together, but of which the natural arrangement is not at present known.

This meagre definition is all that is afforded by the single example of the genus met with, in which about twenty-four entire and fragmentary teeth and six plates have been crushed together in a small patch of about one fourth of an inch in diameter, in black shale. The specimen was discovered in splitting open a slab of the rock, the division taking place in the centre of the specimen. No indication can be seen of the natural position of the teeth and plates; but it can hardly be doubted that they all belonged to one individual, as it would be beyond all reasonable probability that so many diversely formed teeth, of such delicate structure, could have been thus brought together into so small a space by mechanical means, more particularly when it is a very rare circumstance to find, in the same rock, even two detached teeth at all close together; and in only one other instance have I found two Conodonts partially connected together, and these are forms which are present in this compound example. If, however, these various teeth and plates were attached in their natural positions by soft tissues merely, by the decay of these they would be liable to be crushed together into a shapeless mass like that presented by the specimen.

Polygnathus dubius, Hinde. (Pl. XVI. figs. 6–18.)

The only example discovered in which the teeth of this remarkable form are grouped together has been crushed to such an extent that the individual teeth and plates can be only partially distinguished; but the various kinds are met with in a very perfect condition, as so many separate specimens, scattered through the rock. As these detached teeth occur not only in the rock in which the grouped specimen is found, but are widely distributed even in Lower Carboniferous rocks, I append descriptions and figures of the individual teeth and plates.

For the convenience of reference I refer the teeth to pectinate, fimbriate, and crested forms.

1. *Pectinate teeth.*—Of these the kind figured in Pl. XVI. figs. 6–9 has a narrow, slightly arched base and a main tooth which is sometimes produced below the level of the base; the secondary teeth are slender and acute, and vary from 14 to 20 in number. This kind averages about $\frac{3}{4}$ line in length, and is abundant in the "Conodont-bed" of the Hamilton group as well as in the Genesee Shale at North Evans.

Another variety of pectinate compound teeth, shown in Pl. XVI. figs. 10, 11, 12, has the base straight and almost linear; there is no distinctive central tooth, but a series of similarly shaped teeth, sometimes as many as 14, of which the central ones are the longest. Occasionally smaller denticles are intercalated. The base of these forms is about $\frac{3}{4}$ line in length, and the longest teeth from $\frac{3}{8}$ to $\frac{1}{2}$ line long. This variety is very widely distributed. It has been described by Pander under the name of *Centrodus simplex* ('Monograph.' p. 31, tab. 2 A. figs. 2, 3, 5, 6), from the Lower Carboniferous in Russia; it occurs in the same formation at Bedford, Ohio, and also appears in Genesee Shale at Kettle Point, Ontario, as well as at North Evans, New York.

2. *Fimbriate teeth* (Pl. XVI. figs. 13, 14).—The base of these com-

pound teeth is straight, narrow, elongate, and pointed at one extremity; near the opposite end is a delicate, needle-like main tooth with three smaller teeth on one side between it and the end of the base; on the other side, extending to the pointed tip of the base, is a series of very numerous, extremely minute denticles, appearing like a fringe on the upper border of the base. In some examples these small denticles are nearly uniform in size, in others every fourth tooth is larger; but there exists considerable variation in this respect, even in the same specimen. In the example figured (fig. 13), of which the base is $1\frac{1}{5}$ line in length, there are 70 of the small denticles. This form is very abundant and quite as widely distributed as the preceding. It appears to be identical with the fragmentary tooth named by Pander *Centrodus lineatus* ('Monographie,' p. 31, tab. 2 A. fig. 9), from the Lower Carboniferous in Russia; it is in the same formation at Bedford, Ohio, and is also found at Kettle Point and Bear Creek, Ontario, and at North Evans, New York, in the Genesee Shale.

3. *Crested teeth* (Pl. XVI. figs. 15, 16, 17).—Of these there are two varieties present in *Polygnathus dubius*. The first (fig. 15) has the base compressed and nearly of equal width, save at one end, which is abruptly contracted. There are about twenty small teeth or crenulations on the base. The second variety (figs. 16, 17) has one part of the base narrow and thickened, with sometimes a row of minute crenulations on its upper edge; beyond this the base forms a small, flattened, crest-like expansion with from 5 to 8 teeth on its border. Both these varieties are closely allied to the form named by Pander *Gnathodus mosquensis* ('Monographie,' p. 24, tab. 2 A. figs. 10 *a*, *b*, *c*). The second is the more abundant of the two, and three or four individuals can be distinguished in the crushed example of *Polygnathus*.

The small plates associated with the teeth in *Polygnathus dubius* are of an elliptical form with smooth edges (Pl. XVI. fig. 18). One surface is slightly convex, with a slight longitudinal median ridge; the surface, as well as the ridge, is covered with small tubercles frequently with a linear arrangement; the reverse side of the plate is smooth, with faint traces of concentric lines; the two ends are slightly elevated, and there is a median ridge with a small diamond-shaped pit in or near the centre of the plate. Each plate is about $\frac{5}{8}$ line long and $\frac{3}{8}$ line wide. Six of these plates, but all apparently of the same form, can be distinguished in the specimen of *Polygnathus*.

Besides the teeth already referred to, there are fragments of others too imperfect to be recognized, and these may possibly belong to some forms which, occurring as detached specimens, I have described under other names.

The existence of such a variety of teeth and plates in this single example appears to make the question of the affinities of the organism to which they belonged still more complex. Great numbers of teeth compose the lingual ribbon of many mollusks; but in none, that I am aware of, is there a similar variety of form, nor are there any bodies analogous to the tuberculated plates. Nor in existing Myxinoids, to whose teeth the Conodonts are comparable, are similar plates present. Whatever the animal may have been, it appears to have had a very wide distribution both in Devonian and Carboniferous times.

Locality and Formation. The single specimen, in which the above-mentioned teeth and plates are shown together, is from the Genesee Shale (Devonian) at North Evans, N.Y.

Polygnathus duplicatus, Hinde. (Pl. XVI. fig. 19.)

Base of the compound tooth bent at an obtuse angle, narrow, and slightly convex; in the centre a needle-like tooth oblique to the base, with a similar but slightly shorter tooth adjacent to it; this is followed by six acute denticles on one side of the base, and on the opposite side are eleven very small denticles nearly at right angles to the base. Length of base $\frac{5}{8}$ line.

This form is closely allied to some of the pectinate teeth of *P. dubius* and may belong to a mere variety of that species. The detached position of this and the forms described below makes it a necessity to place them under different names, though there is great probability that they do not belong to more than one or two species.

Loc. Bear Creek, Ontario: Genesee Shale.

Polygnathus radiatus, Hinde. (Pl. XVI. fig. 20.)

Tooth very minute; the base curved, narrow, and compressed in the centre; a broad, slightly convex, main tooth inclined to the base; on one side of this there are six, and on the other four flattened, curved denticles. Length of base $\frac{1}{2}$ line.

Loc. Kettle Point, Ontario: Genesee Shale.

Polygnathus immersus, Hinde. (Pl. XVI. fig. 21.)

Tooth minute; base slightly curved and very wide; nearly in the centre is a short, blunted, main tooth, on one side of which there are ten, and on the other eight very delicate, elongated denticles. All these teeth are so deeply imbedded in the delicate transparent base that only the tips project beyond it. Length of base $\frac{5}{8}$ line, of the main tooth $\frac{1}{4}$ line.

This form closely resembles *Ctenognathus Verneuilli*, Pander, from the Devonian of Russia ('Monographie,' p. 32, tab. 2 A. fig. 16).

Loc. Kettle Point, and in erratic boulders on the north shores of Lake Erie, Ontario: Genesee Shale.

Polygnathus nasutus, Hinde. (Pl. XVI. fig. 22.)

Base of tooth narrow, elongated, and straight, terminated at one end by a broad, flattened, depressed main tooth, which projects in a line with the base; below the main tooth, and making an acute angle with the base, is a small arm carrying three denticles; on the base itself are twenty denticles of various lengths. Length of base $1\frac{1}{8}$ line.

Loc. North Evans, New York: Genesee Shale.

Polygnathus princeps, Hinde. (Pl. XVI. fig. 23.)

On a narrow, elongated base there is a series of eleven relatively large and robust teeth, somewhat oval in section. The central teeth are larger than those near the extremities of the base. Length of base 2 lines, of the largest tooth $\frac{5}{8}$ line. *Centrodus simplex*, Pander ('Monographie,' p. 31, tab. 2 A. fig. 3), seems to be a fragment of a similarly large tooth from the Carboniferous of Russia.

Loc. North Evans, New York: from the "Conodont-bed" of the Hamilton group and the Genesee Shale.

Polygnathus coronatus, Hinde. (Pl. XVII. fig. 1.)

Base very narrow and gracefully arched, with seven subequal, relatively large, robust, curved teeth. The teeth in this form are of an ivory-white, whilst the base is brownish and translucent. It is closely allied to *Centrodus convexus*, Pander ('Monographie,' p. 31, tab. 2 A. fig. 4); but has a narrower base, more teeth, and no intercalated small ones. Length of base $\frac{3}{4}$ line, of the longest tooth $\frac{5}{8}$ line.

Loc. Kettle Point, and in erratic boulders on north shore of Lake Erie, Ontario: Genesee Shale.

Polygnathus solidus, Hinde. (Pl. XVII. fig. 2.)

On a short, very thick, and wide base there is a closely arranged series, varying from seven to eleven in number, of subequal, short, stout and obtuse teeth. Very abundant.

Loc. North Evans, New York: from the "Conodont-bed" of the Hamilton group.

Polygnathus crassus, Hinde. (Pl. XVII. fig. 3.)

Base of tooth narrow, curved, and relatively very thick, with a prominent ridge, in which are six obtuse teeth or crenulations; the posterior extremity crest-like, with two stout teeth on the summit. Length $\frac{5}{8}$ line.

This form is allied to the crested teeth of *P. dubius*; but it is a shorter and more robust form.

Loc. North Evans, New York: "Conodont-bed" of the Hamilton group.

Polygnathus? serratus, Hinde. (Pl. XVII. figs. 4 & 5).

Tooth or jaw formed of a thin, curved, and highly convex basal plate, truncated at one end, and with a blunt projection at the opposite extremity. On the upper edge are about thirty minute crenulations or blunted teeth. Length 1 line, width $\frac{3}{8}$ line.

This species and the two following differ from the more typical forms of Conodonts; but as they appear to be connected with the "crested" teeth of *P. dubius*, I place them provisionally under that genus. They have also a resemblance to *Gnathodus mosquensis*, Pander ('Monographie,' p. 33, tab. 2 A. figs. 10 *a, b, c*). *P.? serratus* appears at present only in one place, where, however, it is abundant.

Loc. Kettle Point, Ontario: Genesee Shale.

POLYGNATHUS? ERIENSIS, Hinde. (Pl. XVII. fig. 6.)

Tooth or jaw formed of an oblong, compressed plate, with ten stout, blunt teeth on its upper border. This plate is attached nearly at right angles to a chitinous appendage, nearly of a triangular form, whilst the toothed portion of the jaw is of the usual brownish semi-translucent character common to the majority of the Conodonts; the appendage has a black chitinous appearance. Length $1\frac{5}{8}$ line.

Loc. From an erratic nodule of black Genesee Shale on north shore of Lake Erie, Ontario.

POLYGNATHUS? CURVATUS, Hinde. (Pl. XVII. fig. 7.)

Tooth or jaw formed of a wide, oblong, slightly curved plate with about fourteen blunt teeth or crenulations on the upper border; this plate is attached at right angles to a compressed, sickle-shaped, grooved appendage of a similar structure to that of the preceding species, from which, however, it differs in shape. Length $1\frac{1}{4}$ line.

I have only met with a single specimen.

Loc. Bear Creek, Ontario: Genesee Shale.

POLYGNATHUS PENNATUS, Hinde. (Pl. XVII. fig. 8.)

An elongated oval plate with a longitudinal depressed furrow, in the centre of which rises a slender keel, which is produced beyond the main portion of the plate and has a few blunt tubercles on its crest. Transverse ridges run from the outer edge of the plate to the central furrow. Abundant.

Loc. North Evans, New York: from the "Conodont-bed" of the Hamilton group.

POLYGNATHUS TUBERCULATUS, Hinde. (Pl. XVII. figs. 9 & 10.)

Plate somewhat circular in outline, with a prominent central keel produced and tuberculated; in the lower portion of the plate is a partially detached lobe on either side of the central line; the plate is provided with rows of tubercles which converge towards the centre. The reverse side of a form which appears to belong to this species (fig. 10) has a central ridge with a small diamond-shaped pit just below the centre of the plate; the surface of this reverse side is smooth, with traces of concentric lines. Length of plate and keel $\frac{7}{8}$ line, and $\frac{1}{2}$ line in width.

Loc. North Evans, New York: from the "Conodont-bed" of the Hamilton group.

POLYGNATHUS CRISTATUS, Hinde. (Pl. XVII. fig. 11.)

Plate oval in outline, depressed, convex; the central keel very prominent and with stout teeth or crenulations on its crest; on the plate are two rows, on either side of the central keel, of prominent tubercles. Length $\frac{7}{8}$ line, width $\frac{1}{2}$ line.

Loc. North Evans, New York: from the "Conodont-bed."

POLYGNATHUS TRUNCATUS, Hinde. (Pl. XVII. figs. 12 & 13.)

Plate cordate in outline, with a median keel which is not continued beyond the plate; the convex surface covered with small tubercles. Length $\frac{1}{2}$ line. A variety of this form (fig. 13) appears to have no keel whatever, but a simple tuberculated surface.

Loc. Bear Creek, Ontario: from the Genesee Shale. Also from North Evans, New York: from the "Conodont-bed" of the Hamilton group.

Polygnathus punctatus, Hinde. (Pl. XVII. fig. 14.)

Plate unsymmetrical, flat and thin; a delicate keel which does not reach to the tip, but is produced beyond the lower portion of the plate and has two or three nodes on it; the surface of the plate is covered with very minute tubercles. Length $\frac{5}{8}$ line.

Loc. North Evans, New York: Genesee Shale.

Polygnathus linguiformis, Hinde. (Pl. XVII. fig. 15.)

Plate elongate, one extremity produced into a tongue-like projection, bending downwards; the sides of the plate curving upwards, forming a central trough, from the bottom of which the keel rises, this extends some distance beyond the sides of the plate and has an expanded crenulated crest. The anterior tongue-like projection has several strongly-marked transverse ridges; the lateral surfaces have a few scattered tubercles. Length about 1 line. This peculiar form is very abundant.

Loc. North Evans, New York: from the Conodont-bed of the Hamilton group. Also in erratic boulders in Genesee Shale on north shore of Lake Erie, Ontario.

Polygnathus palmatus, Hinde. (Pl. XVII. figs. 16 & 17.)

Plates elongated, with an unsymmetrical, partially lobed outline, depressed in the central portion, a longitudinal keel, and sometimes a delicate transverse one, extending from one side only to the central depression; surface smooth and polished and with traces of concentric lines; the reverse side of this form also appears to be smooth. Length varying from $\frac{5}{8}$ line to $1\frac{1}{8}$ line, and width between $\frac{1}{2}$ line and $\frac{7}{8}$ line.

In the smooth surface and very irregular outline this differs from all the preceding varieties of these plates. This form is very abundant and widely distributed.

Loc. Kettle Point, Bear Creek, Ontario; North Evans, New York; near Louisville, Kentucky: Genesee Shale.

Polygnathus ? simplex, Hinde. (Pl. XVII. fig. 18.)

Jaw ? resembling a tenter-hook in shape and nearly oval in section; the proximal extremity is smooth and rounded like that of an articular surface; a prominent ridge extends in a median line from this end to near the tip of the hook; the surface of the jaw above this ridge is smooth and glistening, whilst below it very fine parallel lines can be seen. Length of the straight portion $\frac{5}{8}$ line, of the hook $\frac{1}{2}$ line.

These small shining bodies are very abundant in the same beds with the Conodont teeth and plates, and though diverse in form, they correspond in apparent structure and relative dimensions; therefore I regard them as related to the same organisms, and place them provisionally under the same genus with the equally problematical plates and teeth.

Loc. North Evans, New York: from the "Conodont-bed" of the Hamilton group.

EXPLANATION OF THE PLATES.

Plate XV.

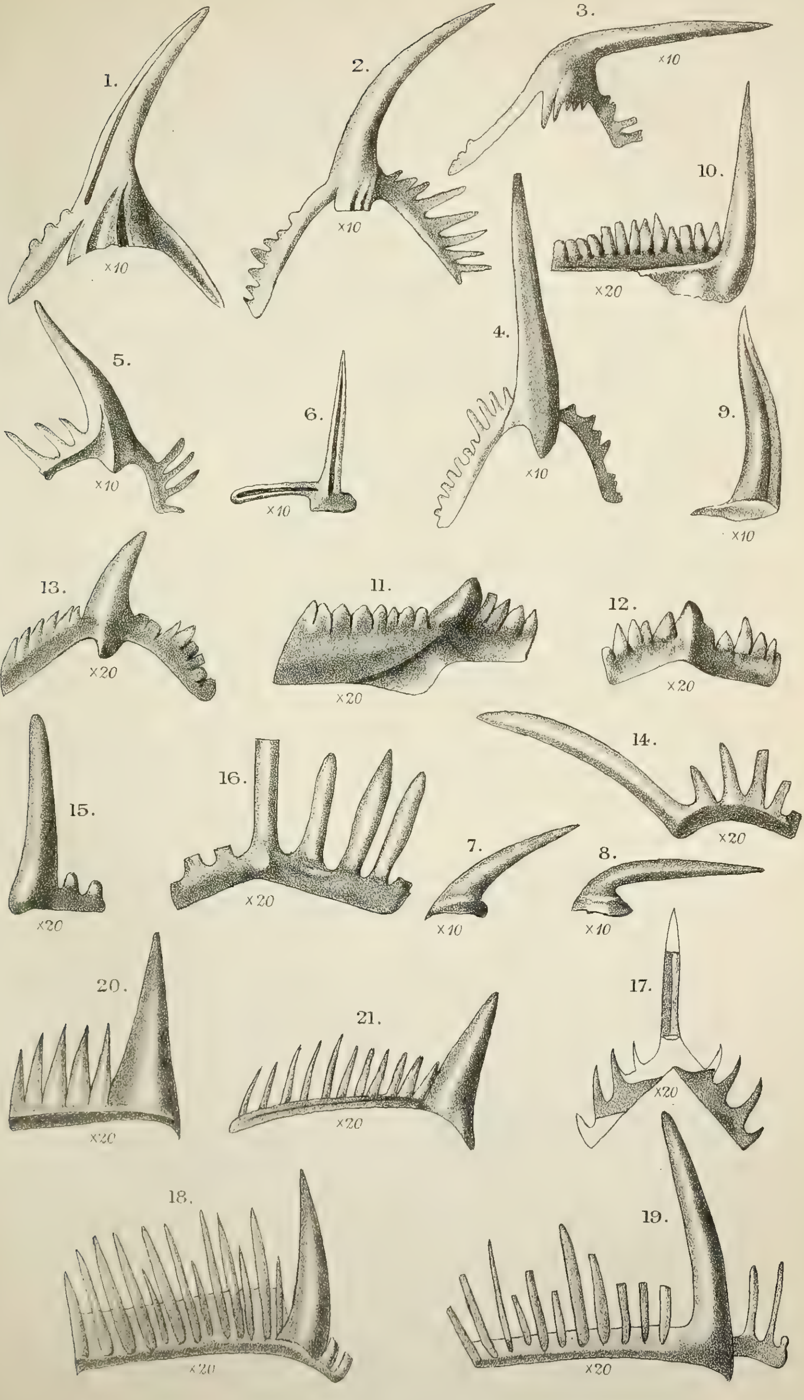
Figs. 1–6. *Prioniodus radicans*, H. Figs. 2, 3, 4, 5 are front views; fig. 1 and 6 show the reverse side with the longitudinal groove: × 10. Grenville, Province Quebec. (Chazy.)
7, 8. *Drepanodus arcuatus*, Pander: × 10. Toronto. (Cincinnati.)
9. *Distacodus incurvus*, Pander: × 10. Toronto. (Cincinnati.)
10. *Prioniodus elegans*, Pander: × 20. Toronto. (Cincinnati.)
11, 12. —— ? *politus*, H.: × 20. Toronto. (Cincinnati.)
13. —— *furcatus*, H.: × 20. Toronto. (Cincinnati.)
14. —— *erraticus*, H.: × 20. North Evans, N.Y. (Hamilton and Carboniferous.)
15. —— *abbreviatus*, H.: × 20. North Evans, N.Y. (Hamilton.)
16. —— *clavatus*, H.: × 20. North Evans, N.Y. (Hamilton.)
17. —— *angulatus*, H.: × 20. North Evans, N.Y. (Genesee and Carboniferous.)
18, 19. —— *acicularis*, H.: × 20. Kettle Point, Ontario. (Genesee.)
20, 21. —— *armatus*, H.: × 20. North Evans, N.Y. (Genesee.)

Plate XVI.

Figs. 1, 2, 3. *Prioniodus spicatus*, H.: × 20. North Evans, N.Y. (Genesee.)
4. —— *Panderi*, H.: × 20. North Evans, N.Y. (Genesee and Hamilton.)
5. —— ? *alatus*, H.: × 10. North Evans, N.Y. (Hamilton.)
6–18. *Polygnathus dubius*, H.: × 20. Figs. 6–12 represent different forms of pectinate teeth; figs. 13 and 14 fimbriate teeth; figs. 15, 16, 17 crested teeth; and fig. 18 shows the reverse side of one of the plates of this species. Kettle Point, Ontario; North Evans, N.Y.; and Bedford, Ohio. (Hamilton, Genesee, and Carboniferous.)
19. —— *duplicatus*, H.: × 20. Bear Creek, Ontario. (Genesee.)
20. —— *radiatus*, H.: × 20. Kettle Point, Ontario. (Genesee.)
21. —— *immersus*, H.: × 20. Kettle Point, Ontario. (Genesee.)
22. —— *nasutus*, H.: × 20. North Evans, N.Y. (Genesee.)
23. —— *princeps*, H.: × 20. North Evans, N.Y. (Genesee and Hamilton.)

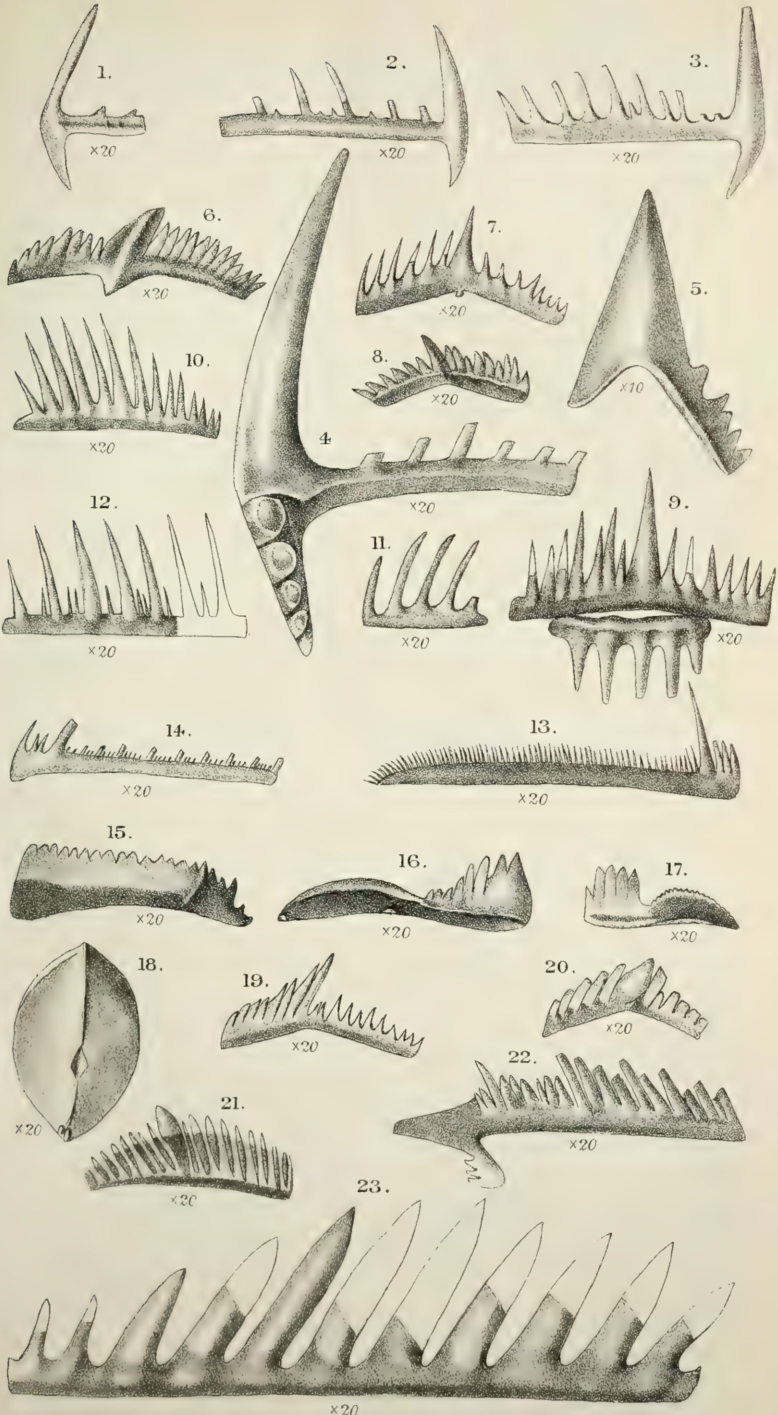
Plate XVII.

Fig. 1. *Polygnathus coronatus*, H.: × 20. Kettle Point, Ontario. (Genesee.)
2. —— *solidus*, H.: × 20. North Evans, N.Y. (Hamilton.)
3. —— *crassus*, H.: × 20. North Evans, N.Y. (Hamilton.)
4, 5. —— ? *serratus*, H.: × 20. Kettle Point, Ontario. (Genesee.)



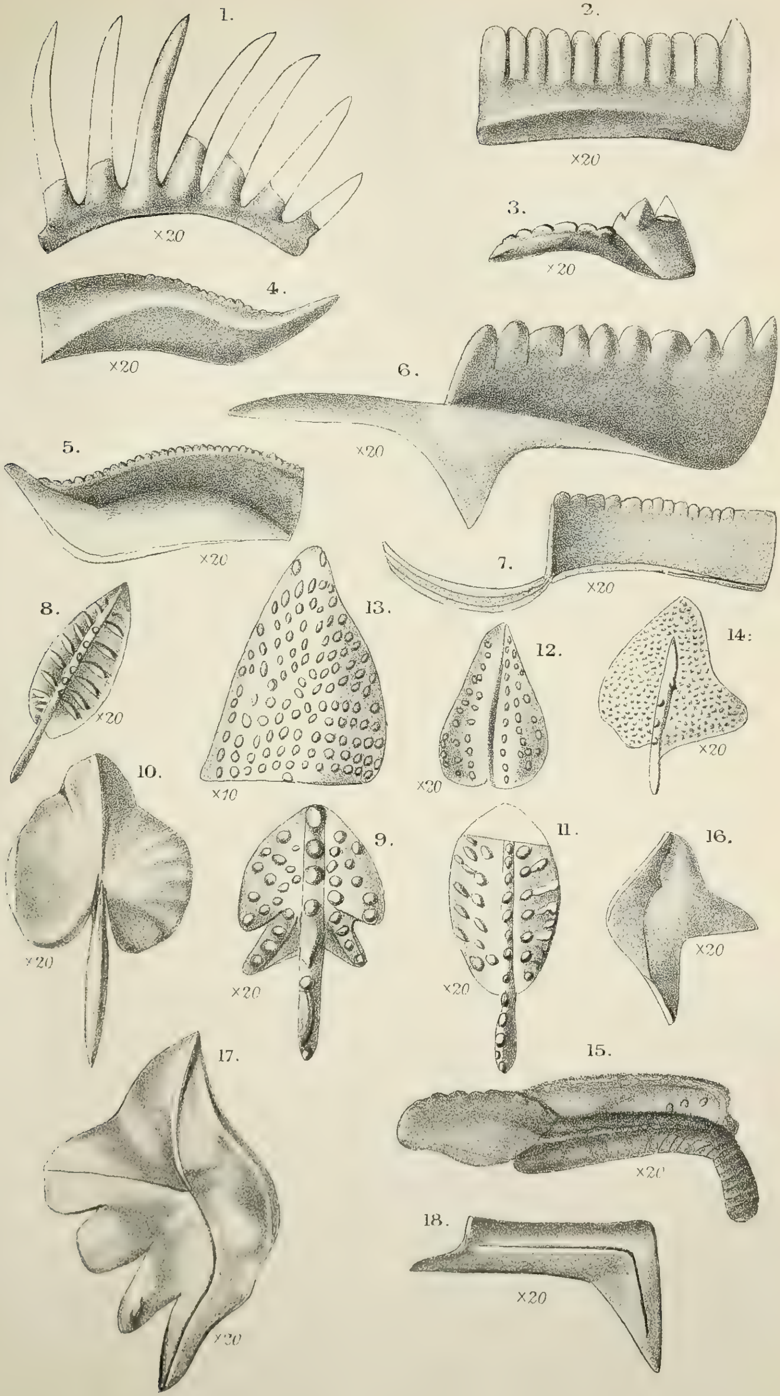
CONODONTS.

Mintern Bros lith.



CONODONTS.

Mintern Bros lith.



CONODONTS.

Mintern Bros lith.

Fig. 6. *Polygnathus? eriensis*, H.: × 20. Lake Erie shore, Ontario. (Genesee.)
7. —— ? *curvatus*, H.: × 20. Bear Creek, Ontario. (Genesee.)
8. —— *pennatus*, H.: × 20. North Evans, N.Y. (Hamilton.)
9, 10. —— *tuberculatus*, H.: × 20. North Evans, N.Y. (Hamilton.)
11. —— *cristatus*, H.: × 20. North Evans, N.Y. (Hamilton.)
12. —— *truncatus*, H.: × 20. Bear Creek, Ontario. (Genesee.)
13. —— *truncatus*, var.: × 20. North Evans, N.Y. (Hamilton.)
14. —— *punctatus*, H.: × 20. North Evans, N.Y. (Genesee.)
15. —— *linguiformis*, H.: × 20. North Evans, N.Y. (Hamilton and Genesee.)
16, 17. —— *palmatus*, H.: × 20. Kettle Point, Ontario. (Genesee.)
18. —— ? *simplex*, H.: × 20. North Evans, N.Y. (Hamilton.)

(For Discussion on this paper, see p. 389.)

30. *On* Annelid Jaws *from the* Cambro-Silurian, Silurian, *and* Devonian Formations *in* Canada *and from the* Lower Carboniferous *in* Scotland. By George Jennings Hinde, Esq., F.G.S. (Read March 12, 1879.)

[Plates XVIII.–XX.]

Introduction.

Up to a comparatively recent period our knowledge of fossil Errant Annelids has been limited to those evidences of their existence afforded by the casts of vertical borings, or of more or less horizontal winding markings with which the surfaces even of some of the earliest stratified rocks are abundantly covered. The resemblance of many of these borings and tracks to those made in the sandy mud of the seashore by existing Annelids is so great, that their origin could not be disputed; but some of these markings have given rise to various opinions as to their origin, some believing them to be the impressions of fucoids, whilst by certain German palæontologists they have been seriously regarded as the casts of Graptolites. Whilst the impressions are of common occurrence, more particularly in the Palæozoic rocks, discoveries of any clearly marked portions of the Errant Annelids themselves have been comparatively few; but when it is considered that almost the only portions of the organism of the existing representatives of these animals capable of fossilization are the chitinous jaws and setæ, and that these are generally very minute, it is not at all surprising that similar small objects, even where they have been preserved, should have eluded observation. It has been my good fortune to meet with a great variety of these jaws in rocks of Palæozoic age in Canada, and also to find a few traces of them in Scotland, of which I purpose giving a description in the present communication.

Bibliography.

Leaving on one side the descriptions which have appeared relating to the *tracks* of Annelids, the first notice which I have seen of the discovery of the jaws of these animals is given by Dr. Heinrich Pander in his 'Monographie der fossilen Fische des silurischen Systems der Russisch-Baltischen Gouvernements,' 1856*. Though Pander did not recognize his specimens as Annelid jaws, and merely noticed the difference between them and Conodonts, there can be no doubt, from his description and figures of *Aulacodus obliquus*, that these small objects, of about a line in length, are, in reality, jaws closely similar to those which I have placed under the genus *Eunicites*. Pander's specimens came from Upper Silurian strata in the Isle of Œsel.

The next account we possess of fossil errant Annelids is by Dr.

* Page 72, pl. iv. fig. 16, *a*, *b*, *c*, *d*.

Ehlers, who, in an article "Ueber fossile Würmer aus dem lithographischen Schiefer in Bayern"*, describes the genera *Eunicites*, *Lumbriconereites*, and *Meringosoma*. In these celebrated lithographic shales the entire form of the Annelid has been preserved, so that even the arrangement of the groups of setæ can be distinguished; but though the lower jaws of the specimens, on account of their possessing a more calcareous structure, still remain, the chitinous upper jaws have disappeared, leaving only their impressions on the matrix.

Lastly, Mr. G. B. Grinnell, of Yale College, Connecticut, described, in 1877†, two specimens of Annelid jaws from the Cincinnati group of the Cambro-Silurian, which he constituted the types of a new genus, *Nereidavus*. It is in the same group of rocks, but about 600 miles distant from Cincinnati, that the majority of my own specimens have been met with.

So far as I am aware, the above are the only records we have of the discovery of the actual remains of Errant Annelids, notwithstanding the great probability of the continued existence of these animals from Cambrian times.

Strata in which the Annelid Jaws are met with.

The lowest strata in the geological scale in which I have found these fossil jaws are a series of micaceous flags and shales, with thin intervening beds of limestone, belonging to the Cincinnati, or, as it was formerly called, the Hudson-River group, probably the equivalent of the Bala in this country. The jaws occur less frequently in the fossiliferous limestone bands than in the flags and shales, whose surfaces are often covered with very various forms of tracks. In these flags, too, a species of Graptolite, *Diplograpsus hudsonicus*, Nicholson ‡, is abundant; and it may be interesting to notice that there is a great apparent resemblance in the character of the material of which these Graptolites and worm-jaws are composed. There are also a few simple and compound Conodonts in the same beds; but these are rare in comparison with the Annelid remains. Though in some strata the worm-jaws are much more abundant than in others, they appear to be very generally distributed throughout this series of rocks, and I have met with them in nearly every exposure in the vicinity of Toronto.

The next higher beds belonging to the Clinton and Niagara formations (Wenlock) in which these jaws are present are separated from the strata at Toronto by a thickness of about 800 feet of shales and sandstones. Those belonging to the Clinton group which contain these fossils are hard grey sandstones and soft shales, with surfaces showing the usual worm-tracks, and for the most part devoid of other fossils. In the Niagara group I have found the jaws in a single thin bed of dark bituminous soft shale, in which are also

* Palæontographica, Dunker und Zittel, Band xvii. 1867–70, p. 145.

† American Journal of Science, Sept. 1877, p. 229.

‡ Palæontology of Ontario, 1875, p. 38.

some Graptolite remains as well as portions of the carapace and masticating apparatus of a species of *Ceratiocaris.*

The few, but well-preserved, examples of jaws from the Hamilton group of the Middle Devonian occur in a very soft mudstone, associated with the spores of Lycopods and Tentaculites.

In the Lower Carboniferous of Scotland the jaws are imbedded in some thin layers of calcareous shale, with Brachiopods and other fossils. As, however, there are beds of coal in the section within a few feet of this shale, it is not likely to have been laid down in deep water.

It will thus be seen that the strata in which these fossil Annelids are present are all more or less shallow-water deposits; and we know that similar sandy and muddy beds are the favourite habitats of these creatures at the present time.

Description of the Jaws.

The Annelid jaws occur as small, dark, shining objects, very varied in form, dispersed through the rock, quite detached from each other and from the positions they occupied in the head of the animal. Occasionally they are met with singly, but more frequently numbers of them are associated on the surface of the same slab of rock, and sometimes the rock is literally covered with the dark shining fragments; most of these, on close examination, are thin chitinous particles without definite shape, and may have been portions of the integument of the animal as well as broken-up fragments of the jaws. Except in cases where they have been long exposed to weathering influences, the jaws are of a bright glossy black tint, not showing any difference in those parts which must have been imbedded in muscular tissue, and which in recent examples are generally of a lighter horn-colour, whilst the free portions of the jaws of the fossil and recent specimens very closely resemble each other in appearance. When greatly weathered the black is changed to a rusty-reddish tint; but they are capable of resisting atmospheric influence to a great degree, and frequently stand out boldly in relief on the surface of very hard rock.

The material of which the jaws are composed appears to be nearly entirely of a chitinous character, and so far free from calcareous matter that it undergoes no change in nitric acid.

There is very great variation in the dimensions of the jaws; the greater number do not average more than $\frac{1}{12}$ inch in length, but a few are $\frac{1}{3}$ inch long and $\frac{1}{10}$ inch wide. In order to form an idea of the relative length of worms with similar jaws, I measured the principal jaw-plate in a specimen of the existing *Eunicea sanguinea*, whose body was 8 inches long; the jaw-plate was $\frac{1}{5}$ inch long and $\frac{1}{15}$ inch wide. If the length of these animals is in proportion to that of their jaws, then the largest of the fossil jaws would belong to an Annelid of about 13 inches in length, whilst the greater part would not be more than $3\frac{1}{4}$ inches long.

I may here enumerate the principal forms of the fossil jaw-plates, giving simply those of which there are comparatively numerous examples.

1. Comparatively elongated and narrow jaws, without any prominent anterior tooth, but with a series, sometimes more than twenty in number, of more or less similar teeth, which gradually diminish in size towards the tapering extremity of the jaw. This form of jaw in some instances is supported on a wide basal flange.

2. Wide and flat, hollow jaws, with the two anterior teeth larger than those following, the posterior extremity truncate, and with a deep furrow or cavity extending nearly to the centre of the plate.

3. Jaws mostly elongate, with a distinct, but not very large, anterior tooth or hook, which is immediately succeeded by a series of smaller teeth.

4. Jaws in which the anterior hook is very largely developed, and the smaller teeth are on the generally straight edge of a wide plate.

5. A simple, more or less curved hook, comparatively narrow throughout.

6. A simple hook with a very wide flange-like extension posteriorly.

7. Sickle-shaped or crescentiform jaws, with a more or less developed rod-shaped extension at one end and a series of small teeth on the curved upper edge.

8. Jaws flattened and subquadrate, also with a rod-like prolongation, the upper toothed edge nearly straight.

9. Small, triangular, arched plates, with a series of teeth of very unequal dimensions.

In attempting to classify these objects great difficulties arise on account of the detached condition of the specimens. As the muscular tissue by which they were attached to the gullet became destroyed, the various plates which compose the complicated jaw-apparatus of these animals were set free and scattered apart over the surface of the rock, and in not a single instance have I discovered the different plates in such a position as to indicate with certainty that they belonged to a single animal. This is the more remarkable from the fact that the isolated jaw-plates are in most beautiful preservation, and could not therefore have been exposed to any very disturbing influences. When it is remembered that the compound jaw-apparatus of Annelids belonging to the existing family of the *Eunicea* is composed of five or six pairs of jaw-plates of different forms and sizes, it will at once be seen how complicated a task it would be to arrange a confused assemblage of these plates under the different individuals, species, and genera to which they belonged; but the work becomes still more perplexing in the case of fossil specimens, where there are at hand very probably only an incomplete series of the different plates, and these may reasonably be supposed to vary from those of their existing descendants. Under these circumstances I have been obliged to describe the fossil jaws separately, but without assuming that each isolated piece belonged to a different species, or even, in some cases, to a different individual, though it may fairly be supposed, from the very numerous specimens, and their wide distribution in time and space, that there were many species of them. The resemblance of many of the fossils to the recent forms is so striking that their respective relations may be seen at a glance; but others vary considerably from all the descriptions of recent forms of jaws which have come under my notice, and their position remains doubtful.

All the forms met with seem to belong to the mouth-apparatus of these animals. Though the chitinous setæ are of as durable material as the jaws, they are, as a rule, much more slender, as well as smaller, consequently more liable to destruction; and I have not recognized any specimens which could be referred to these organs.

After a careful comparison of these fossil jaws with recent examples of the Order Annelida Polychæta or Nereida, I find specimens belonging to the three families of *Eunicea*, Grube; *Lycoridea*, Grube; and *Glycerea*, Grube. By far the larger proportion are included in the family Eunicea; and when the fossils resemble the jaws of the present generic divisions of this family, I have adopted the same term with the terminal addition of *-ites*, following the example of Dr. Ehlers in this respect. Thus in this family there are fossil jaws belonging to the genera *Eunicites*, Ehlers, *Œnonites*, gen. nov., *Arabellites*, gen. nov., *Lumbriconereites*, Ehlers, and *Staurocephalites*, gen. nov. The only genus in the family Lycoridea represented as fossil is *Nereidavus*, Grinnell. Though I regard the specimens on which Mr. Grinnell founded this genus as belonging to another family, I yet retain it for forms which appear to resemble the jaws of the present *Nereis*. Out of a large collection I have only found a single example which could with probability be assigned to *Nereidavus*; and it would thus appear that this important family was not proportionately so well represented in Palæozoic times as at present. I place under *Glycerites* the simple forms of jaws which appear to correspond with those of the existing genus *Glycera*.

I have thought it best to describe the fossil jaws from the different formations separately, and therefore begin with those from the lowest group, that of the Cincinnati or Hudson River. The specimens were all collected by myself from Toronto and its immediate vicinity.

ANNELIDA POLYCHÆTA.

I. *From the Cincinnati or Hudson-River Group at Toronto.*

Genus Eunicites, Ehlers.

Eunicites major, Hinde. (Pl. XVIII. fig. 1.)

Jaw oblong, somewhat flattened, the upper edge curved inwards; the posterior end truncated, with a deep furrow leading to an oval central depression, from which a cavity apparently extends under the front portion of the jaw; the furrow is bounded above and below by rounded ridges. At the front of the jaw are two stout blunted teeth, and the upper edge carries seven or eight short, subequal, rounded teeth.

This is an abundant form, though perfect specimens are rarely met with. It varies greatly in size; the smaller examples are about 1 line long, whilst the largest, as in the specimen figured, are $3\frac{1}{2}$ lines in length and $1\frac{1}{8}$ wide. It may be distinguished from *E. (Nereidavus) varians*, Grinnell, by its truncated extremity and the median furrow and cavity.

EUNICITES (NEREIDAVUS) VARIANS, Grinnell. (Pl. XVIII. figs. 2, 3, 5.)

Nereidavus varians, Grinnell, American Journal of Science, Sept. 1877, p. 229.

Jaw elongated, curved, rounded in front, and convex, widest at about one third the length from the anterior end, and then gradually tapering to a point, the front portion sometimes curved upwards and inwards, the first tooth rounded, somewhat larger than the rest; succeeding this are from two to five, blunted, rounded, upright teeth, and then a series, varying in different specimens, of from nine to fourteen pointed teeth. These latter gradually diminish in size towards the posterior end, and are uniformly directed backwards. The dimensions of the specimens figured are as follows:—fig. 2, $2\frac{1}{8}$ lines long and $\frac{1}{2}$ line wide; fig. 3, 2 lines long and about $\frac{1}{4}$ line in width; fig. 5, $3\frac{1}{8}$ lines long and $\frac{7}{8}$ line wide. Abundant.

As the type specimen figured by Mr. Grinnell is imperfect, showing only the anterior portion of the jaw, I am unable to judge whether my examples are rightly referred to his species; but there is a very close resemblance between his fig. 1 (*op. cit.*) and my fig. 5, which leads me to believe that they are similar. These examples appear to me to correspond more with one of the toothed jaw-plates of *Eunice (Leodice) antennata*, Savigny, than with the jaws of *Nereis*, which in all the examples I have seen are widened at the posterior end for the muscular attanchment, whereas these examples all taper to a point.

EUNICITES CONTORTUS, Hinde. (Pl. XVIII. fig. 4.)

Jaw elongated, very narrow, and tapering to a point, the anterior tooth prominent, nearly upright, not in plane with the rest, and followed by a uniform series of about seventeen pointed teeth, which are all directed backwards, parallel with each other. Length about $1\frac{1}{8}$ line.

This form, besides being much smaller than *E. varians*, has also a more prominent anterior tooth, and the smaller teeth form a uniform series. Not unfrequent.

EUNICITES PERDENTATUS, Hinde. (Pl. XVIII. fig. 6.)

Jaw extremely small, narrow, and gently curved; the anterior end elevated and bent inwards; on this portion are two or three rounded teeth, which are followed by a series of about twenty very minute, subequal, acutely pointed teeth.

The extremely small size, and the absence of a prominent anterior tooth, suffice to distinguish this from the preceding form. It also resembles *E. (Aulacodus) obliquus*, Eichwald (see Pander's Monograph on the Fossil Silurian Fishes, p. 72), which has, however, a much wider base. Length $\frac{5}{8}$ line. Abundant.

Eunicites simplex, Hinde. (Pl. XIX. fig. 2.)

Jaw consisting of a simple, slightly curved hook, narrow throughout, and angular in section. Length $1\frac{1}{8}$ line.

Eunicites gracilis, Hinde. (Pl. XIX. fig. 3.)

Jaw composed of a nearly straight, slightly convex basal portion, with a strongly curved anterior hook. Length 1 line, about $\frac{1}{4}$ line in width.

Eunicites? digitatus, Hinde. (Pl. XIX. fig. 13.)

Jaw very small, triangular, and nearly equilateral. At one extremity are two slender, elongated, nearly straight teeth, behind which, on the straight upper border, are seven minute rounded teeth. Length of the upper edge about $\frac{3}{8}$ line.

Genus Œnonites, Hinde.

Jaws with a more or less curved anterior hook, followed by a series of smaller teeth, similar in character to those of the existing genus *Œnone*.

Œnonites curvidens, Hinde. (Pl. XVIII. fig. 7.)

Jaw nearly straight, with a strongly convex ridge, forming the lower portion of the base; in front a relatively large, very strongly curved tooth, obliquely bent; this is succeeded by fourteen small pointed teeth, carried on a very narrow flattened ridge. Length $\frac{3}{4}$ line, about $\frac{1}{4}$ line in width.

Œnonites inæqualis, Hinde. (Pl. XVIII. fig. 8.)

Jaw nearly straight, tapering to a point; a small projecting appendage below the anterior part of the base, a slightly curved and blunted anterior tooth, succeeded by three minute blunted teeth, behind which are six or seven larger acutely pointed teeth. Length 1 line, width rather more than $\frac{1}{4}$ line.

Œnonites serratus, Hinde. (Pl. XVIII. fig. 9.)

Jaw elongated, narrow, the toothed border slightly arched, truncated at the posterior end, which is wider than the front portion of the jaw, and is slightly concave, with a narrow median furrow. The anterior tooth is but slightly curved, behind which are, first in order, four very small rounded teeth, and then a series of twelve very minute pointed teeth. Length $\frac{5}{8}$ line.

Œnonites rostratus, Hinde. (Pl. XVIII. fig. 10.)

Jaw relatively short, very wide and truncate; a deep furrow just below the toothed edge, extending from the middle to the truncated extremity, and below the termination of the furrow is a projecting knob-like elevation; a stout curved tooth in front, behind which are four claw-shaped teeth, followed by five rounded teeth. Length $\frac{3}{4}$ line, width $\frac{3}{8}$ line nearly.

Œnonites cuneatus, Hinde. (Pl. XVIII. fig. 11.)

Jaw small, compressed, widest in the central portion and tapering gradually to the blunted extremity; a slightly curved anterior tooth, and on the nearly straight upper edge twelve subequal, very minute, rounded teeth. Length $\frac{1}{2}$ line.

Œnonites? carinatus, Hinde. (Pl. XIX. fig. 19.)

Jaw elongate, truncate posteriorly, the front portion slightly convex; a very stout anterior tooth, and towards the end of the jaw five minute blunted teeth on an angular ridge; the central portion of the jaw beneath the ridge deeply concave. Length $\frac{5}{8}$ line.

Genus Arabellites, Hinde.

I propose to include in this genus jaws of widely different form, which have a general resemblance to those of the existing genus *Arabella*, Grube. 1. Jaws with an extremely prominent anterior hook, and a row of smaller teeth on a wide base; 2. Sickle-shaped jaws and allied forms; 3. Jaws subquadrate in form, with a straight upper edge of small teeth. Those of the first division appear to correspond with the first pair, the second resemble the second pair, as figured in Cuvier's 'Règne Animal,' of *Arabella* (*Œnone*) *maculata*, Edwards; whilst the square-shaped jaws I regard as belonging to the lower jaw of Annelids of this genus. Examples of these different forms are very abundant, not only in the Cambro-Silurian, but in all the other formations where the Annelid remains appear.

Arabellites hamatus, Hinde. (Pl. XVIII. fig. 12.)

Jaw oblong, truncate, the wide base nearly of an even width throughout, a knob-like projection in the centre of the lower basal edge, and a similar one at the end; the anterior tooth relatively wide and openly curved. On the upper straight edge are ten subequal rounded teeth. Length $\frac{5}{8}$ line.

Arabellites cornutus, Hinde. (Pl. XVIII. figs. 13, 14, 15.)

Jaw relatively wide, truncate, the lower basal edge curved, with a more or less prominent knob-like elevation in the centre, which is the widest part of the base, the upper edge nearly straight, with a deep furrow just below the teeth extending from the middle to the posterior extremity, beneath which a rounded elevation is sometimes present. In front is an extremely large curved hook, and on the nearly straight upper edge is a series of small teeth, from eleven to twenty in number; those towards the front are conical, whilst further back they gradually diminish in size and become rounded. Fig. 13 is 1 line long and $\frac{3}{8}$ line wide; fig. 14 is $1\frac{1}{2}$ line long and $\frac{1}{2}$ line wide; and fig. 15 is 3 lines long and 1 line wide.

Arabellites cuspidatus, Hinde. (Pl. XVIII. fig. 19.)

Jaw oblong, truncate, flattened, with an elongated depression in the upper posterior portion, the lower and upper borders nearly straight and parallel; in front a stout blunted tooth or hook, which is nearly at right angles with the main portion of the jaw, and on the upper edge about eighteen rounded minute teeth. Length $2\frac{1}{2}$ lines, width $\frac{3}{4}$ line.

Arabellites ovalis, Hinde. (Pl. XVIII. fig. 16.)

Main portion of jaw of an oval figure, with a very large, curved, and slightly twisted hook in front, and eight or nine small pointed teeth. Total length $1\frac{1}{2}$ line, width $\frac{3}{8}$ line.

Arabellites gibbosus, Hinde. (Pl. XVIII. fig. 21.)

Jaw oval and strongly convex, with a well-marked curved line extending from the base of the hook to the extremity; in front is a short, slightly curved, very stout hook; on the main portion of the jaw are ten subequal, oblique, pointed teeth. Length $1\frac{5}{8}$ line, width $\frac{1}{2}$ line.

Arabellites ascialis, Hinde. (Pl. XVIII. fig. 17.)

Jaw narrow, elongated, and tapering to a point; a very long, curved, anterior tooth, not in the same plane with the body of the jaw; on the straight upper edge there are about seven minute acutely pointed teeth. Length 1 line, width $\frac{1}{6}$ line.

Arabellites rectus, Hinde. (Pl. XVIII. fig. 18.)

Main portion of jaw somewhat triangular, widest in front, and gradually tapering to the blunted extremity; in front a very large and robust hook, with a deep longitudinal furrow near the outer side. Six teeth are visible on the upper edge of the jaw. Length $3\frac{1}{2}$ lines, width $\frac{3}{4}$ line.

Arabellites lunatus, Hinde. (Pl. XIX. figs. 4, 5, 6.)

Jaw sickle- or crescent-shaped, one end pointed, the other extended into a rod-like prolongation, the front surface concave. On the curved outer rim of the crescent are from ten to twelve short rounded teeth, the two anterior ones are generally slightly larger and somewhat divergent from the others; in one instance, however, these anterior teeth are not present. In fig. 4 the length of the toothed portion is 1 line, and of the projection $\frac{3}{4}$ line; fig. 5 is $1\frac{1}{2}$ line in length; and fig. 6 is $\frac{7}{8}$ line.

This is a very abundant form, and shows a good deal of variation in different examples.

Arabellites cristatus, Hinde. (Pl. XIX. fig. 7.)

Jaw crescentiform, with but a short angular projection, the front edge curved upwards, surface concave; on the upper border are eleven distinct elevated teeth, the first two of which are smaller and not in plane with the others. Length $\frac{3}{4}$ line.

Arabellites cervicornis, Hinde. (Pl. XIX. figs. 8 & 12.)

Jaws very variable in form, sometimes crescentiform, with a short angular extension in front, at other times elongated and extended below the middle of the jaw; in front there are from two to three relatively large divergent teeth, followed by a series of from four to seven minute acute teeth. Length $\frac{5}{8}$ line.

Arabellites pectinatus, Hinde. (Pl. XIX. fig. 11.)

Jaw rudely triangular, the front portion rounded, pointed posteriorly, the sides meet below to form a short blunted extension nearly below the centre of the jaw; the upper border slightly arched, and carrying about fifteen small teeth, those in front rounded and upright, the others acute and directed backwards. Length $\frac{5}{8}$ line.

Arabellites crenulatus, Hinde. (Pl. XIX. fig. 9.)

Main portion of jaw nearly straight, flattened, and gradually tapering; in front is a short blunted rod-like extension at right angles to the toothed part of the jaw, which carries eight stout teeth, the first of which is small and claw-shaped, the others triangular and acute. Length $\frac{3}{4}$ line. Abundant.

Arabellites quadratus, Hinde. (Pl. XIX. fig. 14.)

Jaw composed of a nearly square, slightly convex plate, with a blunted rod-like appendage projecting obliquely from one of the lower angles; on the upper, nearly straight, edge of the plate is a series of about fifteen small, subequal, rounded teeth or crenulations, whilst just below the upper edge, on what appears to be the posterior side, there is a small spur-like tooth projecting obliquely. Length of the toothed edge $\frac{3}{4}$ line.

This is a very abundant species, and generally very regular in form, though varying considerably in size, some examples being nearly as large again as the specimen figured.

Arabellites scutellatus, Hinde. (Pl. XIX. fig. 16.)

Upper portion of the jaw subquadrate, with a prolonged, gradually narrowing base; surface slightly convex, with a very prominent protuberance at the lower posterior angle; the nearly straight upper border carries eleven teeth, of which the first is pointed, somewhat longer than the rest, and projects outwards; the others are subequal rounded teeth. Length and width each about $\frac{1}{2}$ line. Abundant.

Arabellites? obliquus, Hinde. (Pl. XIX. fig. 15.)

Jaw composed of a comparatively thick, obliquely semioval, concave plate; the lower rounded edge is slightly elevated, the straight upper border has about fifteen small rounded subequal teeth or crenulations. Length $\frac{7}{8}$ line, width $\frac{1}{2}$ line.

Genus Lumbriconereites, Ehlers, 1868.

Lumbriconereites, Ehlers, Palæontographica, Band xvii. p. 159.

Ehlers based this genus on the resemblance of some fossil Annelids in the Solenhofen shales to those of the existing genus *Lumbriconereis*. In his specimens only the lower jaws appear to have been recognizable, whilst my own examples, which I propose to place under this genus, resemble the principal jaw-plate in the upper jaw; they are not unlike the corresponding plate in the jaws of *Eunicites*, but possess a well-defined basal flange or extension.

Lumbriconereites dactylodus, Hinde. (Pl. XVIII. fig. 20.)

Jaw oblong, straight, and nearly of uniform width, in the central portion a well-marked protuberance; at the front end are four curved rounded teeth bent upwards and inwards, whilst on a slightly elevated ridge, which springs obliquely from the basal flange, is a series of eighteen small rounded teeth. Length nearly $2\frac{1}{2}$ lines, width $\frac{3}{4}$ line.

Glycerites, Hinde.

Jaws consisting of a simple curved hook with a wide base, without smaller teeth, resembling those of the existing genus *Glycera*.

Glycerites sulcatus, Hinde. (Pl. XIX. fig. 1.)

Jaw oblong, relatively wide and convex, obliquely truncate; from the truncated end a deep longitudinal furrow extends nearly to the front, where it opens into a cavity which extends below the hook; this is stout, slightly curved, and somewhat bent inwards. Length $1\frac{1}{4}$ line, nearly $\frac{1}{2}$ line in width.

This is a very abundant form, and very distinctly marked by the deep subcentral furrow.

Glycerites sulcatus, var. excavatus. (Pl. XIX. fig. 10.)

The hooked portion in this jaw closely resembles that just described, but the posterior end is relatively wider and hollowed out, and instead of the *central* furrow there is a deep groove which extends round the inner edge of the main portion of the jaw. Length 1 line, width $\frac{1}{2}$ line.

This variety is also comparatively abundant in the same localities with *G. sulcatus*.

In addition to the above, there are some aberrant forms which I am unable to place under any of the known genera of Annelids which have come under my notice. I have figured three examples on Pl. XIX. figs. 17, 18, and 20, and append short descriptions of each.

Fig. 17 is a straight, nearly linear, form, with ten upright teeth, very unequal in size; four of these are very prominent and nearly triangular in form. Total length 1 line.

Fig. 18 is small, narrow, and slightly convex, the front portion convex, rounded, and with a small tooth; the jaw posteriorly is thin and flattened, and has seven minute blunted teeth. Length $\frac{5}{8}$ line.

Fig. 20. Upper portion of jaw oblong and flattened, with six faintly marked crenulations; this part extends downwards, forming a flattened prolongation, first at right angles, and then nearly parallel to the upper part.

II. *Annelid Jaws from the Clinton and Niagara Groups* (*Silurian*).

So far as my researches have extended, these minute jaws are not so widely distributed in the Silurian strata in Canada as in the lower strata of the Cambro-Silurian; but they appear to be abundant in the single locality in which they make their appearance. They are for the most part closely related to the species already described, whilst three forms—*Eunicites major*, *Œnonites inæqualis*, and *Œnonites cuneatus*—occur in these as well as in the lower rocks. The beds yielding these fossils are shown in the same escarpment—the Clinton strata in the lower portion, and about 200 feet higher the bituminous shaly bed of the Niagara, these two rock divisions being only separated by an arbitrary line in this part of Canada. As all the forms described are from Dundas, Ontario, I need only mention after the description of each the particular division from which it came.

Eunicites clintonensis, Hinde. (Pl. XIX. fig. 21.)

Jaw elongated, narrow, with a blunted posterior termination, the anterior portion elevated and slightly curved inwards, the two front teeth rounded and somewhat larger than the rest, followed by a series of about fifteen teeth, gradually diminishing in size towards the extremity of the jaw; the first two in the series are rounded, all the rest are acutely pointed and directed backwards. Length $1\frac{1}{8}$ line, width $\frac{1}{5}$ line.

This form is closely allied to *E. perdentatus*, from which it may be distinguished by its more robust proportions and possessing fewer teeth, though nearly double the size. Abundant.

Clinton formation.

Eunicites coronatus, Hinde. (Pl. XX. fig. 9.)

Jaw somewhat semielliptical in outline and strongly arched, blunted at both ends, and having on the upper border about twelve rounded teeth, of which the first five are subequal, and the others gradually diminish in size. Length $\frac{3}{4}$ line, depth nearly $\frac{3}{8}$ line. Abundant.

Clinton formation.

Eunicites chiromorphus, Hinde. (Pl. XX. fig. 10.)

Jaw forming a triangular plate, with one end pointed and strongly incurved; beginning at the opposite end there is first on the upper border a series of five very large blunted upright teeth, and succeeding these are five very small teeth or crenulations. Length $\frac{7}{8}$ line, width $\frac{5}{8}$ line.

Clinton formation.

Œnonites amplus, Hinde. (Pl. XIX. fig. 23.)

Jaw elongated, nearly straight and flat, relatively wide, and blunted posteriorly; the anterior tooth is partly wanting in the specimen, but it appears to have been slightly curved and larger than the others. Following the first are seven prominent, acutely pointed, conical teeth, and these are succeeded by another series of similarly shaped, but very minute, teeth. Length $\frac{7}{8}$ line, and $\frac{1}{5}$ line wide.

Clinton formation.

Œnonites fragilis, Hinde. (Pl. XX. fig. 3.)

Jaw oblong, short, truncate, and flattened, with a furrow just below the toothed edge in the posterior half of the jaw; the first six teeth are blunted and subequal, followed by six minute teeth. Length $\frac{3}{4}$ line, about $\frac{1}{4}$ line in width.

Though this example differs from the more typical forms of the genus in the absence of a larger tooth or hook in front, in other respects it appears to resemble this genus in possessing a flattened surface and truncated extremity with the usual furrow.

Clinton formation.

Œnonites? infrequens, Hinde. (Pl. XX. fig. 2.)

Jaw elongated, relatively wide, and slightly concave, with the posterior extremity blunted; the front tooth or hook, which has been partly broken off in the specimen, appears to have been nearly upright; on the straight upper edge of the jaw are about twenty-five, very minute, conical, upright teeth. Length $1\frac{1}{4}$ line, and $\frac{1}{4}$ line wide.

Though this form differs considerably from the typical species of this genus, it appears more closely related to it than to *Eunicites*.

Niagara formation.

Arabellites elegans, Hinde. (Pl. XX. figs. 5 & 7.)

Jaw flattened, widest in the central portion, with a small protuberance below, a similar one at the narrow posterior extremity, and a depressed groove below the toothed edge; a large and slightly curved hook in front, and about eleven teeth on the crest of the main portion, the first six of which are pointed and subequal, the others very minute and blunted. Length $\frac{5}{8}$ line, greatest width $\frac{1}{4}$ line. In the same beds is a much smaller form with only six minute, scarcely discernible, teeth, and the anterior hook in proportion. Length of this example $\frac{3}{8}$ line.

This species is closely related to *A. cornutus* from the Cincinnati group; but the hook is less proportionately developed, and the jaw itself is of very much smaller dimensions.

Clinton formation.

Arabellites similis, Hinde. (Pl. XX. fig. 8.)

Jaw very minute, somewhat triangular in form, the pointed extremity nearly below the centre of the jaw, the upper border slightly arched and carrying ten minute teeth, of which the first two are pointed and divergent, the others rounded. Length $\frac{1}{2}$ line.

This species closely resembles *A. pectinatus* from the Cincinnati formation, but it is not so elongated and has fewer denticulations.

Niagara formation.

LUMBRICONEREITES BASALIS, Hinde. (Pl. XIX. fig. 22.)

Jaw with a long, narrow, curved ridge, supported on a wide triangular basal flange; the first tooth is long and nearly horizontal, and apparently forms the commencement of the ridge; on the summit of the ridge there are seventeen, blunted, roughly triangular denticulations unequal in size. Length $1\frac{5}{8}$ line; width, including the flange, $\frac{3}{4}$ line.

Not uncommon, though perfect specimens are rarely met with.

Clinton formation.

LUMBRICONEREITES TRIANGULARIS, Hinde. (Pl. XX. fig. 4.)

Jaw consisting of a flattened triangular basal plate with a very narrow vertical ridge; at the anterior end of the basal plate there are two incurved blunted teeth, whilst the ridge supports a series of eighteen blunted rounded teeth. Length $1\frac{1}{2}$ line, width $\frac{1}{2}$ line.

This species is closely related to *L. dactylodus*, but differs therefrom in the angular outline of the front basal flange.

Clinton formation.

LUMBRICONEREITES ARMATUS, Hinde. (Pl. XX. fig. 6.)

Jaw consisting of a very narrow, vertical, slightly curved ridge, supported by a very wide, somewhat concave, horizontal basal flange, having in front a very prominent claw-shaped tooth, which is nearly in the same plane with the flange itself. On the vertical ridge there are nine sharp-pointed teeth, obliquely directed towards the posterior end of the jaw. Length $1\frac{1}{2}$ line, width $\frac{3}{4}$ line.

I have only met with a single example of this clearly marked species.

Clinton formation.

STAUROCEPHALITES, Hinde.

Jaws of more or less elongated, compressed, denticulate plates, resembling those of the existing genus *Staurocephalus*, Grube. Of this I have met with only one species.

STAUROCEPHALITES NIAGARENSIS, Hinde. (Pl. XX. fig. 1.)

Jaw oblong, the front border slightly curved and extending obliquely downwards, the posterior end rounded; on the upper edge of the plate is a series of sixteen very minute pointed teeth, of which the first is slightly larger than the others, and all are uniformly directed backwards. Length $\frac{5}{8}$ line, about $\frac{1}{6}$ line wide.

This minute jaw is very abundant, but appears to be restricted to the dark shales of the Niagara formation.

Glycerites calceolus, Hinde. (Pl. XX. fig. 11.)

Jaw somewhat triangular, gradually widening to the truncated posterior end; in front a broad, slightly curved, flattened hook; the central portion is depressed, concave, and passes into a hollow beneath the hook. Length $\frac{3}{4}$ line, width $\frac{1}{2}$ line.

This is closely allied to *G. sulcatus*, but is much smaller, and has a shorter and less curved hook and a greater central depression.

Clinton formation.

III. *Annelid Jaws from the Hamilton Group of the Middle Devonian.*

My specimens from this formation have all been found in two or three small slabs of rocks exposed in the bed of the Rivière au Sable, Ontario. Judging from the variety of the specimens it would appear that these animals must have been very numerous in this as well as in the lower formations. One species, *Arabellites similis*, is present in this as well as in the Niagara formation, and some of the other forms are closely allied to those already described.

Eunicites? alveolatus, Hinde. (Pl. XX. figs. 14, 15.)

Jaw composed of a simple, nearly straight, depressed convex, hollow tube, bluntly pointed in front. Fig. 14 is 1 line in length and $\frac{1}{4}$ line wide; fig. 15 is only $\frac{1}{2}$ line long and $\frac{1}{8}$ line wide.

I am doubtful whether these forms may be regarded as modified pincers, and place them provisionally under the above genus.

Eunicites tumidus, Hinde. (Pl. XX. fig. 16.)

Jaw somewhat triangular in form and convex, the front nearly straight and extended downwards to a point, the posterior portion rounded; on the nearly straight upper border are three or four blunted cusp-like teeth, with as many intermediate smaller ones. Length $\frac{1}{2}$ line, nearly the same in width.

Eunicites palmatus, Hinde. (Pl. XX. fig. 17.)

Jaw formed of a nearly flat, subquadrate plate, traversed longitudinally by a slightly elevated ridge, with a small spur-like termination in the middle of the front side; on the upper border are six, relatively large, conical, upright teeth. Length $\frac{1}{2}$ line, width $\frac{3}{8}$ line.

Eunicites nanus, Hinde. (Pl. XX. fig. 18.)

Jaw formed of a very minute, obliquely semioval, slightly convex plate, having on the upper edge a series of about ten very small pointed teeth, of which the first two are more prominent than the rest. Length $\frac{3}{8}$ line, $\frac{1}{4}$ line wide.

Œnonites compactus, Hinde. (Pl. XX. fig. 13.)

Jaw somewhat triangular, compressed, widest beneath the central portion, the lower border slightly elevated; a moderately stout, slightly curved hook in front, and on the gently arched upper edge thirteen, subequal, blunted, minute teeth. Length $\frac{3}{4}$ line, width $\frac{3}{8}$ line.

ARABELLITES POLITUS, Hinde. (Pl. XX. fig. 19.)

Jaw consisting of a nearly flat plate, the front portion rounded and extending below obliquely to a point, the posterior extremity slightly truncate; on the sloping upper edge is a series of twelve pointed teeth, the first of which, though not larger, is opposed in direction to the rest and slightly claw-shaped. Length of the toothed border $\frac{1}{2}$ line, and from the summit to the point $\frac{1}{2}$ line.

ARABELLITES SIMILIS, var. ARCUATUS. (Pl. XX. fig. 20.)

In the Hamilton group there are comparatively numerous specimens which I am unable to distinguish from *A. similis* from the Niagara formation; but in addition to these there are certain examples which show differences which may entitle them to be separated as a variety from that form. In the specimen taken as a type of this variety the jaw is crescentiform and slightly concave, the upper border arched and with about fourteen small teeth, of which the third is larger and more upright than the others. About $\frac{3}{8}$ line in length.

It is a more arched form than *A. similis*, and has a greater number of denticulations.

Genus NEREIDAVUS, Grinnell.

Nereidavus, American Journal of Science, Sept. 1877, p. 229.

This genus was proposed by the author for fossil jaws resembling those of the existing genus *Nereis*. I have only found one example which, in my opinion, can be placed in the genus.

NEREIDAVUS SOLITARIUS, Hinde. (Pl. XX. fig. 12.)

Jaw compressed and relatively wide; at the truncated posterior end of the jaw is a small concave portion which is distinctly marked off from the rest of the jaw by a transverse ridge; in front is a prominent tooth directed forward and slightly out of plane with the rest of the jaw, and on the upper border are ten small, blunted, nearly upright, triangular teeth, followed by numerous very minute crenulations. Length $1\frac{1}{8}$ line, greatest width $\frac{3}{8}$ line.

The forward inclination of the anterior tooth and the marked off portion at the extremity of the jaw, which may have served for a muscular attachment, lead me to think that this may have been one of a pair of jaws carried in the front of the head like those of *Nereis*; in all the examples of that genus, however, which I have seen, the smaller denticulations are directed forward towards the larger tooth, whereas in this fossil example they are nearly upright. As a rule, too, the smaller teeth in *Nereis* are fewer in number than in this example; but this is a feature very liable to variation.

IV. *Annelid Jaws from the Lower Carboniferous of Scotland.*

The specimens which I have collected from the above formation are so few and, for the most part, so fragmentary, that it would have been hardly worth while to mention them but for the consideration that such objects have not, to my knowledge, been previously noticed in any formation in this country, and, further, that not only do they appear in strata of more recent age than those in which I have met with them in America, but they also show a close relationship to those jaws which come from the Cambro-Silurian formation. The paucity of my collection is due to the fact of its having been the result of only two days' search in two or three adjoining quarries in one locality; but, judging from the variety of small detached fragments, it is not improbable that a search specially made for these minute remains will show that they are as abundant in Britain as in Canada. The shaly limestone in which the specimens were imbedded does not appear so favourable for preserving them as the more arenaceous deposits; but they have, when not too much weathered, the same black glistening appearance, and are in a similarly detached condition.

I am only able, from the fragmentary state of the fossils, to give descriptions of four jaws, three of which I include in one species of the genus *Eunicites*, and one belongs to the generally distributed genus *Arabellites*. All the examples are from limestone quarries at Cults, in Fifeshire.

Eunicites affinis, Hinde. (Pl. XX. figs. 21, 22, 23.)

The imperfect specimen (fig. 21) consists of the front portion, with two upright blunted teeth, of a jaw apparently resembling that of *Eunicites major* from the Cincinnati group. The length of the fragment is $1\frac{1}{2}$ line, and its width $\frac{3}{4}$ line.

Fig. 22 is a simple elongated jaw with a short curved tooth, the posterior portion expanded and flattened, whilst the narrow part is angular in section. Length $1\frac{1}{2}$ line.

This appears to be one of the paired pincers of *Eunicites*; it is similar to the form described as *E. simplex*, also from the Cincinnati group; but the hook is shorter and more strongly curved, and the extremity is more compressed.

Fig. 23 is a small, compressed, oblong plate with five rounded teeth, of which the first is curved and projects outwards, and the other four are short, straight, and subequal. It may be a portion of a jaw belonging to *Eunicites*; from its occurrence in close proximity with the simple hook, fig. 22, it is not unlikely to have been from the same Annelid as that specimen.

Arabellites scoticus, Hinde. (Pl. XX. fig. 24.)

Jaw crescentiform, concave, rounded in front, the posterior blunted end somewhat truncate. On the arched crest eight teeth can be distinguished, of which the first is considerably longer than the rest; but as this and the following two have been partially crushed, their original form cannot be satisfactorily ascertained. The smaller teeth are blunted and directed backwards. Length of the crest $1\frac{1}{4}$ line, from the large tooth to the point below $\frac{3}{4}$ line.

This species is allied to *A. lunatus* (Pl. XIX. fig. 5), but differs therefrom in being wider and truncate, as well as in the form of the teeth.

Summary.

In the preceding pages I have described 55 different forms of jaws, of which there are 33 from the Cincinnati group, 13 from the Niagara and Clinton group, 7 from the Hamilton group, of the Canadian rocks, and 2 from the Lower Carboniferous in Scotland. The respective numbers included under the different genera are as follows:—*Eunicites* 14 forms, *Œnonites* 10, *Arabellites* 19, *Staurocephalites* 1, *Lumbriconereites* 4, *Nereidavus* 1, *Glycerites* 3, whilst 3 forms are not referred to any genus. Of many of the forms there are numerous examples, whilst others are represented only as single specimens. Whilst there is thus shown a predominance of forms belonging to the genera *Eunicites*, *Œnonites*, and *Arabellites* (on account of the number and variety of the different jaws in the individuals of these genera, which renders the work of classification to a certain extent doubtful), no definite conclusions can be drawn as to the relative abundance of the different genera. It is quite possible that the number of *species* represented may be less than half the number of forms to which I have given names and descriptions, and they will therefore have to be accepted more for palæontological reference than as indicating so many separate species of these Annelids. It is possible that future discovery will bring to light some of these fossil Annelids with their jaw-plates in their respective positions, which will enable many of the forms described to be placed under a single species; in the mean time I have thought that it would be of interest to geologists to show, what had previously been inferred from the trails and markings, that Errant Annelids were very abundant in the Palæozoic rocks, and that, judging from their jaws, many of them were closely related to existing forms.

EXPLANATION OF THE PLATES.

Plate XVIII.

Fossil Annelid Jaws from the Cincinnati Group.

Fig. 1. *Eunicites major*, H.: × 3. Toronto.
2, 3. —— *varians*, Grinnell: × 6. Toronto.
4. —— *contortus*, H.: × 8. Toronto.
5. —— *varians*, Grinnell: × $3\frac{1}{2}$. Toronto.
6. —— *perdentatus*, H.: × 15. Toronto.
7. *Œnonites curvidens*, H.: × 15. Toronto.
8. —— *inæqualis*, H.: × 13. Toronto.
9. —— *serratus*, H.: × 12. Toronto.
10. —— *rostratus*, H.: × 15. Toronto.
11. —— *cuneatus*, H.: × 16. Toronto.
12. *Arabellites hamatus*, H.: × 20. Toronto
13. —— *cornutus*, H.: × 12. Toronto.

Fig. 14. *Arabellites cornutus*, H.: × 10. Toronto.
15. —— ——, H.: × 5. Toronto.
16. —— *ovalis*, H.: × 10. Toronto.
17. —— *ascialis*, H.: × 13. Toronto.
18. —— *rectus*, H.: × 5. Toronto.
19. —— *cuspidatus*, H.: × 7. Toronto.
20. *Lumbriconereites dactylodus*, H.: × 6. Toronto.
21. *Arabellites gibbosus*, H.: × 10. Toronto.

Plate XIX.

From the Cincinnati Group.

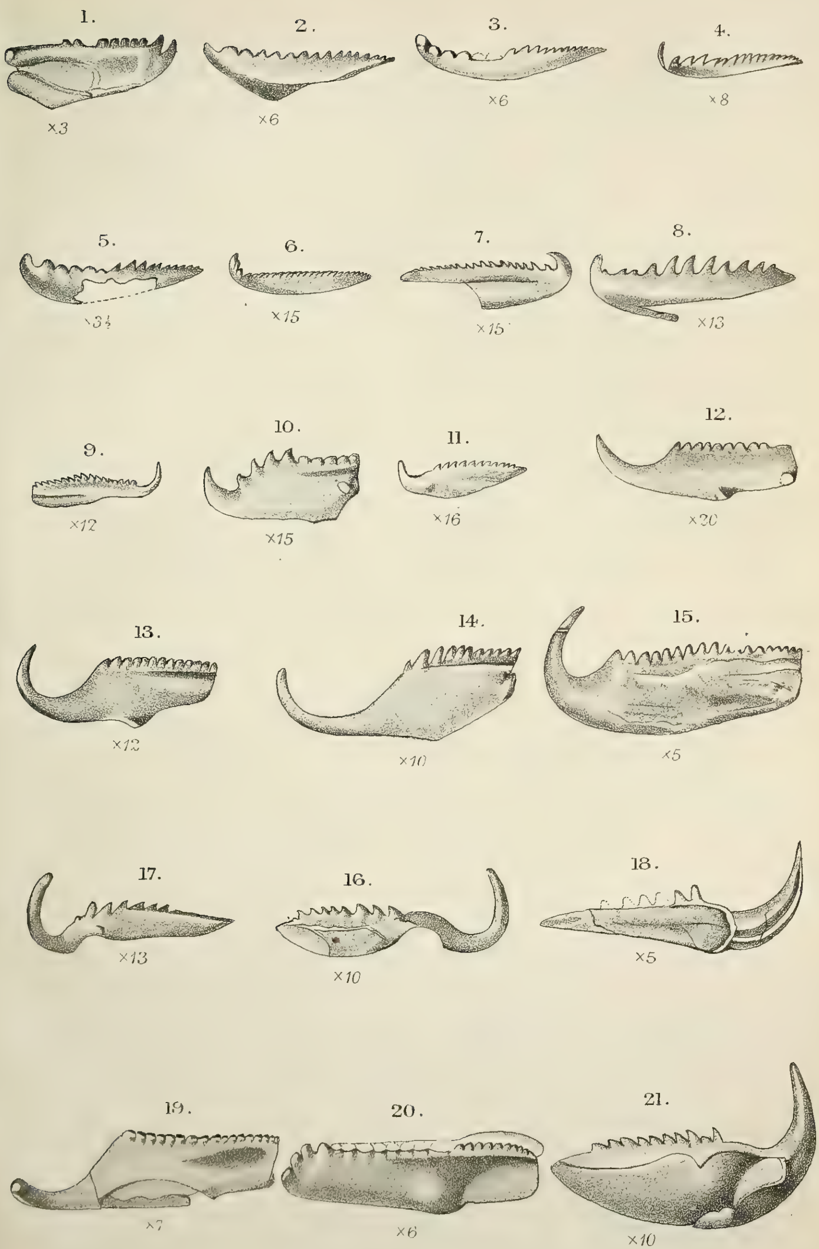
Fig. 1. *Glycerites sulcatus*, H.: × 13. Toronto.
2. *Eunicites simplex*, H.: × 13. Toronto.
3. —— *gracilis*, H.: × 14. Toronto.
4. *Arabellites lunatus*, H.: × 13. Toronto.
5. —— ——, H.: × 10. Toronto.
6. —— ——, H.: × 12. Toronto.
7. —— *cristatus*, H.: × 13. Toronto.
8. —— *cervicornis*, H.: × 14. Toronto.
9. —— *crenulatus*, H.: × 14. Toronto.
10. *Glycerites sulcatus*, var. *excavatus*: × 15. Toronto.
11. *Arabellites pectinatus*, H.: × 16. Toronto.
12. —— *cervicornis*, H.: × 14. Toronto.
13. *Eunicites*? *digitatus*, H.: × 12. Toronto.
14. *Arabellites quadratus*, H.: × 15. Toronto.
15. ——? *obliquus*, H.: × 11. Toronto.
16. —— *scutellatus*, H.: × 16. Toronto.
17. Sp. ind.: × 14. Toronto.
18. —— × 12. Toronto.
19. *Œnonites*? *carinatus*, H.: × 14. Toronto.
20. Sp. ind.: × 15. Toronto.

From the Clinton and Niagara Groups.

21. *Eunicites clintonensis*, H.: × 13. Dundas, Ontario. (Clinton.)
22. *Lumbriconereites basalis*, H.: × 10. Dundas. (Clinton.)
23. *Œnonites amplus*, H.: × 14. Dundas. (Clinton.)

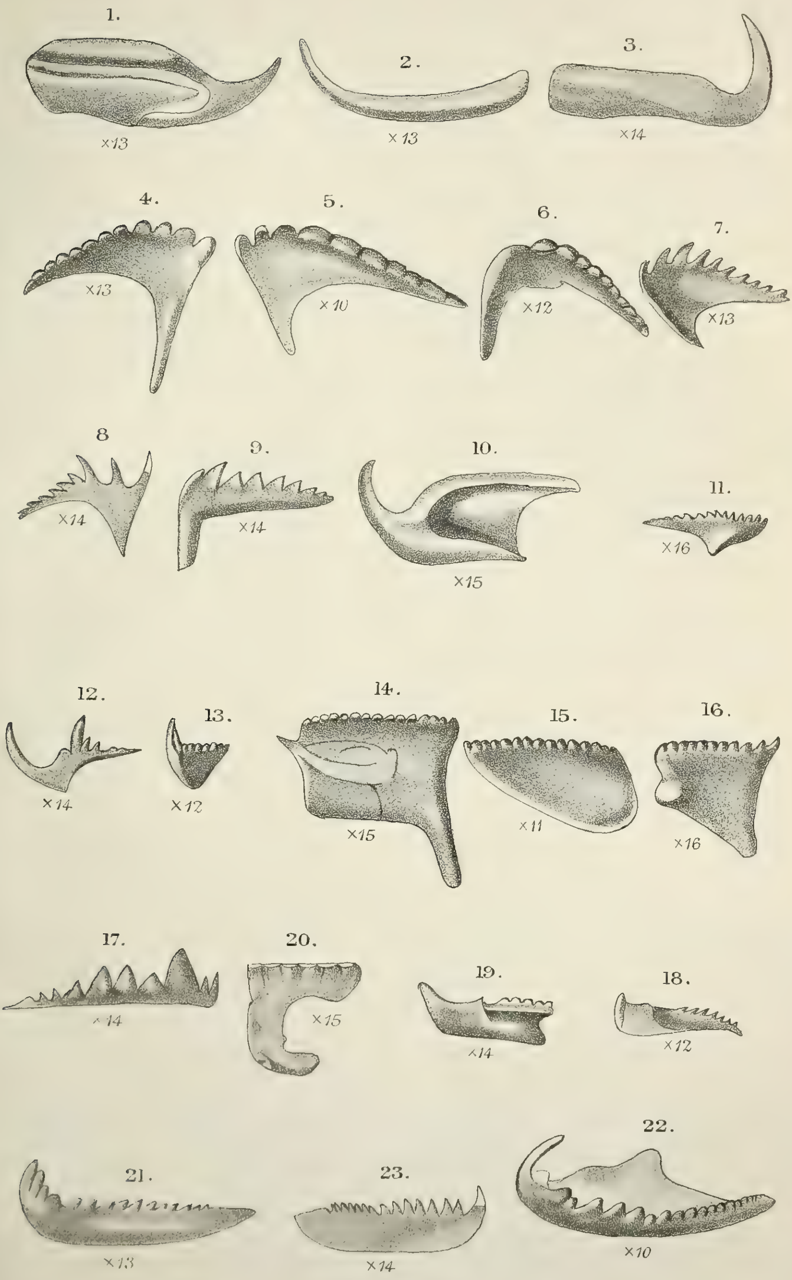
Plate XX.

Fig. 1. *Staurocephalites niagarensis*, H.: × 14. Dundas. (Niagara.)
2. *Œnonites*? *infrequens*, H.: × 14. Dundas. (Niagara.)
3. —— *fragilis*, H.: × 14. Dundas. (Clinton.)
4. *Lumbriconereites triangularis*, H.: × 10. Dundas. (Clinton.)
5. *Arabellites elegans*, H.: × 15. Dundas. (Clinton.)
6. *Lumbriconereites armatus*, H.: × 10. Dundas. (Clinton.)
7. *Arabellites elegans*, H.: × 14. Dundas. (Clinton.)
8. —— *similis*, H.: × 17. Dundas, Ontario. (Niagara.)
9. *Eunicites coronatus*, H.: × 14. Dundas. (Clinton.)
10. —— *chiromorphus*, H.: × 12. Dundas. (Clinton.)
11. *Glycerites calceolus*, H.: × 13. Dundas. (Clinton.)
12. *Nereidavus solitarius*, H.: × 15. Rivière au Sable, Ontario. (Hamilton.)
13. *Œnonites compactus*, H.: × 14. Rivière au Sable. (Hamilton.)
14, 15. *Eunicites*? *alveolatus*, H.: × 15. Rivière au Sable. (Hamilton.)
16. —— *tumidus*, H.: × 13. Rivière au Sable. (Hamilton.)
17. —— *palmatus*, H.: × 15. Rivière au Sable. (Hamilton.)
18. —— *nanus*, H.: × 15. Rivière au Sable. (Hamilton.)



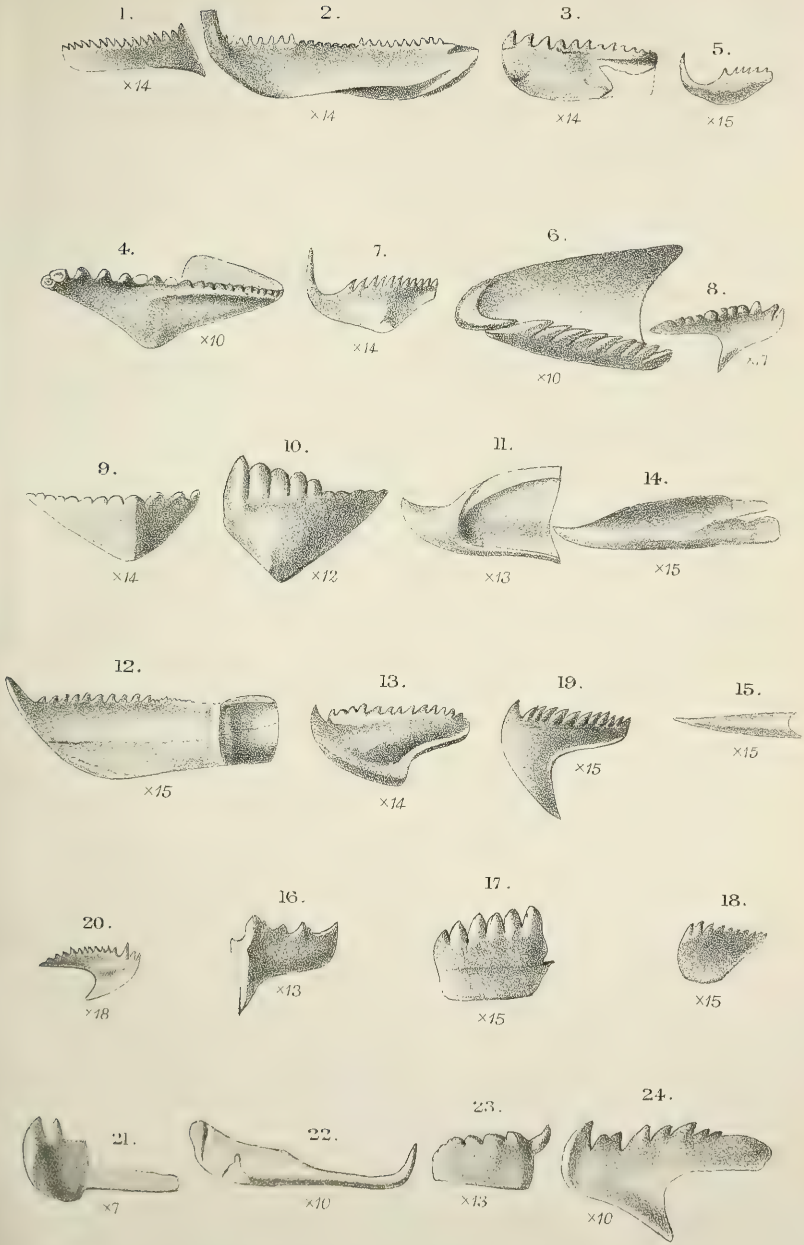
FOSSIL ANNELID JAWS.

Mintern Bros lith.



FOSSIL ANNELID JAWS.

Mintern Bros lith.



FOSSIL ANNELID JAWS.

Mintern Bros lith.

Fig. 19. *Arabellites politus*, H.: × 15. Rivière au Sable. (Hamilton).
20. —— *similis*, var. *arcuatus*: × 18.. From the Lower Carboniferous of Scotland. Rivière au Sable. (Hamilton.)
21, 22, 23. *Eunicites affinis*, H. Cults, Fifeshire. (Lower Carboniferous.)
24. *Arabellites scoticus*, H.: × 1(. Cults, Fifeshire. (Lower Carboniferous.)

Discussion.

Dr. Woodward expressed his admiration of the labour and research displayed in these papers. He was satisfied that the conclusions as regards the Annelid jaws were correct; but that the Conodonts belonged to Myxinoid fishes, he thought was more doubtful, and he suggested that they might possibly be the lingual armature of Nudibranchs. Though some of the Annelid jaws were not unlike the maxillipeds of Crustacea, the Conodonts had no such resemblance.

Dr. Hicks asked if the author had examined earlier formations than the Chazy and Cincinnati groups for remains of this character; for Annelids were very abundant in the Cambrian epoch, though they had apparently left no remains in the form of jaws.

Rev. J. F. Blake said he had a fossil impression of an Annelid from the Ludlow rocks near Llandovery.

Mr. Hinde said he had not found remains earlier than in the rocks which he had described.

31. A Contribution *to the* History *of* Mineral Veins.

By J. Arthur Phillips, Esq., F.G.S. (Read April 30, 1879.)

Certain districts in California are remarkable for their hot springs; and in some of the counties included between the 38th and 40th parallels, and consequently north of the city of San Francisco, sources of this description are of such frequent occurrence that, when viewed from elevated ground, almost every valley is seen to be more or less occupied by wreaths of steam rising from a flow of highly heated waters.

The vents giving issue to these heated waters usually evolve carbonic acid, which is frequently accompanied by various sulphurous gases; such waters are generally alkaline, containing carbonate and sulphate of sodium, as well as, occasionally, alkaline borates. They generally give rise to abundant local incrustations of either silica or calcite, usually more or less mixed with free sulphur. These deposits of sinter often extend, in nearly horizontal layers, to a considerable distance from the orifices from which the waters issue.

When water is ejected from such vents in the form of steam and spray only, while gases are abundantly given off and large amounts of sulphur deposited, the aperture becomes a solfatara.

One of the largest known deposits of sulphur in California occurs in Lake County, a mile beyond the ridge which bounds Borax Lake on its north-eastern side, and is many acres in extent. This "Sulphur Bank," as it is called, is composed of a much decomposed volcanic rock, traversed by numerous fissures, from which gases, steam, and water, either in the form of spray or of vapour, constantly issue; and upon and throughout the entire mass sulphur has been deposited in such large quantities that, at a short distance, the whole appears to consist of that substance. In the immediate neighbourhood of this solfatara are springs which give off carbonic acid, and of which the waters contain carbonates of sodium and of ammonium, chloride of sodium, borax, &c.

The sulphur from this locality always contains a small amount of mercury in the form of cinnabar, and the sides of the fissures in the volcanic rock through which the gases and water make their escape are sometimes coated with gelatinous silica, beneath which is a layer of chalcedony resting upon a stratum of crystalline quartz. This siliceous deposit frequently contains pyrites and a notable percentage of cinnabar, or is stained by a tarry hydrocarbon; while the crystals of quartz often enclose liquid-cavities in which the usual bubbles are distinctly visible.

In the year 1866 I visited Borax Lake and the neighbouring Sulphur Bank in company with Mr. R. Oxland, of Plymouth, who was the first to call attention to the presence of cinnabar in the sulphur from this locality; and in 1868 I published, in the 'Philosophical Magazine,' a paper advocating the probability of certain mineral deposits having been the result of hydrothermal or solfataric action*.

For some years subsequent to my visit this solfatara was worked as a source of sulphur only; but during these operations so large an amount of cinnabar was discovered, both in the decomposed basaltic rock and in the Cretaceous strata through which it has been erupted, as ultimately to lead to the opening up of the cooler portions of the Sulphur Bank as a mercury-mine. This has long yielded large quantities of quicksilver, and affords a striking and instructive example of a recently formed mineral deposit resulting from agencies still somewhat actively in operation; on the table before me will be found not only specimens of this cinnabar but also a specimen of a thin section of recently formed quartz from the face of a fissure in the decomposed basaltic rock.

Many years since, Mr. Oxland found a notable amount of silver in the sinter-like deposit from a hot spring in the county of Colusa; and Professor Whitney, previous to 1865, had been shown at Clear Lake some peculiar and interesting specimens of water-worn cinnabar enclosing specks of gold, said to have been found near Sulphur Springs in the same county of Colusa†.

These, from being water-worn, and from not having been found *in situ*, had necessarily lost a certain portion of the interest which would have otherwise been attached to them; but through the kindness of Mr. Melville Attwood, of San Francisco, a Fellow of this Society, I am enabled to lay before you this evening a specimen of cinnabar from Colusa County, which, having been formed upon one of the surfaces of a fissure, has subsequently become covered by a brilliant deposit of metallic gold.

Steamboat Springs, in the State of Nevada, are situated near the base of a volcanic hill seven miles, in a direct line, north-west of Virginia City and of the famous silver-mines on the Great Comstock lode.

The rock at this place is traversed by several parallel fissures, which either give issue to heated waters or simply throw off clouds of steam. The most active group of these crevices comprehends five parallel longitudinal openings extending, nearly in a straight line, for a distance exceeding a thousand yards; their general direction is nearly north and south, and all of them are included within a zone two hundred yards in width. These crevices are sometimes filled with boiling water which overflows in the form of a rivulet; while at others violent ebullition is heard to be taking place at a short distance below the surface.

These fissures are lined with a siliceous incrustation, which is being constantly deposited, while a central longitudinal opening allows of the escape of gases, steam, and boiling water. The water is slightly alkaline, and contains carbonate of sodium, sul-

* "Notes on the Chemical Geology of the Gold-fields of California," by J. Arthur Phillips, Phil. Mag. 1868, vol. xxxvi. p. 321.

† Geological Survey of California, vol. i. p. 92.

phate of sodium, common salt, &c. Carbonic acid escapes nearly along the whole line; while sulphuretted hydrogen is evolved and sulphur deposited at certain points. The fissures, which appear to have been subjected to a series of repeated widenings, such as would result from an unequal movement of their walls, are lined, sometimes to a thickness of several feet, by incrustations of silica of various degrees of hydration, containing hydrated ferric oxide and, exceptionally, crystals of iron pyrites. This silica exhibits the ribbon-like structure so frequently observed in mineral veins, and when examined under the microscope is observed to consist of alternately amorphous and crystalline bands, sometimes enclosing druses lined with crystals of quartz.

At a distance of nearly a mile, in a westerly direction, from the locality above described is a second group of fissures in every respect similar to those of Steamboat Springs, excepting that they are no longer traversed by hot water, although still at various points giving off steam and carbonic acid. Towards the southern extremity of the principal fissure of this group the siliceous deposit extends considerably beyond the edges of the cleft, and has accumulated to a distance of some ninety yards on each side of the opening.

The silica of this deposit is sometimes chalcedonic and contains nodules of hyalite; by far the larger proportion of it, however, although somewhat friable, is distinctly crystalline, the crystals containing numerous liquid-cavities and exhibiting the usual optical and other characteristics of ordinary quartz. Besides oxides of iron and manganese, this quartz contains small quantities of iron and copper pyrites; and in a paper on the Gold Regions of California, published in the 'Annales des Mines' in 1863, Mr. Laur states that he had found it to contain distinct traces of gold. With regard to these deposits, this gentleman remarks that, so far as auriferous quartz veins are concerned, Steamboat Springs appear to place before us a sort of practical verification of the theory which regards a certain class of metalliferous deposits as being produced by mineral waters in the fissures through which they circulate*.

For many years local attention does not appear to have been directed to this portion of the Steamboat Valley; but in the year 1878 this older fissure was opened by a tunnel to a depth of fifty feet from the surface, and the veinstone was there found so impregnated with cinnabar as to yield large quantities of mercurial ore of considerable commercial value†. At this depth the temperature was not sufficiently high to cause inconvenience to the workmen, and five samples of the ore subjected to assay gave an average yield of 2·90 per cent. of mercury.

Samples taken from the nearly horizontal flats produced by the overflow of the water yielded, on the contrary, traces only of that metal.

Steamboat Springs thus afford another striking example of the

* Annales des Mines, 1863, p. 423.

† Messrs. Humbert, Mining Engineers, San Francisco. Private communication.

recent formation of a considerable metalliferous deposit by the agency of hot springs; and I am, again through the kindness of Mr. Attwood, enabled to lay before the Society a specimen of cinnabar from this place.

In further illustration of the subject I may mention the deposit of bright red cinnabar in a brecciated vein-mass near the hot springs at Calistoga, at the foot of Mount St. Helena. Here fragments of an amorphous siliceous rock are cemented together by crystallized quartz showing distinct lines of accretion; and throughout this minute granules of sulphide of mercury are plentifully disseminated. A hand specimen and a thin section of this veinstone are on the table.

The Great Comstock lode is, as before stated, situate in a volcanic district seven miles south-east of Steamboat Springs, has a nearly similar orientation, and is enclosed between walls either of propylite or of diorite on one side and of propylite on the other. This vein, of which the gangue is chiefly siliceous, although calcite is also sometimes present, was first attacked by the miner in the year 1859, and since that time has yielded silver and gold to the estimated value of above £60,000,000.

The temperature of the waters issuing from mines worked upon the Comstock lode has always been somewhat high, but it was not until they had attained a very considerable depth below the surface that the workmen first became inconvenienced by extraordinary heat. At their present greatest depth (2660 feet) water issues from the rock at a temperature of 157° Fahr. (70° C.); and, according to Prof. John A. Church, of Ohio, who has recently published a valuable paper on the heat of the Comstock mines, at least 4,200,000 tons of water are now annually pumped from the workings at a minimum temperature of 135° Fahr.* He also estimates that to elevate such a large volume of water from the mean temperature of the atmosphere to that which it attains in the mines, would require 47,700 tons of coal. In addition to this, however, 7859 tons of coal would, he calculates, be required to supply the heat absorbed by the air which passes along the various shafts and galleries through which it is diverted for the purposes of ventilation. It follows, therefore, that to develop the total amount of heat necessary to raise the water and air circulating in these mines from the mean temperature of the atmosphere to that which they respectively attain, 55,560 tons of coal or 97,700 cords of firewood would be annually required.

Prof. Church, in his paper, quotes four distinct analyses of waters from the Comstock lode taken at different depths; these, as might have been anticipated, vary somewhat as to the relative proportions of the various substances present; but they contain on an average 42·62 grains of solid matter to the gallon. Of this amount, 20·74 grains are calcic sulphate, 12·13 grains carbonate of potassium, 4·85 grains carbonate of sodium, and ·66 grain of chloride of sodium.

* "The Heat of the Comstock Mines," by John A. Church, E.M., Professor of Mining in the Ohio State University. Presented to the American Institute of Mining Engineers at the Chattanooga Meeting, May 1878.

In order to ascertain, approximately, to what extent the production of the large amount of heat absorbed by the water may be ascribed to oxidation of sulphur and iron, the Professor first calculates the quantity which would be developed by the oxidation of pyrites equivalent to the calcic sulphate in solution. But having found that this amounts to only $\frac{1}{143}$ part of that required, he subsequently seeks another solution for the difficulty, and, without bringing forward any calculations in support of the hypothesis, attributes this enormous development of heat to the kaolinization of felspar contained in the adjacent rocks.

If, however, we apply to the kaolinization of felspar for the heating of water alone a somewhat similar line of reasoning to that adopted by Prof. Church regarding the oxidation of pyrites, we shall find that this source of heat is also utterly inadequate to produce the effects observed.

The average proportion of alkalies contained in the rocks of the district is 6·40 per cent., while the mean of the published analyses gives 11·30 grains of alkalies in 58,373 grains (U. S. gallon) of mine-water. It consequently follows that the 4,200,000 tons of water annually pumped out of the workings must contain 813 tons of alkalies, and that, as these are present in the rocks in the proportion of 6·40 per cent., the felspar in 12,703 tons of rock must be annually kaolinized and the whole of the alkalies removed in solution.

The amount of rock in which the felspar has been kaolinized being 12,703 tons, and the number of tons of water pumped out of the mines 4,200,000, it follows that $\frac{4{,}200{,}000}{12{,}703}=330$ is the number of tons of water heated by each ton of altered rock.

In order, therefore, that one ton of rock should be enabled to heat 330 tons of water only 1° Fahr., and if the specific heat of these rocks be taken at ·1477, which is that of blast-furnace slags, it would require to be heated by the kaolinization of its felspar to a temperature above that of molten gold. Consequently to raise the water 85°, or to a temperature of 135°, at which it issues, the kaolinization of the felspar in each ton of rock would require to elevate it to an extent we are unable to estimate, since there are no means of ascertaining the specific heat of bodies at such enormously high temperatures.

It is therefore evident that the kaolinization of felspar is no more than the oxidation of pyrites an adequate cause to account for the heat of the Comstock lode; and in the present state of our knowledge we cannot regard this phenomenon otherwise than as being a last trace of volcanic activity. Prof. Church adduces the high temperature of the waters of Steamboat Springs as a proof that the rocks of this region are capable of producing sufficient heat to raise large quantities of water to the boiling-point; but these springs give rise to an evolution of sulphuretted hydrogen and to a deposition of sulphur, which cannot be results of the decomposition of felspar. It is probable that the Comstock lode and the hot springs in the Steamboat Valley may have had a somewhat similar origin; but, in the case of the former, volcanic agencies are no longer actively in operation, while both sulphur and sinter have long since been removed from the surface by denudation.

Discussion.

The President remarked upon the interest of the paper in illustrating the method of formation of mineral veins, and asked what the author's opinion was as to the mode in which cinnabar and gold were brought up.

Mr. Bauerman said that in the district described by Mr. Phillips these phenomena were to be seen perhaps on the largest scale in the world. He thought that these deposits of sulphides of volatile metals illustrated those in other parts of the world, as at Almaden, in Spain. There the cinnabar occurred in a pit which was almost vertical, and might be described as a siliceous sponge infiltrated with cinnabar. At the Solfatara, Naples, sulphides of arsenic occurred in the same way; and at Mieres, in Leon, arsenic and mercury were extracted from the same deposit. In these deposits also we had gold, probably reduced from a chloride by sulphide of mercury.

Mr. Attwood corroborated the statements of the author from his knowledge of the district. Three years ago the lower workings of the Comstock lode, some 2300 feet below the surface, were found to be extremely warm, about 100° Fahr.; and at the same time the surrounding vein-matter contained only about 1 per cent. of sulphides and about 99 per cent. of silica, showing that the decomposition of the sulphides could not produce the greatly increased temperature.

Mr. Tendron spoke of mines in Brazil where the heat was inconsiderable, and said that in those mines the gold was invisible and enclosed in either magnetic pyrites, ordinary iron-pyrites, or arsenical pyrites, in the last in the greatest quantity, in the first the least; there was also about 20 per cent. of silver.

Prof. Judd recalled the case of the volcano of Volcano, where there were many small vents depositing sulphide of arsenic, and at night a coloured hydrogen flame could be seen above these vents.

Prof. Ramsay said he had always held that mineral bodies had been deposited from solutions, not sublimations, and inquired if the author thought it likely that in the case of the reefs of Australia, if they were deep beneath the surface and permeated by water, the gold might have been deposited from a state of solution in that water.

Mr. Tendron said that there was no ore in the joints in the clay-slate strata containing the mine he had described, but only in the fissure or walls of contact.

The Author said he had not attempted to explain the chemical actions which took place. The purpose of the paper was to show that these processes were now going on, and that silica might crystallize slowly after deposition. He thought that a volatile mineral like cinnabar would be carried over by steam at a not very high temperature. He doubted whether silica and gold could be volatilized at such temperatures; in most of these vents water in the form of spray appeared to be present, and gold and quartz were, he thought, brought up in solution by it. The great diffusion of the gold might be explained by it and the pyrites being formed *pari passu*. He had never been in Australia; but in California he had never seen an interstratified gold vein, but they were always true veins; and he did not think that quartz veins once formed became subsequently impregnated with gold. No vein with gold was ever practically of much value unless it had sulphides in it, such as pyrites or galena.

32. *On the* Southerly Extension *of the* Hessle Boulder-clay *in* Lincolnshire. By A. J. Jukes-Browne, Esq., B.A., F.G.S. (Read March 26, 1879.)

(Communicated by permission of the Director-General of the Geological Survey.)

Contents.

Introduction.

The group of beds to which in 1867 Messrs. Wood and Rome gave the name of Hessle Sand and Clay * have recently been invested with much greater interest and importance than was originally attached to them by these geologists when they first separated them from the other glacial deposits and described their mode of occurrence in the typical district of Holderness.

In a communication to the 'Geological Magazine' for 1872 †, Mr. Searles Wood, jun., states that he and Mr. Rome, subsequently to the publication of their joint paper, "traced an Upper Boulder-clay and underlying sand through the Vale of York into that of the Tees, which seemed to be a continuation of the Hessle Clay and Sand." They noticed that the thickness of the clay was greater in the north than along the Holderness coast, and stated that they had reason for thinking the same beds extended into Cumberland and even into Scotland.

The same authors had, in 1870, suggested the possibility that this sand and clay might correspond with the middle and upper members of the glacial series in the north-west of England; and in his latest paper (1878) ‡ we find Mr. S. Wood expressing his belief that the Hessle beds, "in the form of a (so called) Middle Sand and Upper Boulder-clay with occasional boulders, extend over the lower ground intervening between the Pennine chain and the coast in Cumberland, Lancashire, and Cheshire, and reach along the north-west coast as far south at least as the north of Carnarvonshire." He remarks upon the similarity of the fauna contained in these Middle Sands to that found in the gravel and sand underlying the Hessle Clay; and he speaks of the southerly extension of this deposit in the following terms:—"The southern limit of the Hessle Clay appears to be at Firsby, on the northern edge of the Lincolnshire Fen; and, so far as I know it, the southern limit of the upper clay of the north-west of England appears to be at the same latitude in the Menai Straits; but on the eastern side the gravels of the formation

* Quart. Journ. Geol. Soc. vol. xxiv. p. 146.
† Geol. Mag. dec. i. vol. ix. p. 175.
‡ Ibid. dec. ii. vol. v. p. 18.

carry the submergence a little further south, viz. over the Cambridgeshire Fen."

These last words have reference to another correlation which Mr. Wood has attempted to establish between the Hessle Sands and certain valley-deposits in the south of England; he has repeatedly urged that the *Cyrena*-brickearths of the Thames valley and the older postglacial gravels in Norfolk and Cambridgeshire were of the same age as the Hessle beds.

Dr. J. Geikie * accepts Mr. S. Wood's correlations, but looks upon the Hessle Clay as a truly glacial deposit; in the occurrence, therefore, of *Cyrena fluminalis* below this clay he sees a proof that the shell "which has been usually looked upon as evidence of the postglacial age of the deposits in which it occurs did really live in interglacial times." He also regards the older river-gravels in S.E. England as belonging to the same period and therefore of interglacial age.

Mr. Skertchly likewise adopts these views, and proceeds to argue for the great age of some of the Suffolk and Cambridgeshire gravels on the ground that there is evidence of their being anterior in date to the formation of the Hessle Boulder-clay.

Since, therefore, the Hessle Clay appears destined to become a stratum of reference, by their relation to which the interglacial or postglacial age of various other deposits, both in the north and south of England, is to be measured, it is of great importance that the limits of its extension should be accurately defined, in order that its relations to gravels of newer and older date may, if possible, be ascertained.

Now its southern boundary has never been satisfactorily determined. Messrs. Wood and Rome, in their original paper, pointed out that it extended down to the edge of the marsh land surrounding the Wash, and that it might be found to underlie part of this ground †, but they did not attempt to trace it beyond Firsby and Steeping.

During the last two years I have been engaged in surveying the southern end of the Lincolnshire Wolds and the country bordering the northern edge of the Fenland. I first made myself acquainted with the character and behaviour of the Hessle Clay between Great Steeping and Burgh, and subsequently followed it westward along the fen edge, the result of my examination being to convince me that not only is the above surmise correct regarding its continuation underneath the fen beds, but also that its surface extension stretches much further westward and southward than had previously been supposed.

I am now permitted to lay before the Society the observations which have led me to this conclusion regarding the southerly prolongation of the Hessle Boulder-clay in Lincolnshire, and to supplement them with some remarks upon the gravels in this and more southern counties which are supposed to belong to the same period of time.

* Great Ice Age, 2nd. edit. p. 379.

† Quart. Journ. Geol. Soc. vol. xxiv. p. 173.

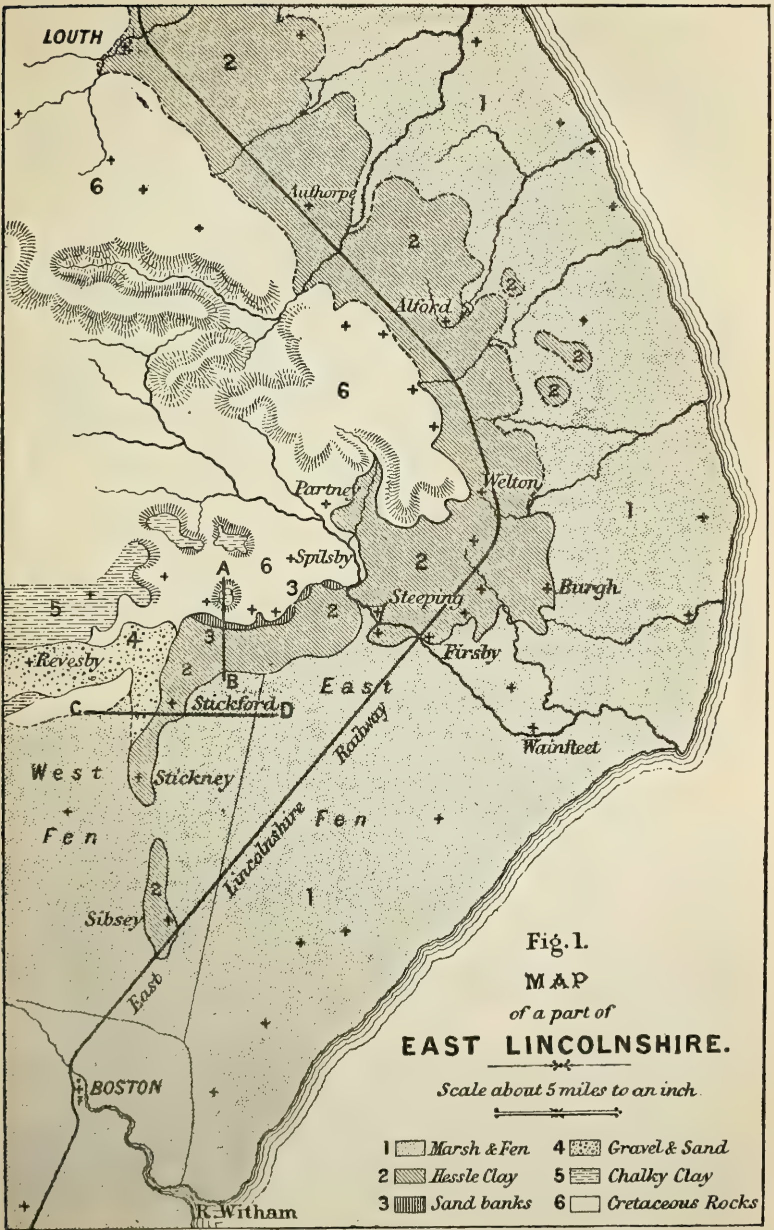


Fig. 1.
MAP
of a part of
EAST LINCOLNSHIRE.

§ 1. *Extension of the Hessle Clay in East Lincolnshire.*

In the first place it will be desirable to identify the Boulder-clay in the district examined by me, with the Hessle Clay of the localities where the latter is typically developed. Fortunately the well-known memoir by Messrs. Wood and Rome renders this an easy task; for they have traced the clay southwards through Lincolnshire to the mouth of the Steeping valley, where I commenced my survey in 1877. The following is their statement regarding the extension of the clay in Lincolnshire* :—

"At the only spot on the Lincolnshire coast which affords a section, namely the low cliff of Cleethorpe, the Hessle clay caps the purple; . . . . From Cleethorpe the Hessle clay extends southwards over the belt of undulating ground called 'The Middle Marsh,' which it envelopes, overlapping the lower part of the eastern Wold-slope. It is well shown around Alford, where the brick-pits afford good sections, and where it is seen to be overlain by 4 or 5 feet of a light-brown silt. . . . Four miles south of Alford the Wolds terminate, and the East Lincolnshire marsh sweeps round to the mouth of the Steeping valley. Fringing that marsh and forming a belt between it and the high ground, the Hessle clay sweeps round also, and occupies (where it opens on the marsh near Firsby) the mouth of the Steeping valley. . . . The southern extension of the Hessle clay beyond the Steeping mouth, near the southern extremity of the Wold, is obscure, owing to the flat nature of the country."

It is its continuation along the borders of this flat fen country that I now proceed to indicate.

From the neighbourhood of Burgh the Boulder-clay dips eastward and southward under the soft clays of the Lincolnshire marshland; its surface boundary, indeed, curves round to the S.W. below Irby, Firsby, and Little Steeping; but the clay itself is unquestionably prolonged beneath the warp and silt of the fen country to the southward; it is exposed beneath these beds at the bottom of the brickyards near Thorpe Culvert Station; but how far it extends due south of this point I have not had any opportunity of ascertaining.

Returning to the vicinity of Little Steeping, it has been traced thence to the S.W. by Toynton Fenside and Keal Coates to Stickford, the course of the Catchwater drain very nearly coinciding with its fenward edge, while its northern boundary skirts the high land formed by the Kimmeridgian and Neocomian beds between Spilsby and Bolingbroke.

Its westward extension, however, terminates at the mouth of the valley in which Bolingbroke its situated; it does not even stretch into this valley, but, ceasing to skirt the edge of the fenland, it is now prolonged southwards through Stickford and Stickney towards Sibsey, forming a narrow ridge or bank which separates the two low-lying districts known respectively by the names of West Fen and East Fen.

* Quart. Journ. Geol. Soc. vol. xxiv. p. 152.

This sudden change in the direction of the bank-like edge of the Hessle Clay is the more remarkable because, throughout the whole of its northern extension it clings closely to the edge of the Wolds, and runs into the depressions and valleys which furrow their eastern slopes. These, as pointed out by Messrs. Wood and Harmer, must have been in existence before the Hessle beds were deposited; and I can quite confirm their account of the positions which these beds occupy in the Steeping valley, and agree with the main inferences deduced from the sections accompanying their paper.

Seeing, therefore, that the Hessle Clay entered the Fen basin in the same manner as it did the Steeping valley, I expected to follow its continuation at the same level along the north border of the Fenland; consequently the abrupt termination of its westward extension at a point about midway along this border, and its bank-like prolongation in a southerly direction, was the more surprising, especially as there did not appear to be any reason why it should not have extended much further westward.

To this peculiarity and the possible reasons for it further reference will be made in the sequel; but I wish to draw attention to it at once as an important and interesting fact.

§ 2. *Description of the Hessle Beds along the North Border of the Fenland.*

I now proceed to give some description of the deposit as exhibited along the line of country above indicated, commencing near Burgh and noting the more important sections which were found in tracing the formation westward.

First, with regard to the Boulder-clay about Burgh, although it varies very much in colour and character, and in the proportion of chalky material which it contains, I have not found it practicable to make any division of it into a newer and older clay.

Burgh itself stands on an eminence composed of sand and gravel, through which wells have been sunk and water reached at a depth of about 20 feet. Whether this sand overlies the Boulder-clay or is a protruding knob of the Hessle Sand, I could not quite satisfy myself, but am inclined to take the latter view, as the clay seemed to close in upon it all round, and was visible at several points on the lower slopes without any strong springs being given off along the line of junction; in colour this Boulder-clay is greyish, but more or less mottled with purplish-brown; and it contains numerous chalk pebbles.

From descriptions of the clay near Burgh, communicated to them by Prof. Judd, Messrs. Wood and Rome concluded that it belonged to the chalky basement clay of their coast section *; but I am inclined to think that it is only a local form of the Hessle Clay. The latter presents itself with normal characters at a large gravel-pit less than a mile west of the town. There is a continuity of Boulder-clay land between this point and the places where a more chalky

* Quart. Journ. Geol. Soc. vol. xxiv. p. 184.

clay is seen; and it did not seem possible to draw any line of separation between them.

Nevertheless it is a fact that the Boulder-clay underlying the marsh-land east of Burgh is of a marly and chalky nature, according to the accounts given by persons acquainted with it. At the brickyard on the Skegness road, I was informed that below the marsh clays, at a depth of about 14 feet, they came to "greyish white clay with chalk stones," into which they had dug 5 feet, but did not know how much deeper it extended.

At Croft brickyard, nearly a mile and a half to the southward, it lies at a depth of 18 feet, and is described as "yellowish marly clay with white chalk pebbles." Nearer Burgh, at Mr. Bland's farm, marly clay was met with in sinking the well at a depth of about 6 feet; and passing through this they found gravel and sand below, obtaining a supply of water at 12 feet.

This marly clay therefore can hardly be the great Chalky Boulder-clay of Mr. Searles Wood, but is probably a continuation of the clay seen in the gravel-pits between Burgh and Bratoft. When this is pumped clear of water the following section is exposed:—

	feet.
Soil and purplish "marl" or clay	3 to 6
Sand with some stony layers	6 to 4
Bed of gravel and stones, resting on a floor of marly clay similar to the topmost bed	3 to 2
	12

From information obtained on the spot it would appear that the gravel and sand form a lenticular deposit in the Boulder-clay. Several large boulders of basalt were thrown out, and were said to have come from the upper clay. The stones in the gravel were mostly chalk and flint; but I noticed also pebbles of red chalk, Neocomian sandstone, quartzite, and shelly limestone.

Mammalian bones are found in some abundance at the bottom of the gravel; and I have to thank Mr. Jabez Good, of Burgh, for transmitting those in his possession to Jermyn Street for examination.

They were determined by Mr. E. T. Newton to belong to *Elephas antiquus*, *Rhinoceros leptorhinus*, and a *Bos* or *Bison*.

At Bratoft another patch of sand comes to the surface, and the Boulder-clay around appears to vary much in thickness. At Irby, gravel has been dug from a similar patch; and between Irby and Firsby a small pit was opened in 1877, one face of which showed a somewhat confused section of gravel, sand, and Boulder-clay interbedded with one another; but the gravel passed under the clay in other parts of the pit.

South of Irby and Firsby the Hessle beds sink under the clays and silts of the fen; but as the latter are nowhere very thick, the Boulder-clay is touched in several brickyards: thus about a mile S.S.E. of Irby marly Boulder-clay is found at a depth of 10½ feet; its thickness here is not more than 10 feet; and there is sand beneath it from which a water-supply is obtained.

The clay here is said to be very marly and full of chalk stones, but that below the fen clay, in another brickyard one mile south of the above, is a red clay with some stones but few chalk pebbles, according to the information given me by Mr. Warth, the owner of the brick-field.

At a neighbouring brickyard a trial sinking had been made in this bottom stony clay for 30 feet without piercing it; probably therefore it continues to stretch under the fen beds for some distance southward.

Returning to Firsby the Boulder-clay is exposed in the railway-cutting near the station; and its peculiarities have been noted by Mr. Skertchly, who describes it at p. 209 of his Memoir on the Fenland (Geological Survey). It is of a reddish brown colour, mottled here and there with bluish grey; small chalk pebbles are scattered through the mass, many of them being soft and easily crushed, derived probably from the Upper Chalk to the north; there are also fragments of other rocks, basalt, limestone, and sandstone; its thickness at the station is 10 feet; and an unfailing supply of water is obtained from the gravel below. When, however, it is traced northwards into the next cutting on the railway its variable character again discloses itself; a clean reddish loam first takes the ground, succeeded by stiff mottled Boulder-clay, which passes a second time into red laminated sandy loam without any stones at all.

Similar beds are shown in vertical succession at an old pit between the railway and Monksthorpe, in the following order.

	feet.
Dark brown Boulder-clay................	3
Reddish loam, without stones	4
Purplish Boulder-clay	3
Gravel and sand..............................	9
	19

In the large pits belonging to Mr. Hardy at Great Steeping, a similar section is exposed: the Boulder-clay is from 8 to 10 feet thick, and is mostly a stiff mottled clay full of chalk pebbles, but passes in one part into a reddish silty loam; underneath there is about 10 ft. of sandy gravel with seams of sand, and a bed of coarse gravel at the bottom; here, again, mammalian bones have been found.

Northward the Boulder-clay extends up the Steeping valley to within a quarter of a mile of Partney church; and a long tongue stretches up the hollow between Partney and Skendleby, but no outliers have been observed further up the main valley. Near Ashby the thin edge of the Hessle Clay may be seen in the river-bank overlying dark Kimmeridge Clay; the former thickens southwards; and the Kimmeridge Clay ceases to be visible below Halton Bridge, where the river enters the ground occupied by the beds of clay and gravel above described.

The lie and position of the Hessle Clay between Steeping and Keal Coates have already been indicated; its surface extension forms a strip of land intervening between the fen and the high ground (see section, fig. 2), and varying in width from a mile to a mile and a half. Its colour and constitution vary considerably: its general character is that of a tough sticky clay, reddish or brownish in colour, mottled and striped with bluish-grey, and usually containing a greater or less quantity of small chalk pebbles, so that the material is locally known as "clay with whites;" but occasionally it passes into a reddish sandy loam which is almost free from stones of any kind.

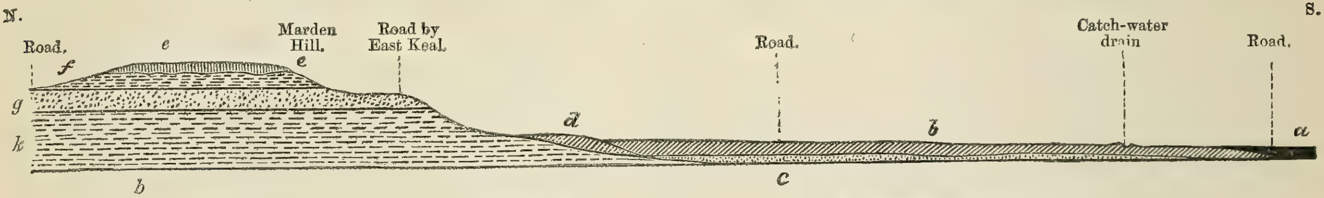
Beds of sand and gravel frequently and perhaps continuously underlie the clay. They rise to within a few feet of the surface in some parts of the area; but towards Keal Coates the ground rises and the clay appears to thicken, a well at the farm near the old windmill west of the village being sunk through 20 feet of the clay into sandy gravel with water.

The northern boundary of the Hessle beds, skirting the foot of the high land, presents a singular feature which much perplexed me when first entering on a survey of the ground. I found the hills to consist of Neocomian sands overlying a dark blue clay, while on the lowermost slopes reddish sand again presented itself with such regularity that it gave one the impression of cropping out from beneath the blue clay, while the Boulder-clay appeared to be banked up against it on the south. Ultimately, however, I found that the blue clay was Kimmeridge Clay, and that the lower sands connected themselves with the Hessle Clay; they form, in fact, a long sandbank marking what appears to be the shore edge of that clay and resulting from the degradation of the Neocomian Sands above. East of Toynton All Saints there is a mound of such sand banked up upon the Kimmeridge Clay as high as the level of its junction with the overlying Neocomian sand, while southward and eastward this sandbank passes into loam and Boulder-clay.

Westward the bank forms a kind of terrace at the foot of the hills, more elevated than the plain of Boulder-clay beyond: see section fig. 2, p. 405, which is drawn along a line running due N. and S., from the eminence called Marden Hill, just N. W. of East Keal, to the edge of the fen below the Catch-water drain, which receives all the drainage from the slopes on this border of the Fenland. The village of West Keal stands on the terrace above mentioned; but here there is less sand, the bank being composed of a strong loam, laminated in places, but finally passing into a loose stony clay that cannot be separated from the mass of the Hessle Clay, though it contains some patches which might almost be called gravel. Such is the character of the deposit along the main road from West Keal to Hagnaby; and it is last seen just before reaching the farmstead called Laythorpe, which stands on the Kimmeridge Clay.

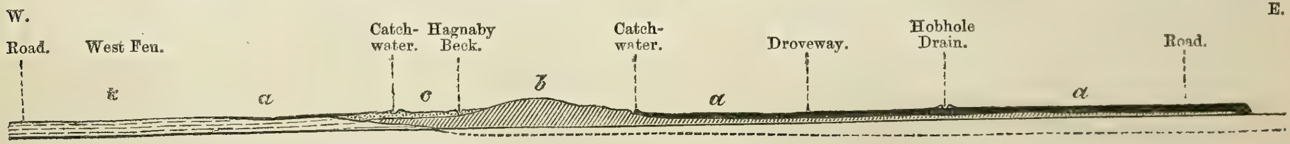
South of this place the country presents an undulating hillocky surface with westerly slopes towards Hagnaby beck, which stream runs through ground occupied by sands and gravels that are apparently of more recent age than the contiguous Hessle Clay. Owing to the more obscure nature of the country, however, I ex-

Fig. 2.—*Section from Marden Hill to East Fen, in the line* A.–B. *in Map.* (Scale, 3 inches to 1 mile.)



a. Fen-beds.
b. Hessle Clay.
c. Hessle Gravel.
d. Sandbank.
e. Chalky Boulder-clay.
f. Middle Neocomian Clay.
g. Lower Neocomian Sandstone.
k. Kimmeridge Clay.

Fig. 3.—*Section from West Fen to East Fen, in the line* C.–D. *in Map.* (Scale, 1 inch to 1 mile.)



a. Fen-beds.
b. Hessle Clay.
c. Sand and gravel.
k. Kimmeridge Clay.

perienced great difficulty in disentangling the various clays and gravels that are met with in this neighbourhood; and I cannot, therefore, speak positively concerning the relation of the Hessle Clay to the other deposits. Below the gravels which occupy the surface about Hagnaby and East Kirkby the blue Kimmeridge Clay is generally found; but occasionally there are intervening patches of a chalky Boulder-clay, different in character and contents from the clay of the Hessle series. The former clay is greyish or yellowish white, full of chalk pebbles, and is similar to that which caps the hills to the northward, although it here descends to the same level as that occupied by the Hessle beds. On this point more will be said in the sequel.

Here, therefore, as before stated, we find the western boundary of the Hessle Clay; but instead of terminating altogether, its surface outcrop is prolonged southward, so as to form an irregular ridge or bank, varying in altitude, but always higher than the fenny lands on either side. This feature is shown in the section, fig. 3, p. 405, which starts from the road north of New Bolingbroke, and intersects the Hessle-Clay bank along a line which passes about one third of a mile south of Stickford church. The extension of the Boulder-clay under East Fen is to some extent hypothetical; but it is founded on the fact that it is seen to slope under the north and west edges of this fen, and that some depth of Boulder-clay was found below 8 feet of peat and clay at Lade-Bank engine, 3 miles to the southward*.

About Stickford the Hessle Clay seems to be in great force; and at the Red Lion Inn a well was dug 60 feet in it without reaching the bottom of the deposit, but finding a weak spring of water at a depth of 30 feet.

Under the N.E. part of the village there is a bed of sand and gravel which yields a supply of water at depths of from 14 to 18 feet. The same brown Boulder-clay may be seen at the S.E. end of the village near the Catch-water drain, and at Bargreen Bridge on the road to Stickney. The ridge at the latter place is reduced to a very narrow neck; and advantage has been taken of this circumstance to cut a channel through it and thus bring the waters of Hagnaby beck into connexion with the Catch-water system of drainage.

About Stickney the ridge widens out again, and strikes nearly due south in the direction of Sibsey. The soil at the surface is a sandy and stony loam; but underneath the same brown Boulder-clay is found.

This district has been surveyed by Mr. S. B. J. Skertchly*; but he naturally regarded the clay composing the ridge as a local variety of that which underlies the fen-basin to the south and west; subsequent mapping has demonstrated its connexion with the Hessle Clay, and has invested this feature with more importance than it would otherwise have possessed. Mr. Skertchly's mapping shows that the continuity of the ridge is interrupted south of Stickney; and

* Geology of the Fenland (Geol. Surv. Mem.), p. 280.

he believes that in early times the river Witham flowed through this gap to the outfall at Wainfleet.

At Sibsey Norland the Boulder-clay sets in again, and appears on the map in the form of a long island rising out of the flat silt-lands which surround it on every side. Mr. Skertchly mentions a well section at Sibsey*, showing Boulder-clay (31 feet) with a vein of sand below yielding a water-supply, as at Stickford.

South of Sibsey the Hessle Clay would appear to sink finally below the level of the fen-deposits, following probably the increasing slope of the floor of the fen-basin in that direction. Mr. Skertchly remarks † that "around Boston Boulder-clay of the dark blue character can be occasionally seen in several of the brickyards at depths of from 15 to 26 feet from the surface. The fen-beds around are much thicker than this; and Boston seems to stand on a submerged bank of Boulder-clay, of which the islands of Sibsey and Stickney are the only parts which appear at the surface."

It will be seen therefore that he regards the Boulder-clay underlying Boston as a continuation of the Sibsey Clay, which now proves to be referable to the Hessle Clay, and is therefore much younger in age than the Boulder-clay underlying the rest of the fen to the west. How far the Hessle Clay may once have extended to the southward cannot at present be ascertained; but it is very unlikely that the deposit should have terminated thus abruptly in the midst of what is now the fenland; for this area seems to have existed, with much the same configuration as now, in times long anterior to the formation of the Hessle beds. We may therefore reasonably expect that they will eventually be recognized in more southerly parts of the fen-basin; but it is very problematical whether any of the gravels in those regions, supposed by some to be contemporaneous with the Hessle Sands, ever had any actual connexion with them.

Mr. Skertchly gives a well section at Fossdyke in which 37 feet of yellow sandy clay intervene between beds that are clearly deposits of fen and Boulder-clay of a light blue colour. It would be idle to speculate upon the probability of this belonging to the Hessle Clay; but the possibility is perhaps worth pointing out.

It may, however, be assumed as more than probable that where Boulder-clay is found to underlie the more recent beds in the fen district east of the bank or ridge above described, such Boulder-clay belongs to the Hessle and not to the older chalky clay.

§ 3. *The Origin and Mode of Formation of the Hessle Clay.*

The geographical disposition and extension of the Hessle Clay in Lincolnshire are suggestive of some remarks regarding the conditions under which it appears to have been accumulated; and in this connexion its relations to the Chalky Boulder-clay or Upper Glacial of Searles Wood become of great importance.

The contrast between the character and behaviour of the two clays is very conspicuous. The configuration of the country during

* Geology of the Fenland (Mem. Geol. Surv.), p. 275.

† *Op. cit.* p. 211.

the formation of the later clay was entirely different from that which obtained in the earlier period: the climate too must have been different; for everything connected with the Hessle Clay points to conditions of much less glacial severity than those which accompanied the formation of the older clay.

Mr. Searles Wood, indeed, deems these facts of such importance that he refuses to admit the newer clay as coming within the limits of the great Glacial Period; he refers its accumulation to a period of minor glaciation, which he considers as *Postglacial*, in the sense that it occurred at a time long after the epoch of major glaciation, to which he would restrict the term *Glacial Period.*

Without altogether assenting to Mr. S. Wood's view of the case, I quite appreciate the importance of the facts to which he draws attention, and the reasons which have led him to adopt this break as the line of division between the Glacial and Postglacial Periods. In conjunction with Mr. Rome he drew two sections across the Steeping valley; and speaking of these they write as follows*:—

"We are thus enabled to see the relative positions of the Hessle clay and of the Glacial clay of mid-Lincolnshire, and the contrast presented by the former as a true Postglacial or valley-formed bed .... to the massive deposit of the latter, out of which and the Wold, together, the trough occupied by the Steeping river has been cut.... The contrast between the chalky clay and the Hessle clay in this section (fig. 9) is too distinct and complete to admit of the possibility of their belonging to the same formation."

The general accuracy of these sections, and of the conclusions drawn therefrom regarding the great lapse of time and the large amount of denudation which must have taken place in the intervening period, are fully confirmed by the results of my own more detailed examination of the country.

The section fig. 2, on p. 405, shows how the Hessle Clay is banked up against the foot of the hills bounding the northern edge of the fenland, and also exemplifies the great difference in the relative positions here occupied by the two Boulder-clays; so rapid, however, is the south-westward declination of the Chalky Boulder-clay, that at a distance of only one mile and a half west of the line of section it is found at the same level as that on which the newer clay occurs. We are therefore led to inquire whether this is merely a coincidence or whether the descent of the Chalky Boulder-clay to to this level has been in any way connected with the limitation of the Hessle Clay to the eastern part of the fen-basin.

To any one now viewing the ground there does not seem any reason why this latter clay should not have extended eastward along the fen-edge to Tattershall and the valley of the Witham. If the wide-spread sand and gravel which covers this district was a continuation of the beds underlying the Hessle Clay, some patches of the superimposed clay must have remained to prove its former existence; but nothing of the kind has been found. If it does exist in any part of this area, it *must* be subjacent to the above-mentioned

* Quart. Journ. Geol. Soc. vol. xxiv. p. 163.

gravels; but wherever Boulder-clay has been seen beneath them it is either the white or the dark blue variety of the Upper Glacial Clay.

About Revesby the chalky or "white clay" is seen to pass downwards into the blue variety as it descends into the fen-basin; and the occurrence of this clay in the very place of the Hessle Clay appears to show that the former has in some way been connected with the absence of the latter.

It has occurred to me as a possible solution of the question that the great Glacial Clay may then have existed in such mass over the northern part of the fen district as to have prevented the influx of the Hessle-sea waters, presenting a line of low cliffs against which the later Boulder-Clay was banked up in the same way as it is against the eastern and southern slopes of the Wolds.

We know that the Glacial Clay did descend into, and probably to a great extent filled up, the great hollow of the Fens; the northward declination of its base-line in Cambridgeshire * has been indicated by Mr. Penning and myself; and we now find it sinking southward in a similar manner from the Lincolnshire highland. Whether the subsequent period was one of emergence or submergence, it was undoubtedly a period of great denudation; and the re-excavation of the fen-basin seems have been one of its results; the position of the Hessle Clay therefore in the north part of the Fenland may indicate one stage of this process.

The only alternative explanation which suggests itself is that the re-excavation of the fen-basin had been completed before the deposition of the Hessle Clay, and that an open bay existed over the site of the present Fenland, and that, as the climate again increased in glacial severity, the inner and shallower part of this bay became blocked up with ice, which presented a lofty ice-wall on the seaward side, and that the Boulder-clay was accumulated on the outside of this wall. This, however, is a mere speculation; and although it would account for the difficulty, there is no collateral evidence to support it; while the former supposition connects itself with two ascertained facts—(1) the occupation of the fen-basin by the Great Chalky Clay, (2) the termination of the Hessle Clay at the point where the older clay descends into the fen country. I am inclined therefore to look upon the first hypothesis as the most probable explanation of the facts.

I also concur with Mr. S. V. Wood in thinking that both the internal structure and general behaviour of the Hessle Clay furnish evidence in favour of the supposition that it was formed along a coast-line by the action of shore-ice. This is a question on which there is great difference of opinion, other writers, notably Dr. James Geikie, holding that this clay in common with all other Boulder-clays is the product of land-ice. Let us therefore reexamine the characters presented by the Hessle Clay throughout its extension in East Lincolnshire.

* Quart. Journ. Geol. Soc. vol. xxxv. p. 198, and 'The Posttertiary Deposits of Cambridgeshire,' Cambridge, 1878, pp. 28 and 77.

Regarding the origin of the materials composing it in the north of the county, Messrs. Wood and Rome remark * that "the colour of the Hessle clay, coupled with the presence of the chalk fragments and the boulders in question, seems to show that it has been mainly formed, and its boulders derived, from the degradation of the purple clay, an admixture of material having been introduced from the chalk which had been laid bare of the Glacial clay during the previous early Postglacial denudation."

All along the eastern slope of the Chalk Wolds, where it may be supposed that the Purple Clay lies underneath, it would appear that the Hessle Clay preserves much the same colour and character; but on reaching the south end of the Wolds and crossing the line along which their scarp must be prolonged as an underground ridge stretching south-eastwards, we find near Burgh a very chalky Boulder-clay; and whether this belongs to the Purple or to the Hessle Clay, I am disposed to attribute its chalkiness to the proximity of the chalk-ridge below.

Moreover, when we are well within the strike of the Neocomian series (clays between thick sandstones), we find that the Hessle Clay puts on a loamy and sandy facies, and that its landward border is actually fringed with sandbanks for some distance. Traced southward to Stickney, it becomes a stiffer and more sticky clay, though still brownish in colour and charged with pebbles of chalk; here it appears to rest on the Kimmeridge Clay, and further south on Upper Glacial Clay of the dark blue colour which it usually presents in this part of the Fenland.

It may have been noticed that in speaking of the clay underlying Boston, which may be part of the Hessle Clay, Mr. Skertchly described it as dark blue in colour; now it is possible that it may have acquired this tint from the erosion of the underlying blue clays, just as further north it appears to take its colour from the Purple Clay. Whether this be the case or not, there is sufficient evidence to show that the colour, character, and constitution of the Hessle Clay are influenced by the nature of the rock beds which underlie it—not, however, after the fashion described by Messrs Tiddeman and Skertchly, where a Boulder-clay derives its colour and character from the rocks *over which it has been pushed* †; the Hessle Clay, on the contrary, seems to exhibit the phenomena we might expect on the supposition that it was formed against a shore-line by the combined action of sea-waves and coast-ice.

I am aware that Dr. James Geikie takes an entirely different view; but his arguments are principally founded upon the supposition that the Hessle Clay behaves in the same manner as the older Boulder-clays. He asserts, in direct opposition to Mr. S. V. Wood's opinion, that "the Hessle boulder-clay yields no proof of a marine

* Quart. Journ. Geol. Soc. vol. xxiv. p. 151.

† Quart. Journ. Geol. Soc. vol. xxviii. p. 484, 'Great Ice Age,' p. 358. I may here remark, however, that this is no proof of the terrestrial origin of such Boulder-Clay; coast-ice breaking up, and drifting in a strong current would leave a similar trail of rock-débris and differently constituted clays.

origin, but is as much a *moraine profonde* as the purple boulder-clay or even as the great chalky till itself. This," he says, "is proved not only by the character of the clay, but also by the mode of its occurrence" *. It does not appear, however, that Dr. Geikie made himself acquainted with its mode of occurrence beyond the limits of the localities which he mentions; he does not attempt to account for the restriction of the deposit to the eastern side of the Wolds, or for its position in the valley of the Steeping. It is unfortunate that Dr. Geikie did not enter more fully into the special behaviour of the Hessle Clay, as it is precisely this which, to my mind, furnishes the strongest arguments in favour of its formation by coast-ice; and the facts stated in the preceding pages appear to constitute difficulties in the application of his land-ice theory.

As regards the characters presented by the Hessle Clay at Kelsea, Dr. Geikie describes them in some detail. He observes that where it rests directly on the Chalk its basement bed is one of angular chalk débris. But this is only what we should expect in the case of a shore deposit; and according to Mr. S. Wood the same bed is found at the base of the Hessle gravel. Mr. Geikie, indeed, admits that no stress can be laid on *this* fact as being specially favourable to the land-ice theory. His next assertion, that there is no trace of bedding in the deposit, must be taken, I presume, as meaning that none was visible in the sections he had the opportunity of seeing; I can vouch for the existence of laminated loams being clearly intercalated in the clay at more than one locality (*vide* pp. 403, 404).

Again, he describes a section where a tongue of the Boulder-clay is intruded among the subjacent sands, and he looks upon this as evidence for the agency of land-ice; I apprehend, however, that the powerful agency of coast-ice is quite adequate to the production of a similar result. Exactly similar phenomena are presented by the so called Cromer till, which is both overlain and underlain by marine deposits, and portions of which are certainly interbedded with the laminated series below. The section given by Mr. Geikie appears therefore equally explicable by the one theory as by the other, and cannot be taken to prove the correctness of his own view. Finally, since we know that coast-ice is capable of accounting for such phenomena as are presented by the Hessle Clay in Lincolnshire, and as no direct evidence for its morainic origin has yet been adduced, I am strongly inclined to adopt the former view, as first suggested by Messrs. Wood and Rome.

The following are the principal facts in favour of this hypothesis:—

(1) The occurrence of marine mollusca in the sands and gravels which underlie it, proving that the area was a sea-bottom at a time immediately preceding the formation of the superjacent clay.

(2) The distinct indications of the frequent interposition of stratifying aqueous agency, viz. the interbedded layers of laminated loam and sand, and the occasional lateral passage of the clay itself into similar laminated loam.

* 'Great Ice Age,' second edition, p. 374.

(3) The occurrence of the Hessle Clay only on the seaward side of the Chalk Wolds, and its position in relation to them, being banked up against their slopes and thrust into their hollows and valleys—such a position at once suggesting the idea of its accumulation along a sinking coast-line.

(4) The frequency of fragments from the softer beds of the Upper Chalk, the change in character and contents beyond the southern end of the Chalk hills, and the sandbanks fringing its westward continuation.

All these facts appear to indicate that the present boundary of the Hessle Clay corresponds with the coast-line of the period during which it was accumulated, that there is a distinct relation between the nature of the rocks composing this coast-line and the varying character of the clay, and that it was formed by the action of coast-ice under the influence of a southward-drifting current. I hold it therefore only reasonable to conclude that no glacier or ice-sheet had any part in the formation of the clay in question, but that its origin is purely littoral and marine.

[Postscript, May 1879.—Recent information obtained while surveying the country between Burgh and Alford has disclosed important facts which are hardly explicable on any other hypothesis than that above mentioned. The Boulder-clays underlie all the newer deposits of the bordering marsh, and rest on a gently sloping *plain of marine denudation*, which extends westward to the foot of a *line of buried chalk-cliffs*; these stretch northward from Welton to Louth, and probably continue along the eastern edge of the Wolds as far as the Humber. The Hessle beds are banked up against these cliffs, well-borings proving a depth of from 40 to 50 feet of clay at distances of only two or three furlongs from its boundary line. Borings at Mablethorpe, on the coast, reach the Chalk at a depth of 84 feet; so that, allowing for difference of surface-level, the buried scar of Chalk has a north-easterly slope of about 1 in 530. The south end of the Chalk Wolds is completely smothered in Boulder-Clay; and at Welton the concealed cliff is probably an exact counterpart of that at Hunstanton.]

§ 4. *The Age and Equivalents of the Hessle Beds.*

Hitherto I have found myself in accord with Mr. Searles Wood in all points concerning the Hessle beds and their mode of occurrence in Lincolnshire; with regard, however, to the connexion which he traces between these beds and certain Postglacial gravels, I am constrained to differ from him; or rather, to speak more correctly, I would enter a verdict of "not proven" against the correlation for which he contends.

This is a matter of some importance, because this correlation lies at the very foundation of the grouping which he proposes in his classification of the Glacial and Postglacial deposits; and in a recent paper he defends this grouping, to which Mr. Geikie had taken exception in his 'Great Ice Age,' and discusses the question at some length*.

* Geological Magazine, dec. 2, vol. v. p. 24.

The point in dispute might at first sight appear to be a mere matter of nomenclature; but the question really involved is whether the Hessle beds are synchronous with the March gravels and with the brickearths of the Thames Valley. Believing, as Mr. Wood does, that the Hessle beds are contemporaneous with deposits in the south of England "which for more than a quarter of a century we have been accustomed to call Postglacial," it is not surprising to find him remarking that, had he not called the former beds Postglacial, his contention of their synchronism with Postglacial deposits would have produced great confusion. All this seems sufficiently reasonable and logical, granting, of course, that the premises are correct; but if these are shown to be unreliable, the whole argument necessarily becomes invalidated.

If we examine the history of the term "*Postglacial*," we shall find that it was adopted by Prof. Prestwich in 1864 to designate the period during which the English river-gravels were deposited, because even the oldest of these could be shown to be of later date than the Great Chalky Boulder-clay of East Anglia, which was then regarded as the only clay formation of the Glacial Period.

When, however, it was subsequently discovered that there were newer Boulder-clays than the so-called Upper Glacial, it became clear that some of the river-gravels might belong to the period during which in the more northern parts of England these later clays were being formed. Mr. Searles Wood saw reason to think this was the case; and he says it was expressly with the object of preventing confusion that he called the Hessle beds Postglacial, because they were, in his opinion, synchronous with the *Cyrena*-brickearths.

Finding also that the Hessle Clay did not present the same characters as the older Boulder-clays, that its mode of occurrence was different, and that it was separated from the older beds by a long interval of time (during which the present valley-system of Lincolnshire was carved out), he thought these were sufficient reasons for regarding the Great Chalky Clay as the last term of the Glacial series, and that the extensive denudation which followed the elevation of these Glacial beds into dry land might be taken as ushering in the Postglacial Period.

He considered that this conclusion was supported by the character of the Molluscan fauna of the Hessle Sands; so that in 1872 he thus stated the case*:—"The Hessle beds do not, I contend, belong to the Glacial period at all. They followed the re-occupation of the terrestrial surface by the Great Mammalia, of the rivers by *Cyrena fluminalis*, and of the seas by a molluscan assemblage, not merely all of living species, but one that differs in but a slight degree from that inhabiting the English coast near at hand."

Such are Mr. S. Wood's grounds of belief; and since the division between the two periods, wherever it is drawn, must, to some extent, be an arbitrary line, there would not be any great objection to this classification, provided that the sequence and parallelism in-

* Geol. Mag. vol. ix. p. 174.

volved therein were properly substantiated; with the same proviso he would be right in saying* that, "if we relegate these Hessle beds to the Glacial group, we abandon the age of deposits as the basis of their nomenclature, for the conditions under which they have been accumulated;" and thus, to be consistent, we should bring the Glacial Period down to the present time.

But is the evidence for the synchronism of the early river-gravels with the Hessle gravel and sand so clear and convincing as Mr. Wood believes? Mr. Geikie appears to accept it without question. I venture to think, on the contrary, that this identification has been made on very slender grounds.

In the first place, no direct evidence has ever been obtained. All the localities mentioned by Mr. Wood are beyond the present known extension of the Hessle Clay; and therefore the best test, that of superposition, cannot be applied. No series of river-gravels comparable with those in Cambridgeshire has yet been traced under the Hessle Clay. I looked carefully for such beds in the Steeping valley, but I found a remarkable absence of river-gravels. It is true that Mr. Wood has made one attempt in this direction; he says†:—"The gravels of this formation, which, in the Cambridgeshire Fen, extend southwards to about lat. 52° 30′, are there and over the Fen northwards uncovered by Boulder-clay; but in Holderness they are so covered." Here he assumes that the gravels in Cambridgeshire and Yorkshire belong to one and the same formation; but he cannot point to any kind of physical connexion between the two, and I have published elsewhere the evidence which leads to the conclusion that the March gravels are the estuarine termination of the oldest river-courses in Cambridgeshire ‡, while the Holderness beds are marine deposits of a littoral character: the argument therefore rests on an assumption, and becomes misleading; for it assumes that the former beds are older than the Hessle Clay because the latter are, and concludes that the latter are Postglacial because the former are supposed to be so.

Beyond the general considerations already indicated, there is only one item of positive evidence for the alledged correlation; and this is the occurrence of a particular shell, *Cyrena fluminalis*, in both sets of deposits; that is to say, Mr. S. Wood regards the occurrence of this shell in isolated and widely separated deposits (some of marine and some of freshwater origin) as evidence of their synchronism. But it seems to me that this is to strain palæontological evidence beyond reasonable limits; and I venture to protest against the manner in which Mr. Wood employs such testimony. His argument concerning the beds below the Cromer till is very similar: he would include in the Glacial Series all the deposits which yield *Tellina balthica*—proceeding therefore on the same principle, viz. that the presence of one particular shell may be taken as conclusive evidence of contemporaneity; and he would separate the Norwich Crag from the Weybourn Sands because it does not contain the

* Geol. Mag. dec. 2, vol. v. p. 18 † *Ib.* dec. 1, vol. ix. p. 177.

‡ *Vide* The Posttertiary Deposits of Cambridgeshire, p. 59.

fossil in question—a fallacy which Mr. H. B. Woodward has exposed in his recent address to the Norwich Geological Society*.

Mr. Wood's dependence on the testimony afforded by the presence of *Cyrena fluminalis* has led him into another error; for he groups together the March and Barnwell gravels, which are now found to be entirely disconnected. The danger of trusting to so small an amount of palæontological evidence is thus illustrated. Deposits which contain similar fossil *assemblages* may be compared; but deposits which only happen to contain *one* fossil in common are palæontologically incomparable.

The testimony in favour of the Postglacial correlations is not even of so plausible a nature as that for the Preglacial classification; for *Cyrena fluminalis* is known to have existed previously during the later Crag-formations; it was probably only banished from England during the coldest times of the Glacial Period, and returned whenever the conditions permitted its existence; it is by no means of universal occurrence in the older river-gravels themselves, its distribution being apparently dependent upon climatic conditions and other circumstances; so that it cannot be used even here as an infallible criterion of age: *e. g.* the Barnwell gravels contain it in abundance; but it has not yet been found in the freshwater portion of the older series above mentioned.

I will now examine on separate and independent grounds the probability of any of the deposits indicated by Mr. S. Wood being contemporaneous with the Hessle Sands.

(1) *The Hunstanton Gravel.* The marine character of this deposit, together with its position above the level of the Fenland, lends some colour to the supposition of its synchronism with the Hessle beds. Mr. Wood thus speaks of it†:—"The Hunstanton gravel resembles in its palæontological aspects the Kelsea Hill bed in consisting entirely of living species, and none but those inhabiting British Seas have yet been obtained by us from it. It is not, however, overlain by any thing answering to the Hessle Clay.... neither does the *Cyrena* occur in it." This raised beach has not, indeed, been fully investigated; and its relation to the other drift beds in the neighbourhood is at present unknown. A careful examination would probably lead to some interesting results; for a little south of the point where the Red Chalk rises to the top of the cliff at Hunstanton, a stiff reddish-brown clay takes the ground, presenting a pebbly base and lying in hollows eroded out of the Carstone; it deepens southwards towards the station and becomes more purple in colour. I hesitate even to hazard the suggestion that this may be a form of the Hessle Clay, as the possibility has only lately occurred to me, and my visit to Hunstanton was anterior to my acquaintance with the latter clay.

(2) *The gravels on the North Edge of the Fen.* I have already stated the reasons which induce me to regard these as *probably* of later date than the Hessle Clay (see p. 414). I admit that, where

* Proc. Norw. Geol. Soc. vol. i. p. 50.

† Introduction to Supplement of 'Crag Mollusca' (Pal. Soc.), p. xxviii.

these gravels abut against the Boulder-clay, the obscurity of the ground renders it dangerous to pronounce a decided opinion on the question*. They have not yet yielded any organic remains; but their mode of occurrence near Kirkby and Revesby is suggestive of a fluviatile origin; moreover their inland and upland continuations appear to be true river-gravels, comparable to those long ridges of gravel in Cambridgeshire which have been described by Mr. Penning and myself—records of a river-system which is older than the valleys of the present streams†. The great outspread of sand and gravel round Tattershall may be the estuarine termination of these ancient Lincolnshire rivers: this is the conclusion to which I am led by the mapping of the district, in its present stage; but the completion of the survey will doubtless throw more light on the matter.

(3) *The March Gravel.* There is no direct connexion between this and the gravels on the north edge of the Fen, as Mr. Wood's language would lead us to suppose. If, however, we assume what I have just indicated as probable, viz. that the remarkable series of ancient river-gravels which occur in Cambridgeshire and Lincolnshire are coeval, then we may naturally conclude that what appear to be their estuarine terminations are likewise of the same age; but as regards the particular epoch of Post-tertiary time to which they belong, we have as yet no testimony which is worthy the name of evidence. We only know that they are of later date than the Great Chalky Boulder-clay; whether they belong to a period anterior or posterior to that which witnessed the formation of the Hessle Clay we have no means of deciding. The probabilities, however, are in favour of their being younger than this clay.

(4) *The Barnwell Gravels.* The mapping of the country round Cambridge demonstrates that these form part of a much newer deposit than the old series of gravel ridges which appear to find their termination at March. They belong to the present, and not to the former valley-system. If therefore the older gravels should eventually prove to be in any way connected with the Hessle series, it is clear that the Barnwell gravel cannot also be of that age; *yet it contains* Cyrena fluminalis *in abundance.* Thus it becomes evident that this shell cannot be depended on as a criterion of age.

(5) *The Nar-valley beds.* Mr. Skertchly looks upon these as newer than the oldest gravels of the Fenland (March &c.) and probably contemporaneous with the beach-gravels‡. This view is antagonistic to that of Mr. Searles Wood, Junior, who thus speaks of them§:—"In all these gravels [Kelsea, Hunstanton, March], as well as in the Nar Brickearth, *Ostrea edulis*, which is absent from all the East Anglian, and, indeed, from all the English Glacial beds, is abundant; and there can be little doubt that the four are synchronous

* A trench carried across the junction-line of the clay and gravel would probably decide this important point.

† Penning, Quart. Journ. Geol. vol. xxxii. p. 191; Jukes-Browne, 'Post-tertiary Deposits of Cambridgeshire,' p. 46.

‡ Geology of the Fenland (Mem. Geol. Survey), p. 235.

§ Introduction to Supplement to the 'Crag Mollusca' (Pal. Soc.), p. xxviii.

and belong to the earlier or *Cyrena fluminalis* part of the Postglacial Period." Now *C. fluminalis* does not occur in the Nar-valley beds; and the *O. edulis* argument is of as little value as that derived from the former shell in other cases. If therefore Mr. Skertchly is right, the Nar beds as well as the Barnwell gravel, will have to be dissociated from the other deposits; and it is quite possible that all four are of entirely different ages.

(6) *The Thames Brickearths.* Since these belong to an entirely different valley-system from that of the fen-basin, it is difficult to see how any absolute correlation, such as that proposed by Mr. Wood, can ever be established. The same remark will apply to the Suffolk and Essex beds containing *Cyrena fluminalis*. They are entirely separated from all the deposits which have any relation to the Hessle beds; and since I claim to have shown that the argument derived from the presence of the *Cyrena* can have very little weight, none but the most general considerations can be brought to bear upon the question. Some results, of an interesting nature and bearing a certain amount of probability, might, indeed, be deduced from a comparison of the fluviatile deposits in the valleys of the Cam and Thames; but the materials for this have only recently been obtained. It may be pointed out that the brickearths with *Cyrena* are not the oldest deposits of the Thames valley; they belong to the lower terraces, which are separated from the higher and older gravels by as wide an interval as that which marks off the Barnwell beds from the older gravels in Cambridgeshire.

Mr. James Geikie * and Mr. Skertchly †, in discussing the age of the Palæolithic deposits, have put forward certain theoretical considerations in support of their view that these beds are of Preglacial and Interglacial age. They draw attention to the fact that the palæolithic implements are generally associated with a mammalian fauna which is very different from that of the Neolithic times, and suggest that the gap between these two periods was caused by the recurrence of glacial conditions.

Mr. Geikie asks, "Why are palæolithic river-gravels restricted to the south-east of England, while neolithic remains occur broadcast throughout these islands? What is the reason for the limitation of the southern mammalia to one small area in the south-east? and why should the mammoth and woolly rhinoceros occur so abundantly in the valley-gravels of that district, while they appear so seldom in the valley-gravels of the north?" The answer which he gives to these queries is, that "the palæolithic deposits are of preglacial and interglacial age, and that none of them are Postglacial."

His arguments are ingenious and worthy of all consideration; but other answers may be given to these questions; the length of the postglacial period may have been greater than he supposes; and the evidence, though somewhat cumulative, is not uniform or entirely convincing. I am inclined to regard even the oldest river-gravels in the south-east of England as truly of Postglacial date, *i. e.* newer than the Hessle Clay; but I grant they *may be* of any age

* Great Ice Age, p. 531. † Geology of the Fenland, p. 208.

later than the Chalky Boulder-clay. All I have attempted to show in the preceding pages is, that the grounds on which the older gravels have been correlated with the Hessle Sands cannot be sustained in the light of more recent researches; and I contend that it is wiser to suspend our judgment concerning the relations which they bear to the Glacial series until more positive evidence has been obtained.

Appendix.

The Deep Well at Boston.

Great importance has recently been given to the details of a deep boring at Boston, which was executed in 1828, and a record of which is preserved in Thomson's 'History of Boston.' This account has been reproduced in the 'Memoir on the Geology of the Fenland,' by Mr. S. B. J. Skertchly. Depending on this record, and mainly on the fact that between the depths of 523 and 530 feet "clay, shells, and *flints*" are said to have occurred, Mr. Skertchly regards the section as giving evidence of the extension of the Glacial series to the enormous depth of nearly 600 feet below Boston.

I cannot but think, however, that the evidence on which this supposition rests is too weak and uncertain to support so startling a conclusion. The description of the beds said to have occurred in the last 80 feet is certainly very extraordinary; but a boring can never be considered of the same evidential value as a section which has at any time been open to observation, and this boring is 50 years old; so that no questions can be asked of the well-sinker. Every one who is accustomed to the reports of such persons is aware of the extraordinary terms they sometimes use, of the necessity there often is for personal cross-examination, and of the liability to error arising from stones and other substances falling into the bore: this error is particularly difficult to eliminate; and I think it may account for some of the appearances in the present case.

Furthermore it is always necessary to translate such accounts into geological language; and it is not always safe to accept the well-sinker's terms in a literal sense. Now in this particular record frequent mention is made of *shells*, *shingle*, and *flint*; and Mr. Skertchly lays great stress on the occurrence of the last of these, because he thinks "this substance can hardly have been mistaken for any other material"*. Mr. Penning, however, has drawn my attention to the fact that in Cambridgeshire the term "flint" is said to be sometimes applied to hard beds and concretions in the Oolitic clays. Speaking of a rocky band in the Oxford Clay, Prof. Seeley says "the workmen call it 'flint,' a name I have also found given in the surrounding district to the septarious concretions of the clays"†.

The *shells* may, of course, be actual fossil shells (*Ostrea*, *Gryphæa*, &c.); but a substance, which was probably selenite, has been described to me as coming up "in bits, like shell or pumice-stone." What the *shingle* may have been is hard to say; but it would be

* Geology of the Fenland, p. 211.

† Seeley, Ann. & Mag. Nat. Hist. ser. 3, vol. x. p. 104.

rash to assert that it can only mean gravel or pebbles; for instance, when it is stated that at a depth of 484 feet "shells, shingle, and clay" were found resting on sand, a *nodule-bed with shells or selenite* forming the base of the great mass of clay may here be indicated: this is merely suggested as a possibility, and as showing how entirely the geological value of the record depends on the interpretation of the terms and details.

I hardly think that we have in this section a reliable basis for such an important theoretical superstructure as that which Mr. Skertchly has built upon it. It is too much to conclude, merely on the strength of this boring, that during the formation of the Middle Glacial Sands the land stood 500 feet higher than it does at present*, especially as the only other deep boring near Boston does not show a trace of such sands below the Boulder-clay, the base of which was reached at a depth of 166½ feet.

It is, on the contrary, quite possible, not to say probable, that the greater part of the boring lies in the Kimmeridge and Oxford Clays. Beds of rock and sand are known to occur in and between these clays not far to the southward; and the isolated reef at Upware attests the occasional and local development of the Coral Rag. Referring to the rock which is reported as reached at a depth of 508½ feet, Mr. Skertchly thinks it was probably a large boulder, since it took four days to pierce, "which would not have been the case had it been a Septaria in the Kimeridge Clay." But a septarian concretion is not the only alternative; and this depth would probably be below the limit of the Kimmeridge Clay: the rock may be a band, like that which occurs at Elsworth, in Cambridgeshire, and for testimony to the hardness of which I may refer to Prof. Seeley's description†. Moreover another "rock" is stated to have occurred 30 or 40 feet lower down in the section.

Now, assuming that the lower part of the boring is in the Oolitic series, it becomes important to determine, if possible, the base of the Boulder-clay; and, in the first place, it may be noted that the boring at Fossdyke (only 7 miles south of Boston) reached the bottom of this clay at a depth of 166½ feet, passing immediately into Kimmeridge Clay, with septarian bands, which was bored to a further depth of 159½ feet. If we examine the account of the Boston well, we find that stones are repeatedly mentioned as occurring in the clay down to a depth of 190 feet, but that below this there is no recorded occurrence of stones throughout a thickness of 294 feet. All this portion of the section is described as "dark clay, with shells," except a band in the middle, 22 feet thick, of "light slate-coloured clay, with large shells." Such a description applies far better to the Kimmeridge or Oxford Clay than to Boulder-clay; for it would be surprising that no stones should have been met with in boring through a thickness of nearly 300 feet of the latter. Moreover, if we place the base of the Boulder-clay at 190 feet, the section then agrees

* See 'Geology of the Fenland,' p. 218.

† Ann. & Mag. Nat. Hist. ser. 3, vol. x. p. 99.

very fairly with the more recent and more accurately described boring at Fossdyke.

The beds below the depth of 484 feet will have a more natural aspect if they are dissociated from the artificial grouping presented by the daily report; for it is clear that one and the same bed often enters into the report of two or more days' progress. In the following, therefore, we have what appears to be the natural descending order of the strata said to have been met with in the last 88 feet:—

		feet.
Shells, shingle, and [? in] dark clay	about	1
Fine sharp sand	more than	5
Dark clay, with shells in the lower part	from 10 to	15
Shingle, flints, and shells		3½
Rock (apparently very hard)		2
Stones mixed with clay, shells and flint near the bottom		19½
Stone, shells, and rock [? rocky layers]		18
Dark clay		7
White sand		11
Umber-like earth		6
		88

Any one reading the original account will see that the terms and expressions employed are those of an ignorant writer; and, making allowance for this, it would seem quite possible that the beds above indicated may really be strata of a local and exceptional character in the upper part of the Oxford Clay. The junction of the Kimmeridge and Oxford Clays in South Lincolnshire is concealed by the overlying fen-deposits, so that we have no means of knowing what beds may or may not be developed about their line of junction.

Without further discussion of this matter, the following generalization of the section seems to me a more probable one than the interpretation proposed by Mr. Skertchly:—

		feet.
Loose earth and silt	Fen-beds	24
Hard earth, mixed with stone and clay.	? Hessle Clay	26
Clay and shells. Clay and flints. Clay and stones.	Boulder-clay	140
Dark clay and shells. Slate-coloured clay, with shells. Dark clay and shells.	Oolitic clays	294
Alternations of sand, clay, "shingle," "stones," and rock.	Beds in or above the Oxford Clay	88
		572

It will be noticed that I have ventured to insert the Hessle Clay. This is, of course, subject to future correction; but the terms used to describe the upper 26 feet of clay are different from those employed afterwards, so that the depth of the Hessle Clay may be indicated here if the conjecture of its occurrence at Boston should prove to be correct.

33. Vectisaurus Valdensis, *a new* Wealden Dinosaur.

By J. W. Hulke, Esq., F.R.S., F.G.S. (Read April 30, 1879.)

[Plate XXI.]

On the 13th of October, 1871, I found, weathered out, lying on the cliff-foot, 300 yards east of the flagstaff near Brixton Chine, Isle of Wight, the fossil remains now submitted to the Society. The extreme autumnal heat had much cracked the surface of the clay in which the bones had been entombed; and these also were shattered into numberless small fragments, most of which could not be joined, so that parts of six vertebræ and of a large flat bone, which I regard as an ilium, were all that could be recovered. Since then I have several times revisited the spot in the hope of finding other portions of the skeleton, but fruitlessly; and as the cliff-foot is now wasted back to such a distance as to make the recovery of it most unlikely, the time has come when, without incurring the charge of undue haste, I may bring under the notice of the Society these evidences of what I venture to think will be received as a new Dinosaurian genus.

Vertebræ.—Of these, four (Nos. 24 (figs. 4–7), 25, 26, 28)* are præsacral, and one (No. 27) postsacral (Pl. XXI. figs. 2, 3). Of the four præsacral vertebræ, three are centra, each retaining its neural arch, and one is represented by a detached neural arch. These præsacral centra are all opisthocœlous. The hollowness of the posterior articular surface (fig. 6) is so decided that its figure may be properly described as cupped. The anterior articular surface (fig. 5) is, in its present state, nearly plane; in none does it exhibit a convexity such as might have been inferred from the hollowness of the posterior surface. This apparent want of correspondence of figure of the two articular surfaces may be due to removal by post mortem maceration of the fibro-cartilaginous layer clothing the fresh bone, the effect of which would be to lessen the convexity and deepen the concavity. The circumferential contour of the articular surfaces is heart-shaped, that of the posterior being fuller than that of the anterior surface. The neural portion of this circumference is, for the anterior surface, nearly straight, for the posterior surface notched. The outer or non-articular surface is concave longitudinally and convex transversely, which gives it the figure of a laterally flattened cylinder bluntly keeled below. A narrow mesial tract of the upper surface of the centrum, visible between the neurapophyses, forms the floor of the neural canal. The neural suture, perceptible in the three vertebræ, descends slightly on the lateral surface of the centrum. Relatively to the length of the centrum, the antero-posterior extent of the neurapophyses is considerable. One vertebra (No. 24, figs. 4–7) retains both præzygapophyses and transverse processes. The former look almost directly upwards with a slight inward slant. The transverse processes are

* The numbers refer to the Catalogue of my collection.

stout and trihedral. Extending directly outwards, they reach to nearly 1·3 inch beyond the root of the neural spine. Their upper surface is a flat triangular table with a rounded apex at the free end. The anterior border, stouter and shorter than the posterior, is impressed with a rib-pit close to the præzygapophysis; and the free end of the process is distinctly articular. The posterior border is produced backwards along the summit of the neural arch to the postzygapophysis, which gives to the transverse process the platform-like figure which has been considered characteristic of Dinosauria. The under surface of the process is upborne by a buttress which, beginning near the posterior inferior angle of the neurapophysis, is directed upwards and forwards, and extended nearly to the free end of the process. No. 28, a neural arch, somewhat squeezed by post mortem pressure, which has become detached from the centrum along the suture, has a similar transverse process to No. 24; but this slants backwards more than directly outwards, and a longer space intervenes between the capitular costal pit near the præzygapophysis and the tubercular articulation at the free end of the process. The anterior border of the process between the two rib-joints has also a linear indentation, against which the rib, when articulated, rested, as in extant crocodiles. The præzygapophyses have a stronger inward inclination in this vertebra than in No. 24. I regard this vertebra (No. 28) as dorsal, and as corresponding nearly to the 15th or 16th præsacral vertebra in *Crocodilus niloticus*. Nos. 25 and 26 are in undoubted natural sequence, the left postzygapophysis of No. 25 being cemented by fossilization to the corresponding præzygapophysis of No. 26. The neural arch is loftier than in No. 24; and the transverse process (lost) appears by its root to have been more slender. The postzygapophyses very considerably overhang the posterior plane of the centrum. The neural spine, which was broken off but lying in juxtaposition with its centrum, is an oblong blade about 4 inches high and having near its free end an antero-posterior extent of 1·2 inch. Its front border is thin; its posterior is cleft towards the base by a deep groove, which, in the articulated vertebral column, received the anterior border of the spinous process of the vertebra behind it.

The postsacral vertebra (figs. 2, 3) has lost its neural arch, which has become separated at the suture. Both articular surfaces are decidedly concave. Their circumferential contour is subcordate: the upper portion, straight, is the widest part of the centrum; it meets the lateral portions somewhat angularly. The lateral surface of the centrum is concave longitudinally, and nearly plane vertically from the neural suture to the lower border, which it meets in a slightly angulated ridge that begins behind at the chevron facet, and is separated from the ridge of the other side by a shallow median depression. On the posterior border of this, the inferior surface of the centrum, the chevron facet is very conspicuous, and it seems almost subdivided. The transverse process (lost) was attached at the line of junction of the neurapophysis and centrum. I take this vertebra to have been not far behind the sacrum, at the root of the tail.

The bone (No. 22) which I regard as an ilium (fig. 1) consists of a deep, flattened, oblong plate, of which one border, the upper, is produced in the form of a stout process for the distance of about 3·5 inches. Towards its free end this process is compressed; and at its base its lower margin curves downwards and then forwards to form with the angle of the lower border one horn of the segment of a circle which constitutes all that remains of this border of the bone. This concavity, which appears to me to be articular, I regard as the iliac portion of the acetabulum; and I look upon the angle just mentioned as the pubic attachment, and the process above it as the præacetabular. That which I consider to be the outer surface of the wide plate, or body, of the ilium is sinuous, being alternately slightly concave and convex, from above downwards; whilst the inner or mesial surface has a stout ridge produced backwards from the præacetabular process, and marked above the acetabulum by pits, which I take to be the impressions of the attachments of the sacral ribs. The remaining fragments of this bone show its postacetabular portion to have been of large extent; unfortunately they could not be reunited so as to give its figure.

The characteristic form of the ilium, with its long præacetabular process, would alone suffice to place the animal represented by these remains in the order Dinosauria; and the wide platform-like root of the transverse process springing from the summit of the lofty neural arch in the dorsal vertebræ corroborates this reference. From the earlier and later Mesozoic Crocodilians with constant amphicœlous centrum (*Teleosauri*, *Goniopholis*) it is easily distinguished by its opisthocœlous dorsal centra. From *Suchosaurus* *, Owen, which it somewhat resembles in the keeled lower border of the centrum, it may be distinguished by the subcordate contour of the articular ends of the dorsal centra. A comparison also of No. 28 with a dorsal vertebra of *Suchosaurus* in which the capitular costal facet occupies the same position relatively to the præzygapophysis as in No. 24, and is therefore presumably from the same part of the vertebral column, shows that in this new Saurian the basal width of the transverse process is much greater relatively to the length of the process than it is in *Suchosaurus*. From *Iguanodon Mantelli* it is easily known by the different form of the ilium and of the caudal vertebræ, as also by the characters of the dorsal vertebræ just described. These criteria also serve to distinguish it from the allied *Hypsilophodon Foxii*. It may be thought incumbent on me to establish its distinctness from *Streptospondylus*; the opisthocœlian form of the dorsal vertebræ seems to require this, convexo-concave vertebræ such as are usually referred to the genus *Streptospondylus*, being not unfrequently found in the Wealden beds in the Isle of Wight. From those of *Streptospondylus recentior*, Owen †, and *S. grandis* (young individuals are of course imagined) my vertebræ differ so obviously in figure and in texture that a mistake is not possible. As little necessary is a formal proof of their distinctness

* From evidence in my possession I rather incline to regard *Suchosaurus* as not improbably a Dinosaur.

† Mantell, Fossils of British Museum.

from *Poikilopleuron*, remains ascribed to a small species of which, *P. pusillus*, are described and figured by R. Owen in the Pal. Soc. Mem. 1876.

For this new Wealden Dinosaur, represented by the remains which I have the honour of now placing before the Society, indicating an individual about 3 feet long, exclusive of tail, I propose the name *Vectisaurus valdensis*, a name suggestive of the locality, *Insula Vectis*, and the formation whence I obtained it.

In the form of the antacetabular process it shows a nearer resemblance to the Iguanodontidæ than to the Megalosauridæ.

EXPLANATION OF PLATE XXI.

Fig. 1. The right ilium, inner surface. *ac*, acetabulum; *pb*, its pubic process; *pr. ac*, præacetabular process.

Fig. 2. Caudal vertebra, posterior surface. *n*, neural canal; *ns*, neurapophysial suture; *ch*, chevron facet.

Fig. 3. Under surface of same.

Figs. 4–7. Thoracic vertebra. Fig. 4, viewed from above; fig. 5, from in front; fig. 6, from behind; fig. 7, side view. *d*, diapophysis; *p*, parapophysis; *prz*, præzygapophysis.

(The figures are of the natural size.)

Discussion.

Prof. Seeley asked the author to what form of Dinosaurs the new genus appeared to him to be most closely related. That the specimens were Dinosaurian, and belonging to a perfectly new genus, there could be no doubt whatever. He remarked that the ribs were united to the termination of the transverse processes of the vertebræ, and that the neural spine was deeply cleft in form.

The Author replied to Prof. Seeley that he regarded the form he had described, as most closely allied, especially in the great length of the præacetabular process, to the Iguanodontidæ; and he pointed out on the transverse process a double costal articulation.

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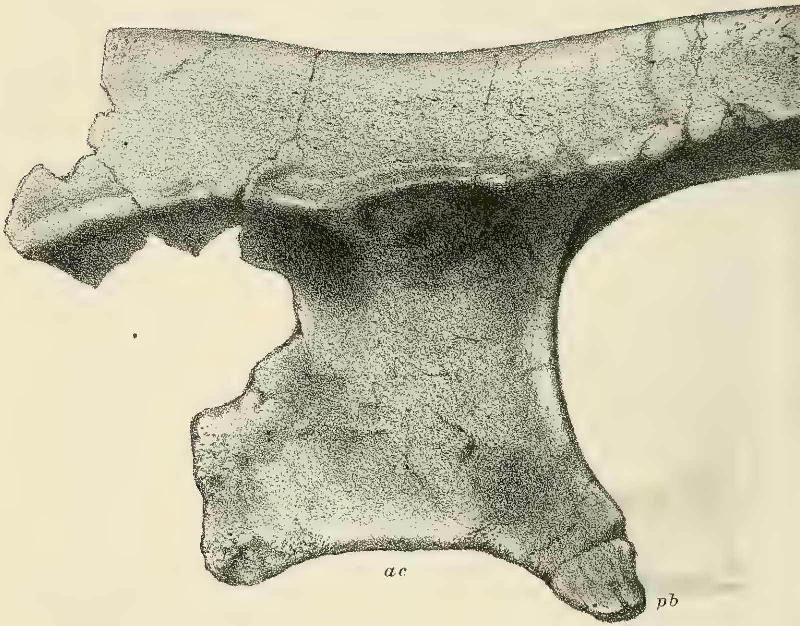

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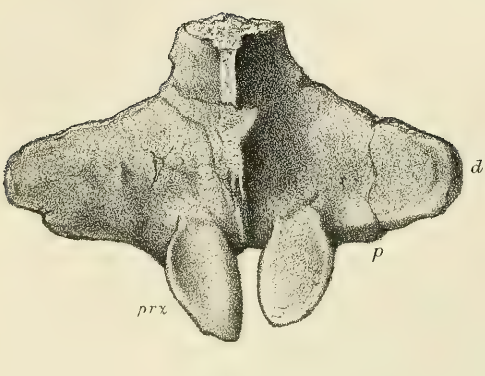

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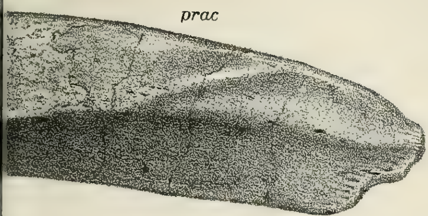
C. Berjeau del.

ILIUM AND VERTEBRÆ (



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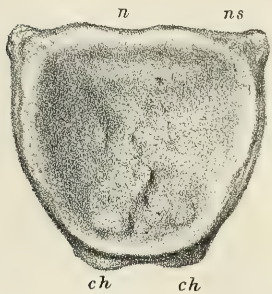

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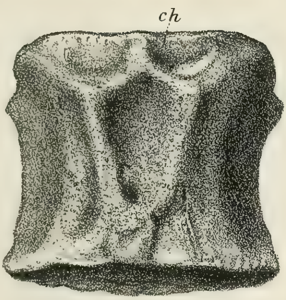

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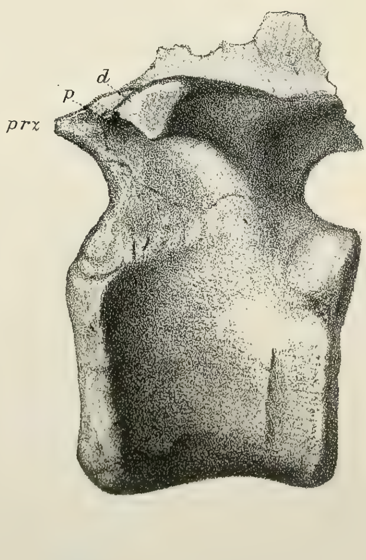

6.

Mintern Bros imp.

VECTISAURUS VALDENSIS.

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Mintern Bros imp.

ILIUM AND VERTEBRÆ OF VECTISAURUS VALDENSIS.

34. RESULTS *of a* SYSTEMATIC SURVEY, *in* 1878, *of the* DIRECTIONS *and* LIMITS *of* DISPERSION, MODE *of* OCCURRENCE, *and* RELATION *to* DRIFT-DEPOSITS *of the* ERRATIC BLOCKS *or* BOULDERS *of the West of* ENGLAND *and East of* WALES, *including a* REVISION *of many Years' previous* OBSERVATIONS. By D. MACKINTOSH, Esq., F.G.S. (Read March 26, 1879.)

[PLATE XXII.]

CONTENTS.

I. INTRODUCTORY REMARKS AND DEFINITIONS.

[THOUGH long familiar with the erratic blocks or (as they are now more generally called) boulders of the west of England, and though I had written many papers on the subject, which appeared in the 'Quart. Journ. Geol. Soc.' and 'Geological Magazine,' I lately saw the necessity for a systematic revision of what I had done, and more especially for an extension of my observations in a south and south-east direction, where they could be made to throw some clear light on the nature and sequence of glacial events*. As no attempt has hitherto been made to treat the subject of erratics as a distinct branch of science, and as most readers might probably expect to find in a paper on the subject little more than an inventory of facts, it may be well to begin with a few remarks and definitions calculated to excite a scientific interest in the subsequent detailed statements.]

1. *Importance of Boulders as a Key to the Interpretation of Glacial Events—Relative Claims of Land-ice and Floating ice.*—Notwithstanding that very few writers on the Glacial period have paid much attention to boulders (one distinguished glacialist told me that he purposely avoided them), I think it can be shown that in an area such as that extending from the south coast of Scotland to the west-midland counties, the positions and directions of dispersion of various kinds of boulders must be capable of throwing much light on the character and mode of action of the ice by which they were transported. An illustration of this may be found in the truly wonderful concentration of granite blocks west and north of Wolverhampton,

* In this undertaking I was aided by the Government-Grant Committee.

the derivation of which I traced many years ago. They must have been carried by a sheet of land-ice fifteen miles in breadth, or by great masses of floating ice; and the blocks must have fallen where the air or the water was sufficiently warm to melt the ice so as to prevent their further transportation; for they terminate too abruptly, and on too extensive a scale, to admit of any other supposition. If land-ice, according to the principles of dynamical science, could not have moved 170 miles on level or undulating ground, without the slightest general fall in the direction of the movement, but, on the contrary, a very considerable rise towards the extremity of its course, then floating ice must have been the transporting agent (see II. § 8). Numerous other instances, showing the importance of boulders as a means of determining the kind of ice-action, will be described in the sequel. Boulders are likewise important as a means of correlating the different deposits of clay, gravel, or sand in which they are imbedded. In this respect they are often more reliable than marine shells, because the latter may have varied with the "submarine climate" of the area over which the invariable erratics were dispersed. Marine shells, however, are very important as indications of changes of climate during the accumulation of drift-deposits in *vertical* succession, as lately shown by Mr. Shone, F.G.S., of Chester, and Dr. Gwyn Jeffreys, F.R.S. (Quart. Journ. Geol. Sec. for May 1878).

2. *Generalization of Facts not premature.*—It has been suggested that for some time to come observers of glacial phenomena should content themselves with collecting facts, and leave the task of generalization to some one who at an indefinitely remote period may be able to collect the results of numerous observations, and frame a general theory of the glacial episode. It ought, however, to be considered that no authors can generalize facts so well as those who have discovered or observed them, and that the progress of science may be obstructed, instead of advanced, by philosophers making systems out of phenomena with which they are not practically acquainted. A mere theorizer is apt to be influenced by what may be called *à priori* likelihood; whereas a practical observer of glacial phenomena finds himself often reduced to the necessity of admitting what he would never have expected. This arises partly from the *abnormal* character of the phenomena with which he has to grapple.

3. *Identification of Boulders—Tests and Countertests.*—To find out the parent rock of a boulder, of course requires that specimens should be compared; but one specimen of each is seldom sufficient, and, unless the rock be very peculiar in composition and structure, it is not always safe to rely on a number of specimens. Where the character of the parent rock is varied and it is possible to trace a similar variety in a single boulder or group of boulders, the work of identification becomes less hazardous. In the case of Criffel granite there is a variety in the rocks *in situ* which is represented among the boulders scattered over the plain on the opposite side of the Solway Frith, and likewise prevalent on the beach north of Parkgate, Cheshire. One variety strongly resembles Mull granite (which

at first sight might be mistaken for the granite of a part, at least, of Cleopatra's needle); but on this beach, in different boulders and pebbles, it can be seen graduating into the typical Criffel. The Arenig rocks *in situ* vary from compact felstone to consolidated volcanic ashes; but all the gradations may be found among the boulders which, at different heights, have been scattered east and north-east. Tracing boulders continuously back to their sources, where it can be done, is the most reliable means of identification. It may here be remarked that it is better to give a general or geological name to the kind of rock of which a boulder consists than a very precise mineralogical name, because many single boulders are large enough to embrace more or less variety in their structure and composition. The appearance of the weathered surface is often almost sufficient to identify a boulder; and the shape and size ought not to be left out of consideration. The Arenig-felstone and Criffel-granite boulders are often very large, almost invariably angular or subangular, and seldom glaciated. The Eskdale-granite and Lake-district-felstone boulders vary in size; but they are generally smaller than the boulders just mentioned, and in most instances are rounded, smoothed, and more or less glaciated*.

4. *Intercrossing of Courses of Boulders.*—In mapping the directions in which boulders have been dispersed, no fact is more clearly brought out than the intercrossing of the courses, not only of local with great boulder-dispersions, but of the latter with each other. For instance, the Eskdale granite which went to Burton (Shropshire), must have crossed the course of the stream of Criffel granite which went to the west and north of Wolverhampton, because Eskdale is situated east of Criffel; and Burton west of Wolverhampton. It is possible that on a small scale this intercrossing of routes may have been effected contemporaneously by upper and under boulder-bearing currents; but it is not likely that the above two large dispersions should have forced their way across each other without being either broken up or commingled to a very much greater extent than is actually the case in their terminal concentrations. As we have reason to believe (see § 5, 7) that boulder-laden currents would change their courses with the rising and falling of the sea-bed, as well as with changes of temperature, it seems most likely that the crossing of the courses of great boulder-dispersions occurred at *different periods*. The great Arenig stream of boulders would appear to have crossed the previous route of the Burton dispersion after the land had become much more deeply submerged (see IV. § 3).

5. *Conterminous Granite and Felstone Dispersions—Effects of local Obstructions.*—Granite and felstone from the Lake-district and granite from Criffel may all three have been transported at different times. In that case nothing but *persistent* (for the required time) local obstructions could have caused their *frontal* boundaries to coincide; and these obstructions may have consisted of suddenly rising ground,

* I may here mention that I have nowhere found a greater amount of agreement in the direction of the longer axes of large boulders than might reasonably be referred to chance.

or suddenly increasing temperature, or both; and land-ice as well as floating ice would be vulnerable to both these kinds of obstructions. Rising ground would furnish the most permanent and fixed obstruction to the transportation of boulders; but in those places where the frontal termination of boulder dispersions is not coincident with rising ground, contermineity of granite and felstone dispersions could only have resulted from close proximity to a persistent current of water (or air?) sufficiently warm to melt the boulder-laden ice. In this way the sharply defined frontal boundary of the Criffel-granite and Lake-district-felstone boulders at Bushbury (near Wolverhampton) may have been made to coincide; for there the rise in the ground is not sufficient to have furnished an obstruction (considering the height of the ground the boulders must previously have surmounted). Neither is the rising ground between Wolverhampton and Bridgenorth sufficiently continuous to have obstructed the further transportation of boulders. A warm current in front, however, would not cause lateral contermineity; and we accordingly find that the Bushbury granite and felstone boulders are not laterally conterminous. As regards the granite and felstone of the Lake-district, their proximity to each other *in situ* renders it likely that in many instances they may have been launched at the same time and kept company until they encountered one of the local obstructions already noticed, in which case they may have been conterminously precipitated both frontally and laterally, as in the case of the Burton concentration (see III. § 7).

6. *Overshot Boulder-loads.*—So far as has yet been discovered, there would appear to be different boulder-groups, like fallen loads, which occur along the same lines of dispersion too regularly to admit of the supposition that one deviated from its straight-onward course so as to come in front of or behind another. In these cases it may be allowable to suppose that one of the boulder-loads came to rest before the other passed over its site, and was precipitated a greater or less distance in advance of it, so as to prevent a commingling of the two boulder-loads. These may be called overshot boulder-loads; but the term may likewise be applied to loads which have passed over the sites of previously precipitated loads obliquely, and not along the same lines of dispersion. Of both these kinds of loads instances will be noticed in the sequel. Some of them are large enough to be called intermediate concentrations.

7. *Changes in the Positions of Boulder-laden Currents accompanying Changes in Surface-level and Temperature.*—It seems very obvious that currents must have changed their positions, and (with the exception of a general southerly trend in the northern drift-area) their directions, as the land sank and rose; and (as a consequence) the depth of the sea varied. This must likewise have been the case as the temperature of the water changed, not only in particular spots, but over the whole of the boulder-strewn area. Facts mentioned in the sequel would seem to show that during the first stages of the submergence the cold, and consequent extent of floating ice, increased southwards, and that during the last stages (while the land was

rising) the cold and ice decreased northwards. This accords with the fact that many of the boulders which must have gone over great heights are found far south, and likewise with the fact that the boulders in the latest of the deposits left by the *great* submergence gradually die out until they disappear in the low-level sands of the Cheshire and Lancashire plain. It is probable that the maximum of cold (during the submergence) was not reached until the land had sunk to a considerable depth. It must have taken much thick ice to transport the myriads of large granite blocks found as far south as Wolverhampton—blocks which could not have reached their destination without a submergence of at least from 500 to 650 feet. It must have taken still thicker ice to have transported the larger Arenig boulders now found around the Clent and Lickey hills, boulders which could not have cleared the Welsh mountains under a less submergence than 1000 feet, at a time when the "cold wall" had been pushed to its extreme southerly position. This low temperature may possibly have continued until the submergence had reached about 1400 feet, the reason for this suggestion being that the shells found on the summit of Moel-y-Tryfaen (near Caernarvon) indicate a colder climate than any shells found at a lower level in the western part of South Britain (see Mr. Shone's paper, Quart. Journ. Geol. Soc. for May 1878, p. 393)*. I do not, however, wish to attach too much value to this suggestion.

8. *Causes of Radiating or Fan-shaped Boulder-dispersions.*—All the great boulder-dispersions, and some of the smaller ones, are more or less *fan-shaped*; in other words, they have radiated from an area much narrower than their terminal breadth. This radiation has occurred not only where the parent area is backed by lower ground, but likewise where it is backed by higher ground, and by ground approximately on the same level. The form of the ground, therefore, has had little to do with the radiating character of the dispersions. The ground behind the parent area is generally destitute, or nearly destitute, of boulders derived from that area. This fact has been advanced as a proof that the distributing agent must have been land-ice, the persistent forward movement of which prevented any dispersion in a contrary or backward direction. The same effect, however, may have been produced by a persistent ice-laden current of water, or by winds mainly blowing from the same point of the compass, but changing their directions within certain limits during the submergence or emergence of the land. It is perhaps worthy of remark, though too much importance ought not to be attached to the fact, that the direction of the main part of the Arenig dispersion coincides with that of the anti-trade winds. The Shap-fell granite †

* The gravel-and-sand (with boulders) very near the highest point of Moel-y-Tryfaen has yielded the following Arctic and Scandinavian shells, which have not yet been found at a lower level in the drifts of Cheshire, Lancashire, &c.:—*Astarte depressa* (*crebricostata*); *Natica affinis*; *Trophon clathratus*, var. *scalariformis*, and var. *Gunneri*.

† Having already, along with other geologists, written on the Shap-fell dispersion, I shall at present only direct attention to the discovery of the *terminal concentration* (with a few stragglers further south) of a stream of Shap-fell

has been chiefly dispersed in much the same direction, the thickest part of both dispersions being in a direction about E.N.E. from the parent area. In the case of the Arenig dispersion the ground behind the parent area is lower than the area itself. In the Shap-fell dispersion the reverse is the case; in other words, the average level of the ground behind the parent area is higher; and this is also the case with the Eskdale area. The Criffel dispersing-area, like the Arenig, is backed by lower ground. In all these cases the ground in front is at the lowest level; and this may have had something to do with the direction of the dispersions. The central direction of the first stage of the Eskdale dispersion is S.S.W.; after its reappearance on the south and east coast of the Irish sea, its central direction is between S. and S.S.E. The central direction of the first stage of the Criffel dispersion may be under the sea, and therefore cannot be ascertained. Southwards it runs S.S.E.

9. *Extent of Area strewn with northern Boulders, and their general Mode of Occurrence.*—Leaving the north, north-east, and east part of the Shap-fell dispersion and the Welsh part of the Arenig dispersion at present out of consideration, the extreme length of the great northern drift-area, from the Solway Frith to the neighbourhood of Bromsgrove (Worcestershire), is nearly 200 miles, and the extreme breadth, from the Forest Smithy (between Buxton and Macclesfield) to Beaumaris*, about 90 miles. Were all the boulders in this area to be disinterred without disturbing their positions horizontally, and were those which have been "massacred," or horizontally displaced, to be restored, and brought to their original sites, I believe they would show little preference for any particular form of ground, whether flat, low, elevated, rising, or falling. As they now exist they are often found on elevated ground; but it is probable that on low ground they are often concealed by the upper Boulder-clay which generally contains very few large boulders. They may often be seen at the bottoms of ravines, where they have been exposed by the brooks washing away the clay or sand in which they were imbedded. They may likewise often be seen accumulated on the upstream side of an eminence or pass; but as regards the latter they are more frequently to be found on the lee side, as if their inertia had carried them forward some distance after grounding. On the large scale the most noticeable fact connected with boulders is their tendency to accumulate near to the commencement or termination of their courses. *Terminal concentrations* may be readily explained by supposing successive accumulation behind (for the required time)

granite blocks around Whasset and Milnethorpe, south of Kendal (Geol. Mag. for July 1871). It must have come from about N. 15° E., or, by way of Kendal, from Wasdale Crag, over ground at least 1300 feet above the present sea-level. Its direction is a little west of the opposite border of the dispersion, which runs north of Wasdale Crag, thus showing that the dispersion radiates over a little more than half a circle. This radiation is not all continuous, however, excepting in the immediate neighbourhood of Wasdale Crag, the Milnethorpe branch being isolated.

* I have not had an opportunity of tracing it further west than Beaumaris.

a permanent obstruction to further transportation. *Initial concentrations* are not so easily explained; but the conjecture may be hazarded that much of the ice which was able to launch the boulders would be incapable of carrying them beyond a small distance. It may likewise be supposed that the parent mountain would protect many of the previously launched boulders in front of it from being carried away, by its interfering with the straight-onward course of currents of air or water or (as some would believe) land-ice. Instances of such concentrations, and also of *intermediate concentrations* arising from local obstructions, will be described in the sequel. Most of the erratic small stones in the northern part of the boulder-strewn area consist of "Silurian grit" from the Lake-district and south of Scotland; and in the plain of Cheshire and Lancashire they are much more frequently flattened and uniformly grooved than any stones of which I can hear in any part of the world, not excepting the neighbourhood of the winter-quarters of the late Arctic expedition*. Among the larger boulders those derived from felspathic rocks generally predominate, excepting in the granite concentrations. Criffel and Eskdale granite come next in order of frequency; and we accordingly find that felstone and granite rocks *in situ* are the most liable to break up into large blocks. In the above boulder-area (away from the Lake-district) I have not seen a single instance of a *perched block*.

II. The great Kirkcudbrightshire Granite-dispersion.

1. *Boulder-supplying Capacity of Criffel—Initial Concentration.* —It is probable that many small Silurian-grit erratics were dispersed from the south of Scotland; but how many it is impossible to say, because (as Prof. Ramsay tells us) they are often quite undistinguishable from Lake-district Silurian grits. The exposures of compact felstone are so limited on the south coast of Scotland as to render it improbable that many of the large felstone blocks of the northern drift-area came from that quarter. It must, however, have sent off a considerable number of large blocks of metamorphic rocks and a few of Silurian grit and slate, as they may be found scattered as far south as the terminal concentration west and north of Wolverhampton. The granite-dispersing capacity of Kirkcudbrightshire must have been very great. There are three granite masses many miles in diameter, but Criffel mountain and the neighbourhood would appear to have sent off the great majority of the boulders. Many parts of the mountain are now covered with loose granite blocks, and the configuration of the ground may have admitted of small glaciers, on the sides of which angular blocks may have fallen. Nearly all the Criffel blocks (as already stated) are angular or subangular, excepting where an approximately spheroidal structure probably existed; and they may have been transported on

* Mr. De Rance, F.G.S., who examined the stones brought home by Capt. Feilden, informs me that they were not so distinctly glaciated as those of the Cheshire and Lancashire plain.

the tops of small icebergs after the sea became deep enough to float them, or they may have escaped being rounded on the sea-shore before being launched by floating coast-ice. I chiefly observed the Criffel boulders on the plain of Cumberland opposite the mountain, where they are very numerous, though I was not able to trace them to a greater height than about 400 feet. Nearly all the different kinds of granite found in the mountain and about Dalbeattie are represented in the south-west part of the plain; but the large-grained granite, or granite with large crystals of felspar, from the lower part of the mountain greatly predominates*.

2. *Dispersion to North Wales.*—Kirkcudbrightshire granite has found its way in small quantities to North Wales, where it may be found along the coast at intervals from Flint to Colwyn Bay, and thence to Penmaenmawr and the neighbourhood of Beaumaris. In the eastern part of North Wales it has seldom penetrated far into the interior, the furthest south boulders of it I have seen being about one mile south of Denbigh, near the Ruthin road. In the western part of North Wales it has gone as far south as the top of Moel-y-Tryfaen, where I found pebbles of it at a height of nearly 1400 feet above the sea. It was accompanied by Eskdale granite; and in the same drift-gravel I found a pebble of unidentified red granite, precisely similar to one I found on the beach of West Cumberland and to another I saw on the beach at Blackpool.

3. *Course of Dispersion along the west Border of the Cumberland Mountains, &c.*—It is impossible to say how much of the Criffel dispersion lies under the Irish Sea. On the coast south of Workington it becomes very narrow; and further south the great road from Whitehaven, by way of Egremont to Ravenglass, roughly describes its eastern boundary. Near St. Bees it comes into rectangular collision with the exodus of fine-grained syenite from Ennerdale. About Drigg it crosses to some extent the course of the commencing Eskdale-granite dispersion, and along the coast becomes slightly intermixed with it; but before reaching the mouth of the estuary of the Duddon, the Criffel boundary goes under the sea to remain concealed† until its reappearance in the neighbourhood of Blackpool, where it is well represented on the beach. From Blackpool south-east I have not explored the boundary, though it probably runs in the direction of Manchester, where, in the Peel-Park "bouldery," I saw one Criffel along with nineteen Eskdale granite boulders. East of Manchester, Criffel boulders are very scarce.

* Criffel granite always contains more or less black mica, a characteristic by which it may generally be distinguished from Eskdale granite; but most of the granite blocks of the *initial* concentration on the plain of Cumberland contain comparatively little black mica. The largest blocks I saw were on the sea-coast at Flimby. Four of them measured about $8\frac{1}{2} \times 7 \times 3$ feet. They presented a rudely linear structure, and one of them contained a dark "whinstone" patch about two feet in diameter. Such patches are very characteristic of Criffel granite, but not exclusively confined to it. Criffel blocks have gone over the plain of Cumberland as far east at least as Gilsland, and up the valley of the Eden (in the teeth of the Shapfell dispersion) further south than Penrith.

† Criffel granite might probably be found among the large granite boulders of Walney island, which I have not seen.

4. *Dispersion to Macclesfield Forest—furthest east and highest Boulders.*—From the neighbourhood of Manchester the east boundary of the Criffel dispersion crosses the western slopes of the Pennine hills to the interior of the very hilly and almost treeless region called Macclesfield Forest. At Macclesfield I took little notice of the transplanted boulders, so as to have more time to examine those *in situ*, or nearly so, on the hill-sides further east. The larger boulders on or near to the Buxton road are chiefly Lake-district felstone and Eskdale granite, the smaller chiefly Lake-district felstone and Criffel granite. In front of and around the 'Setter Dog' inn there are many small Criffel boulders. The highest I could find was about half a mile from the 'Setter Dog,' on the side of the road called Dirty Gate or Chapel Lane, which leads from near the 'Setter Dog' to Forest Chapel. It was associated with three small felstone boulders close to an unroofed cowshed, at a height of about 1400 feet above the sea*. Boulders had previously been reported up to this height by the eminent geologist Mr. Binney, F.R.S., without, however, specifying Eskdale or Criffel granite. The approximate identity in altitude between the Dirty-Gate Criffel boulder and the Moel-y-Tryfaen Criffel pebbles seems to favour the idea of the uniform emergence of the land from the glacial sea. The spot where the sea-shells were found by Prof. Prestwich (1200 feet above the sea) could be looked down upon from the site of the highest Criffel boulder; but as more or less rounded pebbles could be seen all the way between the two, it is possible that a diligent search might disclose gravel with shells at a higher level than 1200 feet. From Macclefield Forest the Criffel boundary runs south along a line not further west than Stoke-on-Trent (where, in clay-pits, I found Criffel predominating over Eskdale granite), Stafford, and Bushbury. Further east than this line a little Criffel granite might be found; but I have not been able to see any as far east as Lichfield. Among the thousands of pebbles which have been brought from the neighbourhood to pave the streets of Lichfield I could detect no granite of any kind, though a coarse kind of Carboniferous grit, which at first sight somewhat resembled granite, might occasionally be seen, and I found a pebble of a dark kind of felspathic rock (probably from Charnwood Forest). In Stafford there are several large boulders of Criffel granite, and in the street pavements a considerable number of Criffel pebbles. At Ashflat clay-pits, south of Stafford, a few Criffel boulders and pebbles may be seen.

5. *Dispersion over the Peninsula of Wirral, Cheshire Plain, &c.—furthest west and highest Boulders.*—One of the main boulder-streams from Criffel would appear to have curved round the west border of the Cumberland mountains, and then gone S.S.E. along the present

* The summit of the eminence on the side of which these boulders occur is 1571 feet above the Ordnance-datum plane; but I could see no trace of rounded gravel or boulders higher up than about 1400 feet. On the summit and declivities of Shining Tor, about six miles east of Macclesfield, I could see no boulders. This eminence is one of the highest of the Pennine range, being upwards of 1700 feet.

bed of the Irish Sea to the peninsula of Wirral and the south-west corner of Lancashire around Liverpool. In the higher part of Liverpool Criffel granite greatly preponderates over Eskdale, and in the back streets there are many large boulders of this granite, which we have no reason to suppose were brought from any considerable distance. In the excavations for the New North Docks numerous large boulders of Scottish "greenstone" were found. But it is chiefly in the peninsula of Wirral, between the estuaries of the Dee and Mersey, that Criffel-granite boulders are found; and there they are associated, not only with "greenstone," but with numerous large boulders of felstone, felspathic porphyry, and strongly marked felspathic breccia (from the Lake-district), which, for reasons already stated (see I. § 7), must have been transported at a separate period. They may be seen in every village in the peninsula; but they occur so plentifully between West Kirby and Parkgate as to suggest the idea of an *intermediate concentration.* They may be best studied on the sea-coast at Dawpool, between the two spots marked "Limekiln" on the one-inch Ordnance Map. There they have been principally washed out of the lower part* of the Lower Boulder-clay, which upward becomes less stony, until it is surmounted by a nearly stoneless sand, which is capped with Upper Boulder-clay. The clay cliffs present a variety of details which are calculated to bewilder the observer who has not frequently studied them as fresh faces are exposed by the constantly encroaching waves. Both upper and lower clays are undoubtedly stratified; and though the erratic stones (which in the lower clay are generally angular or subangular, and in the upper clay more or less rounded) occur in all positions in the clay, relatively to their longer axis, they are sometimes grouped in the same divisional plane, with their upper surfaces striated in the same direction, in this respect somewhat resembling Hugh Miller's "striated pavements." Further south there are many Criffel boulders, especially about Neston, and they may be seen predominating over Eskdale all the way to Chester. The large boulders which may be seen in the poorer quarters of Chester (where they answer the purpose of seats for aged women on summer evenings) have been collected from excavations made for house-sites &c., or brought from the neighbourhood, ever since the time of the Romans. Many of the smaller stones with which the courts and some of the streets are paved are said to have been brought by water from the shores of the estuary of the Dee. Among the stones, as usual, Silurian grit predominates. I once made a survey of all the *large* boulders I could find, which resulted in 41 Lake-district felstones, more or less porphyritic and brecciated; Criffel granite 15; Scottish "greenstone" 9; Eskdale granite 9; Lake-district syenite 2; Carboniferous lime-

* This lower part is a stratified loam (often quaquaversally arranged) in which the boulders and smaller stones are very unequally scattered, many parts of it being almost stoneless. At Dawpool it is the only representative of the Lower Boulder-clay which is exposed on the sea-coast near Bootle, Cumberland, at Blackpool, and in Colwyn Bay, North Wales, where it is underlain by a blue clay almost entirely destitute of erratics, though full of local stones.

stone 2; Silurian grit 2=80. But this survey probably did not include nearly all the large boulders, though I have no doubt of its being approximately correct as regards the great preponderance of Criffel over Eskdale granite, and the preponderance of felspathic boulders over both. South of Chester, on a line with the great highway of boulder-transportation, Criffel-granite boulders become comparatively rare, and this rarity (so far as I have seen) continues until the great terminal concentration is reached. The partial exhaustion of the Criffel dispersion south of Chester may be explained by supposing that while the sea continued shallow the rising ground of the peninsula of Wirral intercepted the boulder-laden ice, and that afterwards as the sea deepened, the ice met with few obstructions or accidents until it reached the border of the warm current south-west and north of Wolverhampton. West of the river Dee a few Criffel-granite boulders may be found, the furthest west (a mere straggler) being about a mile west of Mold. Several may be seen south of Caergwrle and Wrexham. I did not see any in Oswestry large gravel-pit, or further west than between Welsh Frankton and Whittington. The Criffel boundary then runs south to the neighbourhood of Cardington, near Church Stretton (where I saw a small Criffel-granite boulder); but I have not had time to trace its precise course. I have not seen any Criffel boulders at any considerable height along the western boundary; but, from what I can learn from Prof. Hughes, it is probable that they might be found quite 700 feet above the sea between St. Asaph and Halkin mountain.

6. *Dispersion over Delamere and Peckforton Hills.*—Among the numerous large boulders found about Helsby, Frodsham, Overton, and other towns or villages on the north and north-east sides of the Delamere hills, as far south as Delamere church, a few large Criffel-granite boulders may be seen, but Scottish "greenstone" (with a few exceptions*) is absent. On the Peckforton hills, so far as I could see before the late removal of most of the boulders, Criffel-granite boulders were likewise rather scarce, though one of moderate dimensions may still be seen near the tower on Mr. Lee's farm, about 650 feet above the sea. There is a very large Criffel boulder at Barrow (west of the Delamere hills) and a considerable number at Tattenhall, north-west of the Peckforton hills, one being $6 \times 3 \times 3$ feet. In Rock-Savage railway-cutting (near Runcorn, north of the Delamere hills), when first made, two large Criffel-granite boulders, and one large Scottish-"greenstone" boulder might be seen at the *base* of the lower clay † (along with Eskdale-granite boulders). These Criffel granites may possibly lie in the course of the boulder-stream which dropped large blocks at Stafford, Market Drayton, and Bushbury.

7. *Criffel Boulders at Market Drayton, &c.*—Around Market Drayton the Upper Boulder-clay, which covers the greater part of Cheshire like a pall, begins to thin out south-eastward. In a clay-

* One about $3 \times 3 \times 2$ feet may be seen at the corner of a ladies' boarding-school in Overton.

† Several of these boulders had evidently crushed down the Triassic marl on which the Boulder-clay rested, as if they had fallen from a considerable height.

pit near the railway station it is found, as usual, above the middle sand. It contains Bunter pebbles, felstone, &c. The large boulders disclosed by the plough, pick, and spade in the neighbourhood would appear to belong to the base of the sand, the Lower Boulder-clay having thinned out. In Market Drayton I saw a number of very large boulders of Criffel granite, their surfaces, as usual, rough, subangular, or angular. They had been brought from the immediate neighbourhood, or found in digging for house-sites, &c. I could see very little Criffel granite further east than Market Drayton, though between that place and Whitmore railway-station, by way of Ashley, it was not altogether absent. Between Market Drayton and the neighbourhood of Albrighton, Criffel-granite boulders occur at intervals; but scarcely any are to be seen between Crudgington railway-station and Shrewsbury, and very few west of a line drawn from Crudgington to Chester.

8. *Enormous terminal Concentration of Criffel Boulders W.S.W. and North of Wolverhampton—Meeting of a cold with a warm Current?—Floating ice versus Land-ice.*—These granite boulders have often been noticed, but no one attempted to work out their derivation until 1874, when, from a previous familiarity with Criffel granite further north, I had no difficulty in identifying them. They are associated with, or rather overlap, a few large and small Lake-district felstones and porphyries, a very few Eskdale granites and syenites, and a considerable number of Eskdale-granite pebbles*. The non-granitic boulders, which were probably transported along with them, consist of a kind of "greenstone" (lighter-coloured and coarser-grained than that found in Cheshire), Silurian grit, sandstone, slate, and metamorphic rocks. I had seen only one boulder resembling Arenig felstone until very lately, when I stumbled on one 10 feet in length and almost perfectly angular. It had been found on the *surface* of a deposit of clay, afterwards excavated for bricks, near the Wolverhampton cemetery†. On sending a specimen of it to Mr. Horne, F.G.S. (of the Geological Survey of Scotland), he confirmed my opinion that it did not come from the south of Scotland; and on afterwards comparing specimens from it with Arenig specimens, I came to the conclusion that it was a miscarried boulder belonging to the Arenig *overshot* load which was precipitated around the Clent and Lickey hills. Its position on the surface of the clay may have been owing to its having fallen at a later period than the Criffel concentration. In the clay-pit I saw a "greenstone" similar to one of the Criffel varieties, a rounded Lake-district felstone, &c. The great majority of the Criffel-granite boulders lie between 300 and 600 feet above the sea; but they mostly occur in positions, including the lee sides of eminences, which show that the

* These pebbles have been scattered some distance beyond the boundary of the Criffel boulders south of Bridgenorth, south-east of Bushbury, &c., a fact which can be best explained by supposing that the Eskdale granite with the Lake-district felstone had been transported before the Criffel boulders.

† It had previously been seen and made the subject of an open-air lecture by the Rev. H. W. Crosskey and friends.

submergence must have reached at least from 500 to 650 feet (as already stated) before they could have been transported. Most of them consist of a kind of granite which must have come from the upper part of Criffel mountain, and some of them may have come from other granite heights in Kirkcudbrightshire. The larger granite boulders may be seen most thickly congregated about Seisdon, in the lane between Seisdon and the 'Fox' inn, and north of the 'Fox' inn, where I saw many which had lately been dug out of a loamy clay. About Trescott they are very abundant, and many may be seen in the lanes branching off north and south from the Wolverhampton and Bridgenorth road. They are well represented in the streets of Bridgenorth, especially near the river, where I saw no other kind of granite, though a little Eskdale might probably be found. East of Seisdon, along the Wolverhampton road, Criffel granite nearly disappears until the immediate neighbourhood of Wolverhampton is reached. Many large boulders of it may be found in the poorer quarters of the town, especially in back lanes and courts; and numerous moderate-sized ones have been dug out of the numerous clay-pits near the Hospital, Clarkson's clay-pits, &c. North of Wolverhampton, at Bushbury, they are very large and numerous, especially around Moseley Court, near the church, and on the top of Bushbury hill close to a large gravel-pit. They may be found some distance north of Bushbury, but gradually thin out in the direction of Stafford. About Bushbury they are associated with many large Lake-district felstones, which are not conterminous with the granite, excepting on the east, where there may have been a persistent local obstruction (see I. § 5). The great mass of the Criffel concentration between Wolverhampton and Bridgenorth gradually thins out north towards Pattington, though a number of large boulders may be seen at least as far north as Albrighton. The south boundary of the concentration is, in most places, very sharply defined. It extends from a short distance south of Bridgenorth to Mose, and thence by Bobbington to Swindon (near Himley), between which and Stourbridge I could not see a single fragment of granite or any rock foreign to the district. Neither could I see a fragment of foreign rock between Swindon and Dudley. East of Swindon the Criffel boundary runs north-east towards the neighbourhood of Wolverhampton, and thence northward by Bushbury hill. The great Criffel concentration is therefore somewhat crescent-shaped, the convex side being the S.S.E., or the side furthest from the source of the dispersion. In this respect it bears some resemblance to a terrestrial glacial moraine. Its length from the neighbourhood of Bridgenorth to the neighbourhood of Bushbury may be roughly estimated at about fifteen miles, and its breadth about four miles. The largest granite boulders I have seen in this concentration are at Trescott, reaching nearly $5 \times 3\frac{1}{2} \times 3$ feet, and at Bushbury, reaching $4\frac{1}{2} \times 4 \times 3$ feet; but I have been credibly informed that they reach a larger size near Seisdon, and that some very much larger have been buried. There must be many thousands more than $3 \times 2 \times 2$ feet; and taking all sizes down to 1 foot in average diameter, and at the same time making reasonable allowance for those that have been "massacred," reinterred, or not yet disinterred, I think it will follow that the Criffel-granite boulders of this terminal concentration can only be numbered by many thousands. If we make allowances for flattening and striation through being dragged by horses* to their present resting-places, very few of the boulders can be said to be glaciated. Their rough, subangular, and often angular shapes forbid the idea that they were pushed forward *under* a sheet of land-ice. They could not have been transported on the surface of the ice, because no one can suppose that an ice-sheet with its surface *lower* than the part of the mountain from which the boulders must have come could have moved as far as Wolverhampton (170 miles), and during the latter part of the journey up hill. It would be contrary to what we know of the purity of the interior of Antarctic and Arctic ice-walls and icebergs to suppose that so vast an array of boulders could have been carried in the middle of an ice-sheet. It may be suggested that land-ice might have brought the boulders on its surface as far as the peninsula of Wirral, and that they were then transported by icebergs broken off from the end of the ice-sheet; but while the peninsula of Wirral furnishes no evidence of a change in the mode of transportation, it can be shown (see VI. § 1), from a consideration of relative levels, that icebergs could not have retransported the boulders as far as Wolverhampton.

9. *Scottish "Greenstone" Dispersion.*—At Dawpool, on the coast of the estuary of the Dee, the New North Docks, Liverpool, and for some miles around, many very large and small boulders of a dark-coloured and often decomposing "greenstone" may be found. I have traced them as far east as the neighbourhood of Runcorn and Overton, and a little further south than Chester. At the New North Docks, Liverpool, nearly all the large boulders found during the progress of the excavations were "greenstone," and many of them were much flattened and grooved. For a long time I could not trace them to their parent rocks, having failed to see them on the first stage of their journey in any part of the Lake-district. I have lately been led by Dr. James Geike and Mr. Horne (of the Geological Survey of Scotland) to believe that they came from Kirkcudbrightshire or Wigtonshire. Some boulders of a rather different kind of rock (to which the term "greenstone" would formerly have been applied) are to be found associated with the Criffel-granite boulders around Wolverhampton †.

* One boulder in the late Mr. Mander's bouldery, Tettenhall, required fifteen horses to drag it from Trescott.

† Professor Bonney has favoured me with the following remarks on a chip from one of the "greenstone" boulders on the Dawpool coast:—"This slide is composed of triclinic felspar, augite, olivine, and grains of iron peroxide, probably magnetite. There are also a few small scales of brown mica, and a little of some zeolite. The felspar crystals are in very fair preservation, and rather smaller, as a rule, than those of the augite and olivine, which two together make up quite two thirds of the slide, and are not at all decomposed. There is no trace of a glassy residuum. The rock is therefore a rather finely crystalline dolerite (anamesite of many authors). It is obviously hazardous to

III. The great Cumberland Granite- and Felstone-dispersion.

1. *Boulder-supplying capacity of the Lake-district—Commencement of the Dispersion.*—Boulders of felspathic rocks varying from coarse breccia, tuff, or ashes to compact felstone may have gone south from almost any part of the Lake-district situated between Wasdale Crag (Shapfell) and the western boundary of the Cumberland mountains. Though numerous boulders have gone south from the eastern or Westmoreland part of this area, I do not think that many of them (east of the river Leven) have found their way far enough south-west to become incorporated with the great Cumberland and Kirkcudbrightshire dispersions. Many boulders of felspathic rocks, more or less accompanied by fine-grained syenite, must have gone south from the heights around Wastwater and Ennerdale. Initial concentrations of them may be seen near Gosforth and Drigg. Lake-district-felstone boulders have been more generally and numerously distributed than the granite boulders, though they never occur alone in the form of great terminal concentrations. In the Eskdale-granite area there are now many loose blocks so situated that were it again to become submerged beneath an icy sea, they would probably follow the example of their erratic predecessors. Though this area is much smaller than the Criffel area, the ground is much more broken and varied, so as to furnish a greater number (in proportion to its size) of *transportable* blocks. Mr. Aveline (of the Geological Survey) informs me that very little of the Eskdale-granite area rises above 800 feet; and this confirms the idea (already broached) that the main part of the Eskdale dispersion took place before the land had become deeply submerged, and probably before the setting in of the great southerly extension of the Criffel dispersion. Some parts of the Eskdale-granite area, however, exceed 800 feet—for instance, near Devoke Water, 1049 feet, and south of the south-west end of Wastwater Screes escarpment, 1286 feet. The latter altitude is rather more than that of the highest Eskdale-granite boulder I have yet seen, but not so high by about 100 feet as the Eskdale pebbles in gravel near the summit of Moel-y-Tryfaen. All round the mouth of Eskdale, and south in the direction of Bootle, the granite blocks are thickly congregated, and a number of large ones may be found on the west side of Blackcombe Mountain, nearly 1000 feet above the sea, which may have gone from Rough Crag, north of Devoke Water (?). The boundary of the commencement of the dispersion runs along a line drawn from near Irton to a little west of Drigg. Between this line and the east boundary, which runs along the west side of Blackcombe, the dispersion radiates until it is lost under the sea*.

2. *Dispersion to North Wales.*—Boulders and pebbles of Eskdale

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conjecture, from microscopic examination only, the geologic age of an igneous rock; but on the whole it seems to me not improbable that this specimen may be of Miocene age. I am not sure how far south these rocks have been traced along the west coast of Scotland."

* Eskdale granite has generally white or pale pink felspar, very watery-looking quartz, and little or no black shining mica, though silvery mica is sometimes present. It is often *tinged* of a reddish hue. Most of it is coarse-grained.

granite and Lake-district felstone accompany Criffel granite along the north coast of Wales, from Flint to Anglesey. They are most numerous on Halkin Mountain, near Rhos (Colwyn Bay), Llanfairfechan, Bangor, and Beaumaris. They have found their way into the interior as far, at least, as the neighbourhood of Cefn Cave (near St. Asaph) and Moel-y-Tryfaen.

3. *North-east and east boundary of Dispersion—Identification of Blackpool Boulders—highest Boulders in Macclesfield Forest.*—South of the initial concentration, near Silecroft, the east boundary of the granite suddenly bends round and runs up Whicham valley for some distance, as if the boulder-laden ice had been blown aside by wind. After crossing the south-west end of Millom hill, it runs north-east up the Duddon valley, crosses the estuary, and then runs south-east by Great Urswick to the sea. It reappears on the east coast of the Irish Sea some distance north of Blackpool. On Blackpool beach many boulders have been washed out of the Lower Boulder-clay. Eskdale granite predominates over Criffel, and is accompanied by large boulders of Lake-district felstone and Mountain Limestone, the latter from the neighbourhood of Carnforth, Burton in Kendal, &c.* From the north of Blackpool the boundary runs by Longridge to Rochdale, over the western spurs of the Pennine hills, on which Mr. Aitken, F.G.S., has found boulders of pink (Eskdale) granite at a height of 1100 feet, and felstone and syenite at greater heights. From Rochdale it runs south-east to Swineshaw valley (near Staleybridge), where it turns off at right angles to its general course, and goes up the valley to an altitude of at least 900 feet. From Swineshaw valley it runs south into the heart of the western division of the Pennine hills. The furthest east boulder I could find was close to Macclesfield-Forest smithy, which is about five miles east of Macclesfield town. It was a Lake-district felstone about 3 feet in length, and probably about 1300 feet above the sea. Further west, on the south side of the Macclesfield road, I found a similar felstone boulder about $3\frac{1}{2} \times 2\frac{3}{4} \times 1\frac{1}{2}$ foot. Many large felstone and Eskdale boulders may be seen along or near to the road around the 'Setter Dog' inn, and between it and Macclesfield. The highest Eskdale-granite boulder I could find was a short distance east of the 'Setter Dog,' at a height of about 1200 feet above the sea, or very nearly as high as its greatest height in the Lake-district. Among the larger granite boulders Eskdale predominates, among the smaller Criffel. Besides the felstones (which are often porphyritic) and granites, syenite and a kind of rock apparently about midway between syenite and greenstone may often be seen in the neighbourhood of Macclesfield†. South of Macclesfield Forest the boundary of the Eskdale granite and Lake-district felstone runs at least as far east as Harecastle (where I saw a very large Eskdale-granite boulder immediately behind the police-station); Etruria, west of which, in

* They may be traced on their way S.S.W. at Morecambe, near Lancaster.

† Mr. Sainter, F.G.S., in his 'Rambles round Macclesfield,' mentions a boulder of porphyritic felstone, now in Macclesfield Park, which is about 6 feet in average diameter.

Basford village, I saw a newly disinterred Eskdale boulder $4 \times 2\frac{1}{2} \times 2$ feet; Stoke-on-Trent, where Eskdale granite may be found in the clay-pits; and thence to the neighbourhood of Stafford. In Ashflat clay-pits, south of Stafford, Eskdale predominates over Criffel granite. From Stafford the main boundary runs south to Bushbury; but granite pebbles have found their way further east, though none as far as Lichfield. About Bushbury there are many large felstone boulders; one, $3\frac{1}{2} \times 3 \times 3$ feet, is much glaciated: there are likewise several large Eskdale-granite boulders.

4. *Dispersion over the Peninsula of Wirral, Delamere, and Peckforton Hills, Cheshire Plain, &c.*—The largest boulders in Wirral consist of Lake-district felstone* and felspathic breccia. Eskdale-granite boulders are not uncommon; and most of the small granite pebbles are Eskdale. South of Chester, about Farndon &c., most of the granite boulders are Eskdale. From the neighbourhood of Runcorn, south by Frodsham, Overton, Helsby, and on the slopes of the ridge called Delamere Forest, Lake-district-felstone and Eskdale-granite boulders are numerous and often very large. On the east side of Overton hill there is a felstone $5 \times 4 \times 1\frac{1}{2}$ foot, and an Eskdale-granite $4 \times 3 \times 2$ feet. In Frodsham, Helsby, and the neighbourhood I saw many Eskdales from 3 to 4 feet in length. Large Eskdale and felstone boulders may likewise be seen around Delamere church and Eddisbury hill. Mr. Strahan (of the Geological Survey) lately found a boulder of felspathic breccia near Eddisbury hill about 10 feet long, which I missed seeing†. On the Peckforton range of hills, between Lower Burwardsley and Peckforton Point, a number of Eskdale-granite and Lake-district-felstone boulders may be seen. On the west side of Buckley hill, one of the Peckforton range, the boulders reach nearly 700 feet above the sea. Further south, on Mr. Lee's (formerly Mr. Gerrard's) farm, there were, some years ago, many large boulders, chiefly Eskdale-granite, but nearly all of them were lately sold for "rockery" and removed down hill. In Fuller's Moor village, at a much lower level, I counted seventeen boulders, most of them very large and consisting of Eskdale granite. They were not in their original position; but their size must have prevented artificial transportation from any considerable distance, especially in a district where native boulders are far from being scarce.

5. *Felstone Boulders of Ashley Heath &c.*—A zone running S.S.E. from the Mersey over the Delamere hills (on or around which the largest Lake-district felstones are found) along the general course of the miscellaneous boulder-dispersions would pass over the area between Market Drayton and Ashley village. As already stated,

* About Barrow (east of Chester) and the neighbouring villages large Eskdale-granite boulders may be seen.

† On the beach at Dawpool, north of Parkgate, at low water, several very large Lake-district-felstone boulders may be seen, one $6 \times 4 \times 4$ feet. Associated with them there is a boulder $6\frac{1}{2} \times 5 \times 4\frac{1}{2}$ feet, which is somewhat Arenig-looking; but there is a difficulty in understanding how Arenig boulders could have been transported so as to occupy so low a position in the lower clay as that to which this boulder probably belongs.

the large Criffel boulders of Market Drayton are accompanied by large Lake-district felstones, which are probably the product of a previous dispersion. Between Market Drayton and Ashley village large felstone boulders are numerous. Opposite a cottage called the Red Bull (on the Ordnance Map) the exposed part of a partly blasted and partly buried felstone boulder measures $7 \times 3\frac{1}{2}$ feet. Around the little-known eminence called Ashley Heath (which is the highest ground between the Pennine and Welsh hills north of the Wrekin) there are many felstone boulders, and on the summit of the eminence a boulder, probably the same as that noticed many years ago by Mr. Charles Darwin, may be seen. Only $4 \times 3 \times 1$ foot of it is above ground. It is apparently a syenitic kind of greenstone. After much searching I succeeded in finding it with the intelligent assistance of Miss Taylor, of Westfield House. Its height above the sea is about 4 feet below that of the top of Ashley Heath, which is 774 feet above the sea. The Ashley felstone boulders probably lie in the same line of dispersion with those around Bushbury village. At Ashley they are accidentally accompanied by a few, and at Bushbury by many Criffel-granite boulders probably belonging to a later dispersion.

6. *Furthest west and highest Boulders.*—West of the lower course of the river Dee, Eskdale greatly predominates over Criffel granite. It reaches its greatest height (so far as I have noticed) where it extends furthest west—that is, on Halkin Mountain, Flintshire, where numerous pebbles of it may be found quite 900 feet above the sea. Its western boundary runs south by Caergwrle, a short distance west of Wrexham and Ruabon, to Oswestry, where, in a very large gravel-pit, it is well represented. From Oswestry it runs to Church Stretton along a line I have not worked out. The granite is accompanied by Lake-district felstone. Large boulders of both the granite and felstone may be found at Ellesmere, Whitchurch, Wem, Shrewsbury*, on the eastern slope of Haughmond hill, at Admaston, near Wellington, &c.†

7. *Remarkable isolated load of Eskdale-Granite and Lake-district-Felstone Boulders around Burton, Shropshire.*—The boulder-stream which suddenly terminated in this abruptly-bounded concentration probably went south by the neighbourhood of Shrewsbury. It differs from the great Criffel terminal concentration in its terminating suddenly on its up-stream as well as lee side. The area covered by large boulders is about one mile and a half in length and one mile in breadth. The smaller detritus extends a short distance beyond on the lee or south side. The large boulders are most numerous in and around Burton village, where the felstones reach $4 \times 3 \times 1\frac{1}{2}$ foot, and the granites $3\frac{1}{2} \times 2 \times 2$ feet; but they are likewise numerous along the road-side leading up to the gravel-pit near the summit of

* In Shrewsbury, as usual, they are chiefly found in the back streets and courts or in the outskirts.

† The southerly course of the northern boulders has been extensively crossed in a south-easterly direction by boulders from the eastern border of the Welsh mountains. At Ellesmere, for instance, most of the boulders are Welsh.

the hill, which Mr. Maw*, F.G.S., tells me is 800 feet above the sea-level. Here the gravel, which is unstratified, is probably on the horizon of the Lower Boulder-clay of Cheshire and Lancashire. Numerous rounded pebbles of Eskdale granite are found along with Lake-district felstone in the gravel-pit, and many large boulders have been dug out of it†. A very few Criffel-granite boulders are mixed with the others around Burton; and the reason why both are conterminous would appear to be the persistence (for a time) of a local obstruction, probably consisting of the two abruptly rising ridges of Ludlow rocks (between which Burton village is situated), at a time when the land had been submerged to a depth of between 800 and 900 feet, in which case the few Criffel boulders may have arrived before or after the Eskdale precipitation. There are Eskdale-granite stragglers east of Burton, one at Callaughton, $3\frac{1}{2} \times 2 \times 2$ feet, and one, if not more, in Much Wenlock. West of Burton I saw a very few stragglers around Cardington, Gretton, and Enchmarsh, and one in Church Stretton. Inquirers may be benefited by knowing that around Burton boulders are called "pimples."

8. *Supplementary Dispersion of Eskdale- and Criffel-Granite Pebbles along the lower part of the Severn Valley.*—South of Bridgenorth, at least as far as the somewhat elevated ground about Sutton (west of Hampton-Loade railway-station), many pebbles of Eskdale and a few of Criffel granite may be found. Further south they gradually disappear, excepting in the immediate neighbourhood of the river Severn. About Bewdley they are only to be found in or close to the river-channel; and I have reason to believe that this is the case the whole way south as far as they extend, with a very few exceptions, in which stragglers (probably belonging to the great Criffel boulder-dispersion) may have been carried by floating ice. An instance of this occurs on the summit of a knoll, 150 feet above the Severn, at Apperley Court (about halfway between Tewkesbury and Gloucester), where, in a "rockery," there are several small boulders which were found close by, and which, after many attempts at identification, I believe may be South-Scottish granite. If so, they must have been transported about 220 miles‡. But with this and possibly a few other exceptions, the granite pebbles south of Bewdley are confined to low levels bordering the channel of the river. They may have been transported by the river during shallow estuarine conditions after floating ice had entirely, or almost entirely, disappeared; or the transportation may have occurred during a southerly extension of the Upper Boulder-clay submergence through the Ironbridge gap. During my rambles with the Rev. W. S. Symonds (whose kindness it would be difficult for me to repay) I

* Mr. Maw first discovered this group of boulders, but did not specify the kinds of granite.

† Between the gravel-pit and the village I saw a part of a boulder of felspathic breccia $4 \times 2\frac{1}{2} \times 1$ foot, the rest of which had been blasted. I was unable to identify a few of the more or less felspathic boulders, but none of them were of the Arenig type.

‡ My attention was directed to these boulders by the Rev. W. S. Symonds.

found two very decided Eskdale-granite pebbles in front of Hasfield Court, in fine gravel which had been taken from a low level in the neighbourhood. In the streets of Bewdley (and perhaps other towns) there are a few good-sized boulders of granite and felstone; but I have been led to believe that they were artificially transported from the Bridgenorth neighbourhood at a time when the boating traffic on the river Severn was more extensive than at present, owing to the introduction of railways*.

IV. South-easterly Extension of the great Arenig Felstone-dispersion.

1. *Boulder-supplying Capacity of the great Arenig Mountain—Initial, Intermediate, and Terminal Concentrations.*—As I have already described this dispersion in the Quart. Journ. Geol. Soc. for December 1874, my present remarks will be almost entirely additional. The little and great Arenig mountains, and the escarpment running south from the latter, furnish a boulder-dispersing front about nine miles in length†. The great Arenig itself presents a precipitous and block-strewn or block-producing front between two and three miles in length, and quite 1000 feet *above* nearly all the heights over which the boulders have been transported. The radiations of the dispersion include about one fourth of a circle (see I. § 8 and map, Pl. XXII.). Among the initial concentrations the one at the east end of Bala lake is the most thickly strewn. A remarkable intermediate concentration occurs between Bryn Eglwys and Derwen. Terminal concentrations (so far as Wales is concerned) are numerous in the neighbourhood of Llangollen; and there is a remarkable one around Eryrys, near Llanarmon. I traced these boulders in a north-east direction through passes in the Moel Fammau range of hills as far as Halkin Mountain, Flintshire—the north-east direction of their dispersion from the Arenig corresponding to striæ on limestone rocks in Grange quarry, near Holywell. The greatest height at which I have yet found decided Arenig boulders is about 1900 feet. They are generally subangular, often angular, and vary from a very compact light bluish-grey felstone to volcanic ashes‡. Comparatively few of the boulders are distinctly brecciated. They are generally very much larger and very much less rounded than those derived from the Lake-district. The longest I have seen (near Pen-y-bryn, west of Llangollen) is 17 feet.

2. *Boulders around Chirk and Welsh Frankton.*—At the mouth of Llangollen vale, about one third of a mile west of Cefn station, there is an Arenig boulder 15 × 14 × 10 feet above ground; and about

* A few small boulders of granite have been found around Birmingham, but they may be regarded as mere stragglers from the great granite-dispersions. The Rev. J. Caswell found only two small ones in twenty-four square miles (British Association Report on Erratic Blocks for 1877).

† The Aran Mountains further south may have contributed boulders to the Arenig dispersion.

‡ A linear structure is often developed by weathering, and this corroborates the general opinion that they are all consolidated volcanic ashes.

a quarter of a mile south-east of Chirk bridge another 13 × 7 × 3 feet above ground. Between Chirk, Gobowen, Whittington, and Welsh Frankton (near Ellesmere) there are many Arenig boulders. West of Welsh Frankton, close to where the road crosses a canal, there are 8 × 8 feet of an Arenig boulder above ground. One close to Mr. Oswell's house, Welsh Frankton, is quite 8 feet in average diameter. Another, a few yards distant, is $8\frac{1}{2} \times 6 \times 5$ feet. They are accompanied by good-sized boulders of Silurian grit and Carboniferous sandstone and quartzite from the Welsh borders. In the neighbourhood there are many large and small Arenig boulders; and they may be found as far east at least as Ellesmere, accompanied by Mountain Limestone and Millstone Grit from the Welsh borders. It would thus appear that the Arenig dispersion must have cleared the Welsh mountains in the neighbourhood of Llangollen, and partly crossed the southerly course of the Eskdale granite over the Shropshire plain.

3. *Overshot Boulders around the Clent and Lickey Hills* (*probably Arenig*).—South-east of Welsh Frankton I have not had time to look for a continuation of the Arenig dispersion; it may possibly exist under a covering of upper clay. Between Wellington and Wroxeter I saw a few small Arenig-looking boulders; but between Bridgenorth and Wolverhampton there seemed to be few or none of them, though this would most likely be their course to the Clent and Lickey hills, around which many large felstone boulders have been brought to light through the diligent efforts of the Rev. H. W. Crosskey, F.G.S., Secretary of the British-Association Erratic-Block Committee. I examined these boulders, chiefly between Catshill and Hagley *, in a district which seemed to be totally exempt from granite erratics. This fact, combined with the size, shape, and appearance of the surface of the boulders, supplemented by a comparison of specimens, led me to adopt the opinion that they must have come all the way from the great Arenig mountain or the neighbourhood. My acquaintance with the country about Llanymynech, Church Stretton, Burton (Shropshire), Much Wenlock, &c. convinced me that the boulders could not have come over the Welsh mountains from the Arenig mountain along a route further south than the mouth of the Llangollen and Ceiriog valleys; and the discovery of an extension as far as Welsh Frankton and Ellesmere of the Arenig dispersion over the Shropshire plain confirmed the idea that this was the route the boulders must have taken †. The absence of a series of connecting links between Welsh Frankton and the district around the Clent and Lickey hills may be explained by supposing that the ice which carried the boulders over the lesser Welsh eminences was sufficient to float them as far south as the above district. These boulders, therefore, may be regarded as an *overshot* load (or a series of overshot loads) that is shot over the great Criffel terminal concentra-

* I afterwards could not find any as far south as the latitude of Droitwich.

† Similar boulders have been found around Birmingham, including the great Cannon-park boulder, and it is probable that they likewise came from the Arenig area.

tion. But the 10-feet boulder at Wolverhampton and the small boulders near Wroxeter (probably Arenig) show that a few boulders at least may have been *miscarried* or dropped by the way. It is probable that more of these miscarried boulders may yet be discovered. Around the Clent and Lickey hills the boulders are found in a varied deposit which I believe to be a representative of the Lower Boulder-clay of the north-western plain; and it is worthy of remark that in a clay-pit near Preesgweene (Chirk) a number of Arenig boulders may be seen lying on or near to the surface of a Lower Boulder-clay which is surmounted by a nearly stoneless upper or brick-clay (1878). A little consideration will render it probable that the Arenig dispersion did not all at once turn round in the neighbourhood of Welsh Frankton, and then make its way in a straight line to the Clent and Lickey hills, but that it probably curved round as shown in the map. By this time the cold must have increased so as push the "cold wall" as far south as the above hills; for the positions of at least most of the boulders is such as to show that they could not have owed their downfall mainly to the circumstance of being intercepted by these hills. There are large boulders among the hills up to at least 900 feet (as lately ascertained for me by Mr. Amphlett, of Clent), but most of them occur on the south-west side of the range at lower levels*.

V. Chalk-flints and Lias Fossils associated with Northern Boulders.

Chalk-flints have been found by Mr. Aitken, F.G.S., and others high up on the Pennine hills; but as they were more or less associated with worked flints of Neolithic age, there must always be some doubt about their having been transported by natural causes. I shall therefore confine attention to those which have been found imbedded in unmodified drift-deposits. In Boulder-clay, or in gravel, I have found them at Blackpool, Dawpool, Parkgate (numerous), summit of Halkin mountain (about 800 feet above the sea), around Wrexham and Ellesmere, in many parts of the peninsula of Wirral, near Runcorn, Delamere, Crewe, &c. Mr. Darbishire has found them near Leylands (Lancashire); Mr. Watts, F.G.S., at Piethorne, near Rochdale; and Mr. Trimmer on the top of Moel-y-Tryfaen (Caernarvon) at a height of nearly 1400 feet above the sea. All these flints belong to the basin of the Irish Sea, and have almost certainly crossed the general course of the northern boulders on their way from Ireland. *Gryphæa incurva* and a fragment of Lias have been found in drift near Chester (a specimen now in possession of Mr. Shone, F.G.S.), *Gryphæa incurva* by Mr. Watts at Piethorne, by the late Rev. Mr. Thornber at Blackpool, &c. They may have come from Ireland or from the neighbourhood of Carlisle. I found a chalk-flint near Shrewsbury which may have come from Ireland or from Lincoln-

* Should it yet be proved that the above boulders have found their way from West Central Wales by a route distinct from the one I have supposed, it would in no way interfere with the courses I have assigned to the northern-drift boulders.

shire. Mr. Woodward (of Birmingham) found chalk-flints and specimens of *Gryphæa incurva* at Lillieshall (east of Wellington), which probably came from the east. Mr. Maw, F.G.S., found chalk-flints, bits of hard chalk, fragments of Oolite, and Lias fossils at Strethill, near Ironbridge, which probably came from the east, as similar erratics can be traced in an easterly direction. I found a chalk-flint at Seisdon (between Wolverhampton and Bridgenorth); and many chalk-flints along with specimens of *Gryphæa* have been found in the clay-pits around Wolverhampton. All these eastern erratics must have *crossed the course* of the northern boulders near its southerly termination; and as both are found associated in the same drift-deposit, it seems impossible to explain the intercrossing by land-ice or glaciers. I found a number of chalk-flints in the Ashflat clay-pits (south of Stafford) and near Bushbury, which must have come from the east, because they thin out westward, and they are there associated with northern granite- and felstone-boulders. South of Wolverhampton and west of the Dudley and Clent hills the Bunter-pebble drift has not been much mixed with chalk-flints. I could see none about Kidderminster and Droitwich, notwithstanding that in the latter town enormous quantities of gravel had just been thrown out of excavations for drains and house-sites; but I have been assured that they are not entirely absent. South of Worcester a considerable number have crossed the general course of the Bunter-pebble drift as far west as Malvern*. The Rev. W. S. Symonds has found chalk-flints as far west as Hafield Camp, south of Ledbury! They have not only crossed the course of the southerly extension of the Bunter-pebble drift, but likewise the south-easterly course of the angular erratics from the Malvern hills. As most, if not all, of the chalk-flints in the west-midland counties would appear to have come from Lincolnshire, their general course must have been south-west.

VI. Absence of Striated Rock-surfaces over the Southern Part of the Boulder-strewn Area.

1. *Statement of Facts.*—Away from the Welsh hills no decided instance of a striated rock-surface has yet been met with south of the peninsula of Wirral†, and they are almost entirely confined to the extreme northern part of that peninsula. Many of the rocks further south are of much the same kind, and equally adapted to receive and retain ice-marks. It may likewise be remarked that similar exposures of rock-surfaces by the removal of drift are of frequent occurrence. To suppose that the Wirral striated rock-surfaces were

* There must, then, have been a current from the north-east sufficiently cold not to melt the straggling ice by which the flints were transported.

† I lately stumbled on an instance of somewhat doubtful striæ on Haughmond hill (near Shrewsbury), a short distance east of Haughmond Abbey, on the side of an old quarry just beyond a quarry now worked at the termination of the central greenstone protrusion. The direction was about north-west and south-east. If real striæ, they may have been made by ice-borne boulders from North Wales.

caused by a sheet of land-ice which went no further south, and that the boulders found between them and the southerly termination of the northern drift were transported by icebergs broken off the end of the ice-sheet, is opposed by the fact that the levels of the striated rock-surfaces which the bottom of the ice must have touched are generally not more than 100 feet above the present sea-level (near St. Silas's church, Liverpool, about 160 feet); in other words, the levels are so low that the bottom of the icebergs could not have gone over the boulder-strewn higher ground further south, some of which reaches nearly 800 feet. On the other hand, small icebergs or large masses of floating coast-ice, from Kirkcudbrightshire or Cumberland, may have reached the spots where the striated rocks are found, while the higher ground to the south may have checked their further progress. Should it be said that land-ice may have reached as far as the above striated area, and that *after its disappearance* boulders may have been carried by floating ice from their *parent* rocks, it may be replied that we have no evidence of the existence of this land-ice, unless the striated rock-surfaces can be proved to furnish an evidence; but, on the contrary, I think they can be best explained by floating ice.

2. *Age and Origin of the Striated Rock-surfaces around Birkenhead and Liverpool.*—These surfaces are all *flat*, or very nearly so, even where the rock would evidently have admitted of being *rounded*. They often present the appearance of the previously uneven rock-surface having been *uniformly planed down or shaved across*. Mr. Darwin was perhaps the first to make a distinction (in 1842) between rock-surfaces glaciated by land-ice and by floating ice, the former showing a tendency to be *dome-shaped*. In North Wales (where Mr. Darwin studied the phenomena), and still more in the Lake-district, *roches moutonnées* are coextensive with the other traces of land-ice, and we are not justified in assuming the former presence of land-ice where they are entirely absent. All the striated and planed rock-surfaces around Birkenhead and Liverpool are covered (so far as I have seen) with *Upper* Boulder-clay which, *without any change in its character* or intervening detritus, touches the striated rock-surfaces. The latter look as fresh as if they had been formed yesterday; and these facts would seem to point to the conclusion that while the striated surface was still submerged the overlying clay was accumulated.

VII. Remarks on Local Boulder-dispersions.

Boulders have probably been dispersed from either the Delamere or Peckforton hills, as (according to Prof. Hull) they are the nearest localities from which a very large block of calcareous conglomerate I found in Mr. Jones's clay-pit near Wrexham could have been derived. Its course must have crossed that of the Eskdale granite with which, in the clay-pit, it is associated. Haughmond hill has sent off fragments in the direction of Shrewsbury, around which they may be found in the lower gravel and Upper Boulder-clay. According to Mr. Maw the Wrekin and neighbouring eminences must have sent off fragments to Strethill, near Ironbridge *. It is well known that Charnwood Forest and Mount Sorrel have dispersed boulders in many directions—according to Mr. Lucy, F.G.S., as far as the Cotswold hills, and—according to Dr. Buckland, as far south as Abingdon and as far S.S.E. as Dunstable. Should it be surmised that these local dispersions were effected by floating ice *after* the disappearance of the great ice-sheet, it may be replied that many of them have been found imbedded in a Boulder-clay which is probably a continuation of the Great Chalky Clay of the eastern counties.

VIII. Positions of Boulders relatively to the Matrix of Drift-deposits.

1. *Along the Valley of the Dee &c.*—Between Bala Lake and Ruabon the transition from high- to low-level drift, *on the same horizon*, may be clearly seen. Filling up abrupt hollows there is a clay or loam, with boulders, which may have been left by the passage of land-ice. Above this deposit (where it is present), or resting on the rock-surface, there is a heterogeneous accumulation consisting of clay, loam, and unstratified subangular gravel, the whole interspersed with boulders, which, however, are most frequently seen towards the base or top of the formation. This boulder-drift thins out upwards on the hill-sides, where it graduates into a chip-and-splinter drift, with an occasional rounded stone, and large boulders which (where there is little or no drift-matrix) appear on the surface. About Corwen very fine sand with drifted coal (drifted up the valley of the Dee in the teeth of the boulder-dispersion) either comes over this boulder-drift or is interstratified with it. Between Corwen and Ruabon, by way of Llangollen, there is generally but little clay in the boulder-drift, and it is often seen to graduate downward into angular débris and broken-up rock *in situ*. About Ruabon it graduates horizontally into the lowest drift of the plain of Denbighshire and Shropshire, which is either a Boulder-gravel or a Boulder-clay, and the latter graduates northward into the Lower Boulder-clay of the Cheshire and Lancashire plain. Considering the difference of level, the age of these deposits cannot be the same, though they are *horizontally continuous* †. In the Denbighshire plain the Arenig boulders are principally found in the lowest gravel, or gravelly loam, clay, and sand; but in the neighbourhood of the mountains they are not absent from the overlying finer gravel and sand. At a distance from the mountains, in the low-lying fine gravel and sand of Cheshire and Lancashire, boulders are never to be seen. It would be difficult to ascertain whether the Arenig boulders found in the drift-deposits of the Denbighshire plain bordering the Welsh mountains were dispersed during the sinking or rising of the land, or both.

* Mr. Percival has found fragments from the Wrekin area as far S.E. as Moseley near Birmingham, and nearly as far E. as Lichfield.

† For this very convenient phrase I am indebted to Mr. S. V. Wood, jun., F.G.S.

2. *Along the Coast of the Irish Sea &c.*—Assuming the terrestrial origin of the blue clay with local boulders which extends from the neighbourhood of Keswick to the Irish Sea (under all the other drift-deposits), and reappears on the coast of North Wales, and correlating this blue clay with the lowest or "waxy" pinnel of the southern part of the Lake-district, there would still be an extensive heterogeneous deposit of argillaceous, gravelly, and sandy pinnel in and around the borders of the Lake-district; and this, along the shores of Morecambe Bay, may be traced graduating into the Lower Boulder-clay of the plain of Lancashire and Cheshire. The lower part of the clay-cliffs between Bardsea and Baycliff (near Ulverston) are evidently on the same horizon as the lower part of the clay-cliffs at Blackpool, while the latter is a perfect *facsimile* of the lower part of the clay-cliffs at Dawpool, Cheshire (see II. § 5). All along the east coast of the Irish Sea the boulders are most numerous towards the base, or in the loamy part of the Lower Boulder-clay. This would seem to indicate that there must have been a depth of water sufficient to enable the boulder-laden floating ice to clear the minor eminences before much of the lower clay was deposited. The far-transported boulders, such as the Criffel granites around Wolverhampton, differ to a considerable extent from those found at Dawpool, so as to indicate deeper water when they were transported. If so, the Boulder-clay and equivalent gravel and sand around Wolverhampton may represent the upper part of the Boulder-clay of the basin of the Irish Sea.

3. *In the Plain of Cheshire, Shropshire, &c.*—The Upper Boulder-clay of this plain is very extensively distributed, but (as long ago noticed by Prof. Hull) the Lower Boulder-clay is seldom seen south of Chester. It may exist in many abrupt hollows under the great pall of Upper Boulder-clay; but, so far as it can be detected, it gradually degenerates southward until in many places it is only represented by boulder-gravel, earth, sand, or loam (as may be seen at the bottom of Gresford valley, at low levels around Shrewsbury, &c.). This degeneration is evidently owing to a southerly diminution in the supply of the subglacial mud from the Lake-district. It may, however, at first have been more or less present in Shropshire, and used up or carried far away during the accumulation of the cleanly-washed *middle* gravel- and sand-deposit, which, to a considerable extent, consists of erratics which must have been transported during the Lower Boulder-clay period. Up the hill-sides the Lower Boulder-clay degenerates much in the same way as it does southwards, as if the deposition of the clayey matrix had chiefly taken place in the deepest parts of the gradually deepening sea.

4. *Around Wolverhampton, Stafford, &c.*—The great plain of Lancashire, Cheshire, Shropshire, and part of Denbighshire (in other words, the plain lying between the Pennine hills and the Welsh mountains) is separated from the midland area by a waterparting (which is only breached by the river Severn) extending from the neighbourhood of Church Stretton, by way of the Wrekin, Ashley Heath, and Mow Cop, to the Pennine hills. South, south-east, and east of this waterparting the lowest of the two clays of the north-

west plain would appear to be alone, or almost alone, represented. The comparative, if not entire, absence of subglacial mud from the Lake-district beyond this waterparting (the Severn valley perhaps excepted) has probably been compensated by the prevalence of Carboniferous, Permian, Triassic, and Liassic shale, marl, or clay, out of which deposits of clay or loam have been locally worked up. The same kind of boulders occur in this local clay as are found in the lower glacial clay of the north-west; and they must have been transported and precipitated during the same submergence. The clay around Wolverhampton and Stafford, as shown in numerous clay-pits, is very seldom underlain by sand, excepting where there has been a working up of sandstone rock underneath*. There are no clear traces (so far as I have seen) of two Boulder-clays in this district, though sometimes it might be easy to fancy so, because the boulder-bearing clay graduates into sand, loam, and gravel at different levels, though still on the same horizon; in other words, it changes with changes in the character of the underlying or neighbouring strata. In the clay-pits around Wolverhampton and Stafford northern boulders are found at various levels in the clay, but mainly in the upper part near to or on the surface, as if a part of the clay (at least in certain areas) had been deposited before the submergence became sufficiently deep to float boulder-laden ice over the above-mentioned waterparting. At Ashflat clay-pits (south of Stafford) the clay, with many northern erratics, is overlain by gravel and sand which have evidently been washed out of the clay—the junction between the two being very uneven, generally ill-defined, and often presenting the appearance of "pipes." Fine gravel may be seen in Wobaston Big Meadow, further south, and I believe it is underlain by boulder-loam. Most of the large boulders between Wolverhampton and Bridgenorth would appear to be imbedded either in clay or in gravel with a matrix of clay graduating into sand. Most of the boulders which have been removed from the fields were found partly, or almost wholly, above the surface, or not so deeply buried as to elude their being touched by the plough. At first I was deceived by fancying that the occasional occurrence of vertical and, to some extent, grey-faced partings in the clay around Wolverhampton was sufficient to correlate it with the upper clay of the north-west; but I soon found that it was only an accidental resemblance, and that the structure of the two clays was different, the Wolverhampton clay being more or less heterogeneous and incoherent, while the upper clay of the north-west is remarkably homogeneous, tenacious, and compact, characteristics which cause it to slide one portion on another when damp, and when dry to break up in large columnar masses instead of frittering away.

* In the neighbourhood of Birmingham, sand sometimes comes under a loamy clay or gravel; but whether it be a *local variation on the same horizon*, or a westerly representative of Mr. S. V. Wood's Middle Glacial Sand of the eastern counties, I have not had time to ascertain. It ought to be recollected that under the Lower Boulder-clay of the north-west plain there are occasionally sands of local derivation.

IX. Explanation of Map, Plate XXII.

As it is impossible to ascertain the precise routes taken by boulders, in a map it is perhaps least presumptuous to draw straight or slightly curved lines from their sources to their terminations. As most of the Kirkcudbrightshire granite blocks would appear to have been dispersed from Criffel mountain or the neighbourhood, to prevent complication I have represented that mountain as the centre of dispersion. The barrier offered by the westerly extension of the Cumberland mountains renders it necessary to assume a curve in the route taken by these boulders. As I have already described the Shapfell-granite dispersion (see Geol. Mag. for Aug. 1870; and Quart. Journ. Geol. Soc. for Aug. 1873), and as it has been made the subject of papers by other authors, I have only mentioned it in the map. For the same reason the stream of large limestone boulders found along the east coast of Morecambe Bay is merely mentioned. The boulders of Silurian grit, felstone, &c. which went south from the mountain-front of Westmoreland are merely mentioned, as it is not certain that many of them found their way further south than Morecambe Bay. The "greenstone" boulders are not inserted in the map. As the Arenig boulders which are believed to have wandered as far south as the neighbourhood of Bromsgrove would appear to have gone first in an easterly direction, it is obviously necessary that a curved route should be assigned to them in the middle part of their course. *There are probably many boulders which I have not yet seen, and the positions of which, therefore, are not shown in the map.*

An attempt to map the positions and courses of boulders is justified by the fact that most of them have been found more or less imbedded in clay or gravel, at all angles, often standing on end—in other words, in the positions in which they were left by the ice which carried them during the Glacial period.

X. Tabular View of the Successive Stages of the Great Glacial Submergence during which the Boulders of the West of England and North Wales may have been transported.

Feet.		Feet.
2000–1800	Arenig boulders on Moel Gamelin, up to 1897 feet. Continuance of the Arenig dispersion.	2000–1800
1800–1600	Arenig boulders on Cyrn-y-Brain and Cefn-y-fedw. Continuance of the Arenig dispersion.	1800–1600
1600–1400	Continuance of the Arenig dispersion—Boulders around Grouse-box hill, near Llangollen. Probable close of the southerly Lake-district felspathic dispersion.	1600–1400
1400–1200	Criffel-granite boulders east of Macclesfield—Eskdale and Criffel-granite pebbles on Moel-y-Tryfaen. Continuance of the Arenig dispersion—Arenig boulders around Eryrys, and on the Eglwyseg plateau, near Llangollen.	1400–1200
1200–1000	Eskdale-granite boulders east of Macclesfield. Arenig boulders around the Clent and Lickey hills. Free exit of Arenig boulders from North-central Wales by way of the Dee valley—Boulders around Chirk, Welsh Frankton, &c.	1200–1000
1000–800	Probable commencement of the Arenig dispersion to distances greater than the immediate vicinity of the mountain.	1000–800
800–600	Eskdale-granite boulders around Burton, Shropshire. Criffel-granite boulders south and south-east of the Wrekin and Ashley Heath waterparting, including those between Bridgenorth and Bushbury, *viâ* Wolverhampton. Boulders intercepted by the Peckforton hills, Ashley Heath, &c.	800–600
600–400	Probable commencement of the dispersion of the boulders over the Wrekin and Ashley waterparting. Close of the Criffel *initial* dispersion over the south-west part of the Cumberland plain.	600–400
400–200	Boulders intercepted by the Delamere hills, &c. Local and northern boulders in lower gravelly loam and sand of West Shropshire and Denbighshire plain.	400–200
200–Present sea-level.	The boulders at the base and in the mass of the Cheshire and Lancashire Lower Boulder-clay may have been transported while the sea was shallow, or after its depth exceeded 200 feet, and yet before much of the clay was accumulated.	200–Present sea-level.

It is least presumptuous to assume that during the submergence the *relative* levels of different areas were much the same as at present, until the contrary can be proved.

Discussion.

Prof. Ramsay spoke of the value of these detailed observations. He thought that both land-ice and floating ice were concerned in the distribution of erratic boulders, and in many cases these boulders rested on striated surfaces. There were many boulders in Anglesey which had travelled from the north. Most of the northerly striations, he thought, could only be produced by an ice-sheet from the north. Still he had no doubt that there were also floating bergs, as in Cheshire, where boulders were associated with marine shells.

Prof. Hughes had had the pleasure of accompanying Mr. Mackintosh in the field, and testified to the painstaking care with which he gathered information. He thought the facts observed were best explained on the view that, during the period of extreme glaciation in N.W. Europe, the Scandinavian ice overrode every thing; when the cold had abated, and the mountain-ranges had sunk, the Scotch ice pressed out on all sides, encroaching on England and Wales. Next the glaciers of the Lake-district had their own development, pushing against the mountains of North Wales so that the Welsh ice could not travel out along the northern valleys; in confirmation of which he pointed out that the traces of the most ancient glaciation ran, irrespective of level, over hill and dale to the east. During all these periods the sea followed the receding ice as submergence went on; but the drift with flints, such as is found at various levels all round Wales, belonged to a later period and to different conditions.

Prof. Bonney stated that he had examined a collection of boulders made by Mr. Crosskey from near Birmingham, and could confirm Mr. Mackintosh's determination of the three origins of the boulders. He thought that many felstones could be identified, and that the crossing of the boulders could only be explained by floating ice. He could not understand how, if ice came down to Wales from Scandinavia or Scotland, Wales also should not have had glaciers large enough to keep the northern ice at a distance from the mountains.

Dr. Hicks expressed his agreement with the author. In Pembrokeshire foreign rocks were present, apparently coming from the north—he thought, the result of floating ice. Land-glaciers would bring boulders down to the sea, and they would be drifted away by floating ice and currents.

Prof. Ramsay said that he had not asserted that the ice covered Pembrokeshire, so that Dr. Hicks's criticism did not apply.

Dr. Hicks explained that striated rock-surfaces and boulders were common in Pembrokeshire. These he looked upon as evidences of local glaciers previous to the floating-ice period.

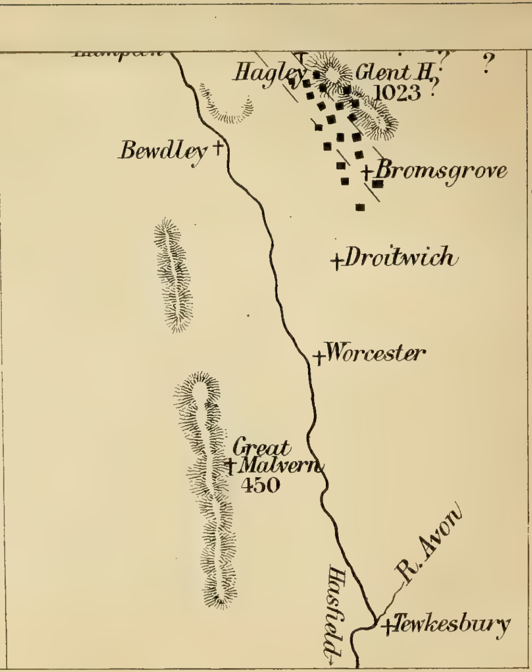
Prof. Seeley referred to the correlation of the drifts proposed by Mr. Mackintosh. He thought we could not assume that the surface had kept the same level above the sea, but that the glacial phenomena were due to the elevation of the north of Europe; and as

MAP

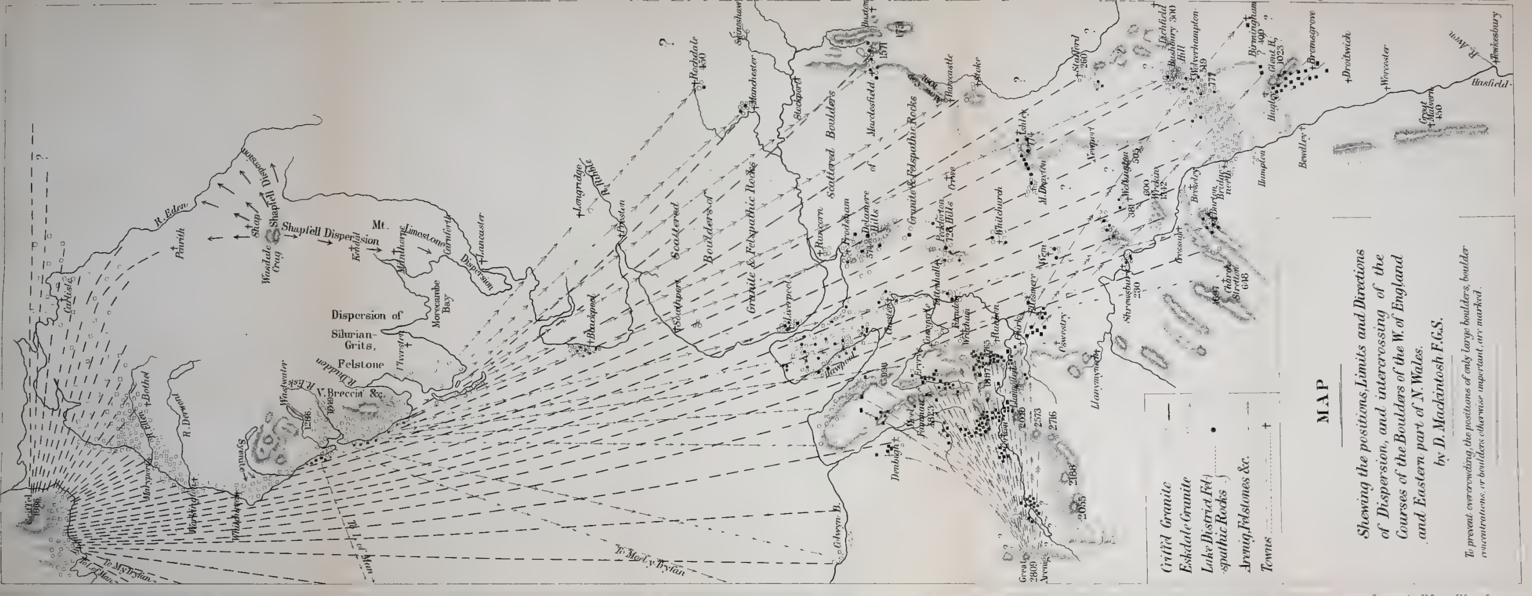
Shewing the positions, Limits and Directions of Dispersion, and intercrossing of the Courses of the Boulders of the W. of England and Eastern part of N. Wales.

by D. Mackintosh F.G.S.

To prevent overcrowding, the positions of only large boulders, boulder concentrations, or boulders otherwise important, are marked.



Dangerfield Lith. 22 Bedford S^t Covent Garden



Danckerfield Lith. 22 Bedford St. Covent Garden.

this declined, the phenomena of the various glacial periods would be produced. He thought boulder-clays and boulders had been re-sorted again and again by the sea.

Mr. De Rance said that in the Lake-district the striæ radiate from the watershed. Hence pebbles derived from the Solway, found in the midland Glacial deposits, could only have come by floating ice; and, further, with these there was evidence, in the Middle Sands, that currents flowed to the S.S.E. The striæ were older than the deposits on them.

Mr. J. F. Campbell expressed his satisfaction at the numerous facts brought forward by Mr. Mackintosh, and instanced the Straits of Belleisle in almost the same latitude, where the existing state of facts explained very well phenomena described by Mr. Mackintosh.

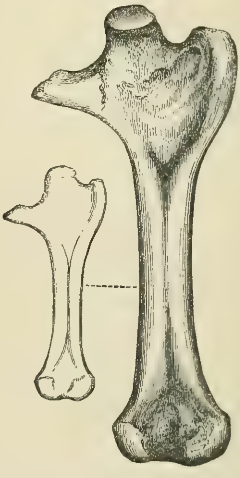
Mr. Mackintosh replied that in the peninsula of Wirral the striæ converged. In Anglesey the striæ were parallel. For replies to some of the speakers he referred to his paper.

35. Note *on a* Femur *and a* Humerus *of a* small Mammal *from the* Stonesfield Slate. By H. G. Seeley, Esq., F.R.S., F.G.S. (Read February 26, 1879.)

While examining, with the assistance of Mr. W. Davies, F.G.S., the unarranged and more fragmentary remains of Pterodactyles from the Stonesfield Slate which are preserved in the British Museum, I was so fortunate as to detect two small slabs which contain, in good preservation, a small mammalian femur and a mammalian humerus of corresponding size. Mr. Davies has had as much of the matrix removed from these bones as was necessary to fully display their essential characters; and I now offer to the Geological Society a brief account of the remains, for the opportunity of making which I would express my thanks to Mr. Waterhouse. It is perhaps impossible to determine with absolute certainty whether they belong to *Amphitherium*, *Phascolotherium*, or to some new type, or whether the bones might not perhaps have belonged to two different animals; but, on the chance of their being naturally associated, the generalized marsupial characters which they manifest make a useful contribution to our knowledge of that animal type, which has hitherto only been known, from Stonesfield, by rami of lower jaws.

Femur.

Fig. 1.—*Femur.*



The outline shows the natural size of the bone.

The right femur rests flat in the matrix, so as to expose the aspect of the bone, which during life was posterior and inferior. The extreme length of the specimen is $1\frac{2}{10}$ inch. It has a straight aspect, is moderately expanded proximally, less enlarged at the distal end, and has the spheroidal articular head inclined to the inner side and looking slightly forward. The most remarkable feature of the specimen is the expansion below the articular head of the two trochanteroid processes, which make the width of the bone in this position something less than $\frac{6}{10}$ inch. The inner trochanter is much the less massive of the two; but its margin is imperfectly preserved, and it was obviously thinner than the great trochanter. It extends proximally to near the base of the proximal articular head of the bone, and had a narrow wing-like extension inward, curving somewhat forward at its proximal margin; but, as preserved, its internal extension beyond the proximal articulation is hardly more than $\frac{1}{20}$ inch. It is in no sense a process, but simply an expansion of the bone, and terminates distally in a short sharp ridge on the angle of the side of the shaft. The external trochanter is much thicker, and extends beyond the border of the articular head for $\frac{2}{10}$ inch. It is separated from this convex surface by a concave excavation about $\frac{1}{10}$ inch wide; and its outer rounded border, which is nearly $\frac{1}{10}$ inch thick, is reflected backward, and terminated proximally in a rounded process, which at the proximal end curves a little forward.

The rounded articular head has no neck connecting it with the shaft; but a constriction extends below the globular surface posteriorly, and another depression is apparently more marked on the anterior aspect. The transverse measurement of the head is about $\frac{3}{20}$ inch, and the antero-posterior measurement is somewhat more. Its depth on the posterior aspect is about $\frac{5}{40}$ inch.

Between the head of the bone and the two trochanters is a concave space, which runs down the shaft for about one third of its length, disappearing in a line as the bone narrows from side to side, and it is deepest towards the great trochanter. There is no trace of an obturator pit, nor of any excavation towards the external trochanter, such as characterizes this part of the bone in the majority of mammals, and especially marsupials; so that at first sight there is a *primâ facie* suggestion in this region of bats, or moles, or of a type allied to the monotremes, in which the trochanters were less developed than in *Ornithorhynchus*; but there are slight concavely curved lines extending between the trochanters and indicating muscular attachment.

The shaft becomes reduced to its least width of about $\frac{3}{20}$ inch near the middle. Its posterior lateral outline is concave, so as to give the distal articulation the aspect of being produced slightly outward. The internal outline is nearly straight between the internal trochanter and the distal articulation. The shaft of the bone is evidently flattened naturally, is straight on the posterior aspect below the trochanters, and becomes convexly curved from side to side. There is a slight groove extending down the length of the shaft in the median line from the external trochanteroid ridge to between the condyles, and gradually widening distally. The width of the bone across the distal condyles is rather less than $\frac{3}{10}$ inch; and though the specimen is not sufficiently developed from the matrix to show the thickness of the condylar end, it was evidently much less thick than is usual among marsupial mammals. The outer condyle is the larger; it has a transversely ovate outline, and is divided on the posterior aspect by a moderately deep depression from the smaller inner condyle, in which the greatest measurement was vertical. The depth of these condyles is about $\frac{1}{10}$ inch, and the shaft above them is concavely excavated.

These are the characters on which the systematic position of the animal must be determined. The bone is altogether less robust and is rather smaller than the same bone in *Ornithorhynchus*, has the trochanters narrower and smaller, the distal condyles narrower, and the articular head directed less upward and more inward. In all these points of difference there is a nearer approach to the femur of *Echidna*, which, however, is twice as long. In that genus the trochanters are relatively less developed, and the head of the bone is less well defined on the inferior aspect, while in the fossil the internal trochanter has a greater proximal extension. Both these genera of living Monotremes agree in possessing a similarly unexcavated condition of the posterior aspect of the external trochanter; and there are enough intermediate steps between the two surviving genera to include such a form as this fossil bone, if there were any corroborative evidence to justify its location in the same order with them.

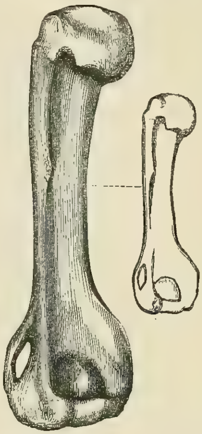
Among the marsupials there are not many in which a sufficiently near correspondence can be detected to justify a comparison. It is only among some of the Phalangers, such as *Phalangista Cookii*, that there is a general resemblance seen in form and type, though the existence in that group of an obturator pit renders detailed comparison impossible. The only other marsupial to which reference may naturally be made is the *Myrmecobius*, interesting from its resemblance to *Amphitherium*; but the bone is relatively shorter than in *Myrmecobius fasciatus*; the condyles at the distal end are relatively much less thickened. The internal trochanter does not extend so far proximally in the recent genus, and the fossil shows no trace of the excavation of the inferior aspect of the proximal end. It may therefore be concluded that the resemblance to Marsupials is, on the whole, less evident than the probable affinity of the bone to a Monotreme. It is interesting that *Amphitherium* has presented characters in the inflected angle of the lower jaw which induces Prof. Owen to dwell on its resemblance to the mole and the hedgehog, and to express a necessary caution against hastily concluding that the animal was not insectivorous. Dr. Gill, one of the most profound systematists of modern times, has sufficiently recognized, in his tabular view of the classification of the Mammalia, the near affinity of the Chiroptera, Insectivora, Rodents, and Edentates with the Marsupial and Monotreme orders; and it is certainly remarkable that this fossil bone, like the jaw referred to, should present characters which necessitate close examination as to its placental or its implacental determination. There are many animals in which the proximal end of the femur has two well-developed trochanters, and from which the obturator pit is absent; but in none do the condyles attain so great a size as in the fossil.

In the Little Ant-eater (*Cyclothurus didactylus*) the femur is $1\frac{3}{10}$ inch long, while the transverse measurement across the trochanters is only $\frac{7}{20}$ inch, so that in this animal the shaft is $3\frac{1}{4}$ times as long as the transverse measurement over the trochanters, while in the fossil the shaft is not more than twice as long as the width over the trochanters. The femur of the Mole has only a general resemblance to the fossil; the trochanters are narrower; the great trochanter is more developed proximally, and the concave area between the trochanters is of an altogether different character. A similar remark applies to the proximal end of the femur of the Hedgehog, which at first sight approximates in form to the fossil.

The Bats probably make a nearer approach than the Insectivora, both trochanters being well developed; but in the Bat there is not the same concave channel extending down the shaft between the trochanters, which is so remarkable a character in the fossil. I am therefore disposed to believe that the Monotreme characters predominate, and justify us in believing that the specimen was implacental, although there may be some reason for believing that it was, to some extent, also marsupial in its characters.

Humerus.

Fig. 2.—*Humerus.*



The outline shows the natural size of the bone.

The right humerus rests flat in the matrix, so as to expose its posterior aspect. It is $1\frac{1}{10}$ inch long, with a globose head, slender shaft, straight on the anterior or inner side, concave on the external or posterior side, and compressed and somewhat expanded at the distal end. It is much more marsupial in its characters than the femur. The head is $\frac{5}{20}$ inch wide, and is rather directed outward and backward; it is about $\frac{2}{10}$ inch deep, and presents a form which is seen in *Phascolarctos*, but which is unusual. The shaft narrows to $\frac{3}{20}$ inch in the middle, where its section would apparently be subtriangular, owing to the inner side of the bone being flattened vertically. This inner side extends upwards so as to form a small trochanter on the inner side of the articular head; but the posterior border of the bone is separated from the head by a well-defined transverse depression. On the proximal half of the inner margin rises a well-defined moderately elevated crest, which, so far as I am aware, is not paralleled in position in any humerus which is comparable with the fossil. The inner side of this ridge is continuous with the flattened inner side of the bone, and it extends up to merge in the trochanter; but the outer side of the ridge is defined by a slight clean groove. The ridge attains its greatest elevation at $\frac{5}{10}$ inch below the articular head of the humerus, and nearly $\frac{9}{20}$ inch from its proximal articular surface. The distal end of the bone lies in the same plane with the proximal end. The external margin is expanded into a thin plate, which has a highly convex external outline. This plate on its posterior aspect is flat and smooth, and in no way defined from the rest of the bone. Its contour helps to form the bow-shaped outline of the external side of the shaft. The inner border of the distal end also expands distally, though not to the same extent. It is less perfectly preserved, but was obviously much thicker and apparently flattened, and makes the width of the distal end in a line with the olecranon pit a trifle over $\frac{6}{20}$ inch. The details of the distal articulation are not well seen; but the bone appears to have been compressed and rounded, and the extension below the olecranon-pit of the condyles is rather less than $\frac{1}{10}$ inch. The olecranon-pit is not very deep, and is transversely ovate, placed a little obliquely, and nearer to the external than to the internal border of the bone. The principal condyle was below the inner half of the olecranon depression, and is partly broken away; but a small second condyle appears below its external corner, and between these there is a narrow smooth impressed intercondylar area, which extends obliquely forward and upward, and indicates the mode of flexure of the fore limb.

The nearest approach to this form of humerus is probably presented by some of the Phalangers, though the ridge, which is lateral on the side of the upper part of the shaft, would need to be turned, together with the head, through a considerable angle before the two forms could be brought into harmony.

On the oblique inner distal border is the usual supracondylar foramen seen in Marsupials and several other orders, which appears to have a vertically ovate outline, and to pass obliquely forward and downward and very slightly inward; it is placed just above the border of the olecranon-pit, and is separated from it by a width of $\frac{1}{10}$ inch. Its inner border is a narrow arch of bone, which is angular, being compressed from the front.

So far we have compared the humerus as though it were an isolated bone; and have ignored the possibility that it might present affinities of the same character as the femur. The difficulties which have presented themselves hitherto in its interpretation are:—(1) the concave anterior or external margin; (2) the ridge running down the superior aspect of the bone from the proximal articular head. But when our comparisons are turned to the *Ornithorhynchus*, singularly modified as the posterior or internal margin of the bone in that genus is, we recognize at once the significance of the characters which have hitherto been so difficult to interpret. In no other genus is the anterior concavity of the bone between the proximal and distal ends so pronounced as in this Monotreme; and although this right humerus presents a form which is more suggestive of a Marsupial in its general aspect, yet in these important characters, as well as in the outward direction of the articular head, it makes an approximation to the *Ornithorhynchus* which there is no reason for believing to be accidental, and every reason to regard as an indication of organic grade. It is not impossible that the Stonesfield animal may have had burrowing habits; but it is highly probable that a humerus so modified as this must have been connected with a pectoral arch like that of a Monotreme in construction, and unlike the ordinary form of the arch in placental Mammals or Marsupials. And if any difficulty should suggest itself in this comparison on the ground of the difference of the bone from the same element in *Ornithorhynchus*, it should be borne in mind that the Monotremes are at present known to us very imperfectly, and that between the Duck-billed Platypus and the *Echidna* there is a wide interval of organization. But perhaps the most interesting evidence of the affinity of the humerus is obtained when we bear in mind that it is found with the femur, and that the two bones correspond in presenting predominant indications of Monotreme characters under the external forms usual among Marsupials.

The only history of these specimens is that they were collected by Mr. S. Peace Pratt, formerly one of the Secretaries of the Geological Society, and presented by him, with four other bones from Stonesfield, to the British Museum. Mammalian remains occur so rarely that there is a strong predisposition to regard these bones as naturally associated; and the somewhat smaller size of the humerus, as compared with the femur, would favour such judgment, however strong the temptation might be to refer the bones to different genera on account of their resemblances to such different types of existing animals. At least, in the absence of evidence to the contrary, it may not be inconvenient to consider them to have been portions of a single individual. There then arises the more difficult question as to whether they pertain to any of the genera of the Stonesfield-Slate mammals hitherto established or not. And necessarily a judgment on this point must be largely founded on probabilities. The comparatively large *Stereognathus* is so generally regarded as placental, that its claims to the humerus and femur may be dismissed. There then remain only *Amphitherium* and *Phascolotherium* with which they may be associated. The size of the bones is not very different from what might be anticipated from the length of the jaws already described in those genera. In many small animals the length of the lower jaw is not greatly different from that of the femur, and the humerus is usually somewhat shorter, though there are many animals in which the skull is much longer than the femur. In *Ornithorhynchus* the lower jaw measures $3\frac{1}{2}$ inches, the femur $1\frac{4}{10}$ inch, the humerus $1\frac{3}{10}$ inch. In *Echidna* the skull is $4\frac{4}{10}$ inches long, the femur $2\frac{5}{10}$ inches, the humerus $1\frac{8}{10}$ inch. In *Didelphis virginiana* the lower jaw is $3\frac{8}{10}$ inches, femur $3\frac{1}{10}$ inches, humerus $2\frac{5}{10}$ inches. In *Myrmecobius fasciatus* the lower jaw is $1\frac{8}{10}$ inch, femur $1\frac{9}{10}$ inch, humerus $1\frac{4}{10}$ inch. In *Phalangista Cookii* the lower jaw is $1\frac{7}{10}$ inch, the femur $2\frac{7}{10}$ inches, the humerus $2\frac{1}{10}$ inches. In *Phascolarctos* the lower jaw is $2\frac{8}{10}$ inches, femur $3\frac{8}{10}$ inches, humerus $2\frac{9}{10}$ inches. In the Little Ant-eater the lower jaw is $1\frac{2}{10}$ inch, the femur $1\frac{3}{10}$ inch, the humerus $\frac{9}{10}$ inch. In the Hedgehog the lower jaw is $1\frac{7}{10}$ inch, and the femur and humerus are of the same length. In the Mole the skull is $1\frac{4}{10}$ inch, femur $\frac{7}{10}$ inch, and humerus $\frac{6}{10}$ inch. In the Beaver the lower jaw is $2\frac{3}{10}$ inches, femur $2\frac{3}{10}$ inches, humerus $1\frac{9}{10}$ inch. In the Marmot the lower jaw is $2\frac{3}{10}$ inches, the femur 3 inches, the humerus $2\frac{5}{10}$ inches.

Now in *Phascolotherium* the length of the jaw is about $1\frac{7}{20}$ inch, and in *Amphitherium* the length of the jaw is about $1\frac{3}{20}$ inch, while the femur described is $1\frac{2}{10}$ inch and the humerus $1\frac{1}{10}$ inch. Thus it is evident that there is not much ground for choice in affiliating the specimens to one genus or the other on the ground of proportion between the jaws and the limb-bones, though the presumptive evidence is strong, so far as size goes, that they might be referable to one of them. On the whole I am inclined to believe that the somewhat insectivorous and strong character of the lower jaw of *Phascolotherium* may perhaps be taken into consideration in connexion with the resemblance which the head of the femur described offers to the bone in some Insectivores, as indicating a habit which would justify us in suspecting that the remains are rather to be referred to that genus. If the three specimens may all be referred to the same genus, they indicate a generalized Marsupial, which certainly suggests evolution from a Monotreme stock, and cannot be placed in any division of the existing Marsupial order.

If the affiliation of these limb-bones to the jaw of *Phascolotherium* be accepted as an identification sufficiently probable to excuse me, in the absence of evidence of their generic distinctness, from the task of founding a new genus and species for the fossils, then a certain appositeness may be recognized in the association of a Marsupial jaw of generalized character with limb-bones indicating a generalized Insectivorous type, modified from a Monotreme stock in the direction of the Marsupial plan, as one of those harmonies which the general truths of the doctrine of evolution would lead us to anticipate; for the researches of Profs. Owen, Gaudry, and Marsh have gone far to prove that every type of mammalian life becomes more generalized when it is traced backwards in time, and presents affinities towards less specialized orders; from which we infer that these, or similar orders, were the parent stock from which the surviving types were derived. Similarly I am inclined to suggest that these remains from Stonesfield justify us in inferring the existence of a generalized order of animals, which were not Marsupials, but from which the Marsupials became evolved.

Discussion.

The President congratulated the author upon the discovery of the importance of these specimens, which had been so long overlooked.

Prof. Prestwich remarked on the interest attaching to the discovery of these remains among old specimens from Stonesfield, since at present the slate-pits at that place are little worked. He suggested that if other store-collections of Stonesfield fossils (like those of Oxford) were overhauled, they might yield equally valuable results to so careful a worker as Prof. Seeley.

Dr. Murie expressed doubts whether the humerus was a right one, and also as to the validity of conclusions derived from a comparison of the lengths of the limb-bones and the lower jaws.

He thought that Prof. Seeley's views as to the predominantly monotrematous character of the animal were hardly supported by the evidence adduced, and that if the jaws of *Phascolotherium* had not before been discovered the identification might not have been made.

Mr. Charlesworth insisted on the important discovery of bones other than mandibular in the Stonesfield Slate, a discovery which had been looked forward to in vain since 1814. He cited and expressed doubt on the explanation of Prof. Owen, that the lower jaws had fallen away from the floating skeletons.

Mr. Blake argued in favour of both the bones belonging to one specimen, and pointed out that the greatly modified bone (the humerus) was the one most likely to vary with the habits of the animal.

Prof. Seeley, in reply, expressed his thanks for the compliments which had been paid him. He defended his identification and interpretation, his comparisons of the lengths of the limb-bones and jaws in different orders of mammals, and his conclusion that the bones had monotreme affinities. He should have arrived at the same conclusion if no jaws had ever been found.

36. *On the* Occurrence *of the* Genus Dithyrocaris *in the* Lower Carboniferous *or* Calciferous Sandstone Series *of* Scotland, *and on that of a* Second Species *of* Anthrapalæmon *in these* Beds. By R. Etheridge, Esq., Jun., F.G.S. (Read April 30, 1879.)

(Published with the permission of the Director-General of the Geological Survey.)

[Plate XXIII.]

1. Introduction.

Since my connexion with H.M. Geological Survey ceased I have been allowed by Prof. Geikie, F.R.S., to make use of some very interesting Crustacean remains collected during the progress of the Survey work, and now beg to offer some remarks upon these specimens. I take this opportunity of expressing my thanks to Prof. Geikie for granting me this privilege. I am also indebted to Dr. Traquair, F.G.S., for the loan of one of the specimens described hereafter.

2. On the Occurrence of Dithyrocaris in the Calciferous Sandstone Series.

The genus *Dithyrocaris* has hitherto been met with in the Scotch Carboniferous system, so far as I am aware, only in the Carboniferous Limestone group proper. The Phyllopods of the Calciferous Sandstone series (= Tuedian beds), or lower section of the Scotch Carboniferous, consist up to the present time of three species, viz.:—*Estheria Peachii*, Jones *; *Leaia*, sp. †; and *Estheria Dawsoni*, Jones ‡. I know of no other form recorded from this series of rocks §.

Some months ago Dr. R. H. Traquair, F.G.S., called my attention to a specimen in the Edinburgh Museum, found by Mr. J. Henderson in the Wardie Shale beds of the Water of Leith, consisting of several semidetached segments of a large crustacean, which, from their general resemblance to those of the Phyllopoda, I conceived were probably the remains of *Dithyrocaris* or an allied genus. Shortly after this discovery my duties in connexion with the Geological Survey led me to examine a collection of Lower Carboniferous fossils made in Roxburghshire by Mr. A. Macconochie, one of the Survey collectors. The specimens of Crustacea obtained by Mr. Macconochie are of great interest, and my thanks are specially due to him for his kindness in immediately calling my attention to them.

The evidence contained in this collection is entirely confirmatory

* Geol. Mag. vii. p. 220.

† *Ibid.* viii. p. 96. Peach, Brit. Assoc. Rep. for 1871, pt. 2, p. 109.

‡ Etheridge, Geol. Mag. dec. 2, 1876, iii. p. 576.

§ *Leaia Jonesii* has since been described (Ann. & Mag. Nat. Hist., April 1879).

of the Wardie Shale specimen being a *Dithyrocaris*; for there body-segments, tail-spines, and portions of the carapace occur in profusion. The discovery of this genus in the Lower Carboniferous series by Messrs Henderson and Macconochie is a point of much interest; and its occurrence in the Wardie Shale beds will form a welcome addition to the fauna described in my paper on that subject *. The following are detailed notes on the specimens.

Dithyrocaris, sp. ind.

Obs. The specimen found by Mr. Henderson is specifically undeterminable, at any rate with our present imperfect knowledge of the species of *Dithyrocaris*. It consists of the impressions of four body-segments, and perhaps portions of two others, crushed sideways. They are in form almost quadrangular above, tapering below; there is no trace of the tail-spines. Scattered over and around the specimens are an immense number of small, circular, crushed, disk-like bodies, some adhering to the segments, others in close proximity to them.

At first sight these little disks might be referred to the sporangia of some Lycopodiaceous plant, such as *Lepidodendron*, *Flemingites*, or *Tasmanites*; but in their present state it is difficult to express an opinion on their nature †. Dr. Woodward does not think they have any organic connexion with the crustacean segments.

Loc. and Horizon. Woodhall, Water of Leith, near Edinburgh, in the Wardie Shale section of the Cement-stone group, L. Carboniferous or Calciferous Sandstone series.

Coll. Museum of Science and Art.

Collector. Mr. John Henderson.

Dithyrocaris testudineus, Scouler. (Pl. XXIII. fig. 1.)

Argas testudineus, Scouler, Records of Gen. Science, 1835, i. p. 136.

Dithyrocaris Scouleri, M'Coy, Synop. Carb. Foss. Ireland, 1844, p. 163, t. 23. f. 2.

D. testudineus, Morris, Cat. Brit. Foss. 2nd ed. 1854, p. 107; Woodward & Etheridge, Brit. Assoc. Report for 1873, pt. 2, p. 92; Woodward & Etheridge, Mem. Geol. Survey Scotl. Expl. 23, 1873, p. 98; Woodward & Etheridge, Geol. Mag. 1873, x. p. 482, t. 16. f. 1; Woodward, Cat. Brit. Foss. Crust. 1877, p. 73; Bigsby, Thesaurus Dev.-Carb. 1878, p. 249.

Obs. This species is represented in the collection from Roxburghshire by two half carapaces. The narrow, strongly and obliquely fringed lateral margins are quite visible; and in one of them there is also to be seen the commencement of one of the rounded ridges within the margins, which gradually turn inwards. On the other

* "On our Present Knowledge of the Invertebrate Fauna of the Lower Carboniferous or Calciferous Sandstone Series of the Edinburgh Neighbourhood, &c.," Quart. Journ. Geol. Soc. xxxiv. p. 1.

† Is it possible that they are the remains of ova adhering to the abdomen?

specimen are the remains of the slightly rounded posterior margin which connects the median ridge of the carapace with the posterior lateral spines on each side. In the figure the two halves of the carapace have been placed in apposition, to show their relation to one another, the dotted portions being restored.

Loc. and Horizon. Tweeden Burn, near junction with Liddel Water, by New Castleton, Roxburghshire; in the Cement-stone group of the Calciferous Sandstone series.

Coll. Geol. Survey of Scotland.

Collector. Mr. A. Macconochie.

DITHYROCARIS TRICORNIS, Scouler.

Argas tricornis, Scouler, Records of Gen. Science 1835, i. p. 136.

Dithyrocaris tricornis, Morris, Cat. Brit. Foss. 2nd ed. 1854, p. 107; Salter & Woodward, Cat. & Chart of Foss. Crustacea, p. 17, f. 12; Woodward & Etheridge, Brit. Assoc. Report for 1873, pt. 2, p. 92; Mem. Geol. Survey Scotl. Expl. 23, 1873, p. 99; Geol. Mag. 1873, x. p. 483, t. 16. f. 2 & 3; Woodward, Cat. Brit. Foss. Crustacea, 1877, p. 73; Bigsby, Thes. Dev.-Carb. 1878, p. 249.

Obs. To this species are referred portions of the two halves of a much larger carapace, disunited, but lying partially over one another. They both exhibit the strongly and obliquely striated lateral margins and the toothed or serrated lateral ridges, terminating in one of the strong recurved posterior spines. There is no trace of the fine ornamentation on the surface exhibited by the specimen discovered by Mr. James Bennie, now in the collection of the Geological Survey of Scotland, and figured by Dr. Woodward and myself. On the contrary, there is evidence of the peculiar striated lamination so often found on the carapace-surface of *D. testudineus*, and seen also on the segments accompanying the specimen before mentioned as found by Mr. Bennie *.

To *D. tricornis* are also referred some strong and bold tail-spines. The side spines measure one inch two lines long, the central one being a trifle shorter. They are ornamented with the before-mentioned laminar striæ, directed longitudinally, with here and there rugosities scattered over the surface.

Loc. and Horizon. Liddel Water, half a mile below New Castleton; Tweeden Burn, near junction with Liddel Water, by New Castleton, Roxburghshire. Cement-stone group of the Calciferous Sandstone series.

Coll. Geological Survey of Scotland.

Collector. Mr. A. Macconochie.

DITHYROCARIS, sp. ind. (Pl. XXIII. figs. 2 & 3.)

Obs. There are in the collection made by Mr. Macconochie four specimens, consisting of abdominal somites and tail-spines, which must have belonged to a species fully as large as *D. tricornis*, Scouler.

* Geol. Mag. x. t. 16. f. 3 *e*.

The form and much greater size at once separate them from *D. testudineus*, Scouler. The most perfect amongst these *disjecta membra* shows traces of seven body-segments and the three tail-spines (Pl. XXIII. fig. 2). The abdominal somites together measure one inch and a half long, and about half an inch in breadth, whilst the spines are fully half an inch long, or possibly a little more. The median spine is the most robust, and is three sixteenths of an inch broad at its base; there is no trace of surface ornamentation. Another specimen (Plate XXIII. fig. 3) exhibits four of the body-segments and the central spine of the tail, giving a total length of one inch and three quarters, of which the spine measures three fourths of an inch. This individual, in the process of fossilization, has been crushed sideways, and indicates that the form of the somites was not cylindrical, as usually supposed, but each segment had a broad epimeral border, quadrate in form and slightly produced at its latero-posterior angles, reminding one of the somites in the abdomen of the Decapoda. This structure is an interesting advance in these old Phyllopods, because, so far as we know, it does not exist in the allied genus *Ceratiocaris*, and is not known in the recent representative *Nebalia*.

Loc. and Horizon. Liddel Water, half a mile below New Castleton, Roxburghshire; in the Cement-stone group of the Calciferous Sandstone series.

Coll. Geol. Survey of Scotland.

Collector. Mr. A. Macconochie.

Dithyrocaris, sp. ind.

Obs. One specimen and its counterpart, not included amongst the foregoing, and very much compressed, consists of two bodies and tails and one carapace. The latter has no trace of the ornamented border of *D. testudineus*, and the tail-spines are very much shorter than many of the specimens previously referred to; one seven, another seven and a half, and again another only six lines long. It is not improbable that these remains may represent a species near *D. granulata*, Woodw. & Eth.*

Loc. and Horizon. Liddel Water, half a mile below New Castleton, Roxburghshire; in the Cement-stone group.

Coll. Geol. Survey of Scotland.

Collector. Mr. A. Macconochie.

3. On Lower Carboniferous Species of Anthrapalæmon.

Since the description of *Anthrapalæmon? Woodwardi*, mihi, appeared, the species has been met with at three other localities in the Lower Carboniferous area of the south of Scotland; in each case the fortunate finder has been Mr. Macconochie. The Cement-stones of Roxburghshire have yielded this peculiar form in some abundance, and in a fine state of preservation, accompanied by the remains of an allied, although larger and quite distinct, species, which I have much pleasure in describing as *A. Macconochii*, after its discoverer.

* Geol. Mag. 1874, i. tab. 5. figs. 2 & 3.

It will be within the recollection of those interested that the type specimen of *A. Woodwardi*, found by Mr. James Bennie at Belhaven Bay, near Dunbar, was in any thing but a good state of preservation, contained in an ironstone nodule. Mr. Macconochie's specimens, on the other hand, are in a Cement-stone, and are preserved in a particularly good state for examination; they will enable me to define the species in a much more accurate manner, to make a few corrections in my former description, and several additions.

The second species, *A. Macconochii*, of which the remains are abundant, is manifestly so different from *A. Woodwardi*, although allied to it, as well as from the other species of the genus, *A. Grossarti*, Salter, *A. dubius*, Prestwich, *A. Russellianus*, Salter, and *A.*? *gracilis*, Meek and Worthen, that I do not hesitate to designate it by a distinct name. The following is a detailed description of the two species.

ANTHRAPALÆMON WOODWARDI, R. Etheridge. (Pl. XXIII. figs. 4–9.)

Anthrapalæmon Woodwardi, R. Eth. Quart. Journ. Geol. Soc. 1877, xxxiii. p. 872, t. 27.

Sp. char. Carapace oblong, narrowing towards the anterior part, and divided into two unequal portions by the cervical groove, the posterior being the largest; relative convexity unknown. Anterior lateral margins not spinous and without serrations; posterior lateral angles rounded; posterior margin concave. Cervical groove strongly marked and widely V-shaped. Middle line of the carapace occupied by a strong ridge continuous with the rostrum and extending to the posterior margin, and flanked on each side by a straight or slightly curved lateral ridge extending from the cervical groove to the posterior margin. Like the central one, these ridges are minutely crenulated. That portion of the carapace anterior to the cervical groove is crushed, and cannot satisfactorily be made out; but it was undoubtedly produced into a rostrum continuous with the central line of the carapace, and narrowing rapidly towards the front. Flagella of the antennæ bent obtusely outwards, of numerous minute subdivisions. Antennæ having a peduncle or protopodite of four segments, and terminating in two slender filamentous whips. First pair of chelate appendages probably present, small, elongate. Eyes large and reticulated. Abdominal segments (as in the generic character) six in number, with pointed pleuræ and a well-marked central line extending throughout their whole length, and corresponding with the central ridge of the carapace; articular area small, but distinctly visible, defined by a small transverse ridge on each segment. Telson primarily consisting of a central hastiform plate, flanked on each side by two lateral caudal swimming-lobes, which arise from and are articulated to the sixth segment of the abdomen.

Obs. The additional light thrown upon this species by the discovery of the present specimens renders some alterations in my previous description * necessary. On the one hand certain statements

* Quart. Journ. Geol. Soc. xxxiii. p. 872.

require modification, and on the other some points are in need of enlargement. For instance, the posterior lateral angles are rounded (Plate XXIII. figs. 5 & 6), and not angular, as previously stated, although there are one or two individuals in which they so appear; I have, however, satisfied myself that this appearance is superinduced, as the angularity must arise from pressure in some particular direction. The figure of the type specimen * from Belhaven Bay showed the central ridge only, and a lateral one on each side of it, although when I came to examine it again, by the aid of the more recently discovered specimens, I found that there did exist the remains of an extension of the carapace on the left-hand side, beyond the marginal line represented in the figure as the lateral border; this marginal line will therefore represent a second ridge which is seen between the secondary ridge and the lateral margins on the carapace of some of the present specimens, and which probably represents the incurved border of the carapace showing through its structure.

Nothing satisfactory in connexion with the antennæ or antennules could be made out in the type specimen; this deficiency we are now able to supply. The form and position of these organs quite support Dr. H. Woodward's view, that the organs in question did not differ essentially in position or form from those usually found in the Macrura. This opinion was expressed by Dr. H. Woodward in opposition to the views held by the late Mr. Salter, who believed the antennules to be long and simple, and placed within the bifid antennæ †.

The peduncles of the antennæ are not distinctly preserved; the flagella, however, are bent obliquely outwards, and are composed of small numerous joints; for their size they are tolerably broad at their bases and taper gradually. The peduncles of the antennules consist of three elongated joints directed forwards, and terminating in two tapering setiform flagella composed of numerous well-marked joints; they diverge nearly at right angles from one another.

We still need accurate information about the rostrum of *A. Woodwardi*. Its position was tolerably well defined in the specimen from Belhaven Bay, now confirmed in one or two of the present specimens; but not in one can I definitely ascertain the presence of serrations along its course.

The crushed condition of the present specimens would not lead us to expect any very marked trace of the eyes; but, notwithstanding this, it is just possible that a certain rounded outline on one side of one of the specimens (Pl. XXIII. fig. 5, *a*) may be one of the eyes, especially as there is a dim trace of faceting. I may state that Dr. Woodward is inclined to this view.

Hitherto, so far as I know, no trace of eyes has been observed in *Anthrapalæmon*. Messrs. Meek and Worthen imagined they had detected ‡ them in one of their examples of *A.*? *gracilis*, M. & W., from Grundy County, Illinois; but more complete specimens §

* *Loc. cit.* t. 27. f. 3 & 3 *a*.
† Trans. Geol. Soc. Glasgow, ii. p. 246.
‡ Illinois Geol. Survey Report, i. p. 407.
§ *Ibid.* iii. p. 554.

showed these supposed eyes to be only the bases of the antennules.

In the type specimen the ridges of the carapace did not exhibit any traces of ornamentation; it is, however, now quite clear that they were finely crenulated in a highly ornamental manner. In the larger species from Roxburghshire, which I have called *A. Macconochii*, the cervical furrow is very strongly marked; but in *A. Woodwardi*, so far as the remains at our disposal enable us to judge, it is not so, except in one or two individuals.

The little object which I have called the first chelate appendage is not so satisfactory in its appearance as either the antennæ or antennules; nevertheless it is in the right position, and has assumed more or less the form of this organ; I may add that Dr. H. Woodward agrees with me in this reference. There extends through the centre of the body, longitudinally, a semiobliterated dark line.

In their final description of the American *A.? gracilis*, Messrs. Meek and Worthen mention and figure what they call segmentary structure within the carapace *. A division into segments probably similar to this is met with in one or two of our specimens (Pl. XXIII. fig. 8). In one in particular there are no less than six of these visible within the crushed-down carapace; in another individual there are five.

Decided traces of ornamentation are not preserved, although in one specimen indications of small tubercles are, I think, traceable anterior to the cervical groove.

In his original description of *Anthrapalæmon Grossarti* Mr. Salter described the pleuræ of the first thoracic segment as abbreviated; but in *A. Woodwardi* I have not been able to detect such a character, nor, in fact, any appreciable difference from the other segments.

I am sorry not to be able to give further details of the thoracic appendages, for they are in a still less satisfactory state than in the Belhaven original. The greatest number discernible in any one specimen is five; it is, however, quite evident from the condition of the fossils that in this case they are not all preserved.

The description of the caudal appendages given in my former account of this species appears to be correct, so far as it goes; I think it not unlikely, however, that the construction of the tail was more complicated than at first supposed, although there is no trace preserved of the very detailed composition exhibited by the tail of *A.? gracilis*, M. & W.

A. Woodwardi must have lived in numbers together, for at two localities its remains are found in large colonies. At one locality, near Dunse, only one individual was met with sufficiently well preserved for examination; but the dark buff shale was full of fragments. At one of the localities in Roxburghshire it is perhaps even still more common; for pieces of the cement-stone in which it is found are literally crammed with the flattened and confused remains.

* Illinois Geol. Report, iii. p. 554, f. A.

Affinities and Differences.—From *Anthrapalæmon Grossarti* Salter *, the present species may be distinguished by the presence of supplementary ridges on the carapace, and by the continuation of the central ridge as far backward as the posterior margin of the carapace. It is also probable that the absence of serrations along the anterior lateral margins, and of a spine at the anterior angles, will be found to be distinctive.

From *A. dubius*, Prestwich †, our Lower Carboniferous form is separated by the presence of an additional ridge on each half of the carapace, and the absence of the serrate margins to the latter.

The number of ridges which traverse the carapace from back to front at once serve as a distinctive character between *A. Russellianus*, Salter ‡, and *A. Woodwardi*. There does not either appear to be any trace in the latter of the deep row of punctations representing the cervical furrow of the former species.

The last species with which we have to compare our form is *A.* ? *gracilis*, Meek and Worthen § ; but I think the truncated posterior margin and serrated lateral edges will be sufficient to separate the two species, to say nothing of the more complex tail of the American form, or of the entire absence of all supplementary carapace-ridges. It becomes a question if the American species can be retained in the genus *Anthrapalæmon*, when we take into consideration the diversity which exists between its telson and that of the type species as described by Mr. Salter.

The affinity of *A. Woodwardi* with either of the foregoing species is not a very strong one; but in the presence of the continuous central ridge of the carapace and of the supplementary lateral ridges it approaches *A. dubius*, Prestwich, and the next form to be described, *A. Macconochii*.

Loc. and Horizon. Many specimens were found in a Cement-stone in the Liddel Water, half a mile below New Castleton, Roxburghshire; a single example was met with (accompanied by *Spirorbis*) in shale in the Tweeden Burn, near the head of Tweeden Plantation, near New Castleton; a third specimen was found in soft shale in a glen at Mains, eight miles N.N.E. of Coldstream; and, lastly, one tolerably perfect example and many fragments occurred in a soft clayey shale on the Blackadder Water, near Pathhead Mill, about two and a half miles S. of Dunse, Berwickshire. The horizon of the whole of these beds is that of the Cement-stone, or Upper Group of the Calciferous or Lower Carboniferous series (=Tuedian).

Coll. Geol. Survey of Scotland.

Collector. Mr. A. Macconochie.

ANTHRAPALÆMON MACCONOCHII, sp. nov. (Pl. XXIII. fig. 10.)

Sp. char. Carapace more or less oval, terminating posteriorly

* Quart. Journ. Geol. Soc. xvii. pp. 530, 531, f. 1–4.

† *Apus*, Trans. Geol. Soc. 2nd ser. v. t. 45. f. 9. *Anthrapalæmon*, Salter, *loc. cit.* pp. 531, 532, f. 6–7 *b*.

‡ *Loc. cit.* xix. p. 520, f. 1, 2.

§ Illinois Geol. Rep. ii. p. 407, t. 32. f. 4 *a–c*.

in two strong incurved spines; anterior margin concave, produced into a central rostrum or mucro; posterior margin also concave, but in an opposite direction to the anterior. Surface divided into two very unequal parts by a wide and well-marked cervical groove, the anterior portion being much the smaller. The lateral margins anterior to the cervical groove are finely and obtusely serrate, and terminate forwards in small short spines; posterior to the groove the margins become thickened and are horizontally crenulate, the crenulations having their convexities directed backwards. The central line of the carapace is occupied by a thickened dorsal ridge continuous from the posterior margin forwards to the cervical groove, and thence connected with the anterior mucro. Proceeding from the posterior incurved spines of the carapace are two almost median-lateral thickened ridges, which gradually curve outwards as they approach the cervical groove, where they terminate. All the ridges present on the carapace are similarly ornamented to the posterior portion of the lateral margins. The cervical groove appears to have a branch on each side directed towards the antero-lateral spines. The rostrum or mucro is tapering and pointed. On each side of the central ridge on that portion of the carapace anterior to the cervical groove are two circular blunt eminences, abutting on the anterior branch of the former. Body-segments and appendages unknown.

Obs. A very marked appearance is given to this fossil by the strongly developed carapace-ridges, with their crenulated striæ, the elongated and incurved posterior angles, and the deeply concave posterior margin of the carapace. Again, the broad and deep cervical groove is another feature to be noted, quite interrupting, as it does, the continuity of the central carapace-ridge with the rostrum; it must, however, be remembered that perhaps the preservation of the integument would considerably lessen this appearance.

Omitting from consideration the presence of the cervical groove and rostrum, the general aspect of this species is very Dithyrocaroid; so much so, that until I had carefully studied the specimens, I was inclined to refer them to that genus.

In no case is the true integument preserved; but the substance of the crustacean is converted into a soft white pulverulent substance, requiring the application of some mucilaginous material for its preservation in the cabinet.

The average size of *A. Macconochii* is about eight lines from the tip of the rostrum to a line drawn between the two posterior angles, and the breadth five lines; one specimen measures ten lines by seven, and there are the mutilated remains of still larger individuals. The smallest example is three and a half lines long by two and a half broad, and very well illustrates the complete dissimilarity of the species from the preceding, *A. Woodwardi*, conclusively showing that one cannot be assumed to be the young or immature form of the other. There appears to be little variation amongst the specimens in the Survey collection; and, strange to say, notwithstanding the number of individuals on some pieces of cement-stone clustered together, there is an entire absence of body-segments, tail-spines, or appendages.

Affinities and Differences.—The backward prolongation of the lateral margins, the absence of the additional carapace-ridges, and other minor features at once distinguish *A. Macconochii* from *A. Woodwardi.*

In the serrate and crenulate lateral margins the present species resembles *A. Grossarti* and *A. dubius.* It differs from the first of these, however, by the posterior extension of the central ridge of the carapace, the presence of supplementary ridges, and the strongly-marked cervical furrow; but, like *A. Grossarti,* it has spines at the anterior angles of the carapace.

There is a marked similarity between *A. Macconochii* and *A. dubius*, Prestwich, in the division of the carapace into two parts by the strongly marked cervical groove, the continuity of the central ridge, the presence of supplementary ridges (or rather furrows in *A. dubius*), and the serration or crenulation of the entire lateral margins. On the other hand, in *A. dubius* the anterior angles of the carapace are not produced into spines, and the incurved posterior angles of *A. Macconochii* are absent.

In *A. Russellianus*, Salter, the form of the carapace is quite different, as also is the character of the rostrum, from what we find them in the species under consideration. The cervical furrow in the latter is continuous, and not represented by a row of deep punctations. It, however, resembles *A. Russellianus* in the serrated lateral margins.

It is hardly necessary to compare our form with *A.? gracilis*, Meek and Worthen, although it will be seen that the latter differs in the truncation of the carapace before and behind, the small part of the lateral margin which is serrate, in the absence of supplementary ridges, &c.

Horizon and Locality. From a Cement-stone on the Tweeden Burn, near the head of Tweeden Plantation, by New Castleton, Roxburghshire. Cement-stone group of the Lower Carboniferous series.

Coll. Geol. Survey of Scotland.

Collector. Mr. A. Macconochie, after whom the species is named.

EXPLANATION OF PLATE XXIII.

Fig. 1. *Dithyrocaris testudineus*, Scouler. Two half carapaces in apposition, and the outline restored: nat. size. Tweeden Burn, near New Castleton.

2. *Dithyrocaris*, sp. ind. Abdominal somites, tail-spines: nat. size. Liddel Water, near ditto.

3. *Dithyrocaris*, sp. ind. Abdominal somites &c., crushed sideways, with an epimeral border and the central tail-spine: nat. size. Liddel Water, ditto.

4. *Anthrapalæmon Woodwardi*, R. Eth. Showing the general characters of the species, including the eyes (restored) and the first pair of chelate appendages: × 7. Liddel Water, near New Castleton.

Fig. 5. The same. A half side view of another specimen, with four of the legs, antennæ, antennules, and one of the eyes, *a* (*in situ*); the chambers for the reception of the branchiæ are also visible through the carapace: × 5. Liddel Water, near New Catleton.

6. The same. A side view, showing the form of the carapace and the pointed pleuræ: × 5½. Liddel Water, as before.

7. The same ?, probably the *Megalops* condition: × 12. Liddel Water, as before.

8. The same, showing the "segmentation" within the carapace, caused by the divisions of the branchial chambers, &c.: × 5½. Liddel Water, as before.

9. The antennæ, antennules, eye, &c., enlarged, from fig. 5.

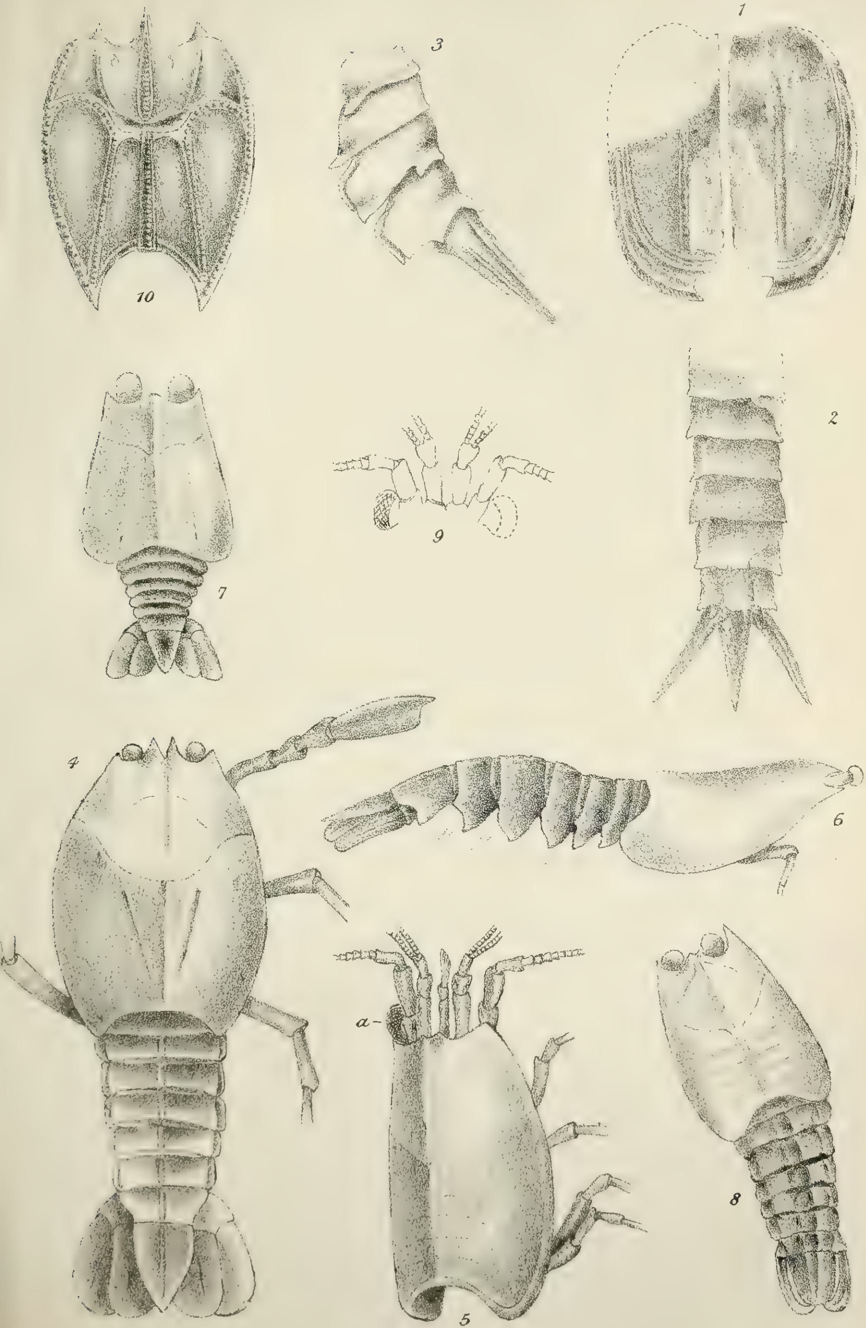
10. *Anthrapalæmon Macconochii*, R. Eth.: × 2. Tweeden Burn, near New Castleton.

Discussion.

Dr. Woodward pointed out that the discoveries of the Author had carried the Macrurous Decapod Crustacea far lower down in the geological series than they had before been found. He had himself examined a species of Macrurous Crustacean from the Carboniferous Limestone.

Rev. J. F. Blake asked, if the legs were six in number and the animal had sessile eyes, what were the grounds on which it was classed as a Decapod.

The Author replied that there is no certain evidence in the specimens as to the number of legs, or as to whether the eyes were sessile or pedunculated; the former are fragmentary and the latter crushed.



A Foord lith.

Hanhart imp.

ANTHRAPALÆMON & DITHYROCARIS.

37. *On the* Silurian District *of* Rhymney *and* Pen-y-lan, Cardiff. By W. J. Sollas, Esq., M.A., F.G.S., Lecturer on Geology, University College, Bristol, and Curator of the Bristol Museum. (Read April 9, 1879.)

[Plate XXIV.]

The occurrence of rocks containing typical Silurian fossils at several places near Cardiff, and over an area mapped as Old Red Sandstone by the Geological Survey, was first brought to my notice by my friends Captain J. Carne Ross, F.G.S., and Mr. W. H. Harris, of Cardiff. This was in the autumn of 1875; and as I was then commencing a stay of six months at Cardiff, I was able to accompany my friends to the sections they had discovered, and to confirm their observations.

Mr. Ross and myself then devoted ourselves to a careful study of the neighbourhood, with the intention of writing a joint paper on the subject; but when we had made a considerable advance in our work, Mr. Ross removed to a distant part of the country, and I was left (much to my regret) to complete the paper without his aid. My friends Messrs. R. Jones and T. Jones, F.G.S., both of Newport, and Messrs. W. H. Harris and J. Storrie, of Cardiff, came, however, to my assistance; and to them I am indebted for many valuable suggestions and for the clearing-up of many doubtful and difficult points.

History.

The whole of the district I am about to describe is coloured as Old Red Sandstone on the maps of the Geological Survey; but that Silurian rocks exist at Pen-y-lan hill and in its neighbourhood was made known so long ago as 1861 by Norman Glass*, who collected a number of fossils from the Pen-y-lan quarry, and sent them for determination to Sir Roderick Murchison and Mr. Salter. A list of these fossils was drawn up by Mr. Salter, and the beds were assigned to the Wenlock series. Mr. Bevan, F.G.S., next examined the district, and published a paper upon it, to which, however, I have not succeeded in obtaining a reference. Mr. Etheridge tells me that Mr. Aveling also has paid a visit to Pen-y-lan; but no record of his observations appears to have been published. I am not aware that any other literature exists on the subject.

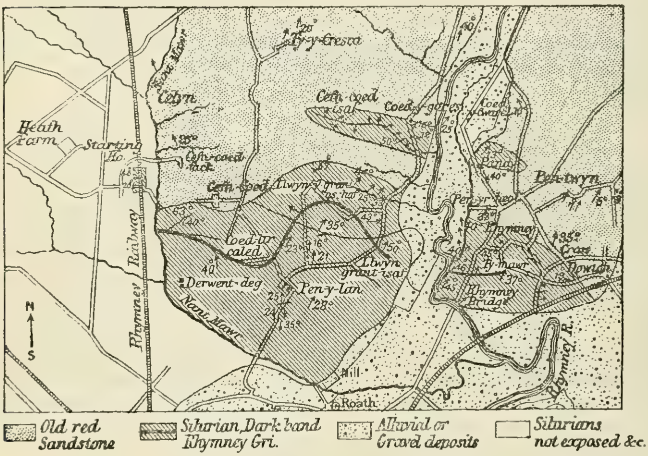
Geographical Distribution.

The alluvial plain on which Cardiff is situated extends northwards to the edge of the old Palæozoic tableland of South Wales, and meets it along a line extending from Llandaff railway-station on the west to Rhymney bridge on the east. From this line to the southern escarpment of the limestone of the Coal-basin the tableland rises gently to the north, and is cut up by three transverse

* 'The Geologist,' 1861, p. 168.

streams into a number of long hilly ranges running north and south. The streams are the river Taff, the river Rhymney, and a small feeder of the latter, which, from one of its branches, we may designate as the Nant Mawr. The hilly ranges consist wholly of Old Red Sandstone, except at their southern terminations, which are composed of the Silurian rocks under description. The Silurian strata east of the Rhymney extend northwards from the Rhymney bridge to a line joining the village of Rhymney on the west with that of Cross Dowton on the east. Between the Rhymney and Nant Mawr the Silurian composes the hills south of a line which commences west of Cefn Coed, continues parallel to and north of the stream flowing past Llwyn-y-grant-uchaf, and ends in the road leading from Pen-y-lan to Lanedern. Between Nant Mawr and the Taff the country south of Heath Farm is completely covered over by coarse gravels and shingles, which conceal every trace of the underlying rocks except at one or two points where they have been cut through by the Rhymney railway. Silurian rocks are thus exposed as far north as the spot marked Starting House on the Ordnance

Fig. 1.—*Geological Sketch Map of the Cardiff Silurian District.*
(Scale, 1 inch to a mile.)



map; and there can be little doubt that they form the southern half at least of the hill on which Heath Farm is situated, and probably extend still further west. A careful search for them in the embankment at Llandaff railway-station revealed, however, nothing but river-gravels, made up chiefly of Old-Red and Carboniferous fragments, with an occasional pebble of doubtful Silurian age.

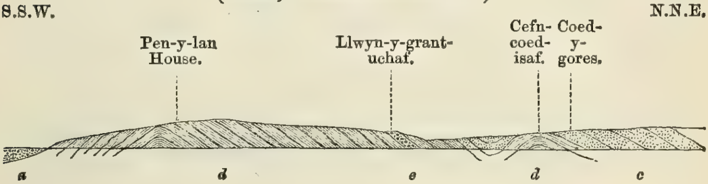
The three districts thus indicated constitute together a single and continuous area, which extends from the Starting House on the west to a little beyond Cross Dowton on the east (a distance of about

2¾ miles), and from a point north of Llwyn-y-grant-uchaf to Ty-y-cyw, near Roath, on the south (a distance a little over a mile and a quarter). Besides this area there is another, which I have not yet mentioned, lying a little to the north of it, and which extends as a narrow band (one sixth of a mile wide) from Cefn-coed-isaf on the west to near Pen-twyn on the east, a distance of a mile and a quarter.

General Structure.

Pen-y-lan (fig. 2).—The southern side of Pen-y-lan hill commences rising from the bordering alluvial plain with a very gentle slope, owing to the soft and easily decomposable nature of the red Silurian shales and sandstones of which it is composed. These are exposed in a ditch on the right-hand side of the road going up the hill, and are there seen to dip from the N.E. towards the S.W. After a while the slope becomes a little steeper and harder grits begin to appear,

Fig. 2.—*Diagrammatic Section from Ty-y-cyw to Coed-y-gores.*
(Scale, 2 inches to a mile.)



a. Gravel. *c.* Old Red Sandstone.
d. Silurian. *e.* Rhymney grit?

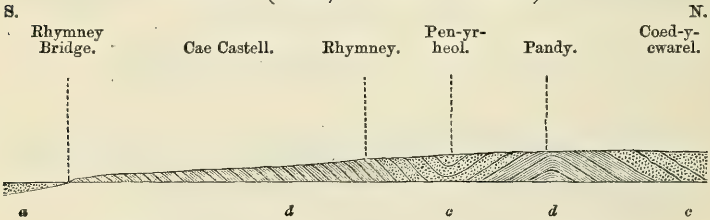
still keeping, however, a dip to the south, till just within twenty-five yards south of Pen-y-lan House the dip changes and turns over towards the north. Accurate measurements made in a ditch on the left-hand side of the road give a strike of 60° to 70° W. of N., with a dip first of 30° to the south and then of 25° to the north.

Thus the hill is traversed by an anticlinal axis running from W.N.W. to E.S.E., the beds to the south of it dipping southwards, and to the north northwards. The northward dip continues as we proceed to the north-east, higher and higher beds of the Silurian being successively introduced till the Old Red Sandstone beds are reached. The dip then rapidly changes; and at the point marked on the Ordnance map by an arrow, near Coed-y-gores, Silurian beds are brought up by a low anticlinal, the axis of which follows the stream descending from Cefn-coed-isaf. At Coed-y-gores itself the Old Red Sandstone is typically present, as may be seen in the river-cliffs washed there by the Rhymney; it dips towards the N.E., and continues to do so for some distance further N.

Rhymney.—On the eastern side of the Rhymney the same arrangement as that just described is to be clearly made out; but the southern half of the Pen-y-lan anticlinal, which on the other side of the river has suffered extensive denudation, has on this wholly disappeared, the first beds met with on crossing the Rhymney bridge having a northerly dip and corresponding with those on the northern side of the Pen-y-lan axis. The dip to the north continues throughout the Silurians on this side of the river, the Old Red Sandstone coming on conformably and dipping at first in the same direction. Its dip, however, is soon reversed, indicating a synclinal fold, on the axis of which Pen-yr-heol is situated. This brings in the Silurians again in a small anticlinal on which Pandy is situated, and which corresponds to the fold on the other side of the river near Cefn-coed-isaf. Past Pandy the Old Red Sandstone again succeeds the Silurian, and is well exposed in a quarry in Coed-y-cwarel, where it exhibits the same northward dip as the Silurians on the north side of the Pandy anticlinal.

The following section (fig. 3) illustrates the structure of the southern end of the Rhymney range of hills:—

Fig. 3.—*Diagrammatic Section from Rhymney Bridge to Coed-y-cwarel.* (Scale, 2 inches to a mile.)



a. Gravel. *c.* Old Red Sandstone. *d.* Silurian.

From the foregoing description, which is founded on a large number of careful measurements of "dips and strikes," one sees that the rocks of our area have been folded from N.N.E. to S.S.W. into a series of folds trending from W.N.W. to E.S.E.

One must not omit to point out, however, that on traversing the district from E. to W. one discovers the existence of a second set of foldings at right angles to the preceding. Thus, on the east of the Rhymney the principal Silurian strata dip to the N.N.E. at first, but more to the north the dip changes and becomes N.N.W., while on the Pen-y-lan side the dip of the corresponding beds is to the N.E. or even due E.; so that the valley of the Rhymney, between Rhymney and Pen-y-lan, lies in the axis of a synclinal fold. Further to the W., again, the dip changes, at first becoming nearly due N. and then N.W., giving to the hill which slopes from Pen-y-lan to Llwyn-y-grant-uchaf an anticlinal structure. Still continuing to the west, we once more find a change in dip, the beds now striking either due north or a little east of it. Thus the Pen-y-lan range of hills, which attains a greater height than the preceding, lies in a wide synclinal fold.

The folds trending more or less north and south are much less marked than those trending east and west. The existence of two intersecting sets of folds, however, is clearly evident, and makes itself inconveniently felt in the great irregularity of dip and strike to which it sometimes locally gives rise.

Succession of the Silurian Strata.

Unless the anticlinal axis of Pen-y-lan hill rises as it passes eastwards towards Rhymney, the beds exposed in the ditch below Pen-y-lan House, on the axis of this anticlinal, must be the oldest in the neighbourhood, and give us therefore a convenient base-line to work up from, the more so as the quarry in Pen-y-lan hill lies on the line of strike of the axis and not far from its exposure in the ditch.

Pen-y-lan Quarry.—This will be found in a field on the side of Pen-y-lan hill, a little south of the "y" in "Pen-y-lan" on the Ordnance Map. It exposes yellowish and greenish-grey mudstones and fine argillaceous sandstones, rather thickly bedded, and traversed by two sets of joints, which, together with the bedding-planes, divide the rock up into a number of roughly cubical blocks. These weather into a spheroidal form, and exhibit an incipient concretionary structure, both concentric and radiating.

The beds strike nearly W.N.W., and dip at an angle of 30° to the N.N.E.

Feeling dissatisfied with my own determination of the fossils I had collected here and elsewhere in the district, I submitted them all to Mr. Etheridge, who with great kindness prepared the lists which are given here and subsequently in the paper. I have ventured to incorporate with the fossils from Pen-y-lan those named for Mr. Norman Glass by Mr. Salter.

Fossils from Pen-y-lan.

(The range of the species is not carried below the Silurian in cases where they descend into the Upper Cambrian.)

	Llandovery.	Wenlock.	Ludlow.
Petraia bina, *Lonsd.*	*	*	
Cyathophyllum elongatum, *Phil.*	*		
Lingula cornea, *Sow.*	......	......	*
Atrypa reticularis, *Linn.*	*	*	*
Leptæna sericea, *Sow.*	*		
—— transversalis, *Dalm.*	*	*	
Strophomena euglypha, *Dalm.*	*	*	*
—— compressa, *Sow.*	*	*	
Spirifer plicatellus, *Linn.*	*	*	*
Meristella tumida, *Dalm.*	*	*	*
Avicula planulata, *Conr.*	*	*	*
Ambonychia tumida, *Soll.*			
Murchisonia pulchra, *M'Coy*	*		
Bellerophon dilatatus, *Sow.*	*	*	
Phacops caudatus, *Brünn.*	*	*	*
—— longicaudatus, *Murch.*	*	*	*
—— Stokesii, *Edw.*	*	*	*
Acidaspis coronata, *Salt.*	......	......	*
Illænus barriensis, *Murch.*	......	*	*
Calymene Blumenbachii, *Brongn.*	*	*	*
Cheirurus bimucronatus, *Murch.*	*	*	
Encrinurus punctatus, *Brünn.*	*	*	*
—— variolaris, *Brongn.*	......	*	

It will be seen from this list that the beds belong to the Wenlock series, though they have very much of a Llandovery facies. The only exclusively Ludlow forms are *Lingula cornea* and *Acidaspis coronata*; and the determination of these rests on somewhat imperfect specimens. On the other hand, we may draw attention to the great abundance of *Petraia bina* and *Encrinurus punctatus*, together with *Leptæna transversalis*, and the occurrence of *Leptæna sericea*. I do not mention *Murchisonia pulchra*, because its determination is somewhat doubtful; nor *Pentamerus oblongus*; for though a fine specimen of this shell was found in the quarry by one of my students, I have not been able to find one myself, and had the misfortune to lose the single specimen which was presented to me. I think, however, that it will be generally allowed that, while the beds are probably Wenlock, they must yet be assigned a position near the base of the series.

The next highest beds in the series are to be found in the ditch on the left-hand side going up Pen-y-lan lane. They consist of hard siliceous grits and soft mudstones. Leaving these we turn down a lane running parallel with and immediately north of the word "Pen-y-lan" on the map, again turn out of this to the left, into a narrow path leading to a farm: here, in a small cutting, we find red or claret-coloured fine argillaceous sandstone, striking 65° W. of N., and dipping at an angle of 27° to the north. These beds are quite unfossiliferous, and closely resemble many parts of the Old Red Sandstone.

A little further, and we come to a quarry cut in a hard siliceous grit, which may be better studied on the other side of the Rhymney, and to which we give the name of the "Rhymney Grit."

Crossing now to the Rhymney ridge, which in practice must be done by continuing along the turnpike road from Roath towards St. Mellons, we first meet with Silurian beds on the right-hand side of the river after crossing the bridge over the Rhymney. They are exposed only at low tides, consist of greyish mudstones passing into argillaceous sandstones, and contain fossils, of which Mr. Ross and myself obtained the following species—*Petraia bina*, *Strophomena depressa*, *Encrinurus punctatus*, *Leptæna sericea*, and others too fragmentary to determine. The strike, as well as we could make it out, is 55° W. of N., and the dip 30° and towards the north.

These beds, then, correspond lithologically and palæontologically with those of Pen-y-lan quarry, and therefore in all probability occupy the same horizon. Indeed, there can be no doubt about this, since they occur at just about the same depth below the characteristic Rhymney grit, which we shall presently describe.

Turning now to the left on crossing the bridge, we walk across a grass-grown tidal flat to the banks of the Rhymney below Cae Castell. Here we meet with a beautiful cliff-section across the Silurian beds—only observable, it is true, between tides, and grass-grown and inaccessible in places, but on the whole displaying the series admirably. The first bed we reach is the Rhymney Grit, which, by a rough triangulation, lies about 380 feet above the Pen-y-lan beds exposed at the bridge. As this grit, however, is displayed more fully in the Rhymney hill at a point just south of the "a" in "Ty-mawr" on the map, we had better take our description of it from the latter place.

Rhymney Quarry.—On entering the quarry, which is cut from W. to E. in the south side of Rhymney hill, one is struck by the massive appearance of its thick-bedded sandstones, which rather suggest at first Old Red Sandstone than Silurian rocks. They have been well quarried into for use as road-metal, for which they might be much more extensively employed, being far better adapted for that purpose than the worthless Lias limestone which is largely used around Cardiff.

The exposed surface of the beds rising from some pools in the quarry exhibit beautifully regular ripple-markings; and in some places the sandstone is extremely false-bedded. The smooth surface of one exposed bed gave a strike of 55° W. of N. with a dip of 33° to the N.E. Large joint-planes are numerous, and are always coated with red oxide of iron.

The following is a section of the beds exposed, in ascending order:—

	ft.	in.
1. Grey sandstone, with iron-stained fossils (*Grammysia cingulata*) and numerous fragments of mineral charcoal	2	0
(In the lower part of this bed is a thin calcareous band of bluish colour, weathering yellowish grey, and containing numerous badly preserved fossils.)		
2. Thin parting of grey-blue clay..		
3. Massive sandstone, with fucoidal remains, becoming flaggy in some places, and showing ripple-marks, in others passing into a fine-grained conglomerate, greyish and bluish in colour at top and bottom, but rusty red in the middle; altogether	23	6
4. Yellow sandstone	0	1
5. Greyish mudstone	2	4
6. Black tenacious clay parting, with light green spots	0	1
7. Massive sandstone, becoming flaggy in places; light grey to brown	21	5
8. Compact fine-grained, yellowish, friable sandstone, with dark-grey fucoidal impressions, patches of mineral charcoal, and red iron-stained casts of fossils, chiefly Lamellibranchs and Univalves; from the prevalence of *Ctenodonta subæqualis*, it may be termed the "*Ctenodonta*-sandstone"	2	7
9. Grey-green shales	1	5
10. Alternating compact and flaggy greyish sandstones	8	10
11. Parting of blue shale	0	2
12. Alternations of compact and flaggy or laminated greyish sandstones	8	0
Total	70	5

Thus, in the Rhymney quarry, we have something like 70 feet of sandstone beds, the lower 40 feet or so being more or less massive in the quarry, though when exposed at the surface they weather into a great number of thin beds. This massive sandstone or grit consists of fine angular particles of colourless quartz, which, though very firmly compacted together, yet leave abundant interstices, which are more or less filled with brown or red oxide of iron. The sandstone thus presents a prevailing reddish tint when the red oxide is abundant; but on minute inspection it is seen to be really greyish or colourless, and only speckled with red dots. This gives it a very characteristic appearance; and as it is the only bed traceable across the country, we may conveniently give it a distinct name, the "Rhymney Grit" appearing to be the most appropriate.

Mr. Storrie, the Curator of the Cardiff Museum, has prepared some thin slices from one of the sandstone beds which contains fragments of mineral charcoal; and these show under the microscope very distinct woody structure. This fact, combined with the leaf-like form of many of the fragments and the spore-like structure of others, leads us to imagine that we have in this mineral charcoal the earliest known occurrence of terrestrial plant-remains in the Silurian series of Europe.

The fossils in the yellow sandstone, or "*Ctenodonta*-bed," which occurs in a recess of the quarry near the top on the north side, are only found as casts. They are very abundant, well defined, and would repay a more extended examination than I have yet been able to give them.

The following is a list of Mr. Etheridge's determinations, to which I have ventured to add one or two of my own making:—

List of Fossils from the Ctenodonta-*bed, Rhymney Quarry.*

	Llandovery.	Wenlock.	Ludlow.
Ctenodonta subæqualis, *Sow.*	*	......	*
Modiolopsis platyphylla, *Salter*	......	......	*
—— elevata, *Sollas.*			
—— acutiprora, *Sollas.*			
Modiola, sp.			
Holopella gracilior, *M'Coy*	......	*	
—— hydropica, *Sollas.*			
—— minuta, *Sollas.*			
Murchisonia gracilis, *Hall.* Llandeilo.			
—— elegans, *Sollas.*			
Pterinea pleuroptera, *Conr.* Caradoc.	......	*	*
——, sp.			
Bellerophon carinatus, *Sow.*	*	......	*
Cyrtoceras, sp.			
Rhynchonella nucula, *Sow.*	*	*	*
Discina rugata, *Sow.*	......	*	*
Spirorbis Lewisii, *Sow.*	......	*	*
Polyzoon.			
Fragments of plants, including *Pachytheca sphærica,* Hooker	......	......	*

An examination of this list appears to indicate Ludlow rather than Llandovery affinities, and thus led me to look for the appearance of the Rhymney Grit near the top of the river-section below Cae Castell. It was therefore with some surprise that, failing to find it there, I afterwards discovered it near the base of that section. This observation, however, cleared up the difficulties which the country had previously presented; and I was subsequently able to trace the Rhymney bed right across the Pen-y-lan district to the Starting-house on Heath-farm hill. It forms a well-marked feature in the country; and quarries have been opened in it at half-a-dozen places along its outcrop.

In one of these quarries, which occurs just on the edge of Coed-tir-Caled, Mr. Ross and I observed false-bedding as perfectly displayed as by many glacial sands.

Several of the joint-planes in this quarry were polished and striated with true slickensides; but no trace of a fault could be found. It is true that the joint-face was coated with hæmatite, and that the striation might be attributed to a fibrous structure in this mineral; but such is not the appearance it has to my eye, and I prefer to believe that it resulted from movements among the already jointed rocks, which took place when the Siluro-Carboniferous country was being elevated above the sea-level.

We may now conveniently resume our description of the river section exposed on the side of Cae Castell, and further north.

River Section.—Above the Rhymney Grit, which we mentioned as occurring at the base of this section, a series of alternating argillaceous and sandstone beds succeeds, to a great extent mud-covered and of no great interest, till at a distance of 107 feet vertically above the Rhymney bed we reach a curious reddish-brown ferruginous mudstone, thickly crowded with a number of irregular concretions or galls, and containing fossils. It is, however, so very badly exposed that I only succeeded in obtaining a single specimen of the latter, which is a well-marked *Grammysia cingulata*. This bed is followed for 11 feet 4 inches by alternating compact flaggy, argillaceous, and siliceous sandstones of a greenish and yellowish-grey colour. A blue crystalline bed of limestone then appears; it is 5 inches thick, and is composed of a number of crushed fossils—*Rhynchonella*, *Orthis*, *Strophomena*, and Encrinite-fragments too imperfect for specific identification. Above this, compact siliceous sandstones, flaggy argillaceous sandstones, and mudstones follow for 8 feet vertically, and then more or less broken ground for about 50 feet vertically, when we reach the following section, which is very clearly exposed in the side of Cae Castell:—

Section in the side of Cae Castell (ascending order).

	ft.	in.
1. Alternations of flaggy fossiliferous and compact siliceous sandstones, of greenish-grey colour, generally micaceous	5	2
2. Grey compact sandstone bed, more or less calcareous	0	10
3. Band of limestone	0	2
4. Flaggy grey siliceous sandstone	1	8
5. Hard grey siliceous limestone, weathering yellowish brown	1	6
6. Siliceous sandstone, with an intercalated band of limestone 1 inch thick	1	4
7. Parting of yellowish calcareous and fossiliferous sandstone	0	2
8. Calcareous fossiliferous sandstone; light bluish grey, weathering yellow	2	2
9. Yellowish and greenish-grey shales	0	6
10. Light-grey crystalline limestone, *full of corals*	0	6
Carry forward	14	0

	ft.	in.
Brought forward	14	0
11. Rusty-red muddy and concretionary bed, calcareous and full of fossils of Wenlock age	2	0
12. Alternations of compact and flaggy sandstones	1	8
13. Fine-grained, compact, argillaceous, claret-coloured sandstone ...	0	11
14. Alternations of flaggy and compact sandstones and mudstones, greenish grey	10	7
15. Greenish-grey shales, with lenticular patches of limestone and fossils	0	9
16. Thin-bedded sandstone and shales, fossiliferous in places	1	9
17. Lenticular patches of limestone	0	2
18. Greenish-grey fossiliferous shales	0	8
19. Thin bed of impure crystalline magnesian limestone, yellowish grey, full of casts of fossils, especially of *Pentamerus lævis* ...	0	3
20. Greenish-grey flaggy sandstone and mudstone	0	9
21. Calcareous sandstone, full of branching *Favosites fibrosus*, which weathers into worm-like holes on the surface	0	2
22. Alternations of greenish-grey mudstones and flagstones, with occasional lenticular patches of limestone	10	5
Total thickness	44	1

The flaggy sandstones and mudstones of this series are mostly more or less micaceous.

The most important beds are those numbered 10, 11, and 19. The first two are the most fossiliferous beds in the neighbourhood; and I obtained, in company with Mr. Ross, the following species, most of which have been named by Mr. Etheridge.

Fossils from the Beds 10 *and* 11 *in the Cae-Castell Section.*

	Llandovery.	Wenlock.	Ludlow.
Cystiphyllum cylindricum, *Lonsd.*	*	*	
Heliolites interstinctus, *Wahl.*	*	*	*
—— tubulatus, *Lonsd.*	*	*	
Omphyma turbinata, *Linn.*	*	*	
Syringopora bifurcata, *Lons.*	*	*	*
—— fascicularis, *E. & H.*	*	*	
Favosites gothlandicus, *Linn.*	*	*	*
—— fibrosus, *Goldf.*	*	*	*
Halysites catenularius, *Linn.*	*	*	
Diastopora consimilis, *Lonsd.* Llandeilo.			
Bellerophon wenlockensis, *Sow.*	......	*	
Euomphalus sculptus, *Sow.*	*	*	*
—— funatus, *Sow.*	*	*	*
Eunema cirrhosum, *Sow.*	......	*	
Acroculia haliotis, *Sow.*	*	*	
Mytilus mytilimeris, *Conr.*	*	*	*
Pentamerus galeatus, *Dalm.*	......	*	*
Stricklandinia lirata?, *Sow.*	*	*	
Atrypa reticularis, *Linn.*	*	*	*
Rhynchonella Wilsoni, *Sow.*	*	*	*
—— borealis, *Schl.*	*	*	
Strophomena euglypha, *Dalm.*	*	*	*
Orthis elegantula, *Dalm.*	*	*	*
Orthoceras angulatum, *Wahl.*	*	*	*
Phacops caudatus, *Brünn.*	*	*	*
Calymene Blumenbachii, *Brongn.*	*	*	*
Illænus barriensis, *Murch.*	*	*	
Tentaculites ornatus, *Sow.*	*	*	

The previously ascertained range of each species is shown in the vertical columns appended to the list, which on mere inspection will convince us of the age of the beds in which the fossils occur. No one I think will hesitate to refer this forty feet or so of the Cae Castell section to the horizon of the Wenlock limestone, although the total thickness of true limestone beds which occur in it does not exceed a foot or two at the most. If this determination be accepted, then the occurrence of bed 19 about 16 feet above the layer of Wenlock corals is somewhat surprising, since the higher bed is crammed with casts of true *Pentamerus oblongus*, var. *lævis*. From the imperfect casts I submitted to Mr. Etheridge he concluded that they probably represented this species; and on sending them to Mr. Davidson he concurred in the opinion of Mr. Etheridge. I have since, however, taken impressions in gutta-percha of some of the best-preserved of the casts; and these convert the probability into a certainty; so that the range of *Pentamerus oblongus*, var. *lævis*, must, in our district at least, be carried considerably above the Llandovery beds and into the middle of the Wenlock. Perhaps, indeed, it ranges still higher; for I find in our museum a solitary specimen bearing the label *Pentamerus lævis*, and imbedded in Aymestry limestone. Above the section just described Silurian beds are exposed almost uninterruptedly for about 150 feet vertically. I took the trouble to measure and describe every separate bed for a thickness of over 100 feet; in this thickness there are 230 separate beds, varying from 1 inch to 2 feet 6 inches in thickness. They consist of alternations of compact fine-grained sandstones, more or less argillaceous thin flaggy sandstones, mudstones and shales, with now and then a thin parting of soapy unctuous clay. The prevailing tints are various shades of greyish green, weathering reddish brown, with here and there a bed of red or claret-colour. Many of the beds are micaceous; some abound in fossils; and others are quite devoid of them. There is no connexion between the colour of the bed and the presence or absence of fossils, the reddish beds containing fossils quite as frequently as the greyish ones. Worm-tracks and fucoidal markings are abundant; and many of the beds are rippled on the surface. Calcareous matter is rare, only one band of impure limstone occurring throughout the series; and that is but 4 inches thick. It appears 100 feet above the base of this section or the top of the preceding one.

The following is a list of the fossils from this section :—

	Llandovery.	Wenlock.	Ludlow.
Bellerophon trilobatus, *Sow.*	*	*	*
Ecculiomphalus lævis, *Sow.*	*	......	*
Murchisonia Lloydii, *Sow.*	......	*	*
Pterinea Sowerbyi, *M'Coy*	......	*	*
—— tenuistriata, *M'Coy*	......	*	*
Cardiola striata, *Sow.*	......	*	*
Orthoceras ibex, *Sow.*	*	*	*
—— perelegans, *Salt.*	......	*	*
—— sp. nov.			
Lingula Lewisii, *Sow.*	......	*	*
Orthis elegantula, *Dalm.*	*	*	*
—— filosa, *Sow.*	*	*	*
Strophomena euglypha, *Dalm.*	*	*	*
—— depressa, *Dalm.*	*	*	*
Chonetes lata, *Von Buch*	......	*	*
—— striatella, *Dalm.*	......	*	*
Leptæna lævigata, *Sow.*	......	*	*
Rhynchonella nucula, *Sow*	*	*	*
—— borealis, *Schl.?*	*	*	
Phacops caudatus, *Brünn.*	*	*	*
Calymene Blumenbachii, *Brongn.*	*	*	*
Homalonotus Knightii, *König*	......	......	*
Trachyderma squamosa, *Phil.*	......	......	*
Syringopora serpens, *Linn*	*	*	
Monticulipora Fletcheri, *E. & H.*	......	*	
Cyathophyllum pseudoceratites, *M'Coy*	......	*	
Worm-burrows and worm-tracks.			

On the evidence of these fossils we may safely refer the beds in which they occur to the Ludlow series, and on stratigraphical grounds to the lower part of that series.

To this series belongs also a peculiar red ferruginous bed which crops out near the end of the ditch on the right-hand side going up Rhymney hill. It contains, amongst others, the following fossils :—

Strophomena filosa, *Sow.*
—— applanata, *Salt.*
Atrypa reticularis, *Linn.*
Orthis lunata, *Sow.*
—— Sowerbyana, *Dav.*
Rhynchonella nucula, *Sow.*
Chonetes, sp.
Mytilus exasperatus, *Salt.*
Pterinea, sp.
Phacops caudatus, *Brünn.*
Proëtus latifrons, *M'Coy.*
Petraia bina, *Lonsd.*
Cyathophyllum, sp.
Nidulites favus, *Salt.*
Syringopora bifurcata, *Lonsd.*
Ptilodictyum, sp.

The succeeding beds are to a great extent concealed for about 140 feet, measured vertically above the top of the preceding exposure; but wherever they can be seen they present the same characters as those just described. After passing this broken ground we meet with several feet of clearly-exposed greenish-grey mudstones, abounding in fossils, of which the following list gives but a very poor idea :—

List of Fossils from Upper Ludlow, Rhymney River Section.

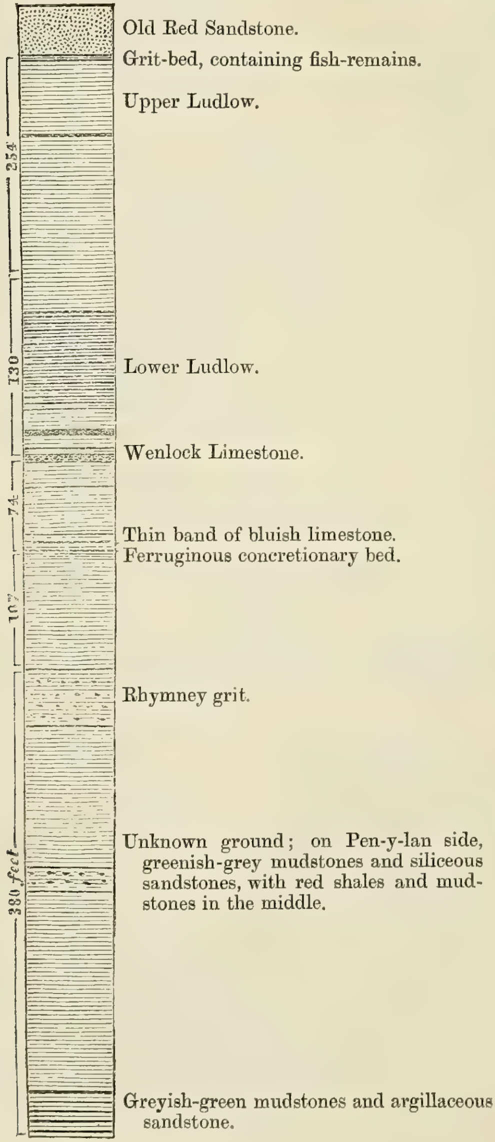
Rhynchonella nucula, *Sow.*
Obolus Davidsoni, var. transversus, *Salt.*
Rhynchonella borealis, *Schl.*
Discina, sp.
Atrypa reticularis, *Linn.*
Orthis elegantula, *Dalm.*
—— filosa, *Sow.*
Spirifer elevatus, *Dalm.*
—— plicatellus, var. radiatus.
Chonetes striatella, *Dalm.*
Pterinea Sowerbyi, *M'Coy.*
Mytilus mytilimeris, *Conrad.*
Murchisonia Lloydii, *Sow.*
Euomphalus sculptus, *Sow.*
—— funatus, *Sow.*
Phacops caudatus, *Brünn.*
Beyrichia gibba, *Salt.*
Cyathophyllum pseudoceratites, *M'Coy.*
Monticulipora pulchella, *M.-Edw.*
Alveolites, sp.
Syringopora bifurcata, *Lonsd.*

The beds just mentioned form the beginning of a low bank, which continues to afford small exposures for some distance northwards. The beds so exposed are all of the Ludlow type, exceedingly like those of the Usk district, greyish and brownish mudstones, with numerous layers of iron-stained fossils, among which *Chonetes striatella*, *Orthis lunata*, and *Strophomena euglypha* are the most abundant. They continue for 74 feet vertically above the first beds of the bank, and then give place to genuine Old Red sandstone and shales; the change takes place very rapidly, Ludlow beds, full of fossils, lying on one side of a small ditch, and deep-red or purplish flaggy micaceous sandstones on the other. Just above the highest Ludlow and below the Old Red Sandstone a brownish grit, speckled with grey felspathic particles, occurs. It abounds in fragments of fish-bones, which, however, with the single exception of some spines of *Onchus tenuistriatus*, are too obscure to be even generically identifiable. I have never been able to find the bed itself, only the fragments which lie upon its outcrop; but Mr. Storrie by digging beneath these has discovered the bed *in situ*, just about the place where I had concluded it must occur.

The general succession of the Silurian beds in the Cardiff area may be summarized in the accompanying general section (fig. 4, p. 488), in which the thicknesses are taken from the Rhymney river exposure.

The total thickness of the Silurian beds exposed is thus about 950 feet; and if the base of the series is Wenlock, as we suppose, and not May Hill in age, then the thickness of the Wenlock may be taken at 581 feet, and of the Ludlow at 364 feet, the relative thicknesses of the two series being much the same as at Usk, though the actual thicknesses are a little greater, as one, indeed, might expect from the replacement of calcareous by sedimentary strata. The uniform character of the whole series is very striking, alternations of sandstone and shales repeating themselves with wearisome monotony, and the total thickness of true limestone not exceeding 3 or 4 feet at the most. The prevalence of sandstone beds, often exhibiting ripple-markings and oblique lamination, and the numerous fragments of plant-remains, all point to a shallow sea not far from land. Even the limestone beds, such as they are, point to the same conclusion; for the interstices between the shells of which they are chiefly composed are not always filled up with limestone, but with angular siliceous particles or true sand-grains, or, it may be, with impure argillaceous mud.

Fig. 4.—*General Section of the Silurian Beds in the Cardiff Area; thicknesses from the Rhymney River Exposure.*



Distribution of Land and Sea.

After the deposition of the Cambrian * (Sedgwick) a wide-spread upheaval seems to have taken place over the Welsh area, producing continental land on the west and north; this is indicated partly by the difference in character of the Silurians in the east and west Welsh districts, and partly by the overlap of the Silurian at Llandeilo-fawr onto the Cambrian, of the Old Red Sandstone onto the Cambrian at Llanddarog, and of the Carboniferous onto the Cambrian at Selbeck.

The thicknesses of the Silurians in the east and west districts respectively are given in the following table.

Eastern districts.	Sedimentary. feet.	Calcareous. feet.
Wenlock Edge	3600	350
Malverns	3650	300
Woolhope	2540	250
May Hill	2740	550
Usk	1100 (?)	270
Western districts.		
Survey section crossing Clun Forest	11,000	0 ?
Builth	5250	10
Llandovery	6400	0 ?
Sawdde	3460	0 ?
Rhymney (Wenlock and Ludlow only)	950	4

From this it would appear that the source of sediment was north and west, and that the area of greatest subsidence also lay in that direction. This is true of the Silurians; and I believe it holds good for the Old Red Sandstone as well. What, then, are the relations of the Devonshire to the Welsh area? One has hitherto supposed that the Silurians were absent in Devonshire, the oldest rocks being the unconformably overlain Cambrians of Start Point; and certainly this would accord very well with the approach to an area of minimum subsidence in a southerly direction, which a study of the Welsh Silurians seems to indicate. On the other hand we have that immense development of Devonian strata in the southern district, which, to my mind, is most feasibly explained by Mr. Hull's hypothesis; and if so, I think, considering the general thinning-out of the Siluro-Carboniferous strata of South Wales from N.W. to S.E., that we are driven to conclude that the Devonshire and Cornish area is a totally distinct one from the Welsh, and was formerly separated from it, if not by a narrow ridge of elevated ground, at least by a more or less stationary sea-floor, which would practically be quite as efficient a barrier.

Relations of the Cardiff Silurians to the Old Red Sandstone.

Wherever a junction is exposed, the Old Red Sandstone of this district succeeds the Silurian with the most perfect conformity. Passage-beds appear to be wanting.

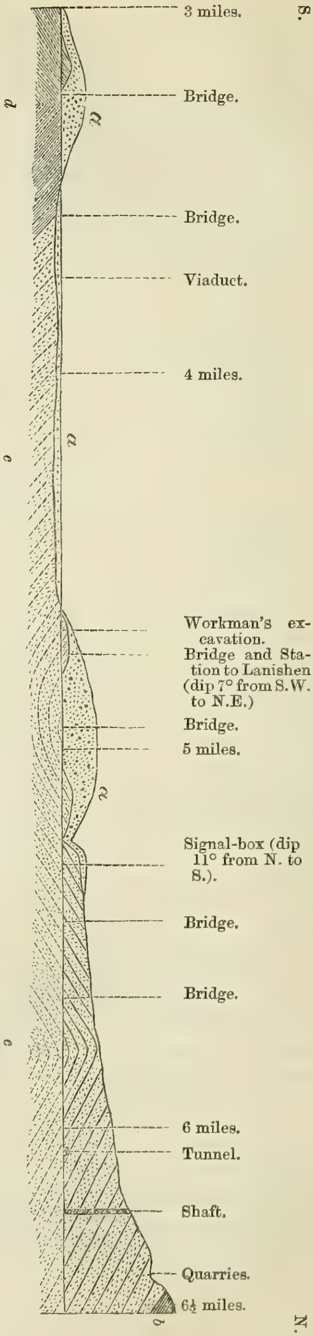
* Wherever the term Cambrian occurs in this paper, it is used in a Sedgwickian sense.

The Old Red Sandstone lies, then, conformably upon the Silurian; it likewise passes conformably beneath the Carboniferous Limestone of the Taff Gorge; and it shows no signs of being unconformable to itself. Thus the existence of an ascertained base-line to the Old Red Sandstone near Cardiff gives us a fresh opportunity for determining the thickness of this formation. Good exposures, however, of the Old Red Sandstone are rare, and over a wide east and west valley south of Lanishen almost entirely wanting. Still certain points of importance can be made out, the best section to follow being that of the Rhymney railway, which, from the Starting House on Heathfarm Hill to the Carboniferous escarpment, cuts directly across the strike of the intermediate Silurian and Old Red Sandstone beds. The section is given here (fig. 5).

On the railway, just south of the Starting House, an anticlinal is seen bringing up the Rhymney Grit and Wenlock beds. The axis of the anticlinal strikes nearly due east and west; and the beds on its north side dip at an angle first of 25° and afterwards of 45° towards the north. The railway is then carried along an embankment, and affords no insight into the nature of the country for a mile after leaving the Silurians. Running parallel with the railway, however, we have on the other side of Nant-mawr the range of hills which stretch from Pen-y-lan northwards; and this supplies us, for the southern half of the interval on the railway, with sections in which the Old Red Sandstone is exposed, with a persistent dip more or less to the north.

The wide east-to-west valley which rendered the railway embank-

Fig. 5.—*Section along the Rhymney Railway, from the Starting House, Heath Farm, to the Edge of the Southern Escarpment of the Welsh Coal-basin.* (Length of section, $3\frac{1}{2}$ miles.)



a. Gravel. *b.* Carboniferous Shales. *c.* Old Red Sandstone. *d.* Silurian.

ment necessary, ceases just before we reach Lanishen station, and the railroad is once more carried through a "cutting." Deposits of gravel, sand, and clay are first exposed; these attain a thickness of as much as 30 feet, and contain here and there large subangular boulders of limestone and grit; one of these boulders, evidently derived from the Mountain Limestone, measured $3 \times 3\frac{1}{2} \times 2$ feet. At the base of these gravels the Old Red Sandstone is exposed at Lanishen station; it there consists of a loose conglomerate which dips from S.W. to N.E. at a low angle. Further on, red shales with calcareous nodules occur beneath the gravel at the signal-box past the fifth mile marked on the section. These beds, also of Old Red age, dip from N. to S. at an angle of about 11°. The half mile between Lanishen and the signal-box, which is covered by gravels, would thus appear to conceal the axis of a synclinal fold.

The southward dip of the Old Red beds, which from this point are continuously exposed, is maintained for half a mile further north; it is then replaced by a dip in the opposite direction, the beds (sandstones, conglomerates, and marls with thin bands of cornstone) rolling over in an anticlinal curve which is beautifully revealed in the banks of the railway-cutting. The dip is now northward, and does not again change within the limits of our section, the Carboniferous shales and limestone coming on conformably with a dip in the same direction, and at a distance of 1188 yards from the place where the axial ridge of our last anticlinal occurs. Over this distance the average dip of the Old Red Sandstone may be taken as about 30°, which gives us 1782 feet as the approximate thickness of the Old Red which lies between the axis of our anticlinal and the base of the Carboniferous series. If only the Silurian had been brought up by the anticlinal, we should now know the thickness of the Old Red in our district; as it is, our knowledge so far amounts to no more than the certainty that this thickness cannot be less than 1782 feet. Let us, however, make an approximate calculation of how much ought to be added to this minimum thickness in order to obtain the total thickness. The beds south of the anticlinal axis appear to dip at a less average angle than those to the north of it, so that we may expect to find them extending over a greater distance than those which they repeat. We return now to the ground beneath which our supposed synclinal lies; and as the position of its axis is not known, we may assume it to lie midway between the signal-box, where the beds dip to S., and Lanishen station, where they dip to N. This midway point is distant 1496 yards from the axis of the Old Red anticlinal; we eliminate this distance from our section, then, as belonging to beds which have already been measured. The dip of the beds between the axis of the synclinal and that of the anticlinal is, as we said, less than 30°; it would not do, therefore, to measure off another 1496 yards to the south as representing the beds repeated on the south side of the synclinal; it will be fairer to take the 1188 yards which the same thickness of beds dipping at 30° would cover for that purpose. Having now allowed for the repetition of the strata on the south side of the anticlinal axis and on the south side of the synclinal axis, in all 2684 yards, we have left a distance of 2024 yards, which is covered by the remaining Old Red beds and by the top of the Silurian series.

This horizontal distance corresponds to a vertical thickness of 3036 feet for beds dipping at an average inclination of 30°. We finally deduct 545 feet, the thickness of the Silurian beds which are known to lie above the Rhymney Grit, and then have a remainder of 2491 feet, which, added to the 1782 feet previously determined, gives us 4273 feet as the total thickness of the Old Red Sandstone in this part of South Wales. Of course this determination is only approximate and depends partly on an assumption ; but I think, if found to err at all, it will rather be on the side of over- than under-estimation of the true thickness. Thus, in passing from the Vans of Brecon, on the north side of the coal-basin, to our area, a distance of about 25 miles, the Old Red Sandstone has lost more than half its thickness. Along with this we find a corresponding thinning-out of the cornstones of the formation, which were much more sparingly represented here than to the north. This is in full accordance with an opinion which I have for a long time entertained, that these calcareous beds are mechanical sedimentary deposits, not immediately derived from organic remains, but only indirectly through the denudation of previously formed limestone beds, belonging probably to the Cambrian formation.

It would be foreign to the subject of this paper to enlarge further on this topic, and I hope to be able to say something more about it on another occasion ; but I may perhaps be allowed to add now that although calcareous beds are generally regarded as in all cases due to deposition from solution either by evaporation or through the immediate agency of living things, yet there are several instances in which they have not been so formed, but have on the contrary been derived from sediments which have been carried in suspension and strewn out in deposits, in just the same fashion as clay or any other mechanical sediment may be. The conglomerates of Mountain Limestone formed on ancient beaches of the Lias are a case in point ; and the pebbles of these conglomerates are frequently as well rounded as any we can find on a beach at the present day. What has become, then, of the asperities and angles which have been worn away during the rounding of the pebbles? The usual reply is, "Dissolved in the surrounding sea-water ;" but it seems to me that there is always the alternative possibility that it has been carried away as mud in suspension, just like any other mud ; and if so, the deposition of such calcareous mud would go far towards explaining the occurrence of calcareous septaria and other nodules, which so frequently occur in red deposits like those of the Old Red Sandstone and the Trias, as well as the formation of the muddy Lias limestones of Penarth Cliffs, which, with their flat even bedding and numerous intercalations of black shales, certainly do not suggest an organic origin. A few oysters and such like shells may have contributed to their growth ; but their general appearance certainly is that of strata formed from sediment carried in suspension, and very different from that presented by a truly organic calcareous rock.

After the foregoing observations, which are to be regarded more or less as a digression, we may return to our determination of the thickness of the Old Red Sandstone in the South-Welsh area, with the object of drawing one or two further inferences from it.

As we have already shown, the Old Red Sandstone thins out from a total thickness of 10,000 or 15,000 to one of 4000 feet in passing from the north to the south side of the South-Welsh coalfield; and from this it would appear that the existence of 13,000 feet of so-called Devonian strata in Devonshire is not by any means so remarkable a fact as it has usually been considered; for if the Old Red Sandstone diminish, as it does, to the extent of one third of its total thickness in crossing the Welsh coalfield, a distance of 19 or 20 miles, certainly the Devonian strata may diminish to a like extent in crossing a like distance, viz. from the North Foreland over the Bristol Channel to the nearest exposed base-line of the Old Red (that is, near Cardiff).

In the next place, the simultaneous thinning-out southwards of the Old Red Sandstone and Silurian of South Wales, and the accompanying change of character in the sediments of the latter formation, alike point to the existence somewhere in the neighbourhood of the Bristol Channel of land or a submerged barrier, which the thickness and proximity of the Devonshire strata forbid us to regard as having had a great extension towards the south; in other words, the land which our observations indicate is no other than the famous barrier which Mr. Etheridge was led long ago to invent in order to divide the Old Red waters from those of the Devonian ocean.

Again, accepting the existence of such a barrier as our observations plainly point to, then we may perhaps be able to explain by its means the intercalation in Devonshire of sandstone beds having Old Red characters, such as the Foreland sandstone, Hangman grit, and Pickwell Down sandstone, with other sediments, both limestone and slates, having true marine and Devonian characters.

Let us suppose first that the depression of our barrier beneath the sea proceeded, as a rule, with such extreme slowness as to maintain generally a separation between the Welsh and Devonian areas; each of these areas may then be subject to independent peculiarities of condition contemporaneously, and red sandstones be laid down to the north while marine limestones are forming the south. Next let us suppose that the rate of subsidence of the barrier became at intervals increased, so that the Devonshire and Welsh areas became one; it would now be possible for similar conditions to exist throughout the conjoined area; Old Red Sandstone conditions or Devonian conditions might either of them prevail over the whole of the Devonshire and Welsh region: *à priori* we could not say which would so prevail, or whether both would exist together; but looking to the extension of sandstones with Old Red characters into Devonshire, and the absence of Devonian strata in Wales, we may fairly conclude that the conditions which did overspread the whole area were those of the Welsh Old Red.

According to the view just advanced the Old Red Sandstone is regarded as the complete equivalent of the Devonian strata, the difference between the Welsh and Devonshire areas chiefly being that in the latter we have an interdigitation of rocks (fossiliferous beds) formed under Devonian conditions with other rocks formed under Welsh conditions (whatever those may have been), while in the former the beds of Old Red Sandstone were deposited under conditions which remained approximately the same from the beginning to the end of the period.

The Old Red Sandstone of South Wales is a continuous deposit from the conformable Silurian at its base to the conformable Carboniferous at its summit; and hence nothing can be clearer than the inference that whatever formations or unconformities occur elsewhere between the top of the Silurian and the bottom of the Carboniferous, they must one and all have taken place during the time that the Welsh Old Red Sandstone was in process of formation; and whatever correlation may be made of the Devonshire beds with corresponding rocks in Ireland or on the Continent, they must at all events, so far as they are admitted to lie between the Silurian and Carboniferous, be regarded as having been formed during the whole or a part of the time known as the Old Red Sandstone period; the genuine Devonian may be the equivalents of the whole or a part of the Old Red Sandstone, but no more.

A word finally, if it be not too far from the point, as to the distribution of areas of elevation, or minimum depression, and of maximum depression over the West-of-England Old Red Sandstone area. The evidence, so far as it goes, certainly points to the existence between the meridians of 3° and 4° of longitude of three more or less east-to-west areas of minimum depression, and of two intervening areas of maximum depression. The zones of minimum depression were (1) a northernmost area over the north part of Wales, which, as shown by the absence of Old Red and the unconformable presence of Carboniferous or Silurian rocks, remained dry land during the Old Red period; (2) a southernmost area, probably the northward extension of the land which afterwards supplied Carboniferous sediments to Devonshire, and indicated partly by the Cambrian rocks of the Dodman and Start Point, which almost certainly formed land during the Silurian period; and (3) the barrier along the Bristol Channel and south of the Mendips, suggested by Mr. Etheridge, and supported by the observations in this paper. The zones of maximum depression were (1) one on the north over South Wales and Hereford, with its axis about the northern escarpment of the South-Wales coal-field; and (2) another on the south over Devonshire and Cornwall, with its axis passing from east to west, probably in the neighbourhood of Plymouth.

The central barrier was subject to movements of depression of very varying rapidity, which led to the introduction at intervals of Old-Red-Sandstone conditions over the Devonshire area, and probably to the piling-up of some 2000 or 3000 feet of Old Red deposits upon the top of the barrier itself. It finally became completely submerged beneath the waters of the Carboniferous sea; and then conditions more like those of the Devonian prevailed over both the Devonshire and Welsh areas. Thus this central barrier seems to have anticipated in a general way the behaviour of the London-and-Harwich axis during the Neocomian and Cretaceous times.

Relations of the Axes of the District with those of the surrounding Country.

On referring to Sheet 36 of the Geological Survey, we shall find the Carboniferous Limestone, which forms the southern escarpment of the coal-basin, bending round southwards from Llanilid to Cowbridge and then striking eastwards towards Leckwith; it forms, indeed, an east-to-west anticlinal, which "noses out" towards Bridgend. The conformable Old Red Sandstone, lying coaxially within it, "noses out" more to the east; so that the anticlinal axis rises in that direction, and thus brings in at length the Silurians of our area. Our area is therefore the lowest and easternmost exposure of a great Siluro-Carboniferous anticlinal which extends from Bridgend in the west to Rhymney in the east. The Old Red and Carboniferous are dislocated by numerous north-and-south faults, from which the Silurian district appears to have escaped. The anticlinal of Silurian near the Starting House is a difficult feature in the country; and some might explain it by a fault, for which, however, there is no other evidence: I am inclined, myself, to regard it as a reappearance of the Cefncoedisaf-to-Pandy anticlinal, and except that traces of this fold will become more evident after a more searching examination of the country between Cefn-coed and Cefn-coed-fach.

To the north of the Rhymney area we have the well-known Usk district, which with its principal anticlinal axis points north and south; and though the axis seems to disappear south of Llandegfydd, yet its continued existence is indicated by patches of Silurian, which crop out about Llanfrechfa and elsewhere, while its influence on our region is shown by the subordinate foldings which cross the latter from north to south. Between Usk and Llantrissant the Carboniferous Limestone lies in a generally N.E. to S.W. curve as it bends from its north and south to its east and west strike; the Old Red Sandstone crops out in a parallel curve, as is shown by exposures S.W. of Newport. There can be little doubt that the Silurian turns round in a similar way below ground, and, I believe, to some extent above ground: at all events Mr. Storrie has met with fragments of Silurian beds near Ty-coch, Marshfield; and though he did not at the time succeed in finding the parent bed, there can be no doubt it was close at hand, and will be found on further search. Mr. Ross also writes me that he has evidence of outcrops of Silurian between Rhymney and Newport.

Descriptions of and Notes on Fossils.

1. Modiolopsis acutiprora, sp. nov. (Pl. XXIV. figs. 21 & 22.)

Shell ovate, convex transversely; umbones not prominent, diagonal ridge faint, existing only as a line of division between two portions of the shell—one larger, antero-inferior, and with a gentle convex slope downwards, the other smaller, postero-superior, and with a somewhat steeper, flatter slope towards the hinge-line. No diagonal furrow. Inferior margin a simple elliptical outline. Preumbonal lobe somewhat ovate, or like a blunted lancet-point in shape. Angle formed by the junction of the hinge-line with the posterior margin obtuse and rounded. Surface covered with very fine concentric striæ.

Length $1\frac{16}{20}''$; breadth $\frac{18}{20}''$.

Remarks. This shell very closely resembles the Upper Cambrian species *M. expansa* (Portlock), but differs from it in having a more curved ventral margin, a sharper preumbonal lobe, a relatively larger antero-inferior and smaller postero-superior region, and in being less compressed.

Casts of the interior and exterior of the shell are exhibited in the same specimen; the internal cast shows a large kidney-shaped impression of the anterior adductor muscle, situated inside the perumbonal lobe, a very distinct simple pallial line parallel with the inferior margin, and a deep round impression of the anterior pedal muscle, just above that of the anterior adductor. The ligamental groove is just visible along the hinge-line. The space between the outer and internal casts is very narrow; so that the shell must have been exceedingly thin.

2. Modiolopsis inflata, M'Coy. (Pl. XXIV. fig. 2.)

The determination of this species rests on a well-preserved internal cast, which presents all the characters of M'Coy's species, the only difference noticeable lying in the somewhat greater elevation of the Cardiff form, and the slightly greater incurving of the ventral margin immediately in front of the diagonal gibbosity. The dimensions of the Cardiff form are—length 0·85″, breadth 0·525″, giving a proportion of $\frac{1000}{617}$, while in M'Coy's form the proportion is $\frac{1000}{570}$. Perhaps my specimen should be regarded as a variety of *M. inflata,* in which case it might be called *M. elevata.*

3. Orthonotus navicula, sp. nov. (Pl. XXIV. figs. 3, 3 *a*.)

Shell elongate, oblong, tumid, especially above; beaks small, meeting over the straight hinge-line in the anterior part of its middle third; lunule shallow, well defined. A transverse furrow in each valve, commencing from the point of the umbones, and descending vertically to the ventral margin, where the two furrows meet. Immediately in front of the cincture so formed the shell bulges out rapidly; behind the cincture the bulging takes place more gradually.

An oblique ridge extends from the posterior side of the beaks to the posterior angle of the shell, dividing the posterior two thirds of the shell into a swollen anterior and a compressed posterior and superior part, which ends above in the straight hinge, and behind in the rounded end of the shell. Shell ornamented with longitudinal rounded ribs, 0·0375″ apart, commencing from the edge of the lunule, and continuing along the valves till they reach the post-umbonal ridge, past which the shell is smooth up to the hinge-line.

Length $\frac{15}{20}$″; breadth $\frac{5}{20}$″; thickness $\frac{6}{20}$″.

Remarks. This shell was found by Mr. John Storrie near Cross Dowton, Rhymney, not far from the outcrop of the Ludlow beds. It was imbedded in a stray fragment of rock lying by the road-side, and not *in situ*, but so exactly similar in lithological character to the adjacent Ludlow beds that no hesitation need be felt in referring the shell to their horizon.

The hinge-line does not show any transverse plaits; but a slight inflection of the valve indicates apparently a cartilage-plate. There is no sign of an escutcheon.

4 Leda? ambigua, sp. nov. (Pl. XXIV. fig. 7.)

Shell oblong ovate, compressed; hinge-line short and straight; margin of valves simple, elliptical, closed; umbones anterior, directed slightly backwards, their posterior edge continued into a ridge ending on the upper part of the posterior margin. Surface covered with exceedingly fine close concentric striæ.

Length $\frac{16}{20}$″; breadth $\frac{9}{20}$″.

Remarks. As the interior of the shell is not visible, and we do not know the characters of the hinge, its reference to *Leda* is in the highest degree doubtful. I have preferred, however, to assign it to this genus with a query rather than to make a new genus to receive it. In general form it is more like a *Yoldia*, while in the character of its striation it exactly resembles *Leda intermedia*, Eth., from the Carboniferous formation. It is in the form of its posterior region that it differs most markedly from both *Yoldia* and *Leda*.

5. Ambonychia? tumida, sp. nov. (Pl. XXIV. fig. 9.)

Shell obliquely trigonal, tumid, truncated in front; anterior aspect heart-shaped; umbones quite anterior, somewhat spirally incurved; hinge-line short and straight; margins simple, close, rounded; a small posterior wing or compressed upper posterior region; surface very finely concentrically striated.

Length $\frac{18}{20}$″; breadth $\frac{13}{20}$″; thickness near beaks, where it is thickest, $\frac{13}{20}$″.

Remarks. It is by no means certain that this species is an *Ambonychia*; the specimen on which it is founded is not quite perfect in front, and might have possessed a small anterior wing. It is somewhat similar to *Amphicœlia*, Hall. To give a rough idea of its general form, one may compare it to some species of *Isocardia* (ex. gr. *I. nitida*, Phillips), or to some forms of *Pholadomya*.

6. Holopella gracilis, sp. nov. (Pl. XXIV. fig. 5.)

Shell slender; apical angle 20°; whorls smooth, very slightly concave, number? (five are shown); sutural angle 70°.

Remarks. This species appears to be intermediate between *H. gracilior* and *H. obsoleta*; its spire is less slender than that of the former, and more slender than that of the latter species, while its whorls are more convex than in *H. gracilior* and less so than in *H. obsoleta.*

7. Holopella hydropica, sp. nov. (Pl. XXIV. fig. 4.)

Shell slender; apical angle (?); whorls smooth, bulging below, contracted above; sutures plain, very slightly imbricating; sutural angle 85°.

Remarks. The form of the whorls of this shell is very characteristic, and much resembles that of the Carboniferous *Loxonema impendens*, M'Coy.

8. Holopella minuta, sp. nov. (Pl. XXIV. fig. 6.)

Shell slender; apical angle 22°; whorls smooth, number? (nine exposed, including globular apical point), twice as wide as high, convex; sutures deep, simple.

Length $\frac{5}{20}$; breadth of lowest whorl $\frac{1}{10}''$.

Remarks. This species is distinguished from *H. gregaria* by its wider and squatter whorls, and from *H. monile* by the same character, as well as by its larger apical angle.

9. Cyclonema angulatum, sp. nov. (Pl. XXIV. fig. 15.)

Shell conical; apical angle 65°; whorls four in number, angulated spirally; on body-whorl 4 angulations at equal distances of $\frac{1}{20}''$ apart, the highest one $\frac{1}{20}''$ below the suture; in the preceding whorl three angulations—one immediately above the lower suture, another in the middle, and the third midway between the median angulation and the upper suture. Surface obliquely striated, striæ very fine and close, crossing the angulations and maintaining the same direction from front to back without inflection completely across each whorl.

Remarks. This shell is distinguished from allied species by the fact that the angulations are not plain along their summit, but crossed by the transverse striæ.

10. Cyclonema simplex, sp. nov. (Pl. XXIV. figs. 10, 10 *a*.)

Shell obtusely conical; apical angle 85°; whorls three or four in number, body-whorl large; mouth not visible, but apparently elliptical in shape with the long axis vertical; surface ornamented with revolving thread-like ridges $\frac{1}{20}''$ apart, with an occasional secondary ridge interposed, and transverse striæ of exceeding fineness, only visible in a good light.

Remarks. This species is exceedingly similar to *Turbo crebristria*, M'Coy, from the Bala Sandstone of Milford, Montgomeryshire.

11. Cyclonema turbinatum, sp. nov. (Pl. XXIV. figs. 1, 1 *a*.)

Shell turbinate; apical angle 55°; whorls four in number; body-whorl large, convex, angulated by revolving ridges—on body-whorl one near the suture, two prominent ones in the middle, and two or three smaller ones near the base; on the preceding whorl three ridges—a strong one near the upper suture, one in the middle, and a faint one near the lower suture; sutures deep; mouth elliptical, long axis vertical, peristome continuous, entire; umbilicus deep, bounded by a curved ridge on its inner side; surface covered with transverse striæ or lines of growth, which cross the longitudinal ridges without deflection.

Remarks. This shell is not likely to be mistaken for any other species; but without careful inspection it might pass for a *Murchisonia*, from which, however, it is distinguished by its entire peristome.

12. Murchisonia elegans, sp. nov. (Pl. XXIV. fig. 8.)

Shell slender; apical angle 21°; whorls (six preserved), prominently keeled, outline concave between line and suture, but consisting of two close threads. Each whorl slightly overlapped by the lower one succeeding it, sutures consequently imbricated and marked by a distinctly raised band. Surface finely striated as in *M. gracilis*.

Length $\frac{8}{20}''$; width $\frac{4}{20}''$.

13. Murchisonia corpulenta, sp. nov. (Pl. XXIV. fig. 11).

Shell conical; apical angle 55°; whorls four in number, convex; body-whorl very large; keel square, prominent between the suture and the middle of the whorl; a faint revolving ridge between the keel and the suture; outer lip deeply incised towards the notch, below the notch projecting convexly. Surface covered by fine, close, thread-like, transverse striæ, repeating the outline of the exterior lip. Where the shell has been removed the cast is round and smooth, except for three or four revolving ridges which run parallel to the keel and below it: these are not visible on the small portion of the shell which remains available for observation.

Remarks. This shell is very similar to *M. subrotundata*, Portlock, and *Pleurotomaria bussacensis*, Sharpe, both Upper Cambrian species; but it differs from both in the greater elevation of its spire and in having the band much nearer to the suture; the revolving lines below the band and visible on the cast, also appear to constitute a difference.

14. Pachytheca sphærica, Hooker.

A number of these organisms occur beautifully preserved in the Rhymney Grit and in the rocks above and below it. They present all the characters of Hooker's species—the spherical form, smooth surface, absence of hilum, thick walls, radiating hexagonal cells, and wide variation in dimensions. With them in some cases are associated plant-remains, which very much resemble fronds of *Rhodymenia ciliata* and other Floridean species of Algæ.

Notes on the Rocks.

1. *Wenlock Limestone.*—The concretionary ferruginous bed which immediately covers over the band of Wenlock corals, exhibits to the naked eye a spherulitic or oolitic appearance, which is due to the presence of a vast number of little, smooth, shining, reddish-brown bodies, having the form of oblate or compressed prolate ellipsoids. These little bodies, which look like so many minute beans or lentils, are present in so large a proportion as to form a great part of the rock, and, from their general appearance and close association with a coral limestone, might be taken at first glance for ferruginous oolitic grains. Their real nature is best made out by a study under the microscope of thin slices of the rock containing them. The rock is not of the same consistence throughout, some portions being harder and more compact than others; and these are the best adapted for slicing. The harder parts occur either as isolated nodules or as cake-like masses adhering to a coral or the remains of some other calcareous organism, the greater hardness and compactness in both cases being probably due to an internal deposition of carbonate of lime, and the adherence in the latter case to the derivation of a part of this deposited carbonate from the calcareous structure on which the hard mass is based. An examination of the slices I have had prepared shows a matrix of clear transparent calcite or dolomite, or of brown opaque finely granular ferruginous material, usually full of dispersed minute angular fragments of calcite and quartz. Imbedded in the matrix are the little lentil-like bodies under consideration, and minute, often fragmentary remains of various calcareous organisms. The former consist of an outer envelope of black iron-oxide surrounding a rounded fragment of calcite of organic origin. The envelope is more or less red on its outer surface; and its thickness is very trifling.

The enclosed calcite may consist of a joint or ossicle of an Encrinite, a fragment of shell derived from a Lamellibranch, or more usually from a Brachiopod, such as *Strophomena*, or a piece of a Bryozoon; or it may be of uncertain nature, or, in rare cases, an oolitic spherule. The broken edges of the shell-fragments are neatly rounded off, as if worn by attrition; and the outer envelope covers them like an even coating of paint. The minute structure of the shell is generally perfectly preserved, the canals of the Brachiopod shells being infiltrated by light-yellowish or deep-brown oxide of iron. The Lamellibranch shells have sometimes been infested by a minute boring fungus or alga, in which case the burrows of these plants are also filled with the infiltrated oxide. The Encrinite-joints exhibit very clearly their characteristic reticulate skeleton, which has usually been more or less completely injected by some compound of iron which now presents a lightish yellow or dark red colour by reflected light; with transmitted light, on the other hand, it is quite black, owing to its complete opacity. Fragments of Encrinital skeletons are also amongst the commonest of those other organic constituents of the rock which are scattered through the matrix without any enveloping ferruginous coat. They then very frequently afford us a complete section (longitudinal or transverse, as the case may be) through one of the disks of the Encrinital stem, their structure being usually wonderfully well preserved—though in some cases, when the ferruginous injection is absent, it has become nearly obliterated by blending as it were with the enclosing calcitic matrix. The Bryozoa sometimes form the nucleus of one of the lentil-like bodies; but more usually we observe them as uncoated sections in the matrix, of considerable size, and, as we have said, only partially enveloped in iron oxide, their cells being filled up with calcite or dolomite, or in many cases with an opaque brownish granular ferruginous material.

Many of the lentil-like bodies show no organic structure within; but in some of them a concentric structure is more or less observable, probably indicating the previous existence of an oolitic granule. Thus alternating opaque brown and transparent colourless or yellowish layers are visible in the sections shown by figs. 24 and 25.

Some few of the lentils enclose irregular, frequently angular, fragments of glauconite, having optical characters identical with the glauconite of the Cambridge Greensand. But while the glauconite in the latter case contains clear and transparent granules, many of which have the form of Coccoliths and Foraminifera, in the former it contains only black and opaque granules of no characteristic form. On treating the rock with dilute acid the calcareous cement which binds its parts together is dissolved away, and the ferruginous concretions are set free; when washed and dried they have very much the appearance of little black pebbles, but exhibit no further characters than those already described. We have seen enough, however, by this, to decide as to their true nature. They are not oolitic granules which have become replaced by iron oxide (or at all events very few of them are so), but simply rounded fragments of organic calcite which have become enveloped in a ferruginous covering. Though these concretions are not oolitic in the ordinary sense of the term, yet oolitic spherules do really occur in the limestone. Thus, on breaking open a compact nodule of carbonate of lime which had been formed about a mass of *Favosites fibrosus* lying in the bed, I noticed a number of little spherical bodies bearing a great resemblance, both on account of their faintly bluish colour and slight translucency and their beautiful pearly lustre, to a number of minute pearls: a thin slice was prepared from this nodule; and the "pearls" were then found lying within the cells of the *Favosites*; they only occurred, however, in those cells which had been filled up with clear transparent dolomitic calcite, and were constantly absent in the cells which had been filled in with ferruginous sand. They were found to consist of a great number of very fine wavy layers or concentric shells of transparent calcite, having a faint brownish colour by transmitted light. Some of the layers were much thicker than others, appearing as comparatively broad bands in section, the rest merely as lines of inappreciable thickness. The pearly lustre of the spherules seen by reflected light appears to be due to the superposition of these immeasurably thin layers one upon another; the bluish tint they exhibit with reflected light may be correlated with the amber or brownish tinge they give to transmitted light, the rays reflected and absorbed being, it would seem, complementary to each other.

Between crossed Nicols they remain dark, though the thicker layers appear a little brighter than the rest; the darkness is also of different intensity along certain lines, producing a very dark cross where deepest. Besides the concentric structure, they exhibit no other—not a trace of radiating fibres, such as one commonly sees in concretions of an oolitic nature.

In one or two instances some of the concentric layers have begun to be stained by iron oxide, which in one case is present in sufficient quantity to form a distinct flake of hæmatite.

In size the grains vary from $\frac{1}{40}''$ to $\frac{1}{250}''$; in form they differ considerably, some giving an almost perfectly circular outline in section, others a polygonal, oval, or even heart-shaped one; but whatever their external contour, they nearly all possess a spherical nucleus, and the nearer the concentric layers are to this and the further from the exterior the more they approximate to the spherical form. As regards the true characters of these grains one feels a certain amount of difficulty. The first point to decide is whether they have been formed *in situ*, or washed in from the exterior. The fact that they only occur in such cells as were shut off from communication with the muddy sea-bottom, and so had become infiltrated with pure crystalline dolomite, seems to point to their formation *in situ*; and this supposition is strengthened by the way in which some of them appear to have adapted themselves in their later stages of growth to the form of the cellules in which they lie, and also to one another when two or more lie in close proximity. Admitting that they were formed in the places where they are now found, one can only conclude, further, that they must have been formed by the successive deposition of coats of carbonate of lime, one over the other concentrically, on some original nucleus. They are therefore oolitic grains without a fibrous structure, and they must have grown by a deposition of carbonate of lime from solution. But why, one cannot help asking, should the deposition of calcareous material have taken place in two very different ways in the same cellule of the *Favosites* (at first about nuclei concentrically, without apparently giving rise to a crystalline structure, and afterwards generally, filling up the cellule with a confusedly crystalline mass of dolomitic calcite)? One almost feels tempted to regard the oolitic granules as "calculi" formed during the lifetime of the *Favosites*; and though such a supposition is not probable, it yet may afford us a hint as to the true explanation; for immediately after the death of the *Favosites* a good deal of organic matter would be set free, and would pervade not only the surrounding water, but the several cells of the organism. Unfortunately we do not know much about the precise mode in which the presence of organic matter influences the mode of deposition of mineral substances; but that it does exert a special influence of some sort is pretty generally admitted; and it may be just possible that the oolitic granules were formed so long as organic matter existed in the mineralizing waters, and that ordinary crystalline dolomite began to be deposited as the organic matter disappeared. (A qualitative analysis which I made of this rock, showed the presence of a considerable quantity of both magnesia and phosphoric acid.)

Reviewing the knowledge we have acquired of the ferruginous Wenlock limestone, we are now in a position to give a short history of the course of its formation. At first there existed a plentiful growth of very various calcareous organisms, which by their death and subsequent decay furnished a considerable quantity of calcareous fragments to the deposits accumulating on the sea-floor. Some of these fragments were rounded into minute pebbles either by solution in carbonated waters or by mechanical attrition—most probably by attrition, since they are now often only small fragments of what were once large shells, and their surfaces are smoother than they would be had they been eroded by solution. Others of the fragments retained completely their original organic form; and yet others again were broken up into fine angular detritus, and mingled by a slowly moving current of water with occasional grains of broken quartz, or finely divided ferruginous mud. The calcareous sand thus produced appears next to have been permeated by an infiltration of ferruginous water, which thus made incursions into the Silurian sea long before the time of the Old Red Sandstone. This led to the injection of ferruginous matter into the canals of the Brachiopod shells and the interstices of the Encrinital skeletons, and also to the building-up of successive coats of iron oxide around many of the rounded calcareous fragments. Grains of glauconite, which had probably been previously formed, were also enveloped in this material. At the same time, or perhaps previous to the influx of ferruginous waters, oolitic granules were being formed within the closed chambers of such coral-like structures as now contain them. Finally the incoherent mass of sand and mud and granules was cemented together in places into compact nodules and patches, by the deposition partly of iron oxide, but chiefly of carbonates of lime and magnesia.

2. *Band of Limestone above the Rhymney Grit.*—The cut and polished surface of this rock shows a number of white, green, and pinkpatches set in a greenish-grey ground, corresponding to a number of fragments of organic calcite imbedded in a matrix of very fine quartz sand, the whole being cemented together by an impure glauconitic mineral.

The organic remains revealed in these sections by the microscope are very numerous and interesting: good sections of Bryozoa are frequently seen; Brachiopoda are plentiful, very often in a fragmentary state, but never incrusted with iron oxide, or rounded at the edges: univalves with their shells converted into the crystalline state are not rare; Encrinite skeletons are abundant; and Foraminifera resembling *Nodosaria* and *Rotalina* are observable now and then.

The calcareous parts of the foregoing organisms retain, as a rule, their calcareous composition; but the hollow spaces within them have become filled up with a material which has a greenish-white appearance by reflected light, and either a green or a brownish colour with transmitted light: the same material cements together the quartz which fills up the spaces in the rock not otherwise occupied by organic constituents. When it is green both by reflected and transmitted light, it is insoluble in acids and probably exists as a more or less pure silicate of iron; when it is brown by transmitted light it is soluble in hydrochloric acid and probably consists of calcite coloured by admixture with the iron silicate. It is the soluble material which chiefly binds the quartz sand together.

The injection of the Encrinital skeletons by the green silicate has led to the preservation of their structure in a wonderfully complete manner.

Scattered irregularly through the matrix of the rock, and arranged along regular lines within some of the constituent shelly fragments, occur a number of little spherules of iron-pyrites, precisely similar to those described in my paper on *Pharetrospongia* (Quart. Journ. Geol. Soc. vol. xxxiii. pp. 250, 251). I now find that these are very common constituents of certain calcareous rocks; they are beautifully exhibited by the Lias limestone of Aberthaw and Penarth, South Wales, and may easily be obtained for observation by treating the limestone with dilute hydrochloric acid, when they are left as an insoluble residue. Examined as opaque objects under the microscope, they are seen to be covered on the surface by brilliant crystalline facets, and look very much as the curious iron-pyrites concretions of the Chalk would do if reduced to the same insignificant dimensions; nor do I doubt that the latter only differ from the former in this respect —that is to say, as regards relative size. In the matrix of the Lias limestone they can be traced, as in *Pharetrospongia*, passing into an oxidized state, staining at the same time the surrounding limestone with the products of their decomposition, and finally giving rise to globules of clear, transparent, blood-red hæmatite. The size of the hæmatite globules is much more uniform than that of the iron-pyrites concretions, a large sphere of pyrites resolving itself during oxidation into a great number of smaller globules of hæmatite, which then remain all grouped together as if subordinate parts of a common spherule, thus giving rise to the idea that they might be spores or sporangia, as I suggested in the paper before alluded to (see figs. 15 and 16, pl. xi. *loc. cit.*).

Precisely similar but isolated globules of hæmatite are found within the canals of fossil Nummuline Foraminifera, and in this position have been mistaken for the ova of the animal. I have now seen them associated with concretions of pyrites in the crystalline calcite filling up the interspaces of *Stauronema*, inside the hollowed-out spicules of *Pharetrospongia*, dispersed throughout the Lias limestone of S. Wales and the shelly limestone of the Rhymney Silurians, as well as in the canals of a fossil *Operculina*. In all these positions they present a nearly uniform size and the same essential characters.

I do not doubt, therefore, that the red globules of hæmatite have been derived by oxidation from the spherical concretions of pyrites; and I believe the latter to result from the unhindered crystallization round nuclear centres of iron sulphide, resulting from the reduction of salts of iron which were diffused in solution throughout the limestone before it became consolidated, or through the canals of Foraminifera before they had become completely fossilized.

In concluding the description of the limestone, one may mention that on being heated with hydrochloric acid it dissolves, leaving behind an insoluble gritty mud of a dark greenish colour. Dried and mounted in balsam, this mud is found to consist of grains of siliceous sand, globules of iron-pyrites, and casts in green silicate of minute univalves, Foraminifera, Encrinital skeletons, and the canals of Brachiopod shells. The Encrinital casts are very beautiful objects, and reproduce the form of the network so perfectly as to mislead one at first into regarding them rather as pseudomorphs of that network than as casts of its meshes.

3. *Iron Galls in the Ferruginous-mud Bed above the Rhymney Grit.*—These, when examined in thin slices under the microscope, show a dark chocolate-coloured, quite opaque matrix of iron oxide, through which are scattered more or less sparingly a number of very minute sharply angular fragments of calcite, with here and there a grain of quartz. No concentric or radiating structure is visible with transmitted light; but with reflected light a faint concentric line of darker colour than the general surface can be made out near the external edge. A chemical analysis of one of these galls, hastily made by Mr. James, of University College, Bristol, gave the following results:—

Ferric oxide	77·6
Silica, soluble and insoluble	12·9
Carbonic anhydride	2·9
Calcium oxide	6·6
	100·0

4. *Ferruginous Staining of Ludlow Sandstones.*—Some of the greenish-coloured sandstones of the Lower Ludlow are occasionally penetrated by thin strings of a bright red colour, due to the infiltration of red oxide of iron after consolidation; sometimes the red oxide is present in such quantity as to form thin strings, about $\frac{1}{10}''$ wide, of fibrous göthite, in which case the adjacent stone is stained red for a considerable distance, $\frac{1}{2}$ to 1 inch, on each side of the pure mineral. The strict parallelism of the edges of the stained bands to the joints and bedding-planes of the sandstone proves the infiltration to have been subsequent to the consolidation and jointing of the rock.

5. *Göthite in Bedding-planes of Rocks immediately below the Rhymney Grit.*—In the Rhymney quarry an irregular bed or series of lenticular patches of göthite occurs just below the Grit, close to the thin calcareous seam seen here; it is from 1 to 2 inches in thickness, very pure, and cavernous in the middle, the surface of the hollows being frequently lined by scalenohedra of calcite, or dog-tooth spar.

EXPLANATION OF PLATE XXIV.

Figs. 1 & 1 *a*. *Cyclonema turbinatum*, sp. n. Ludlow, Cae Castell, Rhymney river. Natural size.

2. *Modiolopsis inflata*, M'Coy, var. *elevata*, Soll. Natural cast of right valve. "Ctenodonta"-bed, Wenlock, Rhymney Quarry. Nat. size.

3 & 3 *a*. *Orthonotus navicula*, sp. n. Ludlow, picked up near Cross Dowton, Rhymney. Nat. size.

4. *Holopella hydropica*, sp. n. "Ctenodonta"-bed, Wenlock, Rhymney Quarry. Nat. size.

5. *Holopella gracilis*, sp. n. "Ctenodonta"-bed, Rhymney Quarry. Nat. size.

6. *Holopella minuta*, sp. n. "Ctenodonta"-bed, Rhymney Quarry. Nat. size.

7. *Leda* (?) *ambigua*, sp. n. Ludlow, Cae Castell, Rhymney river. Nat. size.

8. *Murchisonia elegans*, sp. n. "Ctenodonta"-bed, Rhymney Quarry. Nat. size.

9. *Ambonychia* (?) *tumida*, sp. n. Lower Wenlock, Pen-y-lan Quarry. Nat. size.

10 & 10 *a*. *Cyclonema simplex*, sp. n. Wenlock limestone, Cae Castell, Rhymney river. 10 *a*. Exterior of a part of the body-whorl to show the ornamentation. Nat. size.

11. *Murchisonia corpulenta*, sp. n. Wenlock limestone, Cae Castell, Rhymney river. Nat. size.

12. Oolitic granules contained in a cell of *Favosites fibrosus*. *a*, *a*. The containing cell-wall. Wenlock limestone, Cae Castell, Rhymney. Transv. sect. (× 30.)

13. Granule of black iron oxide (*a*), containing an angular fragment of glauconite (*b*). Transv. sect. Wenlock limestone, Cae Castell, Rhymney. (× 30.)

14. Glauconite cast of a Foraminifer dissolved out from the bed of limestone occurring just above the Rhymney grit in the Cae Castell section. (× 30.)

15. *Cyclonema angulatum*, sp. n. Lower Wenlock, Pen-y-lan Quarry. Nat. size.

16. Ellipsoidal granule of granular calcite surrounded by a film of black iron oxide. Tang. sect. Wenlock limestone. (× 30.)

17. Two oolitic granules which have become joined together in the last stages of growth. Transv. sect. Wenlock limestone. (× 30.)

18 & 19. Oolitic grains in the cells of *Favosites fibrosus*, showing modification of spherical form produced by adaptation during growth. Transv. sect. Wenlock limestone. (× 30.)

20. Oolitic grain with deeply inflected margin, lying in the centre of a cell of *F. fibrosus*. Transv. sect. Wenlock limestone. (× 30.)

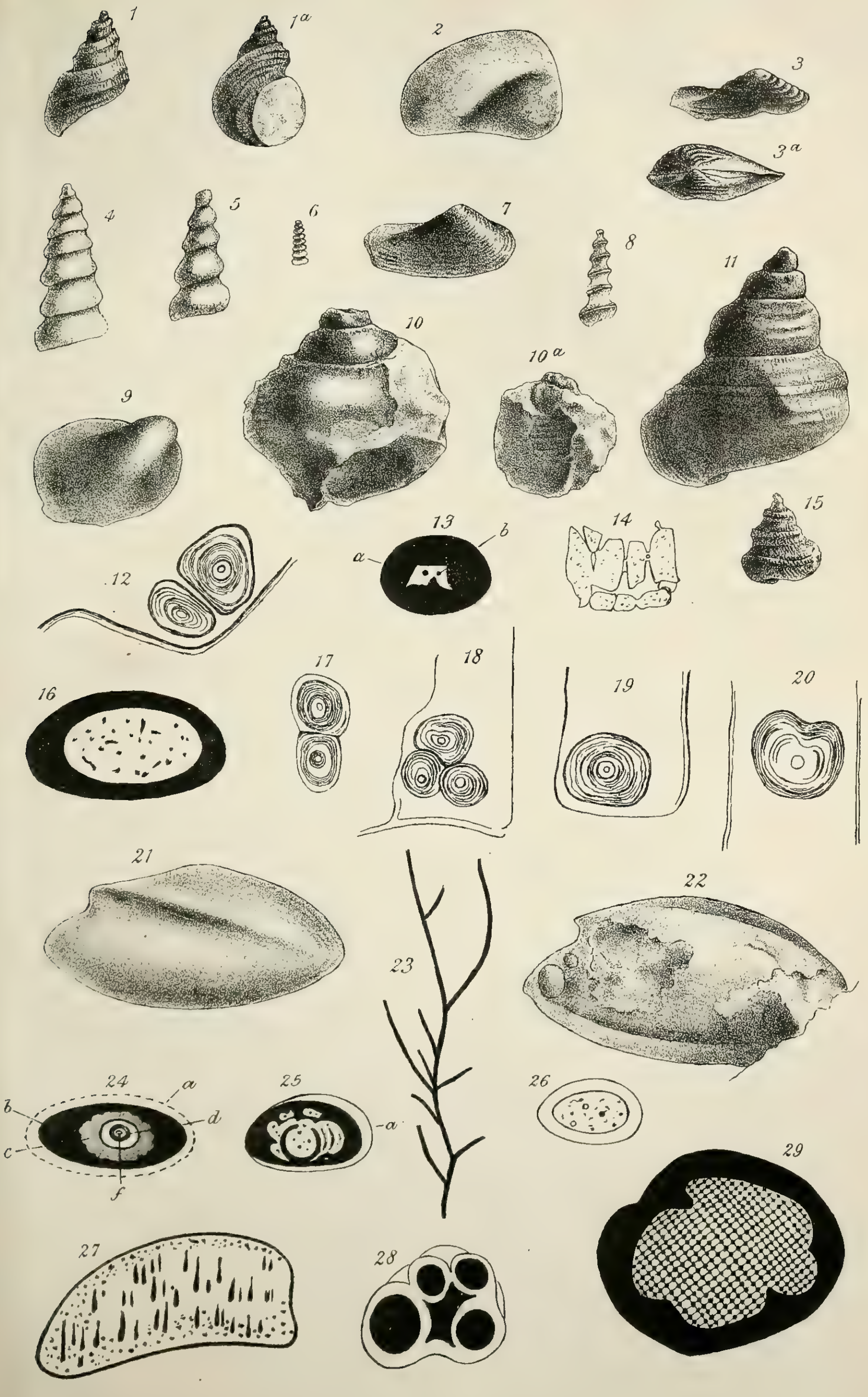
21 & 22. *Modiolopsis acutiprora*, sp. n. 21, natural cast of the exterior; 22, of the interior, of the left valve. "Ctenodonta"-bed, Wenlock, Rhymney Quarry. Nat. size.

23. An Alga from Ludlow beds, Cae Castell, Rhymney. (× 2.)

24. Ferruginous grain from Wenlock limestone, Cae Castell. *a*. External layer of granules suspended in the surrounding matrix of clear calcite. *b*. Zone of black iron oxide. *c*. Zone of brownish-red opaque ferruginous material. *d*. Zone of transparent brownish calcite. *f*. White opaque nucleus. Transv. sect. (× 30.)

25. Ferruginous grain from Wenlock limestone, Cae Castell, having the form of an Entomostracan valve. *a*. Black iron oxide surrounding the granule and forming more or less concentric rings within it. This structure may result from the infiltration of an oolitic grain by iron-oxide. Transv. sect. (× 30.)

26. Elliptical ring of clear calcite, surrounded by brown opaque matrix and enclosing sand grains cemented by ferruginous matter. Similar



A.S. Foord lith.

Hanhart imp

SILURIAN FOSSILS FROM RHYMNEY.

rings appear in thin slices of the limestone lying above the Rhymney grit. Transv. sect. from Wenlock limestone, Cae Castell. (× 30.)

Fig. 27. Fragment of the shell of a Brachiopod, its angles having been rounded off, its surface enveloped and its canals infiltrated with dark-brown iron oxide. Transv. sect., from Wenlock limestone. (× 30.)

28. Section of a Foraminifer infiltrated with greenish silicate from limestone above the Rhymney grit. (× 50.)

29. Ferruginous granule enclosing a disk of an Encrinital stem, which had been infiltrated by dark-brown iron oxide. Transv., sect., Wenlock limestone, Cae Castell. (× 50.)

Discussion.

The President confirmed the views of the author as to the non-organic origin of the Cornstones, and that a few limestones are to some extent of mechanical origin and derived from older limestones.

Prof. Ramsay spoke of the difficulty of getting the corrections made by the Geological Survey engraved on the Ordnance Maps. The original mapping was done as long ago as 1842, but has since been corrected; and the Upper Silurian strata of the region described by Mr. Sollas have been added to the Map.

Mr. Blake confirmed the accuracy of the author's descriptions from his own observation. He stated that in mineral character the Upper Silurian and Old Red Sandstone are very similar.

Mr. Jukes-Browne asked if there was any evidence of any break in the Old Red Sandstone.

Dr. Hicks stated that a species of *Pentamerus*, of long range, was found in the Caradoc, Llandovery, and Wenlock, and therefore that it was difficult frequently to assign an exact horizon to some fossils.

Dr. Duncan could not agree with Dr. Hicks that the Upper Silurian and Lower Silurian could not be distinguished from one another by their fossils. He thought that the grouping of certain forms was quite distinct in the two series.

Mr. Sollas replied to the President that he was glad to receive such important confirmation of his observations; to Prof. Ramsay that Mr. Sollas had himself found a fine-grained calcareous marl in the gravel-pit of Barnwell, Cambridge, to be composed chiefly of coccoliths, which had been derived from the denudation of the Chalk hills of Cambridgeshire, and that calcareous sediment, consisting of coccoliths, was still in process of mechanical transportation by the river Cam; to Mr. Blake that the species of *Pentacrinus* found above the Wenlock limestone, though smaller than the ordinary *P. oblongus*, was not smaller than its variety, *P. lævis*, and that the red colour of the rocks is to a great extent merely superficial; to Dr. Hicks that he agreed with him in thinking that the range of several Upper Cambrian species may have to be extended; to Mr. Jukes-Browne that there was no discernible unconformity in the Welsh Old Red, and that the overlap near Llandeilo was that of the Siluro-Carboniferous series onto the Cambrian and not due to an unconformity between the members of the Siluro-Carboniferous itself; and to Dr. Duncan that he hoped the corals referred to by him might receive the attention of one who understood them so well.

38. *On* Perlitic *and* Spherulitic Structures *in the* Lavas *of the* Glyder Fawr, North Wales. By Frank Rutley, Esq., F.G.S., H.M. Geological Survey. (Read March 12, 1879.)

(Communicated by permission of the Director-General of the Geological Survey.)

Among the specimens belonging to the rock-collection in Jermyn Street of the various rocks which constitute the Glyders on the north side of the Pass of Llanberis, and which have been mapped by the Geological Survey as felstones and felspathic traps, and described by Professor Ramsay as lava-flows, I have discovered one which presents unquestionable perlitic structure. (The specimen is marked 376, wall-case 41 in the published catalogue.) The rock is associated with Bala-beds, and is overlain by shales containing fossils similar to those which occur in the Bala Limestone.

It presents the appearance of a felstone to the naked eye, and by polarized light, under the microscope, it shows the microcrystalline structure which felstones so commonly exhibit. It is now practically a felstone; once it was a vitreous lava. Portions of the specimen show a coarsely vesicular structure; and the vesicles are, for the most part, filled by crystalline aggregates of quartz.

The above observations perfectly confirm the early conclusions formed by the Survey, which express as much truth as it was possible to arrive at in the absence of microscopic investigation.

The only additional information now procured is that the lava in question was once vitreous, and that it still shows the perlitic structure as clearly as the perlites of Saxony, which are of Tertiary age. The accompanying figure will sufficiently demonstrate this fact.

Section of Perlite of Esgair-felen, Y Glyder Fawr, the highest of the Lava-flows. × 5.

Some of the other felstones of the Glyders show spherulitic structure; and in some cases, indeed, they consist almost exclusively of little bodies which frequently present ill-defined or even serrated or denticulate boundaries, as though their configuration had been affected by the crystallization of the surrounding matter. These *may* be considered spherulitic rhyolites. If this assumption be true, the spherules, or pseudo-spherules, must be regarded as crystalline structures emanating from separate points of devitrification. In the rocks of this kind which I have examined I have met with no trace of perlitic structure. Other felstones from the Llanberis neighbourhood give evidence of fluxion by the presence of irregular bands, which merely differ from the surrounding matter in texture, and simply imply a difference in the character of two imperfectly incorporated glasses of different densities, a difference which is still demonstrated by variation in the texture or grain of the devitrification products. Some of the felstones of the Glyders contain spheroidal bodies, occasionally as large as filberts. These are not true spherulites. I believe that they are now being examined and will shortly be described by Prof. Bonney; and since they are in such able hands, I leave them alone, resting assured that due justice will be done to them. In conclusion I have merely to remark that what I have often expressed as a belief is now, to some small extent, demonstrated—namely, that some of the Welsh felstones are the representatives of formerly vitreous rocks.

It is interesting to find that, from the Lower Silurian period until the present day, time has failed to efface from some of these lavas the structural features which characterize rocks of a vitreous nature, although they have long ceased to possess the physical characters by which vitreous rocks are commonly distinguished.

It is only by the recognition of structural peculiarities that we can hope to demonstrate the original character of some of our most interesting palæozoic lavas.

Devitrification has, no doubt, often obliterated these structures. We then have no clue whatever to the conditions under which such rocks have been erupted; and in view of this fact we can hardly look forward to the day when felstones will be struck off the roll of normal eruptive rocks. In many cases felstones are essentially devitrified hyaline rhyolites; but it seems impossible to demonstrate that they are so in all instances. At the present time the felstones offer some of the greatest difficulties and the greatest attractions to the student of petrology.

Discussion.

Prof. Bonney stated that there could be no doubt the Wrekin rocks were much older than those of the Snowdonian district. He quite agreed with the author that this specimen was a true perlite. He mentioned the fact that the lavas of Bala age in Wales were generally vitreous, and instanced some remarkable cases of spherulitic structure from that district.

Prof. Judd stated that among the most ancient rocks of the north-west of Scotland were lavas showing spherulitic and fluidal structure. These were also common in the Old Red Sandstone lavas. He thought that as the spherulitic, perlitic, and fluidal structures were, in rocks of modern date, confined to vitreous varieties, the inference was safe, when applied to ancient rocks, that they were once glass.

Dr. Sheibner asked if an analysis of the rock had been made. If the rock was a true perlite, there should be about 80 per cent. of silica; if the rock was altered, one might expect a large excess of magnesia.

Prof. Ramsay said that the character of these lava-flows was evident even without microscopic examination. He recapitulated the evidence which had persuaded him of this when surveying the district, and expressed doubt as to the rocks at the base of the Cambrian in North Wales being true lava-flows.

Dr. Hicks said he thought there was no reason why a perlitic structure should not occur in rocks of Bala age. He thought the first spherulitic rocks recognized in this country had come from rocks of Arvonian age at St. David's.

Mr. Bauerman said that modern lava-flows often cover very large areas, as in North America and India; so the mere distance of the Wrekin from Wales would be no difficulty.

Mr. Rutley doubted whether spherulitic structure was always connected with vitreous. He did not see that the presence of magnesia would prove or disprove alteration. He did not think a rock could be vitreous if solidified at a great depth, since it would hardly be able to cool with sufficient rapidity.

39. *On some* Three-toed Footprints *from the* Triassic Conglomerate *of* South Wales. By W. J. Sollas, Esq., M.A., F.G.S., Lecturer on Geology at University College, Bristol. (Read April 9, 1879.)

In the summer of 1878 an artist friend, Mr. T. H. Thomas, was passing through Newton Nottage, a village near Porth-Cawl, Glamorganshire, when his attention was arrested by some three-toed footprints, deeply impressed in the surface of a slab of rock and rendered particularly visible by the slanting rays of the setting sun. Understanding the full value of his discovery, he at once communicated it to Mr. R. W. Jones of Newport, Monmouthshire, who, with his brother, Mr. T. Jones, Jun., F.G.S., takes a deep interest in every thing connected with the progress of geology. Mr. T. Jones at once commissioned Mr. J. Storrie, the valued Curator of the Cardiff Museum, to obtain casts of the footprints in plaster of Paris; and Mr. R. W. Jones suggested that casts should also be taken of the footprints of some living birds for comparison.

Accordingly Mr. Storrie set about his work, which he most successfully accomplished; and Mr. Thomas and myself obtained casts, in mud and in modelling-clay, of the footprints of an Emu living in the Gardens of the Clifton Zoological Society, and of a Rhea and a Cassowary which are preserved in a stuffed state in the Bristol Museum. Finally all the accumulated facts and material were placed in my hands for description.

The Slab of Stone.—This is now lying in the N.E. corner of the green in front of the church at Newton Nottage*. At one time it lay in front of the steps of the village inn, and has suffered more or less wear in places in consequence, but not enough to obliterate the characters of the best-marked impressions. It measures 5 feet 6 in. by 6 feet 1 in., and consists of a breccia or conglomerate of small limestone fragments similar to that exposed in a quarry near to Schorlon, half a mile west of Newton Nottage, and which has been mapped as Trias by the Geological Survey. Mr. R. W. Jones's section is as follows:—

Section in Quarry at Schorlon, Newton Nottage.

	feet.
Red conglomerate containing pebbles of Carboniferous Limestone ...	3
Flaggy calcareous beds, with frequent subangular pebbles of Limestone	6

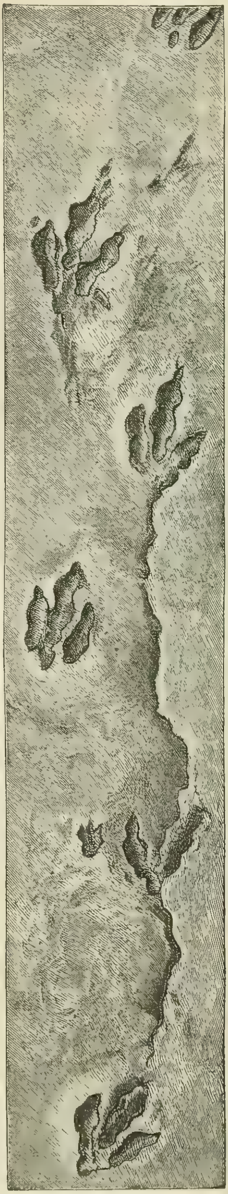
The slab bearing footprints is lithologically similar to the lower beds.

The beds of this quarry lie at the base of a range of Carboniferous Limestone hills trending from S.W. by S. north-eastwards.

The Footprints.—These are five in number, lying one in front of the other on each side of a mesial line. The hindermost, which we shall call No. 1, was impressed by a left foot; and so were Nos. 3 and

* It has since been placed in the Cardiff Museum.

5 counting forwards. Nos. 2 and 4 are right feet. The distance between the heel of No. 1 and that of No. 3, is 3 feet 6 inches, between Nos. 3 and 5, 3 feet 2 inches, and between Nos. 2 and 4, 2 feet 10 inches.



Series of five three-toed footprints, Dolomitic Conglomerate, Newton Notage, Glamorganshire: $\frac{1}{18}$th nat. size. Drawn by T. H. Thomas Esq.

Thus the average stride was 3 feet 2 inches long; and the deviations from this seem to suggest that the animal which made the marks was picking its way through what was very pebbly ground. It does not seem to have been always successful in doing so; for in the case of footprint No. 1 the end of the middle toe has been planted right on a large limestone pebble, which seems to have quickened the pace of the creature; at all events the succeeding stride is the longest of the three.

The best-marked of the footprints are Nos. 1, 3, 4 and 5; and as these do not differ in any essential detail, but only vary in the greater or less perfect state of their preservation, it will conduce to brevity if I describe the characters of a single one of them, selecting the most perfect and supplying its deficiencies from the others.

This footprint, then, shows the marks of three toes, diverging from a posterior heel. The middle toe is the most regularly defined; the outer toe comes next in regularity, and the inner last. The outer toe is confluent with the heel; the middle and inner toes are separated from it and from each other.

The print of the middle toe is deeply impressed, forming a straight rounded channel, $6\frac{1}{2}$ inches long, and contracted and swollen at intervals in correspondence with the number and position of the phalanges of the original digit. Thus we find the first phalangeal region of the digit very well defined, especially at its proximal end; then follow the second and third, not quite so marked, but quite well enough to be clearly distinguishable; and finally there is a terminal acutely angular pit, which represents the nail and its associated ossicle. From the point of the nail to the back of the heel measures 10 inches.

The outer toe-print is likewise a straight gutter-like depression. It originates from a well-marked heel, from which it is separated by a slight contraction only. It is differentiated into not more than two regions—a single long proximal one, deepest distally, and a sharp ungual pit.

The inner toe is $5\frac{1}{2}$ inches long, and is divided into three imperfectly defined phalangeal swellings, of which the middle one is deepest; the terminal one is possibly ungual. It is not straight like the others, but curiously splayed outwards, being swollen first on its outer side towards its base, and afterwards on its inner side towards the middle toe, thus giving it a sigmoidal form. The angle contained between the inner and outer toes is 50°, between the inner and middle 26°, and between the middle and outer 24°. The spread from the point of the outer to that of the inner toe is $6\frac{1}{2}$ inches in length; the projection of the middle toe beyond a line joining the points of the inner and outer toes is $3\frac{1}{2}$ inches.

The measurements of the various parts of the five footprints are embodied in a table given later on, where measurements of the footprints of various Ratitous birds are also given for comparison.

The footprints of the Emu, taken in modelling-clay and afterwards reproduced in plaster of Paris, are remarkably similar in general character to those just described. There is a very deeply impressed almost hemispherical cavity for the heel-point; an elongated rounded groove represents the outer toe, and a small pointed impression its nail. The middle toe is represented by three broad rounded phalangeal depressions, and a pointed ungual pit. The proximal phalange is most deeply impressed; and it is worth noticing that while the prints of the middle and inner toes are quite separated from that of the heel, the outer toe-print, on the contrary, is connected with it by a shallow depression, faintly reminding us of the deep groove which similarly connects the outer toe with the heel in the fossil foot-marks. The inner toe-print consists of a single elongated pit with a terminal depression. On comparing the regions of the sole of the Emu's foot with its skeletal structure, one is struck with their wide divergence in details, which clearly shows the futility of too closely arguing in all cases from the skeletal structure of a foot to the impression it might make on the surface of a sedimentary deposit. Thus, while the feet of most of the Ratitæ possess a prominent heel, the end of the tarso-metatarsal bone, on the other hand, does not appear to reach the level of the ground; so too, while the articulations of the phalanges are the most swollen parts of the digital skeleton, on the sole of the foot they are the least so, owing to the excessive development of tissue over the middle of the phalangeal bones; and, finally, while the inner toe possesses three phalanges in all, and the outer toe as many as five, yet the imprints left by these digits on the ground show only two depressions in each case—one a mere pit indicating the nail, the other a long groove representing all the rest of the phalanges. Moreover the number of phalanges indicated varies with the way the foot is set on the ground; thus in one instance the Emu in our Zoological Gardens so stepped as to run the second and third phalangeal imprints of its middle toe into one.

The casts taken from the Rhea and Cassowary in our Museum are, I fear, not trustworthy, as the feet seem to have lost a good deal of their original form in the setting-up. Still they are available for measurements of length, which are given in the following table:—

Linear and Angular Measurements of Fossil Foot-prints, and Foot-prints of Ratitous Birds.

Footprint.	Length of toes.		Distance from point of toe to commencement of heel.			Angle between the toes.			Spread.	Projection of Middle toe.	Stride.
	I.	M.	I.	M.	O.	O.I.	I.M.	O.M.			
No. 1, Left ...	$5\frac{1}{2}$	$6\frac{1}{4}$	$7\frac{1}{2}$	10	$7\frac{1}{2}$	52°	30°	22°	$6\frac{1}{2}$	$3\frac{1}{2}$	
2, Right	$5\frac{1}{2}$	...	...	...	...	...	...	...	6	...	3′ 2″
3, Left ...	$4\frac{1}{2}$	$6\frac{1}{2}$	7	$9\frac{1}{2}$	$6\frac{5}{8}$	44°	24°	20°	$6\frac{1}{2}$	$3\frac{1}{2}$	
4, Right	5?	$6\frac{1}{2}$	$7\frac{1}{4}$	10	$6\frac{1}{2}$	...	24°	...	...	...	
5, Left...	$4\frac{3}{4}$	7	$7\frac{1}{4}$	$10\frac{1}{4}$	$7\frac{1}{8}$	51°	27°	24°	$6\frac{1}{2}$	$3\frac{1}{2}$	
Average	5	$6\frac{1}{4}$	$7\frac{1}{4}$	10	7	49°	27°	22°	$6\frac{1}{2}$	$3\frac{1}{2}$	
Emu	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$7\frac{3}{4}$	$5\frac{1}{2}$	66°	22°	44°	$6\frac{1}{2}$	$3\frac{1}{2}$	{ 2′ 8″ walking. 3′ 8″ running.
Cassowary ...	$3\frac{3}{4}$	...	$5\frac{3}{4}$	8	$7\frac{1}{2}$	47°	29°	18°	$5\frac{1}{2}$	2	
Rhea	$3\frac{1}{2}$	5	$3\frac{1}{2}$	5	$3\frac{1}{2}$	93°	43°	50°	5	$2\frac{1}{2}$	

The linear measurements of this table are given in inches. I=inner, M=middle, O=outer. Spread=length of a straight line joining the extremities of the inner and outer toes. Projection of the middle toe=distance it extends beyond the line of spread.

It will be noticed that the projection of the middle toe and the "spread" are the same in the Emu as in the fossil tracks, notwithstanding the difference in their other dimensions. In size and angular measurements the nearest approach to our footprints is made by the Cassowary. It may be added here that the height of the Emu we examined was 5′ 9″, of the Cassowary 4′, measured from the ground to the top of the crest. Reasoning on the ratio of the height to the length of the foot, this would give the animal of the ichnites a height of from 5′ to 7′ 8″ thus:—

$$\frac{5' 9''}{7\frac{3}{4}''} = \frac{7' 8''}{10''} \text{ or } \frac{4'}{8''} = \frac{5'}{10''}.$$

Emu. Fossil. Cassowary. Fossil.

So complete is the agreement in all essential points between the footprints in the Triassic conglomerate and those of the living

Emu, that, leaving all other considerations out of the question, one would not feel much hesitation in declaring for the Avian and, indeed, Ratitous character of the animal which produced the former. But the other considerations are too important to be overlooked. Although the remains of fossil vertebrates have in several instances been discovered in the Triassic deposits of S.W. England, yet none have hitherto been referred or referable to Birds; on the other hand many of them are true Reptiles, though with extraordinarily strong ornithic affinities. The existence of Dinosaurs during the Trias gives, indeed, a strong *primâ facie* probability to the supposition that these associated bird-like footprints were really produced by some form of Ornithic Reptile.

The occurrence of *Thecodontosaurus* and *Palæosaurus* in the magnesian conglomerate of Durdham Down, Bristol, which is on the same parallel of latitude as Newton Nottage, and only 45 miles distant, is very suggestive; and I cannot help thinking that one or other of the animals which possessed the bones must have been a near relation to that which has left its footprints in the magnesian conglomerate of S. Wales.

A comparison of these footprints with those figured by Hitchcock shows that they must be referred to the genus *Brontozoum*, of which they will form a new species, which I propose to call *Brontozoum Thomasi*, in honour of its discoverer.

Supplement by J. Storrie, Esq., *Curator of the Cardiff Museum.*

These beds are mapped by the Geological Survey as dolomitic conglomerate and marlstones, and appear to lie in a depression of the Carboniferous Limestone, by which they are bounded on all sides except the W., where they dip gradually into the sea. Immediately behind the village of Newton on the N. they are deposited close up to the base of the Limestone cliff, on which most of the village is built; and they are shown all along the road to Nottage at intervals, forming a sort of natural pitching for the road. At Schorlon, where this stone was dug up, I was unable to examine them on account of the snow; but in the small exposures I saw they seem to dip very slightly, perhaps 2 or 3 degrees W. As it was useless, on account of the weather, to attempt any thing more here, I proceeded to Porth-Cawl, and striking W. along the shore found that the Carboniferous beds still maintained the same general characters as at Newton, and had a slight dip W.N.W. of about 8 degrees. About $\frac{3}{4}$ of a mile past the Rest, a fault about 25 to 30 yards in width occurs, in which the Limestone-beds are thrown nearly vertical and considerably crushed. The conglomerate comes in here right up to the edge of the fault, and is nearly horizontal at the point of junction, but increases in dip gradually as it extends westwards till it passes under the channel and blown sands at a general dip of about 10 degrees. I examined bed after bed as I walked along the shore with the hope of meeting one of something like the same texture as the stone, or to try for any signs of other footsteps; but I was unable to find either*. Once or twice I had some slight hope, as the beds grew finer in texture occasionally; but they generally soon acquired their normal character. Nothing satisfactory can be done there till a little finer weather comes.

I prepared sections from the stone and also from some of the pieces in the quarry near where it was said to have been found. Under the microscope the slide from the stone itself shows clearly its conglomeratic character. One of the pebbles of an angular shape contains Foraminifera, some of the species of which are identical with those found in the bed on the new road leading from the Avon river to Clifton down, and marked No. 5 in Mr. Stoddart's section of the Avon beds; there are also a few small shells like *Rotalia*; but I cannot have the species identified, and it may perhaps be new. The greater part of the slide consists of minute reddish grains principally coloured by iron, and minute fragments of blackish particles of uncertain origin.

Another section of the same stone consists wholly of an oolitic structure closely resembling, if not quite identical with, that shown by the bed exposed in a roadside quarry about three miles north of Cowbridge, near Ystrad Owen; this bed so far as I know, has not been identified with any other bed either in the Avon or any other section.

No. 3 slide is not from the stone itself, but from one in the same quarry, and contains a common species of *Syringopora*, a coral frequent in the Carboniferous Limestone and not confined to any particular horizon; it seems to occur very abundantly in the conglomerate, as all along the road-side, where the walls are built of it, patches of this coral occur here and there in the blocks.

No. 4 slide is also from a piece from the same quarry, and contains *Spirorbis* nearly as abundantly and in much better preservation than in any pieces I have found before. I have found them in pretty fair condition in a bed at the old quarry at Rurbina, about a mile east of Castle Coch, where they occur at the base of the Lower Carboniferous slates.

This leads me to believe that this conglomerate was formed from the débris of a shore where the lower Carboniferous shales and limestone formed the sea-cliff, and where no trace of other beds were present; no doubt they were laid down exactly as the beds in the Channel are at present from the washings of the cliffs at Penarth.

Discussion.

Prof. Hull pointed out that Prof. Marsh had suggested that the supposed footprints of birds in the Connecticut valley may probably have been made by Dinosaurs.

* Additional specimens of similar footprints have since been found "puddled together" at Newton.

40. *On Remains of* Mastodon *and other* Vertebrata *of the* Miocene Beds *of the* Maltese Islands. By A. Leith Adams, Esq., F.R.S., F.G.S, Professor of Natural History in Queen's College, Cork. (Read December 18, 1878).

[Plate XXV.]

The well-deserved reputation maintained by the Maltese Islands in connexion with their fossil fauna has been increased by a discovery lately made by my distinguished friend Mr. C. A. Wright, F.L.S. In a collection of animal remains he has lately forwarded to me from the Miocene beds of the islands, among other interesting relics I find two molars of Mastodon. The finding of Proboscideans in the rock-strata is of especial concern, and cannot prove otherwise than suggestive with reference to the historical geology of the deposits. I propose therefore, in the first place, to epitomize the main facts relating to the structure and stratigraphical arrangement of the beds and their characteristic fossils, considering especially how far there is evidence of any of the fauna having been derived from older formations. In the second place, I will enumerate all the Vertebrata hitherto discovered in the Miocene beds. The Invertebrata have been carefully described or named by Forbes*, Wright†, Davidson‡, Rupert Jones§, Martin Duncan‖, and Woodward¶. As described in a previous paper**, Maltese formations are divisible into (1) the Upper Limestone, (2) Sand bed, (3) Marl, (4) Calcareous Sandstone, (5) Lower Limestone; all of which are conformable.

I. The Upper Limestone attains its greatest depth in the island of Comino, which is composed of it entirely, attaining a thickness of about 250 feet above the sea-level. It is the surface-formation along the western portion of Malta and the highlands of Gozo; but I doubt if its original thickness is preserved anywhere. Indications of more recent beds are seen in blocks of weathered limestone known as the Gozo marble, which are seen strewing the valley eastward of the light-house on the northern shore, and in fragments of a black marble or limestone which strew the sides and summits of the Gozo hills††. Like all the other beds, it has been extensively

* Proc. Geol. Soc. vol. iv. p. 230.

† Ann. & Mag. Nat. Hist. ser. 2, vol. xv.; Quart. Journ. Geol. Soc. vol. xx. p. 474.

‡ Ann. & Mag. Nat. Hist. ser. 3, vol. xiv.; & Geol. Mag. 1864.

§ Geologist, April 1864, & Geol. Mag. vol. i. p. 102.

‖ Geol. Mag. vol. i. p. 97.

¶ Report Brit. Assoc. 1872, p. 325. Dr. Woodward is engaged in working out the Crustacea collected by me in the Maltese Islands.

** Quart. Journ. Geol. Soc. vol. xx. p. 470. See also Spratt, Proceed. Geol. Soc. vol. iv. p. 225. The geological map appended to the author's memoir on the elephants of Malta in the Trans. Zool. Soc. vol. ix. pl. xxii. may be referred to with advantage.

†† A fragment of this limestone, examined by Professor Rupert Jones, F.R.S., showed *Amphistegina* and ossicles of Asteroidea. There can, I believe, be little doubt that these fragments have no connexion whatever with any of the existent formations of the islands. (Geol. Mag. vol. iii. p. 152.)

denuded at different points, and is being now rapidly broken up by aqueous and atmospheric agencies. In its structure the following characters seem constant. (1) The upper portion is much broken and intersected by cracks and fissures, forming a rubbly white limestone, which forms the surface rock of the Benjemma plateau. (2) The above passes imperceptibly into a yellowish white rock, which is soft and forms almost a calcareous sandstone easily acted on by the weather, as is well seen on the cliffs west of Città Vecchia. (3) The last gradually merges into a red limestone of considerable durability and composed more or less of Corallines, Nullipores, Polyzoa, &c. It forms a prominent feature in the cliffs of Gozo and south-western aspects of Malta.

The invertebrate fossils of the Upper Limestone are numerous; but it is markedly poor in vertebrata as compared with the underlying formations.

The following Brachiopoda collected by me in the Upper Limestone have been determined by Mr. Davidson*, F.R.S.,—*Terebratula sinuosa*, *Megerlia truncata*, *Argiope decollata*, *Rhynchonella bipartita*.

The Mollusca are represented by at least five species of *Pecten*—to wit, *P. Pandora*, *P. burdigalensis*, *P. Beudanti*, *P. scabellus*, *P. varius*—and 3 or 4 undetermined species. *Spondylus quinquecostatus* is common. Casts of *Conus*, *Venus*, *Cardium*, *Turritella*, *Haliotis*, *Murex*, *Fusus*, and other genera are not uncommon†.

The Echinodermata amount to 25 species, of which ten seem peculiar, whilst *Clypeaster altus*, *C. marginatus*, and *Cidaris melitensis* are among the most common species, and they are likewise met with in the Sand bed.

II. The Sand bed is the most variable of all the formations, both as relates to its mineral composition and its organic remains. The point of transition between it and the Red Limestone is often imperceptible, the latter gradually becoming less compact and more granular until it degenerates into an indurated red sand made up more or less of the *Heterostegina depressa*, which forms horizontal bands along cliff-sections or lies in disordered masses throughout many feet perpendicularly. These characters are displayed in cliff-exposures south of Dingli in Malta, and in the ravines of Emthaleb and Ramla Bay in Gozo.

Sometimes the Upper Limestone gradually merges into a black indurated sand composed of particles of glauconite, felspar, topaz, &c., which forms a variegated bed made up of black, green, brown, and red sands intermixed and stratified. This variety is well seen on the scarp of the hill of Chelmus in Gozo, where it is fully 30 feet in thickness. Altogether the greatest depth attained by the Sand bed may be little less than 60 feet.

The characteristic fossil of this bed is undoubtedly the Forami-

* Annals & Mag. Nat. Hist. vol. xiv. (3rd Series), & Geol. Mag. 1864.

† Author's 'Notes of a Naturalist in the Nile Valley and Malta,' p. 266. The Maltese Miocene Mollusca were first named by the late Professor Edward Forbes: see Proceedings Geol. Soc. vol. iv. pp. 230 & 231.

nifer just named, which, however, is not confined to it, but is met with in all the beds, although never in the exceeding numbers which characterize the red or *Heterostegina*-stratum.

Of Vertebrata, out of 15 forms in the Sand bed, only two species of Pycnodont fishes have, so far as I know, turned up in the Upper Limestone.

There is, however, a decided agreement between the Invertebrata, as is shown by no less than 14 genera and many species being common to both.

The genus *Pecten*, so plentiful in the Maltese Miocene, is represented in the Sand bed by four species, also met with in the Upper Limestone. Of the Brachiopoda, *Terebratula sinuosa* and *Megerlia truncata* are common to both formations, besides nine species of Echinodermata, whilst nearly all the Polyzoa, Cœlenterata, and Protozoa seem undistinguishable.

III. The Marl bed varies very much in thickness, thinning out for a depth of upwards of a hundred feet to scarcely an indication of its presence. It is the most perishable of the beds, and is being rapidly denuded. It varies in colour and composition, from a dark blue or drab colour to a light brown or grey; some sorts form a fair plastic clay, being both stiff and tenacious, whilst the light-coloured run in the form of horizontal bands.

Of foreign components, nodules of sulphuret and peroxide of iron, and gypsum, are plentiful, and often incrust the fossil remains, whilst the crystalline and lamellar varieties of gypsum are also common. Besides these, nodules of an ochreous-coloured clay *perforated by Pholad-borings*, and containing casts of these mollusks, are not rare, and are apparently *derivative*.

The most characteristic fossils of the Marl are a cuttle-bone of a small *Sepia* and casts of *Nautilus*, which Dr. Woodward, F.R.S., and his late brother, Dr. S. P. Woodward, F.G.S., assured me are undistinguishable from the typical specimen of *Nautilus ziczac*.

The organic remains are not, as a rule, in a good state of preservation; however, out of 25 genera and species of Mollusca belonging to the Sand bed, I have recognized as many as 13 in the Marl. The only Brachiopod of the two upper formations that I have likewise found in the Marl is *Terebratula sinuosa*, which is not uncommon, and is the only representative of the group I have seen from this bed.

Of the 11 Echinodermata of the Sand bed not a single species has turned up hitherto to my knowledge in the Marl; but *Echinolampas Laurillardi* is common to the Marl and the Upper Limestone, whilst *Hemiaster Scillæ* makes its first appearance in the Marl. These are the only Echinida I have found in the latter, excepting ossicles of undetermined species of Asteroidea, which are found in all the formations.

IV. The Calcareous Sandstone.

The point of transition between the Marl and the Calcareous Sandstone is often abrupt.

The latter presents considerable variability both in the general character of the rock and its components. The most interesting are four well-marked seams of nodules, which differ considerably. Many of these lumps contain casts of Mollusca, and display appearances of having been rolled. They may be irregular in shape and consistence, or polished and rounded. The following is the result of very many careful examinations of cliff- and horizontal sections of this formation made by me during five years' work on the Maltese deposits.

The uppermost portion of the bed is composed of a pale grey freestone, soft and easily worked. Traversing this bed is a band of nodules, for the most part rounded and loosely arranged : it often thins out to a mere indication of a bed ; indeed it would seem to be sometimes wanting. This, the First Nodule seam, is generally characterized by the abundance of casts of what have been supposed to be a Pteropod allied to *Hyalea*, and a *Vaginella* undistinguishable from *V. depressa*.

About eight feet below the last nodule-seam, in a fawn-coloured sandstone, is the Second Nodule seam, which is readily distinguished, not only from its position but from the small round nodules and their loose arrangement. They are usually of a brown colour ; and when broken present no apparent characters distinct from those of the parent rock. The thickness of the band is often from three to four feet. It abounds with organic remains, and has produced nearly all the Vertebrata and the majority of the Invertebrata of the Calcareous Sandstone. It is a famous horizon from which the teeth of Squalidæ are obtained.

About the middle of the bed a few scattered nodules of a light green colour extend in broken lines, but rarely agglomerated ; and they are not unfrequently absent.

About thirty feet below the second seam is the Third, distinguishable by the irregular shape of its nodules, which are of a dark brown colour, firmly cemented together, and apparently of the same mineral structure as the parent rock. They repose on a surface broken up by pot-holes and crevices, in which many of the nodules are contained. This stratum is highly fossiliferous ; but, from the firmness and hardness of the matrix, organic remains are extracted with difficulty. It varies in thickness from 1 to 4 feet, and may be seen to the greatest advantage on the shore-line westward of the lighthouse of Gozo.

From twenty-four to forty feet below the last is the Fourth Seam in a pale-coloured sandstone. It is made up of light-brown nodules of irregular shape and of variable thickness. It marks the point of transition between the Calcareous Sandstone and Lower Limestone beds. Sometimes a seam of rounded nodules of limestone traverses the rock in place of these calcareous nodules ; the former differ in their waterworn aspect and the great firmness of their matrix, which is composed of fragments of shells of various forms found in both formations. Moreover the fourth nodule seam may be replaced by lines of broken shells.

As to the mineral composition of the nodules generally, I repeat that there was apparently no distinction to be made between them and detached fragments of the parent-rock or of the Lower Limestone, as the case might be. They had the aspect of having been washed and worn by marine action, and contained the fossils of the bed and many forms not found in it.

The greatest thickness of the calcareous sandstone may be a little over 200 feet.

Besides the nodule seams, interspersed throughout the bed are dense bands and nodules of chert, of a grey-brown colour and conchoidal fracture. These may take the shape of rounded masses, but are oftener seen forming thin seams in a pale-coloured sandstone towards the base of the bed. Concretionary nodules of red hæmatite and clay-ironstone are also met with throughout the bed, but in greatest abundance in the upper parts near to the marl; also in the same situation nodules of crystallized gypsum appear, even below the first nodule seam, where lumps of iron-pyrites, with sulphur in small quantities, are met with as in the overlying marl.

The Vertebrata will be noticed in the sequel.

The invertebrate fauna of the Calcareous Sandstone and the nodule seams are conspicuously represented by *Pecten* and Echinida, *Pecten cristatus*, Bronn?, *P. scabellus*, and *P. squamulosus* being plentiful. *Clavagella* and from 2 to 3 species of *Scalaria*, and *Spondylus*, *Ostrea Boblayei*, and *O. Virleti* are common, besides numerous other species *.

Out of 21 forms met with in the Marl, about 12 affect also the Calcareous Sandstone and its nodule bands.

The Brachiopoda are *Terebratula sinuosa*, *T. minor*, *Terebratulina caput-serpentis*, and *Thecidium Adamsi*, the first being the only one common also to the marl.

Of 22 species of Echinodermata found in the Calcareous Sandstone, 9 are common to it and the Upper Limestone, whilst 4 are also common to the Sand bed, and 2 are also found in the Marl.

Foraminifera in this bed are noticed Geol. Mag. vol. iii. p. 152.

V. The Lower Limestone has its upper horizon marked by what I have named the "Transition or *Scutella*-bed" †.

The upper portion of this stratum passes so imperceptibly into the Calcareous Sandstone that, were it not for certain organic remains which constantly mark the point of transition, it would be difficult to define where the one ends and the other begins.

The saucer-shaped *Scutella subrotunda* and the *Orbitoides Mantelli* ‡ congregate in the above situation in great abundance.

The Lower Limestone presents considerable variability. It may be concretionary and oolitic in its composition, or irregularly compact and often semicrystalline. Large portions are made up of broken shells, Corallines and Foraminifera, whilst the structure of much of the upper parts is made of globular white nodules, strewn irregularly throughout a lamellar or concentric bedding.

The colour varies from a pure white to a cream-colour.

* Author, *op. cit.* p. 129; Forbes, Proc. Geol. Soc. iv. p. 230.
† *Op. cit.* p. 138. ‡ Geol. Mag. vol. i. p. 104, and vol. iii. p. 152.

The Lower Limestone attains a height of about 400 feet above the sea-level.

A nodule-seam frequently replaces the *Scutella-* or *Orbitoides*-stratum, and is made up of detached fragments of the parent rock and the Calcareous Sandstone firmly cemented together. At Ras-el-Kala, in Gozo, it is represented by a remarkable bed of oyster-shells, chiefly belonging to *Ostrea Boblayei*.

The difficulties attending examinations of the cliff-sections, together with the indifferent state of preservation, render the enumeration of the fauna of the lowermost bed more imperfect than that of the others. Besides the foregoing, *Ostrea navicularis*, a fossil of the Sand bed, is also common in the lowermost rock. *Pecten cristatus*, Bronn ?, is apparently also plentiful, together with *P. squamulosus* of the Sand and Calcareous Sandstone; and what has been named *P. varius* is also apparently common to all the formations excepting the Calcareous Sandstone. *Spondylus quinquecostatus*, or else a very closely allied species, is common to the Upper and Lower Limestones besides the Calcareous Sandstone. But the characteristic and most plentiful fossils, especially in the uppermost portions of the Lower Limestone, are casts of *Conus*, some of large size, and other genera not sufficiently preserved to admit of specific determination, among others *Haliotis*, of which there are apparently more than one species; indeed the genus is represented in all the formations.

The Brachiopoda are *Terebratula minor* and *Thecidium Adamsi*, common also to the Calcareous Sandstone.

The Echinodermata identified by me amount to 20 species, of which 13 are also common to the Calcareous Sandstone, 1 (*H. scillæ*) to the Marl, 3 to the Sand bed, and 11 to the Upper Limestone—to wit, *Cidaris melitensis*, *Psammechinus Ducei*, *Echinolampas Kleinii*, *Hemiaster Cotteaui*, *Schizaster Scillæ*, *S. Parkinsonii* (the most common Echinoid in the Maltese rocks), *Toxobrissus crescenticus*, *Brissus cylindricus*, *B. oblongus*, *Eupatagus De-Koninckii*, *Spatangus delphinus*.

Foraminifera in this bed, noticed in Geol. Mag. vol. iii. p. 152.

I must here take notice of a remark of M. Fuchs in a note to his paper on the "Age of the Tertiary Beds of Malta" *, wherein he observes "that the statement advanced by Spratt, Adams, and other authors, that the same species of *Pecten* and Echinida recur in the Lower as well as in the Upper Limestone," is not correct, and that the error may have arisen from confounding *P. Haueri* and *deletus* of the lower beds with *P. spinulosus* and *costatus*, which occur equally plentifully in the upper beds. Again, the writer observes "that, with the exception of the *Thecidium Adamsi* from the Lower Limestone, all the remaining Brachiopoda were exceedingly rare, although, according to the statements of the authors, they are said to occur not only in great quantities, but are even said sometimes to form whole banks." M. Fuchs further states that "he was unable

* Berichte der Akademie der Wissenschaften, Munich, lxx. p. 92.

to discover *Terebratula ampulla*, *T. minor*, and *Terebratulina caput-serpentis*." He moreover, in consequence of his failure to discover these species, supposes, as they are plentiful in the Pliocene of Sicily, that certain specimens described by Davidson were imported from that island and incorporated with the Maltese Miocene.

With reference to the Pectens above mentioned, whilst I admit the possibility of confounding the broken and scarcely, at the best, entire specimens from the Lower Limestone with *T. spinulosus* and *T. costatus*, so plentiful in the red or coralline bed of the Upper Limestone, I must aver, so far as the Brachiopoda and Echinodermata, whose distributions have just been detailed, are concerned, I see no reason whatever to retract any thing that I have stated, or in the observations made by me in the papers on these two groups, so ably described by my distinguished friends, Dr. Wright, F.R.S., F.G.S.*, and Mr. Davidson, F.R.S.† At the same time I quite agree with the latter that the so-called "Maltese" *Waldheimia Garibaldiana* ‡ has assuredly no claims to be so considered; and I can suggest the probable cause of M. Fuchs's bad fortune in not finding fossils in the Maltese beds where his predecessors assert they are common, by the circumstance that as the majority of the specimens are obtained from cliff and horizontal sections, where the rock decomposing leaves the fossil prominently exposed, it so happened that during a period of nearly six years I was almost constantly engaged with others in making collections wherever the nature of the ground would permit a sound footing; so that many exposures, once extremely prolific of fossils, became absolutely denuded of every vestige of animal remains recognizable, at all events, to the naked eye.

Consequent on the apparent discrepancies between the uppermost and lowermost beds, M. Fuchs, in his able and interesting paper just referred to, divides the Maltese beds into two groups, which he considers are "palæontologically most sharply separated from one another, and have only a very few fossils in common"—a statement true in some degree, but certainly not to the extent he imagines; nor is it so pronounced as, in my opinion, to warrant the removal of the uppermost beds from the other formations.

I shall now proceed to the consideration of the vertebrate fauna of the formations.

VERTEBRATA.

Mammalia.

Mastodon angustidens? (Plate XXV. figs. 5, 5 *a*.)

The specimens by which the presence of remains of Mastodon in the lower beds of the Miocene formations of the Island of Gozo is established, comprehend two imperfect molars. Fig. 5 retains only

* *Op. cit.* p. 474. † Ann. & Mag. Nat. Hist. ser. 3, vol. xiv. p. 5.
‡ Geologist, 1862, p. 446, pl. 24. f. 19.

the two anterior and one of the middle ridges, the remainder of the crown having been broken recently and lost.

The other tooth is still more imperfect, only one of the anterior and middle nipples remaining. It differs, however, from the former crown; for whilst its anterior ridges have also been quite recently broken off, the surface of the tooth, where the two companion ridges of those still extant should be, is firmly incrusted with the matrix, showing that the enamel had been denuded prior to or during the imbedment of the tooth.

Both molars have the bases of their crowns where the fangs originate also covered with the characteristic calcareous sandstone of the islands.

Mr. Wright informed me that he procured the specimens from a native boy, and that he visited the spot and fully confirmed the statements of the finder. The specimens were found at different times by the same lad, and were cut out of the solid compact Calcareous Sandstone *.

The specimen fig. 5, was discovered in October 1871, on one of the "nodule-seams" of the Calcareous Sandstone, close to the shore, and nearly at the sea-level, in the Bay of Marsa el Forno, on the N.E. of Gozo.

The other tooth "was found in December 1873 in the same horizon, but at a distance of a few hundred yards further westward, near the promontory called Kola Baida."

The characters and state of detrition of the crowns are the same in both teeth, which are no doubt penultimate molars.

That they belonged to a trilophodont Mastodon seems to me probable from the diminished extent of continuity, indicating a surface barely sufficient for two additional ridges, and which must have been smaller a good deal than those still existing.

Both molars, especially that shown in fig. 5, display much roughening (*r*) of the enamel around the base of the ridges and outlying mamillæ. In these respects, as in the presence of other digitations on the crown and sides of the ridges, they approach *M. angustidens* rather than *M. Borsoni* in character.

A broad pressure-mark (*p*) is seen on either tooth on the talon.

The dimensions and characters, so far as procurable, agree with those of the penultimate of *M. angustidens*; but altogether they are insufficient for the differentiation of species.

PHOCA RUGOSIDENS, Owen.

Professor Owen, to whom I sent the teeth (Pl. XXV. figs. 1, 2) from Malta, has named them *rugosidens*, from the pronounced roughening of the enamel. Altogether four specimens were discovered in the Calcareous Sandstone of Gozo †, two of which, from Mr. Wright's collection, are also represented with the above.

* The matrix corresponded with the locality pointed out. In the case of fig. 5, Mr. Wright examined the cutting made with a knife in the rock to extract the specimen.

† Notes of a Naturalist, p. 269.

The British Museum possesses the portion of a left ramus, shown in Pl. XXV. fig. 1. It is No. 33243 of the Palæontological Collection, and was presented by Earl Ducie. The fragment is incrusted with gypseous crystals and matrix of the Marl bed. Unfortunately the teeth are wanting; the jaw, however, in general characters is decidedly phocine, whilst the rather unusual depth of the horizontal ramus and the unusually high angle formed in front by the coronoid furnish important characters.

Canine teeth of large size, and referable to Phocidæ, are common in the Sand bed, and are also somewhat plentiful in the nodule-seams of the Calcareous Sandstone. Two portions, a fang and crown, in Mr. Wright's collection, are from the black-grained variety of the Sand bed. The former shows a maximum girth of fang of about 4½ inches; and the enamel is rough, like that of the grinders just referred to.

Thus the genus *Phoca* is represented from the Sand, Marl, and Calcareous Sandstone.

Squalodon.

The well-known fragment of a jaw with three teeth in place, discovered by Scilla in Malta about 1670 *, and now in the Woodwardian Museum, Cambridge, is the only instance I know of carnivorous Cetaceans from these beds. The matrix would indicate that it was obtained from one of the nodule seams of the Calcareous Sandstone. Hitherto it has been included in the genus *Zeuglodon*; but the much smaller dimensions and more triangular and serrated teeth place it with Grateloup's genus *Squalodon*.

Delphinus.

Professor Owen recognized remains of more than one species of *Delphinus* in Admiral Spratt's collection from the Sand bed †; and fragments of jaws with teeth *in situ* were recognized by me in collections made by the late Captain Strickland from the Calcareous Sandstone.

Large-sized Cetacean vertebræ are not uncommon in nearly all the beds, but especially in the Sand bed, where I also discovered the greater portion of a mandible ‡.

Halitherium Schinzi? Kaup.

Remains referable to the genus *Halitherium* have been already recorded from Maltese Miocene formations, as follows:—

1. A molar from a nodule bed of Calcareous Sandstone, and an "ear-bone" composed of the periotic and tympanic, together with several caudal vertebræ, from the Sand bed §.

2. I have also figured and described a similar tooth (possibly a

* Vana Speculazione, Tab. i.–iii.: Naples, 1670.

† Proc. Geol. Soc. London, vol. iv. p. 230.

‡ *Op. cit.* p. 134.

§ Quart. Journ. Geol. Soc. vol. xxii. p. 595.

penultimate true molar) in my work on Malta *, from the Lower Limestone.

3. In the notice of the foregoing I refer to a fragment of a jaw with two teeth *in situ*. This interesting relic, now in the British Museum, was found in Gozo, and might have been lost but for the vigilant eyes of Mr. Wright, who brought it to the notice of Admiral Spratt. It is the specimen examined by Falconer, and which he compared with *Halitherium* and *Listriodon*, and has justly referred to the former †. The limestone matrix seen on the specimen indicates the uppermost or else the lowermost formation; which, it is impossible to say.

The specimen No. 4085 is a fragment of a left maxilla, about 3½ inches in length. The outer table is removed, showing the fangs of the penultimate true molar. Part of the socket of the ultimate molar remains; the penultimate is entire, whilst the antepenultimate has lost a portion of the crown externally. The crown of the last premolar is broken off; and a pit in front indicates the position of the preceding tooth.

The jaw is shown, crown and profile, natural size, in Plate XXV. figs. 3 and 3 *a*. The second true molar is quite unworn, like the preceding specimen. It displays the two ridges with a deep open internal valley and the two pits, one anteriorly and the other on the posterior aspect of the crown. The dimensions of this tooth are as follows:—

	millim.
Length including fangs	34
Antero-posterior diameter of crown	20
Breadth of crown	21
Height of crown	14

4. The broken crown from Mr. Wright's collection (Plate XXV. fig. 4) carries good evidence of the formation in which it was found, being incrusted with a matrix of red sand from the Sand bed in Gozo ‡. The crown-pattern is characteristic; and the tooth is probable a penultimate true molar of the mandible.

5. Several vertebræ covered with clay and crystals of gypsum, together with fragments of ribs, are in the British Museum. They show that they were derived from the marl and nodule seams of the Calcareous Sandstone, whilst the characters assimilate to the same parts of *Halitherium*, not so cogently, however, as the preceding.

I take this opportunity of correcting a mistake made in my former communication to the Society §, wherein I state that remains of Dugong are also found in the Maltese rocks. This I have since discovered is

* Notes of a Naturalist in the Nile Valley and Malta, p. 268.

† Palæontological Memoirs, vol. ii. p. 304.

‡ Professor Owen, as far back as 1843, recognized bones, "apparently of a Manatee," in Admiral Spratt's collections from the Sand bed (Proc. Geol. Soc. London, vol. iv. p. 230).

§ Quart. Journ. Geol. Soc. vol. xxii. p. 598; also 'Notes of a Naturalist in the Nile Valley,' p. 265, where I have erroneously included the Manatee and Dugong besides the *Halitherium*.

not the case, and that all Sirenian remains which have come under my notice may be referred to *Halitherium*.

From the data here furnished the *Halitherium* has left its remains in all the Maltese formations excepting the Upper Limestone.

Reptilia.

Ichthyosaurus gaudensis, Hulke*.

The above was discovered in the Calcareous Sandstone, it was said, of Gozo. I was long familiar with the specimen, and urged the late Captain Strickland to send it to England for comparison. There can be no question of its being from the Miocene of the Maltese Islands.

Melitosaurus champsoides, Owen.

Besides the original specimen described by Owen and now in the British Museum from the Calcareous Sandstone of Gozo, there is a tooth undistinguishable from that of this species in Mr. Wright's collection, seemingly from the nodule-bed of the same formation.

Crocodilus gaudensis, Hulke†.

This specimen was obtained from the Calcareous Sandstone of either Malta or Gozo. Of its origin there cannot be any doubt, as I had frequently examined it in Captain Strickland's museum, and it was sent at my instigation to England for comparison. Indeed there are indications in the public and private collections in Valetta of more than one species of *Crocodilus* from the Calcareous Sandstone and its "nodule seams."

Pisces.

Stereodus melitensis, Owen.

The only example known to me of this "Cycloid with Sauroid dentition" is that described by Professor Owen in the Geological Magazine, vol. ii. p. 145. It was obtained from the upper portion of the Calcareous Sandstone in the quarry of Lucca, Malta.

Myliobates toliapicus?

Teeth of more than one species are found in the Sand, Marl, Sandstone, Calcareous, and Lower Limestone beds.

Specimens from the first and last named beds did not appear to differ in any particulars from *M. toliapicus* of Agassiz, whilst spines of large size are not rare in the Marl.

Otobates subconvexus, Agassiz.

Several teeth from the Sand bed, and less entire specimens from the Marl, in which they are plentiful, cannot be distinguished from the above.

* Quart. Journ. Geol. Soc. vol. xxvii. p. 29. † Ibid. p. 30.

Squalidæ *.

The Sharks' remains are the most varied and numerous of all the vertebrates of the Maltese Miocene. Their teeth have found their way into almost every public collection in Europe, and continue to furnish employment to persons who make it their business to dispose of them to travellers. With the exception of the Upper Limestone, they have been found in all the beds. From a large experience in collecting and determining the Maltese species, I have been enabled to furnish the following Table of their stratigraphical distribution.

	Upper Limestone.	Sand.	Marl.	Calcareous Sandstone.	Lower Limestone.
Carcharodon megalodon.	...	*	*	*	*
Carcharias productus ...	...	*	*	*	*
Oxyrhina xiphodon	...	*	...	*	
—— hastilis	...	*	...	*	
—— Mantelli	...	*			
Hemipristis serra	...	*	...	*	
—— paucidens	...	*	...	*	
Corax aduncus	...	*			
Odontaspis Hopei?	...	...	*	*	
Lamna elegans	...	...	...	*	

So far as I know, none of these Squalidæ has been discovered in the upper and middle portions of the Upper Limestone. They suddenly appear, however, at the point of junction between the Red Limestone and the Sand bed, where they are plentiful, especially *Carcharodon megalodon*, some of the largest specimens of the teeth of which have been discovered here. The Maltese historian, Boisgelin, refers to one as much as 7 inches on its largest side †; and I have referred to a tooth from the black sand 6·3 inches in length ‡. It is in this bed, and the Calcareous Sandstone, more especially in the upper "nodule seams," that they abound, and in the latter associated with Mollusca and Echinodermata.

I have rarely found teeth in the Lower Limestone, and these only of the two species recorded above.

As regards numbers, they are met with in the order given, the two rarest being *Odontaspis Hopei* (which, however, I have not seen with its dentils), and *Lamna elegans*.

Notidanus primigenius?

A tooth resembling that of this species is figured by Scilla §;

* Nearly all the Maltese Sharks were long since determined, more or less exactly, by Sir Philip Grey Egerton, Proc. Geol. Soc. vol. iv. p. 230.

† Boisgelin's 'Malta,' p. 33. ‡ *Op. cit.* p. 139.

§ Vana Speculazione, plate 2.

and this is the only record of its existence in the Maltese strata. The specimen was, perhaps, from the Calcareous Sandstone.

Platax Woodwardi, Agassiz.

Several specimens discovered by me in the Calcareous Sandstone of Malta were subsequently determined by the late Dr. S. P. Woodward, F.G.S. They were of the pear-shaped outline, with a process and small indentation on one side, representing the concretionary appendage of the vertebræ and ribs, like the specimens common in the Red Crag.

Diodon.

This group is represented by teeth varying much in dimensions. It is one of the few vertebrates hitherto discovered in the Upper Limestone, where, doubtless, there are more than one species. Teeth are not uncommon in the Calcareous Sandstone, but chiefly in the nodule seams; whilst unusually large specimens indicate very large globe fishes in the Lower Limestone.

Sphærodus.

This genus is well dispersed throughout all the beds, and was evidently represented by several distinct forms. Teeth of a species not distinguishable from those of *S. gigas*, Pictet, are rather common in the Sand bed. I have seen impressions of the greater portions of the skeleton of a fish of the type of *Sphærodus* in the Calcareous Sandstone, where the smaller teeth are occasionally found. I quite anticipate that the future will show a large addition to the Pycnodont fishes of the Maltese Miocene beds.

The question whether the stratified seams of nodules and the lumps of yellow clay with pholad-borings met with in the Marl together with other adventitious materials and their associated animal remains belong to the same period as the beds in which they are found, seems to me scarcely to admit of a positive answer at present.

The lumps of ochreous-coloured clay met with in masses several inches in circumference are very irregularly dispersed throughout the Marl, and seem to have been derived from the degradation of older beds. The hardened nodules of the Calcareous Sandstone with particles of Sharks teeth and tests of Echinidæ and Mollusca found in their interior, together with the abundant animal remains associated with them, might point to their redeposition. But a very large number of the species found in the nodule-seams are also dispersed throughout the beds in situations where their appearance indicates a tranquil deposition, as further shown by the entire skeletons of fishes &c. found along with them. At the same time the *Mastodon*, *Halitherium*, *Squalodon*, and *Delphinus*, more or less met with in all excepting the Upper Limestone, seem to preserve the Miocene facies both for the nodule seams and the respective beds in which the remains are found.

EXPLANATION OF PLATE XXV.

Fig. 1. Fragment of a left ramus of a mandible of *Phoca*: nat. size.
2, 2 *a*, 2 *b*, 2 *c*. Four teeth of *Phoca rugasidens*, Owen: nat. size.
3 & 3 *a*. Crown and profile views of a portion of a left maxilla of *Halitherium Schinzi*?, Kaup: nat. size.
4. Crown view of a lower penultimate? molar of *Halitherium Schinzi*?, Kaup: nat. size.
5 & 5 *a*. Crown and profile of molar of *Mastodon*: nat. size.

Discussion.

The President remarked that, according to observations which he had lately made, rocks appeared often to suffer contemporaneous erosion, frequently being broken up into small fragments and redeposited.

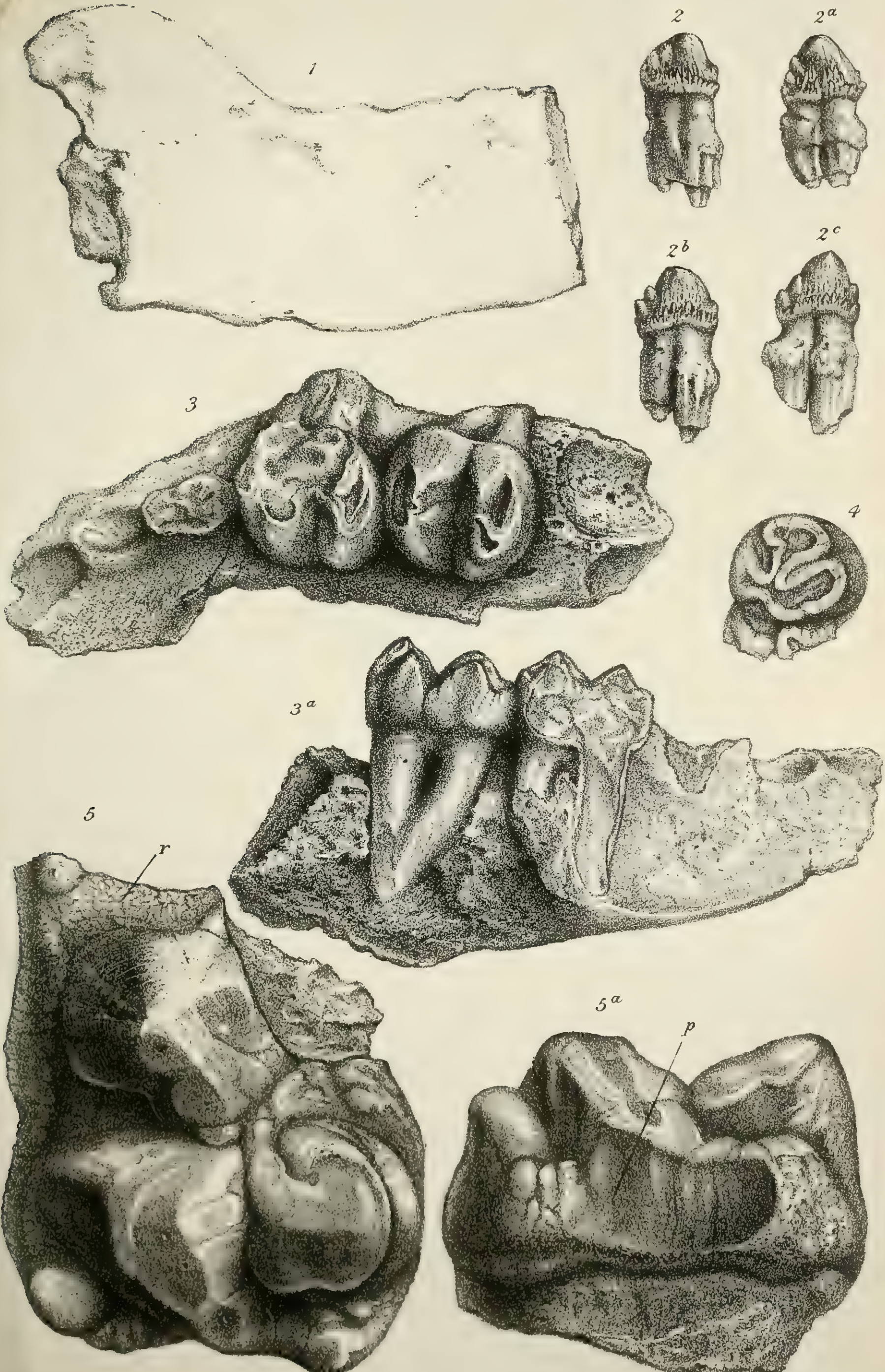
Prof. Boyd Dawkins was of opinion that the *Ichthyosaurus* belonged to quite a different stage of evolution from that of the Miocene Mammalia. In illustration of the association of fossils with those of a different age, the *Ichthyosaurus* and *Sphærodus gigas* in the Neocomian beds of Bedfordshire and Cambridge might be quoted, derived from the Kimmeridge Clay; and he thought there was no reason to believe that *Ichthyosaurus* lived in the Miocene period in Europe. The specimens mentioned in the paper were probably derived.

Prof. Duncan thought that many of the fossils mentioned in connexion with the nodules were *remaniés*. As regards the age of the beds, his investigation of the corals had led him to the conclusion that they were Upper Miocene. He thought that the district bore evidence of subsidence. If the age of the upper deposits in Malta was Pliocene (as it might be), the whole might be connected with the upheaval of the Apennines. He thought Malta marked a point of near approach between the European and African continents.

Mr. Hulke stated that he had dealt with the *Ichthyosaurus* jaw from Malta simply as an anatomical question, not with reference to the deposits whence it had come. Still he must say it did not look worn, and the teeth were very like those of *I. enthekiodon* from the Kimmeridge Clay. However, on the point of age he would express no opinion.

Mr. Charlesworth, remembering how opinion had changed on the subject of *Trigonia*, did not see why an *Ichthyosaurus* might not have survived to the Tertiary period. Caution, however, was necessary; for Cretaceous fossils were often found in the Pliocene, and it was often hard to say whether fossils were derivative or not. He argued, from his view of the nodules in the Crag and the Lias, that they were concretionary. He thought that, from the evidence before the Society, the species of *Mastodon* could not be determined.

Prof. T. R. Jones expressed his gratitude for the information given by Prof. Leith Adams in his paper on the *Mastodon* of Malta,



C. Berjeau lith.

Hanhart imp

MALTESE MAMMALS.

as regards both the fossils and the stratigraphical details. He offered some remarks on the structure of the island and of its strata.

Mr. Hulke remarked that we now knew that many of the old life-forms had a wide range in space and time. For example, the *Iguanodon* was once supposed to be restricted to the Wealden; but he thought there was clear evidence that it lived in Purbeck time, and also in all probability (from the evidence of a femur in the British Museum) survived to the Maestricht Chalk.

Prof. Seeley said the Woodwardian Museum contained *Icthyosaurus* vertebræ from the London Clay of Sheppey, which might or might not be derived, possibly Liassic, as he rather suspected, possibly a new form.

41. Notes *on the* Structure *of the* Palæozoic Districts *of* West Somerset. By A. Champernowne, Esq., M.A., F.G.S., and W. A. E. Ussher, Esq., F.G.S. (Read May 14, 1879.)

Introduction.

In the following account of traverses made during the past autumn across some of the classical ground of West Somerset and its confines, we do not aim at any extensive alteration in principle of the work wrought by the master hand of De la Beche, and given to the scientific world forty years ago *.

Notwithstanding the encyclopædic paper of Mr. Etheridge †, wherein both the physical and palæontological relations of the North-Devon rocks are so ably worked out, instances of unbelief will occur where ocular evidence is wanting, prompted perhaps by a hankering after the apparently simple version of the structure of North Devon put forward by the late lamented Prof. Jukes ‡. Although the ground has been carefully gone over in Mr. Etheridge's paper, such a confirmation of his views as the infilling of minor stratigraphical details affords may not be altogether unworthy of attention.

The classification which De la Beche's unequalled description of the North-Devon rocks suggests was put into form by the late Prof. Phillips, who, however, included the unfossiliferous grits and slates of Pickwell Down with the slates of Mortehoe as one division §. Although these divisions were similarly treated by Mr. Hall in 1865 and 1867 ||, a more detailed description mitigated an error of classification which that gentleman has since abandoned. Mr. Hall informed us that the term Pickwell-Down Sandstone was applied to that division by Prof. Jukes, acting on his suggestion. To Mr. Hall belongs the credit of inaugurating the present more complete classification, which rightly distinguishes the position of the Lower Pilton, or Baggy Beds in the upper part of the series ¶. This classification was, with some slight modifications, retained by Mr. Etheridge, and has been adopted by us. With this introduction, we shall commence with our westernmost traverses.

* Report on Geol. of Cornw. & Dev. ch. 3, &c.

† Q. J. G. S. vol. xxiii. p. 568.

‡ Q. J. G. S. vol. xxxii. p. 320, and additional Notes, &c.

§ Pal. Foss. Devon, Cornwall, and W. Somerset, pp. 183–193.

|| Lecture to Exeter Naturalists' Club, Sept. 23, 1865; and Q. J. G. S. vol. xxiii. p. 372.

¶ It should be mentioned that Mr. Hall has abandoned the term conglomerate as applicable to any of the N. Devon Devonian rocks, the concretionary structure in the Pickwell Down division to which it was applied being too insignificant to merit the designation.

From Dulverton Station to Dunster (fig. 1).

Dulverton Station is situated upon the junction between the Culm-measures and Pilton slates. Towards Brushford, Pilton fossils were obtained in nearly vertical slates, passing insensibly into the Culm-measures in the railway-cuttings. The well-marked feature of Hulverton Hill (to the south of the railway) is formed by the characteristic Culm-measure rocks, which, along a line nearly east and west from Coddon Hill (south of Barnstaple) form here and there bold hog-backed or conical hills, notably at Swimbridge. These beds are easily distinguishable by their baked appearance, whitish, buff, or dark-grey colour, and frequent chertoid texture; they consist of thick shales or thin fine-grained grits in tabular layers, so intersected by even joints as to afford a valuable road-metal without further fracture. In a quarry on Hulverton Hill the Coddon beds dip S. 10 E. at 80°. To the north of the railway, to the east of Brushford, grey Pilton slates, vertical, and striking as at Hulverton Hill, are exposed in a quarry, from which Prof. Phillips obtained many of his best specimens.

By the highroad to Dulverton, at a mile from the station, bluish-grey slates, with thin even beds of limestone and grit, containing quartz, dip S. at from 45° to 65°. In Pixton Park a southerly dip of 45° was obtained near the gatehouse, where the grey slates strike parallel with the Culm rocks of Hulverton Hill. A little northward of Combe Farm, so far as meagre surface evidence may be relied upon, a band of buff or brownish grits, either belonging to the *Cucullæa*-zone or occurring above it in the Pilton beds, crosses the highroad, forming the crest of an anticline; for towards Dulverton the Pilton beds dip N. at 75°, and near the bridge across the Barle N. 30° W. at 20°.

Just above Dulverton church the grey slates suddenly give place to lilac-red slates and grits, so characteristic of the upper part of the Pickwell Down division, which is further evidenced by features and surface indications as far north as Court Down. This junction is evidently a fault, both from dissimilarity in amount and direction exhibited by the dips on either side of it, and from the absence of the *Cucullæa*-grits and olive slates (forming together the Baggy Beds, or Lower part of the Pilton series). Proceeding eastward to Hele Bridge, further evidence of the fault is furnished by a developed continuation of the grit band before noticed near Combe Farm. The beds are exposed in Pixton Park, near a gate-house, and dip N.W. at 55°. Immediately on the north of the highroad they end off sharply against the Pickwell Down division. From Hele Bridge northward to Barlynch Abbey, where it is exposed in quarries, the Pickwell * series is amply evidenced by characteristic surface-stones, vegetation, and form of ground. To the north of the Abbey a quarry about 25 feet in height exposes light grey or greenish and faint reddish grits with red markings in places, dipping S. 15° E., with undulations, at an average angle of 45°. A cleavage structure

* We omit the fuller title for the sake of brevity.

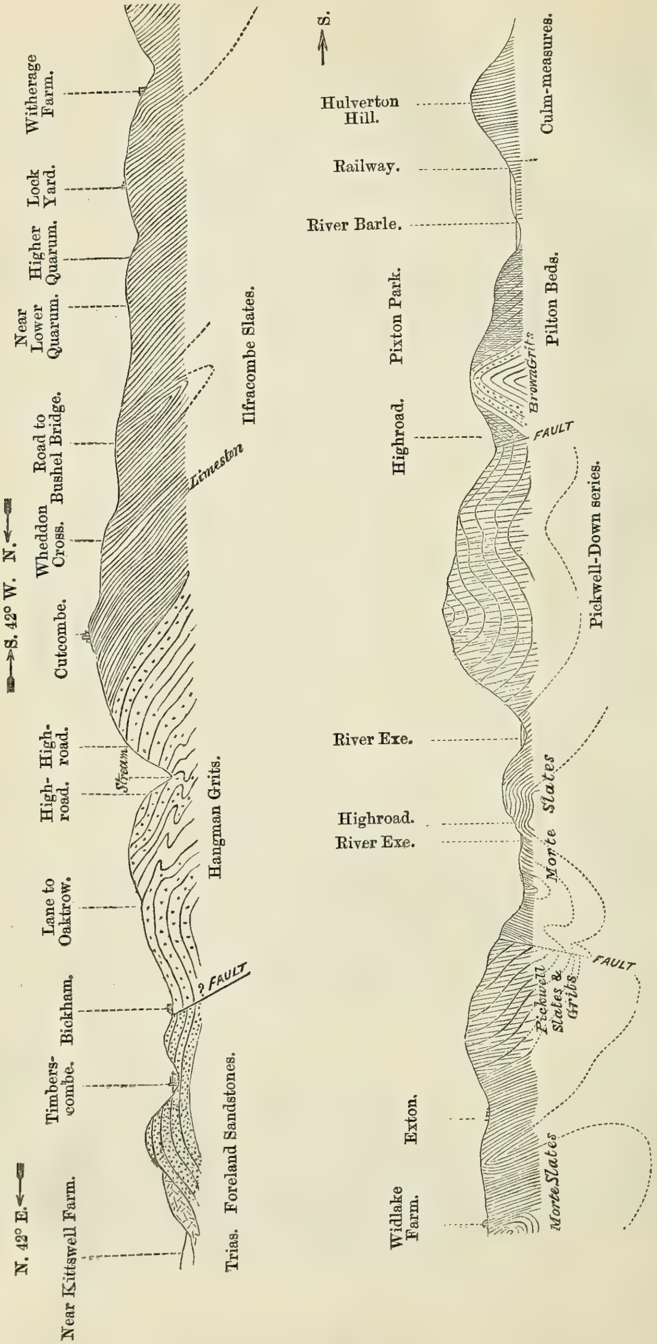


Fig. 1.—*Section from Hulverton Hill, near Dulverton Station, northwards to Wheddon Cross, and thence N. 42° E. to Timberscombe.*

is here and there developed in directions parallel to the joints; in places the undulating surfaces of the joint-planes resemble the adjacent markings by the road, attributed by Prof. Jukes to ice mamillation. In the vicinity of this spot the Pickwell beds seem to form a syncline, as northerly dips are met with near the Abbey on the south.

Near Oxgrove an appearance of northerly dip is probably occasioned by joints in the direction of the cleavage. At a quarter of a mile north of Oxgrove we appear to cross the junction between the Pickwell series and underlying division of greenish and grey slates of Morte and Ilfracombe (called after the typical localities in which their upper unfossiliferous and lower fossiliferous beds are respectively developed). Greyish schistose or irregular slates near Oatway are apparently intersected by joint-planes dipping N. at 70°, whilst the bedding seems to follow the direction of the cleavage, dipping S. 10° E. at 70°. In places the slaty laminæ thicken into impersistent lenticular gritty bands. At Chilly Bridge characteristic Morte slates are exposed. Due east of Kent's Mill the slates dip E. 20° S. at about 50°; a few chains to the north grey uneven or schistose slates, with vertical cleavage, seem to dip N. 20° W. at from 60° to 70°. At about one third of a mile north from the above a northerly dip is exhibited.

At the junction of the Ordnance map sheets 20 and 21, grey grits and purplish slates are associated with greenish and bluish grey slates, proving a repetition of the Pickwell series, in a syncline, aided by fault. From the occurrence of Pickwell beds to the north and north-west, we have little hesitation in saying that the Morte slates of Chilly Bridge form an anticline, throwing off the Pickwell beds on the north and south, and passing under them on the west towards Drayton Farm.

At Clammer irregular or schistose slates and slaty grits, with vertical cleavage, and in colour more allied to the Morte than the Pickwell beds *, seem to dip S. to S. 20 E. at 50°. A contrary dip, N. 20 W. at 70°, is suggested by divisional planes, apparently joints. Near Clammer bedding and cleavage-planes appear to run in the same direction, but the joints seem to be vertical. From Clammer to Bridgetown slaty lilac or purplish grits and slates are associated with grey slates, and undoubtedly belong to the lower part of the Pickwell series, from evidence obtained to the west of the Exe valley. Near Bridgetown lilac or purplish and grey slates, uniformly coated with lichen, and presenting a grey weathered surface, are finely exposed in the road-cutting. The cleavage-planes, inclined southward at 60° to 70°, are intersected by two or three impersistent lines, apparently bedding-planes, giving a southerly dip of 13°.

At Bridgetown the dip is S. at about 65°; and the lower parts of the Pickwell-Down series, forming a passage into the Morte slates, rest upon them in strict conformity, the junction-line having been

* Compare greenish grits and slaty beds near Drayton and Slade Farms in Pickwell series, Barle Valley, two miles above Dulverton.

traced westward from the bank of the Barle (opposite Bridgetown), where Morte slates are shown normally dipping under the Pickwell beds.

From Exton to Cutcombe no further evidence of the Pickwell series is obtainable by the highroad, although, to the south of Winsford, a strip of the lowest part of that series, represented by intercalations of purplish, buff, and greenish slates, appears to be brought down by fault or undulation between Yellowcombe and Winsford, but in insufficient force to permit of their extension eastward to Widlake, where a dip of 50° to the S. was obtained in Morte slates.

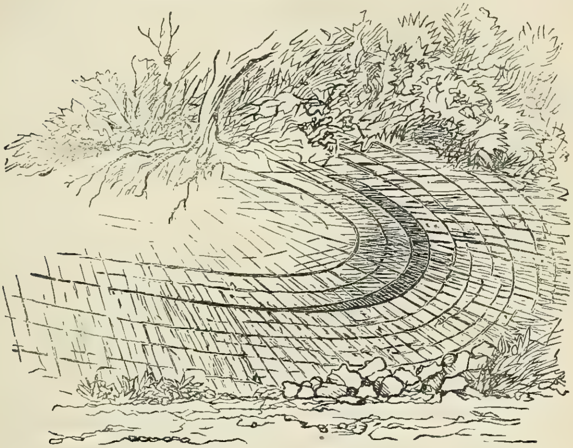
Near Lock Yard the slates dip as at Widlake. West of Lower Quarum they are stained reddish, and exhibit a tendency to slaty grit. From Lower Quarum to Whiten Farm the slates have a steady southerly dip at 40° to 50° where exposed. The bedding seems to follow the direction of the cleavage at right angles to the joints eastward of Hoe Farm. It is impossible to distinguish the Morte and Ilfracombe varieties of this great series of slates by any definite boundary; a provisional line might be dotted through Eyeson Hill or Lower Quarum. At the Mill, between Whiten Farm and Luckwell Bridge, the Wheddon-Cross limestone-beds mentioned by Mr. Etheridge are well exposed; they consist of about 30 feet of dark bluish-grey limestone, partaking in every respect of the cleavage, which is here in the same plane with the bedding. The laminæ are frequently coated with films of dark grey shimmering shale. Faint traces of crinoids and corals were noticed on the bedding- or cleavage-surfaces. At about 15 feet from the top of the section the laminæ have, in places, coalesced to form even beds of limestone 2 or 3 inches in thickness. The dip is S. 10° E. at 45°.

From Wheddon Cross the features of the underlying series, the Hangman grits, are well shown in the range of hills of which Dunkery Beacon forms the highest point.

The junction of the Morte and Ilfracombe slates with the underlying Hangman grits takes place near the bend in the highroad north of Cutcombe, where slaty beds rest upon coarse thin even-bedded slaty grits, resting on red and brownish, rather coarse, thick-bedded grits, with an occasional tendency to schistose structure, and dipping S. 30° E. at from 10° to 13°. The strike changes slightly, but the angle of dip remains constant, in the three quarries by the highroad. From this point to Timberscombe, grits with shales intercalated prevail. A quarry by the highroad N.W. of Oaktrow shows a most remarkable unisynclinal curve, rough-cleaved greyish and reddish grits folding back upon themselves, as shown in the sketch (fig. 2), the cleavage beautifully converging upon the axis of the curve. The height of the section is about 20 feet.

By the lane leading southward to Oaktrow from the highroad grey and reddish slaty shales and schists are associated with reddish-brown grits, apparently undulating, in which a northerly dip of 7° was obtained. A quarry on the east side of Timberscombe exposes dark chocolate-brown, red, and greyish grits, in places quartzose, split off by numerous irregular joints, sometimes glazed with hæmatite, and approximating to a slaty structure in places; bands of chocolate-coloured clayey shale are occasionally interstratified. The beds dip S. at 5°.

Fig. 2.—*Unisynclinal Curve in Hangman Beds, near Oaktrow.* (Height of section 20–25 feet.)



From here to Dunster grits are evidenced by surface-stones, but no sections were observed. If the Timberscombe grits belong to the Foreland group (as similar beds are exposed near Porlock), a fault between Bickham and Withycombe must bring the Hangman and Foreland groups into juxtaposition, cutting out the intermediate Lynton beds; and this we hope to prove by the next traverse.

From Dunster to the Foreland.

As in the previous traverse no beds equivalent to the even grey grits and fossiliferous schists of Lynton were crossed, Mr. Etheridge having clearly shown the mantling of the Ilfracombe slates and associated limestones round the east end of the Croydon-Hill anticlinal, formed of Hangman grits, and as in our traverse from Williton to Cannington, hereafter to be described, we were unable to trace the Lynton division, it was of the utmost importance to account for its disappearance, and for the great breadth of grits occupying the area from Cutcombe, on the south, to North Hill, near Minehead, on the north.

The south side of Grabbist Hill consists of reddish-brown grits, in which no reliable dips were obtainable till we reached Slatcombe, near Wooton Courtney, where the beds dip N. 15° E. at from 5° to 20°. On the western flanks of Grabbist Hill, near Lower Knoll, hard reddish-brown siliceous grits with numerous irregular joints, and slaty beds intercalated, dip E. at from 5° to 20°, and at Tivington N.E. at 30°.

The valley between Grabbist Hill and Luckham is occupied by red sands, breccias, and marls of the Triassic series, in part concealed by alluvia. The relations of the Triassic beds in an area in which they may be expected to present much local lithological variation, and where they would naturally attenuate, notwithstanding very high dips, throw hardly any light upon the disturbances affecting the older rocks; but a much more careful study of the latter than we were able to make would no doubt clear up much that is ambiguous in the relations of the Trias, and show whether beds of Pre-Keuper age had been deposited in the area to the west of Williton, as lithological similarities seem to suggest.

From Luckham to Stoke Pero the surface is strewn with fragments of grit. At about half a mile east from Cloutsham coarse red and lilac quartzose grits are exposed, dipping E. 25° S. at 10°.

In the stream between Cloutsham and Bagley siliceous grits dip eastward at 20°. Near Cloutsham and Brackslade no dips are obtainable; red and brown grit-stones are scattered over the surface. Near Stoke Pero a south-easterly dip of 23° was obtained in red and brown grits. The grits in this neighbourhood approach rather to the Hangman than the Foreland type; so that the sharp bend in the stream to the north of Cloutsham may be due to a dislocation bringing up Foreland beds to the north.

By the road from Stoke Pero towards Bendles Barrows siliceous grit-stones of the Hangman type are strewn over the surface.

On ascending the opposite slope of the valley to the west of Stoke Pero a thick head of brown grit-stones conceals the rock. At the head of a stream-gorge, at about half a mile south of Wilmotsham, buff slaty grit gives a surface-dip S. 30° E. at about 15°. By the road southward from Pool, where the bend is shown on the map (to the N.E. of Bendles Barrows), a section 5 feet deep exposes greenish slaty grits or thick slates, apparently vertical and striking N.E., terminally curved.

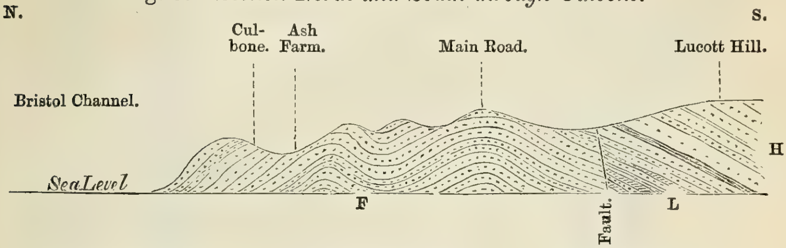
Westward of Bendles Barrows, in and by the road over Lucott Hill, at a few chains south of the stream, grey slaty beds are intercalated in red and coarse brown grits, dipping S.W. at from 20° to 40°. As their strike coincides in direction with that of the greenish slates on the other side of Bendles Barrows before mentioned, we have here the evidence of intercalation of slaty materials with grits of the Hangman series which is so well shown in the cliff-face of the Little Hangman Hill, on the North-Devon coast.

On the southern slope of Lucott Hill a northerly surface-dip was obtained in slaty grits; at the road-junction on the hill greenish and red grits and slaty beds seem to dip S. 10° W.

From Lucott Hill (fig. 3) we struck into the East-Lynn valley at a point due west of the bottom of the word "*Lucott*" on the map, where we observed hard thick-bedded greyish siliceous grits of the Hangman series dipping southward at from 20° to 25°. Proceeding down the valley, at about ten chains from the above, a south-easterly dip of

35° was obtained. At about ten chains further on Hangman grits, containing raddled grey schistose beds, dip southward at 20°, and S. 20° E. at 30°, and rest in strict conformity upon the characteristic

Fig. 3.—*Section North and South through Culbone.*



F. Foreland sandstone. L. Lynton beds. H. Hangman grits.

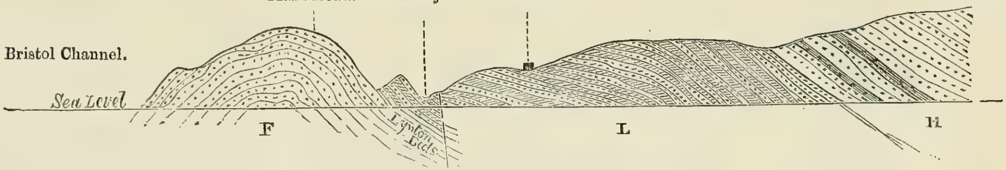
warm-grey, evenly bedded fine grits and grey schists of the Lynton division, which form a low crag or ridge feature in the valley, dipping S. 25° E. at 25°. At about 15 chains from this junction a tributary streamlet joins the East Lynn; proceeding along it, we observed the same even flaggy Lynton grits dipping S. 15° E. at 20°, at a point about 15 chains from the main stream.

Having thus terminated the Lynton beds in the East-Lynn valley by a conformable junction with the Hangman grits, we will retrace our steps, and, starting from Porlock to Countesbury, and then to Oareford, endeavour to show that the absence of the Lynton beds on Lucott Hill, and to the east of it, is due to a fault following the general trend of the East-Lynn valley. On ascending Porlock Hill from Porlock, chocolate-grits, resembling those of Timberscombe (as before stated), with irregular schistose beds, dip E. 12° S. at 50°, and N. 30° E. at 70°, the change in dip being apparently due to a fault. A little further on they dip N. 30° E. at from 60° to 65°.

The evidence on Porlock Hill is confined to surface-stones till we come to a section about 10 chains east from the turning to West Porlock shown on the map, but now no longer in existence; here the grey, buff, and red fissile grits so characteristic of the Foreland group are apparently horizontal. The present road to West Porlock joins the main road at a point on the map where the letter *W* of the words *White Stones* touches it. By this road, near West Porlock on the north-west of Whitestone Park, red grits dip N. 10° W. at 55°. Midway between this observation and Westacot similar red grits (rather fine-grained) exhibited a northerly dip of 20° and a doubtful southerly dip of 50°, which may be along joint-surfaces. South of Westacot an easterly dip of 55° was furnished by greenish-grey and reddish fine fissile grits, in which we obtained several casts of small bivalves. About halfway between this section and the main road, on Porlock Hill, similar beds afforded a dip E. 20° S. at 25°.

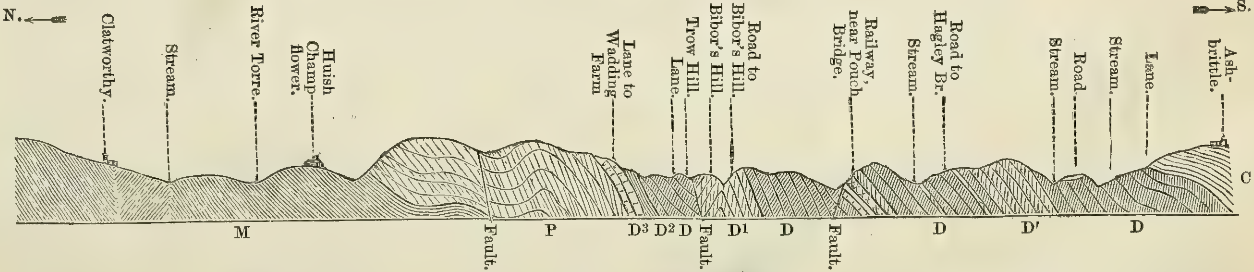
From White Stones to Countesbury, in the adjoining map (sheet 27), no pits deep enough to afford reliable dips were observed from

Fig. 4.—*Section North and South through Withycombe Farm, near Oare.*



F. Foreland Sandstones. L. Lynton beds, even grey grits and schists. H. Hangman Grits.

Fig. 5.—*Section from Ashbrittle to Clatworthy in the Torre Valley.*



Pilton beds { C. Culm-measures.
D. Grey Pilton slates.
D1. Grits and slaty beds.

Baggy beds { D2. Olive slates (*Lingula*).
D3. Grits and slate beds (*Cucullæa*).

P. Pickwell-Down grits and slaty beds.
M. Morte slates, greenish grey, with quartz veins.

the highroad; the surface-stones everywhere consist of red, buff, brownish, whitish, greenish, or grey fissile or flaggy fine-grained grits, generally of sombre tints.

By the road from Porlock and Oare Hills to Oareford grey and purplish or red fine-grained flaggy grits are evidenced by numerous surface-stones. At a bend in the road, not shown in the map, just above the East Lynn Valley, dark grey and red fine-grained grits and schistose beds of the Foreland group exhibit contrary dips of about W. 10° S. and S. 20° E., at angles apparently conforming to the slope of the hill. In the valley below the above observation, dark grey Lynton grits, even-bedded and evenly jointed, with occasional grey schistose intercalations, are exposed by the East Lynn, and in little hills or crags of a somewhat conical shape, which are so characteristic of the Lynton grits, and, as before stated, occur near their junction with the Hangman group in this valley. By the stream and in the crags the Lynton beds dip S.E. and E.S.E., generally at an angle of 55°. At Oareford houses grey schists strike S. 20° W., apparently dipping E. 20° S. at from 30° to 50°. Near Withycombe Farm purplish-grey Lynton grits strike in a north-easterly direction. North of Withycombe Farm bluish schistose grits dip E. 40° S. at 40°.

At about half a mile north of Withycombe Farm (fig. 4) the character of the ground alters, being marshy and much lower about Oare. This change is due to a great fault crossing the Oareford road below the contrary dips (exhibited by the Foreland grits, as before stated), and probably continuing along the valley to the north of Cloutsham, and thence by Bickham to Withycombe. Continuing this line westward to the coast at a point north of the camp (between Countesbury and Lynmouth), where evidences of fault are conspicuous in the cliffs, we find that it separates Foreland grits on the north from Lynton beds (with tolerably steady southerly dip) on the south, the straight boundary line between the divisions being apparently only broken in two places by fringing masses of Lynton beds thrust up with the Foreland grits on which they rest—viz. for more than a mile near Combe Farm (sheet 27), and eastward of Oare. The conformable superposition of the Lynton beds on the Foreland group is best seen near Oare. By the farmyard on the north bank of the East Lynn at Oare, hard lilac, buff, and grey fine-grained grits with reddish markings, and jointed in all directions, are exposed in a quarry, and dip S.E. at 30°. From this quarry northward to the highroad, by the gully which usurps the place of the path shown on the map, Foreland grits are evidenced by a thick head of characteristic stones.

At about five chains eastward of the farmhouse fine-grained grey even-bedded Lynton grits and grey schists dip S.E. at 40° by the stream, and are shown further on preserving the same direction of dip at increasing angles. This upcast mass of Lynton beds makes a marked feature at its junction with the Foreland grits on which it rests, forming a steep ridge that trends N.E. to about ten chains from the main road, whence the boundary deflects with a minor feature along the slope of Oare Hill to the fault which cuts it off somewhere near the road to Oareford.

From the foregoing evidences we have no hesitation in saying that the absence of the Lynton beds from Lucott Hill eastward is due to a great fault which extends from the point whence the coast deflects N.N.E. to the Foreland, following the East-Lynn valley (but cutting across the bends in the stream) as far as Oareford, whence skirting the north of Lucott Hill it appears to pass by Cloutsham Ball (name not on the map), and probably runs through Bickham to Withycombe on the north of Croydon Hill. This fault appears to be Pre-Triassic; but of this we cannot be certain without carefully examining the Triassic districts of Luckham, Wooton Courtney, and Withycombe.

Mr. Etheridge advocates the existence of a fault from the Foreland to Minehead*, and also suggests that the lowest beds are obscured by "an extensive fault affecting the Foreland Sandstones" †. The correctness of the latter suggestion we have endeavoured to prove; but we confine the anticlinal structure (also said to obscure the relations of the beds) to the higher ground composed of Foreland grits between Countesbury and Porlock, as we have failed to detect any signs of such structure in the East-Lynn valley. Of the fault between the Foreland and Minehead we could obtain no direct evidence in the limited area gone over, but, judging from slight indications, think the existence of such a fault, obscuring the relations of the grits of the Foreland group *inter se*, by no means improbable.

The Torre Valley (fig. 5).

The village of Ashbrittle is situated on dark bluish slates or thick shaly beds of the Coddon-Hill type, and exhibiting its characteristic features in adjacent hill-summits to the west of the village. The Culm beds are exposed near Trace Bridge, dipping S.E. at 45°.

Whatever cleavage may at times be developed in the argillaceous parts of this upper series of Devon and Cornwall, it here at least coincides with the bedding. A line south of Coalman's Mill, passing between Chequeridge and Pitt Farms, divides the Culm-shales (which near Pitt Farm are nearly horizontal) from the light-grey slates of the Pilton series. Near Coalman's Mill *Spirifera Urii* occurred in bluish-grey slates which dip S.E. At Stawley the strike has altered, giving a S.S.W. and S.W. dip; and north of Stawley Parsonage, between that and Hagley Bridge, a marked feature is caused by reddish, greyish, and greenish grits and slaty beds: occasional red-brown sandy seams suggested a decomposed limestone.

These beds were noticed by De la Beche (Geol. Report, Cornwall, Devon, &c., pp. 53 and 104); they contain many fossils (*Spirifera disjuncta*, *Streptorhynchus*, a Pilton Crinoid, &c.). Mr. Hall com-

* Quart. Journ. Geol. Soc. vol. xxiii. p. 595. † Ibid. p. 694.

pares this local development of grit in the Pilton series with similar fossiliferous grits near Braunton. The beds dip S.S.W. and S.W. at from 32° to 34°, and at Kittisford Barton S. at 37°.

Northward from Hagley Bridge the Pilton beds are represented by slates in which grits were observed in the lane north of Surridge, dipping from S.E. to S. at from 40° to 60°. Whether this change in strike may be natural or the effect of a fault bounding the northern slopes of Stawley Parsonage hill, we must, without further investigation, leave as conjectural.

In the railway-cutting to the west of Pouch Bridge rather dark grey slates, tough grey grits, and films of limestone dip S. 20° E. at 43°. They embrace some brown arenaceous beds, due, as Mr. Hall thinks, to decomposition of limestone. Mr. Hall found Pilton fossils in these beds.

In the cuttings east of Pouch Bridge slates are exposed changing abruptly from dark bluish-grey to light grey. Blue-black slates have been turned out of the tunnel near Hellings, and yielded (so-called) *Petraia celtica*. The occurrence of similar beds at Venn-Cross station, where they contain Septaria, induced us to think that a strip of Culm-measures had been brought down by an E. and W. fault; but as the Pilton beds are often dark-coloured, we have abandoned this idea. In the lane north of Pouch-Bridge viaduct light-grey argillaceous slates dipping southward contain *Petraia celtica* &c.

Pilton slates with unreliable surface-dips are visible as far north as Rockhouse Inn, where a large quarry, by the turning to Bibor's Hill, exposes dark-grey raddled grits and slaty beds, containing Pilton fossils, and occasionally brown seams (decomposed limestones) with organic remains. The beds dip from S. 15° E. to S.E. at angles of from 65° to 75°.

On the southern slope of Bibor's Hill very hard irregularly jointed grey grits and slaty beds dip N. 30° W. at 55°, thus proving the structure to be a natural or faulted anticlinal. From their breadth of outcrop in this district the components of the Pilton beds appear to be repeated both by fault and flexure; and from lithological similarity, we are inclined to regard the Bibor's-Hill beds as a repetition of those on Stawley Parsonage hill, probably by a fault running in an easterly and westerly direction, not far north of Pouch-Bridge viaduct. As the Bibor's-Hill beds do not appear to outcrop north of Iron Hill, the grey slates which continue thence to the farmhouses south of Wadding were probably dislocated by the continuation of a fault shown in the railway-cutting (north of Bathealton), where it throws down Trias on the south. This view is strengthened by contrary dips, S.S.E. at 60° and N. 15° W. at 60°, respectively obtained on the hill-slope and by the lane to Chipstable (to the east of Trow-Hill Farm).

In a small section at the farm, south of Wadding, Mr. Hall fixed the junction between the grey Pilton slates with limestone bands and the olive slates, which in this district form the upper part of the Baggy beds. The beds dip S. 15° E. at 70°. In these greenish slates Mr. Hall obtained a *Lingula*. An even conformable junction trending W. 20° S. and E. 20° N. separates them from lilac and reddish grits and slaty beds shown in a quarry a few chains north of Wadding Farm, dipping S. 15° E. at 35°. Mr. Hall identified these beds as *Cucullœa*-grits; lithologically we should have been unable to distinguish them from the Pickwell grits and slaty beds, upon which they rest conformably, forming a narrow zone about twelve chains in width along the southern flanks of the Pickwell range, and scarcely distinguishable by feature. In this zone, S. of Challich Farm, south-easterly dips of 50° to 55° were obtained, and casts of *Cucullœa* were found by Mr. Hall.

In the Tone valley, at a few chains north of the *Cucullœa*-zone, a dip S. 15° E. at 50° was obtained in Pickwell beds; thence to Washbattle Mills the characteristic features and vegetation of the Pickwell series, constituting the high land of Heydon and Main Downs, are unmistakable; but the exposures of rock were too slight to afford reliable dips. A fault with a southerly downthrow, of which evidence has been obtained near Wiveliscombe, may cross the Tone valley near Challich Farm.

On emerging from the narrow river-gorge (of the Tone) which intersects the Pickwellian range, we have the clearest evidence of perfect conformity between this series and the underlying Morte slates at Washbattle Mills, by a slight deflection of the junction in accordance with the physical features, a character distinctly exhibited in its prolongation westwards. There are no conglomerates to be seen, nor any thing to indicate a lapse of time between these two subdivisions in North Devon or West Somerset.

Morte slates are shown immediately above the junction on the road to Huish Champflower. The boundary follows the road from the Mill eastward to Higher Raddon, and is concealed by Triassic rocks near Langley. Along this line the character of the grits * is exhibited in three small quarries on the northern slope of Main Down and at Higher Raddon, where the beds show S.S.-easterly dips of from 35° to 45°.

Following the boundary of the Trias and the Morte slates, the character of the latter is well shown in Oakhampton House slate-quarries, where the characteristic grey slates are somewhat raddled in places, the cleavage and bedding being apparently coincident, and dipping S. 15°–20° E. at 70°: by the highroad to Pitsford Hill the same southerly dip has been noticed. We did not continue this traverse into sheet 20, but obtained good evidence of the undulations in the greenish quartz-veined slates of the Morte series which are shown in the accompanying section (fig. 5).

Across the Quantocks to Cannington Park.

At Staple Hill foot, near West Quantocks Head, the boundary of the older rocks is sharply defined. Purplish grits in broken condition are seen at the cottages; and on reaching the open ground a

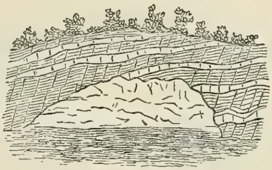
* Lilac, red, and purplish-grey grits and slaty beds.

quarry exposes red-brown and lilac grits and splintery shales, which dip N. 15° W. at 25°, and are much cut up with irregular joints. The spot is about a quarter of a mile due south of West Quantocks Head.

To the south of the above, in the gully east of Weacombe, a quarry is opened in similar grits, fine-grained, and partly greenish, dipping N. 35° W. at 20°. A quarter of a mile further up the valley grits with schistose intercalations dip N. 10° W. at from 40° to 50°. From here across the summit of the range the surface-stones (the only evidence obtainable) are generally of coarse siliceous grit, reminding one of the upper beds of the Great Hangman *; but where the paths to Hutsham and Holford divide, the rock shown in the path is *in situ*, and apparently horizontal.

At the foot of the hills at Holford is a large quarry of grits and clay shale, which dip N.E. at angles varying from 15° to 30°. The beds in the upper part are thin quartzose red-speckled grey grits, associated with greenish-grey shale, and resting irregularly upon a boss of similar grit (fig. 6), thick-bedded, into which the shales dove-

Fig. 6.—*Boss of Grit in Shales with thin-bedded Grits, Holford Quarry.* (Vertical scale, 1 in. = 40 feet.)



tail in one or two places, showing a lenticular character in the beds. At a bend in the highroad, just south of Holford, quartzose grits, with some even-bedded finer-grained beds and redder in tint, show dips changing from E. 30° N. at 40° to E. at 25°. From Holford, following the turnpike road to Nether Stowey, a quarry by Sherwage Wood shows red-brown grits, with general dip N. 30° E. at 10°. At turning to Doddington, Triassic rocks cross the road; at turn to Perry Mill Farm, reddish grits and shales dip E. 35° N. at 40°.

From Nether Stowey to Cannington and Bridgewater the Palæozoic rocks occur as inliers only, here and there amidst the Triassic sediments. Of these we have only occasion to refer to that of Radlet Farm on the south of the road, and those of Ashford Mill and Cannington on the north. The inlier at Radlet consists of fine reddish grits and shales. Padnoller beds are similar grits and shales, affected by an east and west fault, which bounds the last-mentioned inlier on the north.

Immediately to the north of Cannington an E. and W. ridge, two miles long, consists of purplish-grey arenaceous mudstones, finely

* See Symonds's 'Records of the Rocks,' p. 264.

micaceous and sectile. In the roads north from Cannington to Cannington Park the surface-dip seems to be southward, with undulations. An exposure in an adjacent field showed red-brown shales with occasional greenish mottling, under red Triassic sand, near the northern margin of the patch. With the conditions under which these inliers present themselves there is such a constant chance of raddling from Trias, that the colours of these soft arenaceous mudstones cannot be considered of much value, and they may be of almost any age, from the Culm-measures downwards.

Their relations with the Cannington-Park limestones are obscured by Triassic sands occupying the valley between the inliers. Large E. and W. faults prevail in the Bridgewater area, notably one on the south of Fiddington, with downthrow on the south; and this, if continuous, would make the Cannington inlier above the limestone; but the frequency of these Post-Triassic disturbances along E. and W. lines would justify a belief in precedent lines of fracture in similar directions concealed by the Trias; so that in the absence of any evidence of relations between the Cannington and Cannington-Park inliers, it seems not unreasonable to regard their junction as a pre-Triassic fault, probably of great magnitude.

The limestone is well bedded, and intersected by numerous irregular joints. As far as evidence goes, the dips in the quarry by the road on the south side of the park would make the strike of the limestone at right angles to the trend of the adjacent inlier, *i. e.* the reverse of what would happen were their relations normal. On the N.W. side of the quarry the dips range from W. 42° S. at 20° to S. 25° W. at 25°; and on the N.E. face the beds dip E. 30° S. at 40°. A similar change of dip is observable on the south side of the quarry. In the S.W. corner, near the entrance, the beds dip W. at 70°, and W. 15° S. at 55°, whilst on the S.E. a dip E. 20° N. at 38° is observable, also S. 42° E. at 20°. The beds therefore form an anticline, the axis of which trends in a N. and S. direction. In one part of the southern face two fissures filled with Triassic sand were observed.

The limestone is of light grey and dove-coloured tints, intersected by pinkish veins and strings of calcite. Much is of oolitic structure, identical with that of the Mountain Limestone at Clifton, and also on Broadfield Down, near Yatton. We have never seen oolitic structure in any of the South-Devon limestones. Traces of crinoidal stems and corals we observed on the spot, but nothing that could be identified.

In the Taunton Museum we were shown the following specimens:—(1) *Productus*, of small size, apparently *P. cora*, as it has the wrinkled ears and delicate rounded striæ of that species, labelled "J.H. Payne, Cannington Park Limestone, October 24th, 1851;" (2) *Lithostrotion*, two fine polished specimens of a cæspitose form, apparently *L. Martini*; (3) *Lithostrotion basaltiforme*; the Corals from the Baker Collection. (With regard to No. 3, the identification is open to question.)

The Cannington-Park limestone we should unquestionably consider Carboniferous Limestone *. The South-Devon limestones most resembling it are the great mass north of Dainton Tunnel, traversed by the Great Western Railway, the Connator-Hill limestone adjoining the Totnes and Newton turnpike road, as well as that of Barton, near Torquay. These are all light-coloured, partially dolomitized (the first two scarcely fossiliferous), and with bedding undistinguishable; hence their resemblance cannot be called intimate.

The bedded and usually dark-coloured limestones at Daddyhole Plain, near Torquay, at West Ogwell and Bradley, at Dartington, and other localities too numerous to mention, have, neither in fossils nor lithologically, the slightest resemblance to the Cannington rock; but they have, on the contrary, a decided similarity, which amounts at times to identity, to the limestones of Asholt.

On recrossing the Quantocks to Bishops-Lydeard, we observed on Asholt Common a quarry of uneven dark bluish-grey limestone, often shelvy, of a character met with so constantly in South Devon. This seems to overlie red-brown grits, dipping S. 20° E. at from 40° to 60° on the north of Asholt Common. Behind Lower-Asholt schoolhouse the character of the Devonian limestone developed in a horseshoe form, with Merridge as the centre of the curve, is shown at its western extremity to consist of reddish and bluish 'shelvy' limestone, full of calcite, and intersected by a small fault. These we agree with previous writers (especially Sir H. De la Beche and Mr. Etheridge) in referring to the Ilfracombe series, of which the southern part of the Quantocks appears to consist.

Another very strong reason for the identification of the Cannington-Park limestone with the Carboniferous Limestone of the Mendips, of which we think it forms the southern margin (the connexion being concealed by intervening Secondary rocks), is the entire absence of shaly structure or associated detrital matter, which are so often characteristic features in the Devonian limestones.

In conclusion, we have to express our thanks to Mr. Hall for the kind assistance he has rendered in the particulars in connexion with which his name has been associated in this paper.

* This view is confirmed by Mr. Tawney in an exhaustive paper on the subject (Proc. Brist. Nat. Soc. vol. i. part 3, p. 380), in which he mentions his discovery *in situ* of *Lithostrotion irregulare* and crushed shells, perhaps *Terebulata hastata*, or possibly *Athyris*, also a small *Productus elegans*, or young *P. punctatus*, and part of a stem of *Actinocrinus*, obtained by Mr. Winwood. He coincides in Mr. S. G. Perceval's opinion that the limestone is undoubtedly Upper Carboniferous Limestone, and mentions that gentleman's determination of the fossils presented to the Taunton Museum by Mr. Baker—*Lithostrotion Martini*, *L. irregulare*, *L. aranea*, *Clisiophyllum turbinatum*, *Syringopora ramulosa*. He also considers that from this identification of its age "it follows that it is totally disconnected with the Quantock series seen a few hundred yards off." In this unqualified opinion we cannot agree, as it is by no means certain that the adjacent Palæozoic inliers belong to the Quantock series.

Mr. Tawney noticed the anticlinal structure we have described, and says, "The fault spoken of by Sir H. De la Beche must certainly exist."

Discussion.

Prof. Seeley said he had examined the district some years since, rather carefully, and wished to ask Mr. Ussher a few questions. He himself thought he had made out the sequence and mineral structure of the beds, as he did not think the distinctions already established could be always identified; he also demurred to the faults mentioned by the authors. Fossils are rare in many parts of the series. He wished therefore to know on what authority the authors had made their divisions.

Mr. Winwood said he knew the country, and had found many fossils in places where Prof. Seeley said he had not found them. He described various localities and the results of his examination.

Mr. Ussher stated that he had traced the subdivisions, both by feature and by lithological character, over an area exceeding 300 square miles, and that the faults were well founded.

42. Contributions *to the Knowledge of* Fossil Crustacea. By Henry Woodward, Esq., LL.D., F.R.S., F.G.S., of the British Museum. (Read May 28, 1879.)

[Plate XXVI.]

I. *On a fossil* Squilla *from the London Clay of Highgate—part of the "Wetherell Collection" in the British Museum.* (Plate XXVI. fig. 1.)

The Stomapoda (as restricted by Prof. Huxley, and) represented at the present day by *Squilla*, *Pseudosquilla*, *Gonodactylus*, and *Coronis*, are not only interesting from the fact that they differ widely in many important points of structure from all other Crustacea; but, from their extensive distribution over the seas of the globe, they bear evidence of high antiquity, and justly challenge the attention of the palæontologist.

Two causes, however, may probably assist in explaining the rare occurrence of *Squilla* in a fossil state:—first, the thinness of its test, which would render it less likely to be preserved; and, secondly, the fact that *Squilla* lives in, comparatively speaking, deep water, and prefers *clear water* undisturbed by sedimentary deposits.

Fossil *Squillæ* have been described by Münster, in 1839, from the lithographic stone of Solenhofen, Bavaria, under the name of *Sculda pennata* (Beiträge, vol. iii. t. 4. fig. 4), and by the same author from the Eocene of Monte Bolca, near Verona, Italy, under the name of *Squilla antiqua* (Beiträge, vol. v. t. 9. f. 11).

The British Museum possesses very perfect specimens of *Squilla* from the lithographic stone of Solenhofen (part of the late Dr. Häberlein's collection, see Plate XXVI. fig. 5); but I have not seen the fossil *Squilla* from Monte Bolca, and, although the figure given by Münster is sufficient to prove it to be a veritable *Squilla*, it is of no value for the purpose of critical comparison.

The specimen about to be described, although merely a portion of an abdomen, is so characteristic of the genus *Squilla* that it deserves to be recorded in our list of British fossil Crustacea.

To Prof. Wood-Mason is due to the credit of noticing the generic characters of this fossil, in a hasty survey of the "Wetherell Collection" some time since: it may appropriately be noticed now together with other fossil *Squillæ* of still older date.

The fossil, which is preserved (as is usual with organic remains in the London Clay) in a phosphatic nodule of unequal hardness, has only in part been developed with success, and exhibits five well-preserved segments (XIV–XVIII), a portion of the carapace, traces of the thoracic appendages, and those of the XXth segment preceding the telson.

It presents the same glossy-black enamelled surface characteristic of Macruran-Decapod remains from the London Clay.

With the exception of the small anterior thoracic one (xiv), each abdominal segment (xv–xviii), has a single oblong punctum on either side near the lateral margin of the tergum; and each of the three most posterior somites (xvi–xviii), bears two small subcentral puncta on its anterior border, whilst the two hindmost rings (xvii & xviii) have each a single central punctum on its posterior border. The epimeral portion of each somite is separated from its tergal portion by a well-defined and prominent ridge running parallel to the lateral border, which is truncated and marked by a second ridge on its margin, the latero-posterior angle of each segment being produced backwards into a small acute tooth. As is characteristic of the modern *Squillæ*, the abdominal segments of this fossil form increase in breadth from the thorax backwards, the xvth measuring 27 millims. over the tergum, and the xviiith measuring 34 millims. The length of the segments is as follows;—

xivth (thoracic)	4	millims.	long.
xvth (abdominal)	6	,,	,,
xvith ,,	8	,,	,,
xviith ,,	6*	,,	,,
xviiith ,,	8	,,	,,

The estimated length of the three remaining segments may be arrived at pretty correctly by measuring from the hinder border of the xviiith somite to the margin of the telson, or xxist somite, which is indicated upon the nodule by a line of projecting spines marking its posterior border.

Estimated length of	xixth (abdominal)	segment	8 millims.
,, ,,	xxth ,,	,,	10 ,,
,, ,,	xxist ,,	or telson	17 ,,

A comparison of our fossil with various recent species has been made. It differs from *Pseudosquilla Lessoni* in that the segments in the latter are quite smooth and there are no lateral ridges or puncta.

In *Gonodactylus chiragra* and in *G. cultrifer* the body-segments are also smooth, without ridges.

In *Squilla mantis* there are two dorsal ridges and two epimeral ridges on each somite.

In the British *Squilla Desmarestii* (Pl. XXVI. fig. 2) there are no dorsal ridges, but there are two epimeral ridges on each somite.

In a recent *Squilla* brought home by J. Beete Jukes (when naturalist on board H.M.S. 'Fly' in 1842–3–4) from Australia, nearly allied to *S. Desmarestii*, *but not named*†, the dorsal ridges are also absent; and there are only two lateral ridges on the epimera. In this species then, so widely distributed, we find the nearest living ally to our London-Clay fossil.

I would propose for this new Eocene form the name of *Squilla*

* The margin of this segment is slightly imperfect; it may therefore perhaps have been deeper.

† I am indebted to my colleague Dr. A. Günther, F.R.S., Keeper of the Zoological Department, for kindly giving me facility for examining and comparing this fossil with the fine series of recent specimens in the Museum.

Wetherelli, in memory of my old friend Mr. N. T. Wetherell, F.G.S., of Highgate, to whose care and assiduity in collecting and preserving the fossil remains of this formation we are indebted for our knowledge of this new Crustacean.

II. *On* Necroscilla Wilsoni, *a supposed Stomapod Crustacean, from the Middle Coal-Measures, Cossall, near Ilkeston.* (Plate XXVI. fig. 3.)

I am indebted to Mr. Edward Wilson, F.G.S., of Nottingham, for the opportunity of examining this new and very interesting fossil. It is preserved in a nodule of clay-ironstone, similar to those which have yielded such beautiful fossils in the Shropshire and Staffordshire coalfields, and from one of which Mr. Wilson obtained (in 1876) the chelate palpus and five abdominal somites of a Scorpion (see Quart. Journ. Geol. Soc. vol. xxxii. pl. viii. figs. 2 & 3, p. 58). Although the specimen is only a portion of a Crustacean, consisting of the five posterior abdominal somites and the "telson" or terminal segment, yet, from the form of the latter and the presence of appendages to the penultimate somite, I venture to think it deserving of description.

The length of the specimen is 21 millimetres, and the breadth of the somites 9 mm.; breadth of caudal portion with lateral appendages $11\frac{1}{2}$ mm. Save for a number of minute fractures of the surface of the fossil (giving to it what connoisseurs of old china would term a "crackled" surface), the specimen is without ornamentation. The somites are quadrate; their postero-lateral angles are slightly produced; the fifth somite, or that immediately preceding the telson, has its latero-posterior angles emarginate to give insertion to the paired appendages on either side. The outer limb (or exopodite) consists of three joints:—a short, somewhat triangular, basal or proximal joint, 3 millims. long by 2 millims. broad; an oblong median joint, 4 millims. long by 2 millims. broad; and a semicircular terminal palette, 2 millims. long by 2 millims. broad at its straight proximal margin.

The inner appendage (or epipodite) is a much more slender appendage than that outside the proximal joint to which it is articulated; it is perhaps composed of two joints.

The telson measures 6 millims. in breadth at its anterior border, where it unites with the penultimate segment; the sides converge towards the posterior margin, where it is 4 millims. broad. The hind border is produced on the median line into a small blunt prominence, or tooth, on either side of which it is roundly emarginated, to give insertion to two small hastiform spines, which are articulated to the margin of the telson. Two other fixed spines ornament the lateral border of the telson on the outer side of the two movable ones.

I know of only one Coal-measure crustacean which might possibly be related to the fossil under consideration: it is the *Diplostylus*

Dawsoni of Salter, from the Coal-measures of Nova Scotia (see Quart. Journ. Geol. Soc. 1863, vol. xix. p. 77). This little Crustacean is known, like our specimen, only by the five posterior rings and the telson. There are no appendages to the penultimate somite; and there are four small movable obovate palettes attached to the latero-posterior border of the telson, which has three serrations on the mesial line.

Mr. Salter refers *Diplostylus* to the Amphipoda, comparing it with the Hyperina; but the two small obovate palettes attached to the border of the shield-shaped telson of *Diplostylus*, which are little more than movable spines, do not appear to me to correspond with the jointed abdominal appendages of the posterior somites of Hyperina.

In the specimen now under consideration the pair of natatory appendages arise from the somite immediately preceding the telson; and in this respect they agree with the posterior pair of swimming-feet in *Squilla* and many of the Isopoda.

Comparing our fossil with the recent genus *Pseudosquilla*, we observe that in both there are a pair of small movable spines attached to the posterior border of the telson.

But the outer swimming-appendage of the penultimate somite has not the spinose border to its second joint—a very constant character in all the modern *Squillæ*, with the single exception of the genus *Coronis*, in which the segments of the body are also destitute of ridges.

As we know so little, however, at present, of this Carboniferous Crustacean, I think it is prudent to avoid speaking with too much assurance as to its zoological affinities, although I incline to regard it as nearer to the Stomapoda than to the Isopoda.

It is highly probable also that Dr. Dawson's *Diplostylus* may have been related to this Crustacean; but as it does not appear that *D. Dawsoni* possessed appendages to the penultimate body-segment, whereas our specimen has a pair of well-developed bifid swimming-feet, we cannot refer them to the same genus. I propose, then, to name this fossil crustacean *Necroscilla Wilsoni*, believing that by recording its discovery further elucidation of this old form will result.

III. *On the Discovery of a fossil* Squilla *in the Cretaceous Deposits of Hâkel, in the Lebanon, Syria.* (Plate XXVI. fig. 4.)

For a knowledge of this and other new and interesting forms of Cretaceous Crustacea from the Lebanon I am indebted to the labours of the Rev. E. R. Lewis, M.A., F.G.S., Professor in the Syrian Protestant College, Beirût.

The fossils from these Cretaceous rocks of the Lebanon are obtained from two localities, Hâkel and Sahel-Alma. Of these Hâkel is the oldest known locality, though it has been rarely visited. The only geologists who have actually visited it of late years are M. Humbert, Prof. Lewis, Dr. Oscar Fraas, and the Hon. Robert Marsham. M. Humbert and Prof. Lewis have alone given any account of the locality. Prof. Lewis says :—"Hâkel can be reached in one hard day from Beirût. By following the sea-coast to Jebail (the ancient Byblus), a small seaport town between Beirût and Tripoli, then striking N.E. (over the *débris* of old and ruined temples and towers, which once covered the locality) towards Amshît; leaving it on the left and turning nearly east, we follow the windings of a ridge which looks abruptly down upon deep valleys on either side. After four hours hard travelling from Jebail, Hâkel is reached." Prof. Lewis estimates the height of Hâkel at 800 to 1000 feet only*, and its distance from the sea in a straight line at about six miles; but the road is very difficult and the travelling execrable. Passing through the village on the right of the stream (which in winter is a torrent), we must follow the valley to its head in order to reach the celebrated Fish-quarries. About a mile up, the sides of the valley approach each other, and the valley becomes choked with masses of rock which have fallen from the precipitous sides. The strata on the left as we ascend are regularly superposed, a fine section cut by the stream being exposed to view. On the right the strata present only a confused mass of débris. Ascending still higher over the fallen masses, we find the strata beneath our feet are steeply inclined. The valley here expands into a large amphitheatre, narrowed below and above, but widening in the middle.

The strata far above our heads correspond with those on the opposite side of the valley; but below they lie at so great an inclination that it is difficult to walk upon them. This slope of the strata extends from high up in the hill-side far down into the valley, and has, M. Humbert thinks, occasioned landslips, and is itself the cause of the steep inclination of the lower strata, as where undisturbed they lie horizontally.

He points out that the valley of Hâkel is one of erosion, and that there is evidence on its northern side of the different levels at which the old stream has flowed. Harder and more resisting strata project from the cliff at various heights, and alternate with softer beds, which being more easily disintegrated have been deeply eroded. This process of destruction going on for centuries fully explains the vast mass of débris filling the lower portion of the valley†.

The surface of most of the slabs in this quarry exhibit upon their bedding-planes and laminæ numbers of specimens of *Clupea brevissima*, *Clupea Bottæ*, fragments of *Eurypholis Boissieri*, and numerous other fishes, together with remains of Crustacea, many of which are new to science.

The neat little Stomapod under notice (Pl. XXVI. fig. 4) measures 40 millimetres in length, and is preserved on the surface of a slab of compact, fine-grained, cream-coloured limestone, on the

* M. Botta says of Hâkel:—"This place is situated in a deep valley at a great height above the sea; for one has to ascend for six hours to reach it, and the clouds traverse it."

† Abstract of paper on the Fossil-Fish Localities of the Lebanon, by the Rev. Prof. Lewis, M.A., F.G.S., Geol. Mag. 1878, p. 214.

thin slabs of which such rich and varied fish-remains have been discovered.

The fossil lies upon its left side, and exhibits the cephalic shield, with the eyes, antennules, antennæ, and the great recurved monodactylous maxillipeds, *m, m* (one of which is displaced and lies on the opposite side). The thoracic and abdominal somites are much compressed. Only a trace of the thoracic limbs is seen. None of the other paired appendages are preserved until the twentieth pair, which have the characteristic form and serrated outer border(*s*) to the penultimate joint peculiar to modern *Squilla*. The terminal palette of this swimming-foot is lost (as is also the case with the specimens from Solenhofen); but this is, no doubt, due to the weakness of its articulation to the penultimate joint.

The telson was ornamented with a spinose border; but it is not sufficiently well preserved to be described in detail. The segments of the abdomen are smooth, and nearly of equal size, the posterior ones being the broadest.

The borders of the epimera are without spines, and quadrate in form. The segments are smooth, not being divided by epimeral or tergal ridges as in the modern *Squilla*, in this respect resembling *Coronis* and *Gonodactylus*; yet the presence of the great toothed second pair of maxillipeds certainly affines it to *Squilla* rather than to one of the allied genera. Like the Eocene form from the London Clay, it is probably nearly related to the widely-distributed *S. Desmarestii*.

In point of size this Cretaceous form agrees closely with the species described from Solenhofen (see Pl. XXVI. fig. 5); but the segments of the Jurassic form are all highly ornamented with spines and costæ, whereas the later Cretaceous form is destitute of ornamentation on the segments.

Dimensions of Cretaceous *Squilla*.

	Length. millim.	Breadth. millim.
Carapace	8	6
4 thoracic somites	6	6
6 abdominal somites......	19	7
Telson or 21st somite	7	x
Antennæ	7	

I dedicate this interesting specimen to Prof. E. R. Lewis, F.G.S., the discoverer, naming it *Squilla Lewisii*.

IV. *On the Occurrence of a Fossil King-crab* (Limulus syriacus) *in the Cretaceous Formation of the Lebanon.* (Plate XXVI. fig. 6.)

The proposition that if any animal be found, both in a living state and also fossil in some early formation, it may justly be concluded that it has survived during the period represented by the deposition of all the intermediate formations, from the time of its first appearance to the present day, has met with such frequent confirmation, that it may now be considered an axiom of palæontology.

The discovery of *Limulus* in the Cretaceous formation long subsequent to its early determination from the older Solenhofen Limestone, affords another illustration of the truth of this proposition.

So long ago as 1838, Prof. J. van der Hoeven published his memoir ('Recherches sur l'Histoire Naturelle et l'Anatomie des Limules,' Leyden, 4to, 1838, pp. 1–48, 7 plates), in which, in addition to a very excellent anatomical description of modern *Limulus*, which he separates into four species, he gives descriptions of six species which occur fossil in the Lithographic stone (Upper White Jura) of Solenhofen, Bavaria.

From our present knowledge of modern *Limulus*, both on the eastern coast of North America and in the seas of China and Japan, where it occurs in great abundance, it seems highly improbable that six species would really be found in so limited a spot as Solenhofen in Bavaria. Probably not more than two species occur living at the present day.

One of these, *Limulus polyphemus*, alone occupies the eastern seaboard of North America, from New England to the shores of the Gulf of Mexico, and is *numerically* in the greatest abundance. The other, *Limulus longispina* or *L. moluccanus*, occupies a part of the eastern seaboard of China, and is found around the Japanese and Moluccan Islands, covering even a wider area than its American contemporary.

The species now discovered by Prof. Lewis in the Cretaceous rocks of Hâkel, fills a hiatus long felt, and serves to bring nearer the Oolitic *Limuli* and the existing forms of King-crab.

Only one slab is preserved, the counterpart having been lost; it presents about three fourths of the specimen preserved as a flattened impression on the slab, and was obtained, like the *Squilla Lewisii*, from Hâkel, in the Lebanon.

If perfect, the cephalic shield would have measured about 13 centimetres in breadth by 7 centims. deep, the thoracico-abdominal shield being 7 centims. at its widest (anterior) part, diminishing to 4 centims. at its hinder border, the length being $5\frac{1}{2}$ centims.; the telson or tailspine measures 11 centims. in length. 5 movable and six fixed spines alternate along the border of the thoracico-abdominal somites, which are coalesced, as in modern *Limulus*, to form the postcephalic buckler. No limbs are preserved.

In point of size this specimen closely agrees with *L. Walchii*, Desmar., from Solenhofen.

I propose for this Cretaceous form the trivial name of *L. syriacus*.

DESCRIPTION OF PLATE XXVI.

Fig. 1. *Squilla Wetherelli*, H. Woodward. London-clay, Highgate: figured of the natural size. The shaded portions show the actual part of the fossil preserved. (The original preserved in the British Mnseum.)

2. *Squilla Desmarestii*, Risso. Recent British. (Copied from Bell's 'British Stalk-eyed Crustacea.') *m m*, the great-toothed monodactylous maxillipeds; *s s*, serrated outer border of penultimate joint of swimming-appendage.

3. *Necroscilla Wilsoni*, H. Woodw. Middle Coal-measures, Cossall, near Ilkeston, Derbyshire. (From the cabinet of E. Wilson, Esq., F.G.S., Nottingham.) Enlarged 3 times nat. size.

4. *Squilla Lewisii*, H. Woodw. From the Cretaceous strata of Hâkel, in the Lebanon, Syria. Enlarged 3 times. (From Prof. E. R. Lewis's collection.)

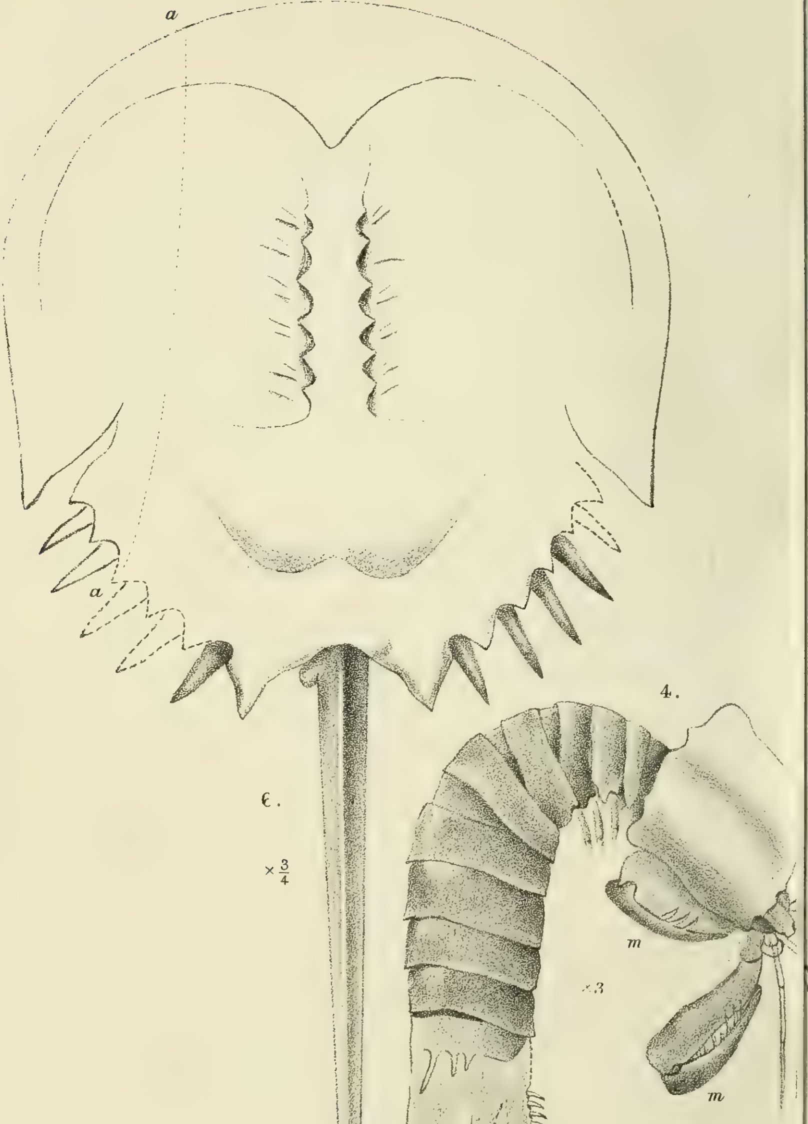
5, *Squilla* (*Sculda*) *pennata*, Münst., sp. Lithographic stone, Solenhofen, Bavaria. (Original in the British Museum; part of Häberlein collection.) Enlarged 3 times.

6. *Limulus syriacus*, H. Woodw. Cretaceous, Hâkel, Syria (collected by Prof. E. R. Lewis; now in the British Museum). Reduced to about ¼th nat. size. The portion cut off by the line *e e* is restored; the rest is preserved as an impression on a flat slab of limestone.

Discussion.

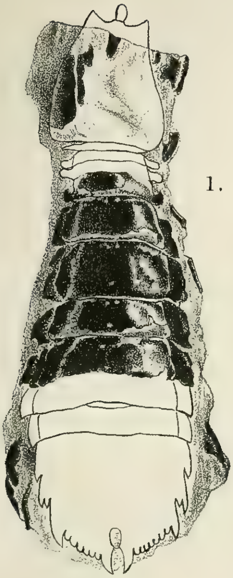
Rev. P. B. Brodie stated that he possessed a *Squilla* from the Lias.

Dr. Woodward said he had had specimens like *Squilla* from the Lias; but they were only the young of *Eryon*, which were liable to be mistaken for *Squilla*, these two forms having much in common.



A. S. Foord lith.

FOSSIL



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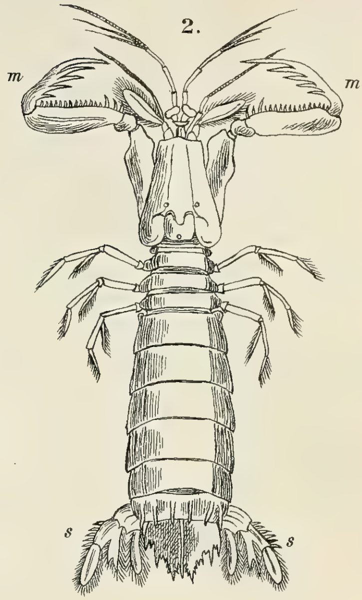

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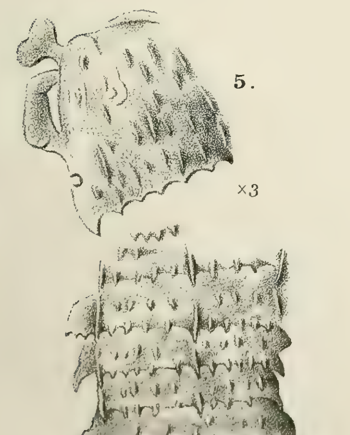

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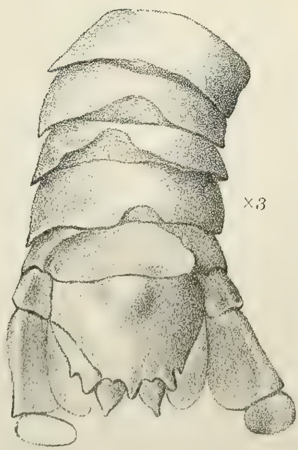
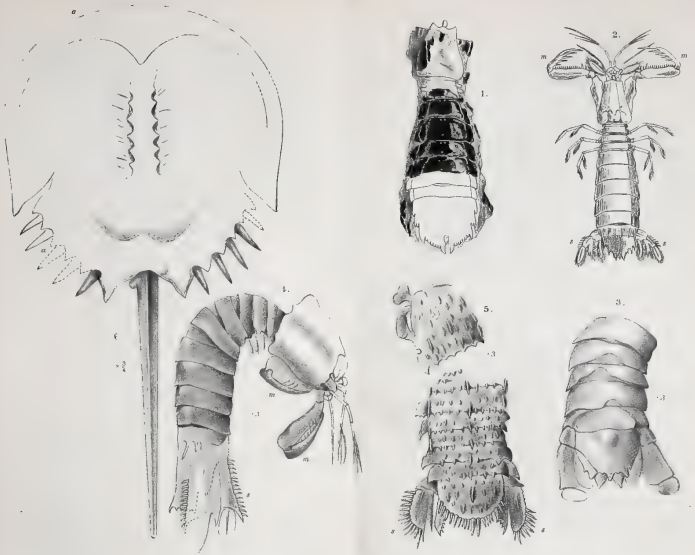


×3

USTACEA.

Mintern Bros imp.



A. S. Foord lith.

FOSSIL CRUSTACEA.

Mintern Bros imp.

43. *On the* Endothiodont Reptilia, *with Evidence of the Species* Endothiodon uniseries, *Ow.* By Professor Owen, C.B., F.R.S., F.G.S., &c. (Read May 28, 1879.)

[Plate XXVII.]

In the 'Descriptive and Illustrated Catalogue of the Fossil Reptilia of South Africa in the Collection of the British Museum'* a genus *Endothiodon* and the species *bathystoma* were founded on a portion of a skull and of a mandible from the Trias of Gouph † (p. 66, pls. lxvi. & lxvii.). The alveolar border of the upper jaw was subtrenchant, with a caniniform process on each side, as in *Oudenodon*. A section being made of this part, there was exposed, as in *Oudenodon magnus* (op. cit. p. 56, pl. liv., *c'*), a close osseous tissue, without trace of a canine or of a socket for any rudiment or germ of tooth (*op. cit.* p. 66, pl. lxvi., *c' c'*); whence I inferred that such premaxillo-maxillary margin might have been sheathed, as in Chelonia, with horn. The opposing outer border of the portion of the mandible presented a similar toothless, subtrenchant character, but was extended in an unusual degree internal to such margin, giving great transverse thickness to the rami from the symphysis as far backward as the dentary element was preserved.

On the palatal surface of the crushed cranial fragment a single median palato-narial aperture was exposed, and some small cylindroid teeth appeared to be scattered in two or more rows on each side of the palate (*ibid.* pl. lxvii. figs. 1 & 4). Sections of the mandible showed that such teeth had been opposed by similar ones developed in the thick inner border internal to the edentulous alveolar margin.

In the anterior portion of a mandible of the same species of *Endothiodon* subsequently discovered at "the Kloof" under the "Nieuwoeldt range" of the 'Gouph' tract, and transmitted by Thomas Bain, Esq., I had a horizontal section made of the right dentary, and exposed three series of teeth or portions of them, affording satisfactory confirmation of the dental character which the more fragmentary fossil previously at my command had less completely indicated (*op. cit.* p. 66, pl. lxvii. figs. 2 & 5).

In the section figured (Pl. XXVII. fig. 1) the innermost row of mandibular teeth, eleven in number (1–11), commences 1 inch 9 lines behind the foremost part preserved of the symphysis (the apex of which is wanting), and the row terminates 4 inches from that part. The form of each tooth is subcircular, the diameter varies from 6 to 4 millims.; the hindmost tooth shows the smallest size, the other ten

* 4to, 1876.

† A district bounded on the north by the Nieuwoeldt plateau, on the south by Zwarte Bay, on the east by Beaufort West, and on the west by Karoo Poort.

are subequal. A small pulp-cavity, circular in transverse section, is exposed in each tooth, larger in the first than in the rest. The series deviates very slightly from a straight line.

The second row (1′–10′) begins outside of and opposite to the interval between the eighth and ninth teeth of the inner row. Ten teeth are exposed, in section, in the second row, which extends 1 inch 4 lines behind the last tooth of the inner row. There is a fragment of what seems to be a tooth anterior to the first of the second row, and which would indicate that this row included eleven teeth like the inner row.

The foremost evidence of a tooth of the outer row (1*–6*) appears opposite the interval between the second and third of the middle row; it is represented by the outer half of the shell of an incompletely calcified crown. It is succeeded by a similar evidence of the coronal shell of a second tooth. The third, opposite the interval between the fourth and fifth of the middle row, shows the circular wall of the crown almost complete. The fourth and fifth teeth are fragmentary. The sixth tooth outside the interval between the seventh and eighth teeth of the middle row shows the entire section of its crown with a less wide pulp-cavity; it had been cut across nearer the apex. A seventh tooth of the outer row is less satisfactorily seen, and there are feeble indications of an eighth tooth.

Three teeth in the same transverse line are thus shown, composed of the tenth and eleventh of the inner row, the third and fourth of the middle row, and the first and second of the outer row. The best-shown teeth of the outer row have the same shape and nearly the same size as the others, but have wider pulp-cavities, which may indicate either that they have been cut across nearer their base or were less advanced in formation.

The larger portion of mandible of *Endothiodon bathystoma* here described and figured closely corresponds in size and shape with the similar portion originally described and figured (*op. cit.* pl. lxvii. figs. 2–5). In both the apex of the symphysis has been broken off; but in the later-received specimen above described the thick alveolar border of the right dentary had undergone less damage and was consequently selected for the section figured. That of the left dentary, though more abraded, permits eleven teeth of the middle row to be traced, the series commencing a little in advance of that of the right side, unless the fragmentary indication of the foremost tooth of that side be rightly interpreted.

The first, second, and third teeth of the middle row, left ramus, show, in section, a slightly incurved part of the periphery next the contiguous tooth of the inner row, such as one might see in a similar transverse section of the deciduous and successional teeth in the alveoli of a crocodile; but in such section the old tooth, the completed crown of which was being pressed upon by the new tooth, shows a more solid structure with minor indications of a pulp-cavity. In the three foremost teeth of the second row of *Endothiodon* the pulp-cavity is as large as in the three hindmost teeth of the inner row, and, moreover, the teeth of the middle row which follow and seem not to have a parallel continuation backward of the inner row, are circular in section and have not been indented through such relative position. Nor is that position, where it obtains, such as to suggest that the inner row could push out the teeth outside them. I conclude, therefore, that the three rows of palatal teeth † indicated in the type example of *Endothiodon bathystoma* were normally opposed by three rows of similarly shaped and slightly smaller teeth of the lower jaw.

ENDOTHIODON UNISERIES, Ow.

This species is founded upon the fore half of a skull including nearly the same parts and proportions thereof as the fossil indicative of the genus (*op. cit.* pl. lxvii.), but it has not been subject to the same pressure and distortion. It is of smaller size and differs more markedly in having but a single row of teeth on each side of the palate, which some may deem to justify a distinct generic appellation. It is, however, a reptile of the same singular and well-marked type as is exemplified by the fossils of *Endothiodon bathystoma*. As in that species, the trenchant alveolar border of the upper jaw commences with a caniniform process (Pl. XXVII. fig. 2, *c*), to the fore and inner part of which the premaxillary (ib. 22*) contributes a larger share than is indicated by the suture shown in the section of this quasi-canine in *Endothiodon bathystoma* (op. cit. pl. lxvii. fig. 6).

Of this process on the right side of the present species I also made a transverse section (fig. 3, 21*, 22**), and exposed only the osseous tissue, of which the outer part was of almost dentinal hardness, and the inner part closely or minutely cancellous. This process, howsoever covered in the recent reptile, would be used as a dental weapon, and have the same title to be called 'tooth' as that part in the beak of the Falcon.

The trenchant border of the maxillary, continued from the proportion which it contributes (figs. 2 & 3, 21*) to the caniniform process, describes a slight curve convex downward, concave outward, and gradually gains in thickness—though this may be partly due to abrasion of the original margin, which at the hinder third of both right and left maxillary exposes the same dense texture as in the caniniform process.

The premaxillary contributes the anterior third of the outer and the whole of the inner half of this process (fig. 3, 22**), being continued backward along the inside of the maxillary portion (ib. 21**). The suture exposed in the section (fig. 3, between 21* & 22*) extends upon the palatal surface of the skull along the fore border of the maxillary, 21′, and palatine, 20′, plates in a sigmoid course curving backward to the fore part of the vomer, 13. The premaxillo-vomerine suture is shown at 13′, fig. 3, Pl. XXVII. The interpremaxillary suture is obliterated, and the confluent pair of bones con-

† The pulp-cavity exposed by section of the palatal teeth, in the multiserial arrangement, shows a bright red tint, indicative of the ferruginous colouring-matter of the blood, in the type specimen of *Endothiodon bathystoma*.

tribute to form the roof of a large, deep, and smooth depression (ib. 22″) at the fore part of the palate. This depression is bounded laterally by the caniniform processes and anteriorly by the deflected fore end of the beak-shaped premaxillary. It has not the pair of longitudinal ridges at the fore part as in *Dicynodon* (op. cit. p. 46, pl. xxxix. 22′, pl. xliv. fig. 2, 22*), and in this respect resembles *Oudenodon* (op. cit. pl. lvi. fig. 2, 22); but *Endothiodon uniseries*, like *E. bathystoma*, repeats the same palatal character as in both those Anomodonts, in the vault-like expanse of the fore part of the roof of the mouth †.

From the hind part of the concavity the confluent premaxillaries are continued backward as a narrow process, convex lengthwise and across, perforated by a premaxillary slit (ib. ib. *a p*) and terminating pointedly between the parial vomerine plates (ib. 13, 13).

The nostrils (figs. 2 & 5, *n n*) are divided anteriorly by the deflected fore part of their roof, the fore end of which is broken off, showing the thickness of the nasal septum at that part (Pl. XXVII. fig. 5, *n s*). Each nostril has a trilobed shape; the fore lobe is defined from the hind one by the deflected fore part of an antero-posteriorly extended large and massive nasal bone (figs. 2, 4, 5, 15). The third smaller and lower lobe of the nostril extends between the premaxillary (fig. 2, 22*) and maxillary (ib. 21*) into the base of the caniniform process. The antero-posterior extent of the nostril is 1 inch 6 lines, the vertical diameter is 8 lines. It markedly differs in shape, and independently of distortion, from that of the nostril of *Endothiodon bathystoma* (op. cit. pl. lxvi., *n*), in which, however, the same extension of the cavity into the premaxillo-maxillary cleft at the base of the caniniform process is shown. The suture between the maxillary (21) and the nasal (15) has the same course in *Endothiodon uniseries* as in *Endothiodon bathystoma*.

The resemblance of the outer nostril to that in *Oudenodon magnus* (op. cit. pl. liv.) may be noted, in which a hinder lobe or division of that orifice is indicated by a prominence of the upper border, due apparently to a similar forward extension and descent of the nasal bone. The lower border of the nostril is also notched where it is continued into the premaxillo-maxillary suture (see also *Oudenodon Bainii*, op. cit. pl. lx. fig. 1, *n*); but this is more in advance of the caniniform process in *Oudenodon* than in *Endothiodon*.

The nasals (15) are separated from each other, as in most Birds, by the backward extension to the frontals (11) of a long and strong nasal or facial production of the premaxillary (fig. 4, 22). The transverse convexity and longitudinal deflection of this part of the premaxillary is as well marked in the smaller as in the larger species, and recalled the proportions of the same bone in *Aptornis otidiformis* ‡.

† The roof of the corresponding palatal concavity in *Dinornis robustus* shows a single median ridge ('Extinct Birds of New Zealand,' 4to, vol. ii. pl. lxv. fig. 1, 22).

‡ Memoirs on the Extinct Wingless Birds of New Zealand, 4to, vol. ii. pl. xliii. figs. 1 and 2.

The median line of the palate, in *Endothiodon uniseries*, describes a strong sigmoid curve, concave downward at its anterior half, convex at its middle to where the vomerine plates (13) pass into the palato-naris (*p n*, fig. 3). This aperture is single, pyriform, about an inch broad at the part preserved where the skull has been broken across. The narrower fore part is partially divided by the vomer (ib. 13), which sinks into the opening as the palate is viewed from the basal aspect shown in fig. 3; and there the two thin vertical lamellæ divide the nasal passages. The common hinder aperture beyond is bounded laterally by the thick and deep pterygoids (24). The vomerine lamellæ, as they emerge at the fore and narrow part of the palato-naris, become thickened, with smoothly rounded palatal margins, and are divided by sutures from the intervening perforated palatal process (*a p*) of the premaxillary.

The pterygoidean side walls of the palato-naris (ib. 24), smoothly concave mesially, swell out upon the palatal surface into irregularly convex tracts, 1 inch 4 lines in length, 7 lines in breadth posteriorly, and gradually narrowing to a point anteriorly, these pointed ends being divided from the bilamellar vomer by fissures (ib. *f*) conducting to the palato-naris. The pterygoids are divided by a groove from the palatal bones (ib. 20), supporting the single row of palatal teeth.

These teeth are nine in number on each side, disposed lengthwise in a slight curve concave outwards and parallel with that curvature of the alveolar border of the maxillary (ib. 21); from which border each tooth-series is separated by a shallow groove, 4 or 5 lines in width, along which extends the suture, of which the fore part is seen between 21′ and 20′, fig. 3. The teeth, which are all seen in transverse fracture, the crown-summits having been broken away, are subcylindrical in shape, composed of hard dentine, and without any exposure of a pulp-cavity at the line of fracture, which is nearly on a level with the supporting bone. The teeth are of equal or almost equal size, 6 to 7 millims. in diameter; the length of each series is 2 inches 4 lines. It is to be presumed that they were opposed by a similar single series on an answerable part of a broad upper surface of the dentary element of the mandible, since the number of palatal teeth, somewhat confusedly distributed in the type specimen of *E. bathystoma*, indicates an arrangement in three longitudinal rows, as in the lower jaw, Pl. XXVII. fig. 1.

The orbit in *Endothiodon uniseries* (fig. 2, *o*) is somewhat narrow vertically at the fore part and gradually widens, as far as its bony boundaries have been preserved, the lower one having been broken across at 2 inches distance from the fore part of the orbit, the upper one about 1½ inch from the same part. The lower boundary extends outwards, and the fracture has taken place at the beginning of the zygomatic arch which supports a part of the malar (ib. 26). The upper boundary terminates behind in the fractured surface of a tuberous and slightly deflected postfrontal, 12. Whether this was continued downward, as in *Oudenodon* (op. cit.

pl. lx. fig. 2), remains to be determined by more perfect specimens of *Endothiodon*.

The hind portion of the broken specimen of *Endothiodon uniseries* includes the fore part of the temporal fossa (fig. 2, *t*). The rhinencephalic canal (fig. 3, *rh.*), 6 lines in width, 3 lines in height, is exposed at the fracture in advance of the prosencephalic cavity; its fractured roof includes a vertical thickness of more than an inch of solid bone. Density and massiveness are eminent characteristics of the skull of the present Triassic reptile. The upper surface anterior to the temporal fossæ is boldly and irregularly sculptured. The convex nasal process of the premaxillary (fig. 4, 22′), with the anterior ends of the frontals (11) interwedged, is divided by large and deep channels from the elongate similarly convex and rugous nasals, 15, and prefrontals, 14, which augment the breadth of the cranio-facial platform. The prefrontal, 14, develops a roughened boss at the fore part of the orbit, anterior to which boss opens a large pseudo-narial foramen (fig. 2, *a*), the homologue of that which, in *Teleosaurus* *, also coexists with a true external nostril.

The postfrontal, 12, develops a similar boss, and the lower intermediate part of the upper border of the orbit may be contributed by either a superorbital bone or by an outward extension of the frontal, 11′.

The numerous fissures and irregular indentations over the tuberous and wrinkled upper surface of the skull render the determination of sutures between the frontals and superorbitals more or less ambiguous; but the example of *Oudenodon Greyi* (op. cit. pl. lxii. fig. 2, 11), in which the mid frontals are plainly divided by a suture from a narrow superorbital bone, weighs towards the belief of a similar ossicle, as marked at 11′ in fig. 4, Pl. XXVII., completing the upper rim of the orbit, on a lower level than the pre- and postfrontals, in *Endothiodon uniseries*.

I come now to the question of the additional light thrown by the skull of this species on the affinities of the genus in the Reptilian class. Amongst the cranial characters of the order Anomodontia are the following:—Premaxillaries confluent, forming a single edentulous beak-shaped bone, sending upward and backward a 'nasal process,' and forming below the roof of an anterior palatal vault, from which roof a process is continued backward to the vomer.' 'The nasal bones more or less divided by interposition of the nasal process on the premaxillary'†. Vomer consisting of a pair of vertical lamellæ contributing little to the bony roof of the mouth, dividing the narial passages at some distance from the wide and single palato-naris or posterior nostril."

In these characters *Endothiodon* agrees with the Anomodontia and,

* 'Hist. of Brit. Foss. Reptiles,' part. iii. (Crocodilia, pl. i. fig. 2, *a*).

† The sutures demonstrating this character are well shown in the skull of *Ptychognathus declivis* (Foss. Rept. S. Afr. pl. xlv. figs. 2, 15, & 22). The divided condition of the nasals and their relation to the outer nostrils repeat, in Birds, the structure here shown in Anomodonts. See *Dinornis robustus*, 'Wingless Birds of New Zealand,' pl. lxiv. figs. 2, 15, 22; and *Aptornis*, pl. lxxxiii. figs. 15 & 22.

in that order, resembles the Oudenodonts in the absence of the parial ridges projecting from the fore part of the roof of the premaxillary palatine vault; also in the presence of a caniniform process on each side of the alveolar border of the upper jaw, and in the tuberous prominence of the nasal bones above the nostrils—a character which is present in *Oudenodon prognathus* (tom. cit. pl. lxi. fig. 1, 15, "the supernarial tuberosity is relatively large," p. 59). In *Oudenodon magnus* also "a low protuberance of the nasal (pl. liv., 15) overhangs part of the nostril" (p. 56). The anteriorly contracted orbit, in the vertical direction, notable in both species of *Endothiodon*, is characteristic also of *Oudenodon prognathus* (tom. cit. pl. lxi. fig. 1, *o*).

In both species of *Endothiodon* the skull is relatively more produced anterior to the orbits than in most other Anomodonts: the nostrils are more advanced, and both the premaxillary and the maxillary bones contribute to the formation of the caniniform process. In connexion with this difference we find a greater relative anteroposterior extent of the nasal bones, and the occurrence of a pseudonarial opening between the nasal and postfrontal bones.

Dicynodon, the type of the order Anomodontia, shows a marked modification of the reptilian structure in the reduction of the dental system to the single pair of upper canines. In *Oudenodon* this modification is carried to the Chelonian extreme of an entire loss of teeth; but the cranial characters are Anomodont, not Chelonian.

Both *Oudenodon* and *Endothiodon* indicate a derivation from *Dicynodon* by the caniniform processes of the upper jaw, although all trace of tooth and socket is obliterated in the numerous specimens which I have subjected to examination. The combination of two bones in the formation of this process in *Endothiodon* is significant of its original edentulous condition in that genus, especially as the premaxillary constitutes the larger proportion of the process. In *Oudenodon* the process is exclusively formed by the maxillary.

With the above-cited evidence of adherence to the Anomodont type of reptilian skull, I regard the development of teeth internal to the alveolar margins of both upper and lower jaws as a character of family value in the order. The single row of palatal teeth in *Endothiodon uniseries* recalls the outer row of small teeth in *Placodus gigas*, Agassiz, and *Placodus Andriani*, Münster. The development of the premaxillaries along the upper and fore part of the skull and the position of the nostrils are also resemblances of the anomalous Muschelkalk reptile to the Anomodonts of the Cape Trias. The dental characteristics of *Endothiodon*, as of *Placodus*, doubtless related to the crushing for food of contemporary testaceous and crustaceous Invertebrates.

The palatal teeth in *Batrachiderpeton lineatum*, Hancock and Atthey, closely resemble in size and disposition those of *Endothiodon uniseries*; but in the Labyrinthodont from the Coal-shale they are associated with both premaxillary and vomerine teeth*. It is interesting to trace, however, the continuance of a common ichthyic

* 'Natural History Transactions of Northumberland and Durham,' vol. iv. plate iv. fig. 2, *i*.

and batrachial dental character cropping up, so to speak, in exceptional cases of Reptilia, rising toward the establishment of the crocodilian type, above which group of advanced Reptilia calcified palatal teeth no longer appear in the vertebrate series.

EXPLANATION OF PLATE XXVII.

Fig. 1. Section of part of right mandibular ramus, exposing the three rows of teeth, *Endothiodon bathystoma*.
2. Side view of fore part of skull, *Endothiodon uniseries*.
3. Under view of the same.
4. Upper view of the same (one half nat. size).
5. Front view of the same (*ib.*).

(All the other figures are of the natural size.)

Discussion.

Prof. Seeley inquired whether Prof. Owen had examined into the resemblances between *Endothiodon* and those European Muschelkalk reptiles which form the genus *Placodus*. The superficial resemblance was the more suggestive since animals closely allied to the South-African Anomodonts had already been described from Permian rocks in Russia. He also inquired as to the nature of the cranial characters which led the author to class the Endothiodont group rather with the Anomodonts than with those animals which Prof. Owen had called Theriodontia.

Prof. Owen replied that the great point of distinction between the Theriodontia and Anomodontia was that in the former the teeth are developed on the alveolar border of the jaws, not on the palate. In *Endothiodon* the teeth are palatal, and, as in *Oudenodon*, there are no teeth on the margin of the upper jaw. Other secondary points of distinction also go with these.

Fig. 2.

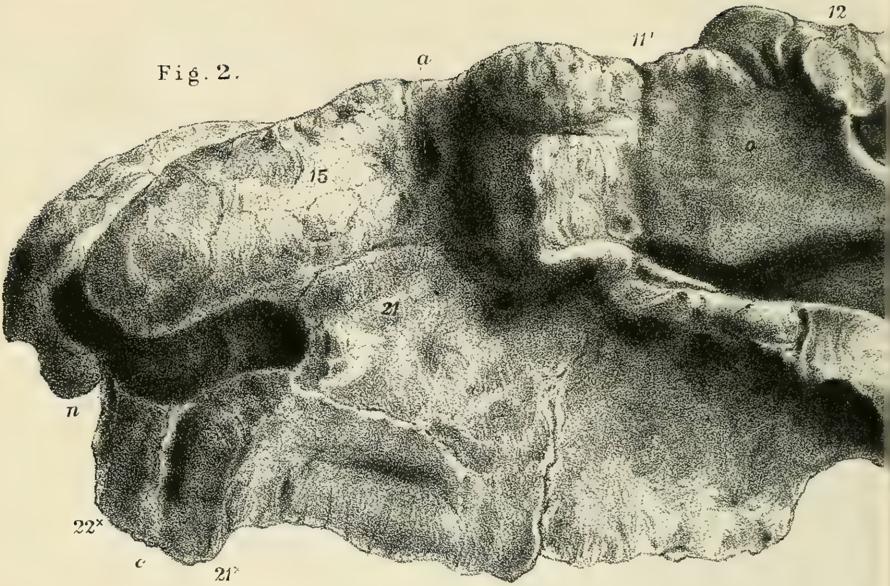


Fig. 4.

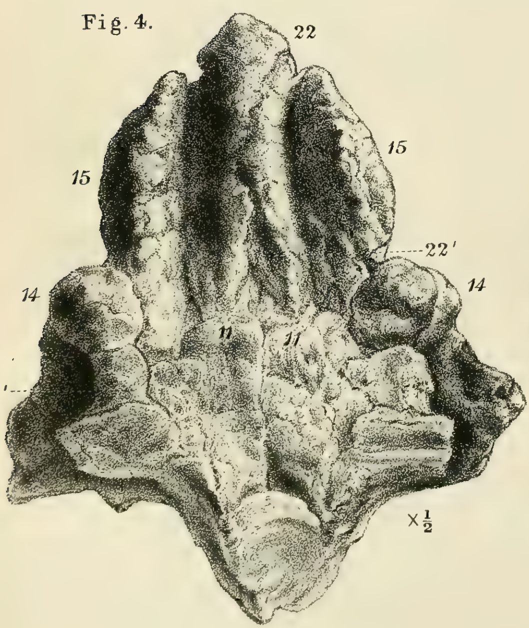


Fig. 5.

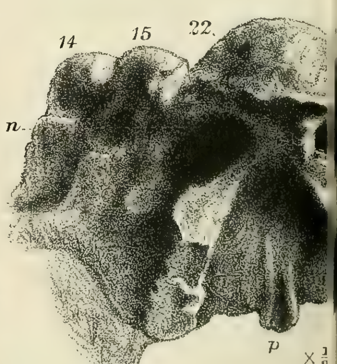


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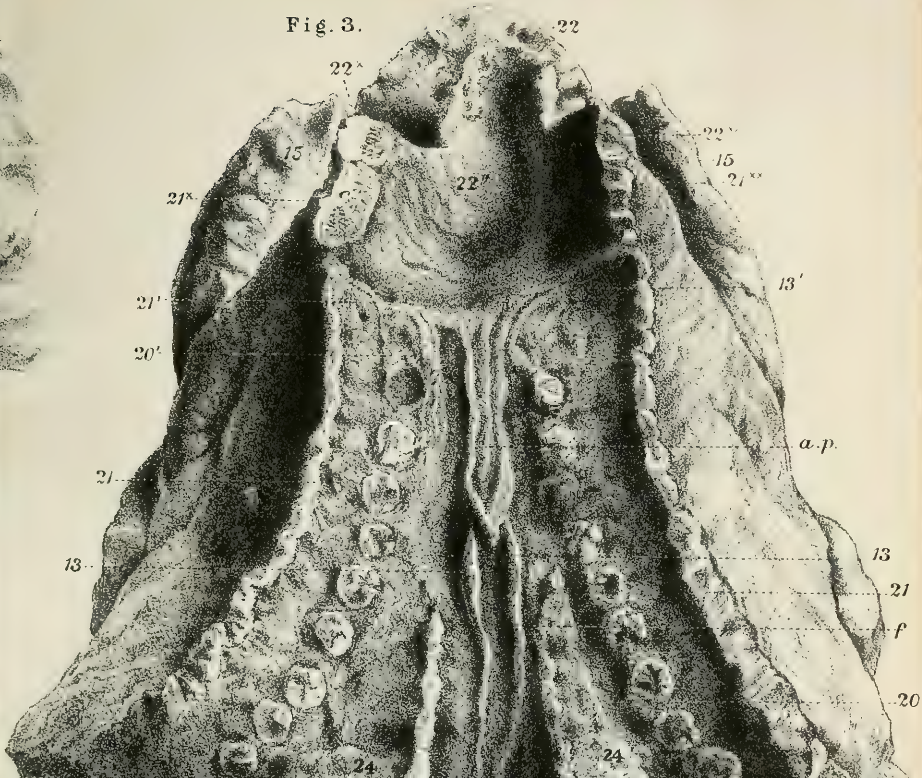
Fig. 1. E. BATHYS

Fig. 3.



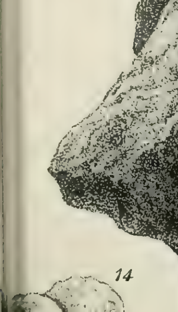
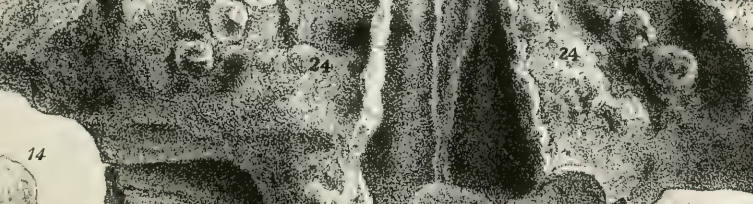


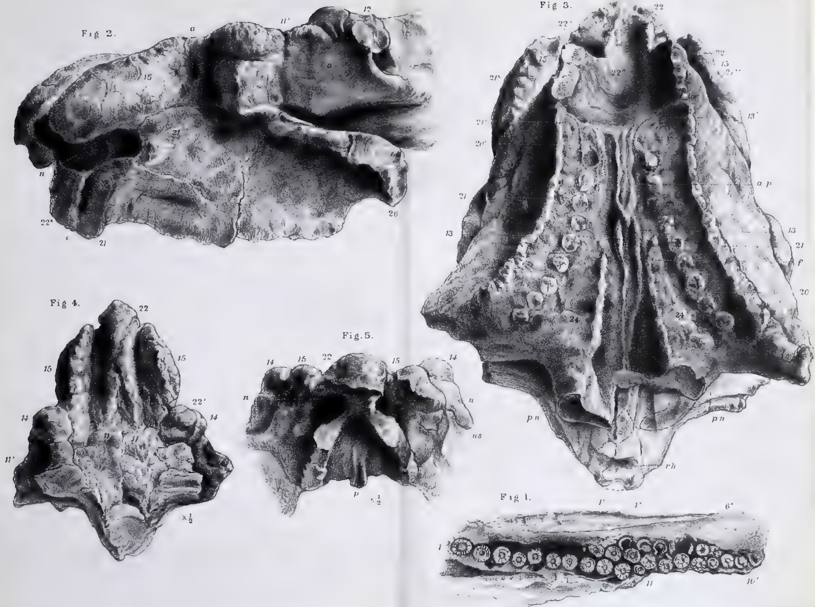
Fig. 1.



HIODON.

Figs. 2 – 5. E. UNISERIES

Mintern Bros imp.



A.S Foord del. Mintern Bros imp.

ENDOTHIODON.
Fig 1 E. BATHYSTOMA. Figs 2 - 5 E. UNISERIES.

44. DESCRIPTION *of the* SPECIES *of the* OSTRACODOUS GENUS BAIRDIA, *M'Coy, from the* CARBONIFEROUS STRATA *of* GREAT BRITAIN. By Professor T. RUPERT JONES, F.R.S., F.G.S., and JAMES W. KIRKBY, Esq. (Read May 28, 1879.)

[PLATES* XXVIII.–XXXII.]

THE genus *Bairdia* was instituted by Professor M'Coy, in 1844, for the reception of two species of Entomostraca from the Carboniferous Limestone of Ireland. Since then other species belonging to the same genus have been described from the rocks of the same age occurring in Scotland, Bohemia, Russia, and Australia; and many species have been made known from the Silurian, Permian, Triassic, Jurassic, Cretaceous, and Tertiary strata, as well as from existing British and foreign seas.

The recent forms of *Bairdia* are all marine, and are found at various depths, ranging from 10 to 500 fathoms; and the Carboniferous species (and those found in other formations) occur in limestones, and calcareous ironstones and shales, together with Corals, Crinoids, Polyzoa, and marine Shells of all classes.

Bairdia, in fact, is exceptionally marine in its mode of occurrence in Carboniferous strata. Other marine genera of Palæozoic Entomostraca often have some stray species occurring with equivocal associates. *Leperditia*, for example, which is a markedly marine genus, has one representative, *L. scotoburdigalensis*, met with as a very common fossil in the Calciferous-Sandstone series of the east of Scotland, where it repeatedly occurs with the remains of *Lepidodendron*, *Sphenopteris*, and Ganoid Fishes. *Beyrichia*, another marine group, has *B. arcuata* as a Coal-measure species, occurring with Plants, Fishes, and other fossils characteristic of that formation, but of dubious habitat. And so with *Kirkbya*, all the species of which are marine, though at times two of them, *K. plicata* and *K. spiralis*, appear in Lower-Carboniferous strata with *Sphenopteris affinis*, *Lepidodendron*, and *Stigmaria*.

We do not say that such doubtful companions indicate purely freshwater habits on the part of these Entomostraca, though such occurrences must mean differences in physical conditions compared with those prevailing during the formation of the limestones and other calcareous beds in which the species of these genera are usually found. Among the *Bairdiæ* we know of no such exceptions to the rule; they never occur with Fish- or Plant-remains. In the thin limestones intercalated in the thick Calciferous-Sandstone series of Fifeshire *B. plebeia*, *B. Hisingeri*, and *Leperditia scotoburdigalensis* occur, with *Orthoceras*, *Murchisonia*, *Schizodus*, and other marine shells; but the *Bairdiæ* always disappear, as well as the Mollusca, in the

* The cost of lithographing these Plates has been defrayed by a grant from the Royal Society.

intermediate beds, though *L. scotoburdigalensis* continues on in the shales and ironstones, where Plant- and Fish-remains come in as common fossils. We may here mention that six or seven species of the Ostracodous genus *Carbonia* *, with varieties, appear to have been constant inhabitants of the freshwater or brackish lagoons and shallow shore-waters where the British Coal-measures were formed; and they have not been found in any *marine* stratum of the Carboniferous series.

The *Bairdiæ* which we have to describe in this paper include all that are known from British Carboniferous strata. They are from the Upper and Lower divisions of the Carboniferous-Limestone series and the Calciferous-Sandstone series of Scotland, from the Yoredale Rocks and Scar Limestone of the Northern Counties of England, and from the Carboniferous Limestone of Wales and the West of England. The lowest portion of the series where they have been seen is probably the Calciferous Sandstone of Fife, where *B. plebeia*, *B. nitida*, and *B. siliquoides* are found from 3000 to 3800 feet below the base of the Carboniferous-Limestone series. The highest position in which Carboniferous *Bairdiæ* have been found in Scotland is in the upper division of the Carboniferous Limestone; and in England they occur in a somewhat equivalent position in the upper beds of the Yoredale Rocks. Though we have no specimens from the Millstone-grit or the Coal-measures, it is evident that several of the species continued to exist, in other areas, during the deposition of these Upper Carboniferous strata, for they reappear in abundance in the Permian rocks of Durham and Yorkshire and of Germany.

It should be mentioned that we are largely indebted to Mr. John Young, of Glasgow, for specimens and for information as to distribution; also to Messrs. James Thomson, James Armstrong, and David Robertson, of the same city; to Mr. J. R. J. Hunter, of Braidwood; to Mr. R. Etheridge, Jun., formerly of the Geological Survey of Scotland, now of the British Museum; to Mr. Charles Moore, of Bath, Dr. H. B. Holl, and others. Our examination of hundreds of specimens belonging to the Geological Survey of Scotland has greatly enlarged our knowledge of these Entomostraca.

Bairdia, M'Coy.

Professor M'Coy briefly described the genus as:—"Shell elongate, fusiform, suddenly tapering at both ends; a very short proportion of the valve overlaps the abdominal margin."

The generic characters have been more fully noticed by one of us in a 'Monograph of the Entomostraca of the Cretaceous Formation,' 1849, p. 22, and in a paper on "Permian Entomostraca from Durham," 'Trans. Tyneside Field-Club,' vol. iv. 1859, p. 139. More recently Prof. G. S. Brady has given an account of the genus, from a study of the recent species, in the 'Transactions of the Linnean Society,' vol. xxvi. p. 388, and the 'Transactions of the Zoological Society,' vol. x. p. 383.

* See Ann. & Mag. Nat. Hist. ser. 5, vol. iii. p. 28, pls. ii. & iii.

The Carboniferous (and Permian) forms are, like many others, usually more or less subdeltoidal in the general shape of the carapace, with the posterior end the smallest, and often pointed or rostrate. Other forms are subcylindrical, and others subovate, in outline. The left valve always overlaps the right along both margins, but most strongly and regularly on the dorsal margin. The surface is usually smooth, though occasionally pitted. In some examples the muscle-spot is seen; it consists of a congeries of small raised spots (seen as depressions on the internal casts), circularly arranged within a faintly sunken area.

1. Bairdia curta, M'Coy. Plate XXVIII. figs. 1–8.

Bairdia curtus (only partly exposed in its matrix *), M'Coy, 1844, Synopsis Carboniferous Limestone Fossils of Ireland, p. 164, pl. xxiii. fig. 6.

Cythere (*Bairdia*) *curta*, Jones, 1849, in King's Monograph of Permian Fossils, p. 61, pl. xviii. fig. 3.

Bairdia curta (freed from its matrix), Jones, 1870, Monthly Microscopical Journal, vol. iv. p. 185, pl. lxi. fig. 1.

After some oscillation of opinion, we think it best to look upon *B. curta* as distinct from *B. plebeia*. We discussed this question in 1859, when describing some Permian *Bairdiæ* †; and we returned to it in 1866, when we were inclined to look upon the two forms as belonging to one species ‡. But after further examination, with the help of additional material, it appears to be *least* objectionable to consider those specimens which have the anterior extremity angulated above as belonging to *B. curta*, and the specimens with the same extremity rounded both above and below as belonging to *B. plebeia*. In coming to this decision we are aware that the most is made of small differences, and that the existence of intermediate forms is in a measure ignored. But this is only what we have had to do in studying the Carboniferous *Bairdiæ* generally, and to some extent among the Ostracoda from other formations. The longer we investigate, and the more specimens we examine, the greater difficulty do we find in grouping the various forms and varieties into species. Doubtless had we the animal, as well as the carapace that enclosed it, to assist us in determining the species, important differences might be seen, which are only hinted at in the materials preserved to us §. And this possibility has been allowed to have some weight in the present instance as well as in others. We describe the species under notice as follows:—

* See 'Transact. Tyneside Field-Club,' vol. iv. p. 151; and Ann. & Mag. N. H. ser. 3, vol. xviii. p. 42.

† Trans. Tyneside Field-Club, 1859, vol. iv. p. 150.

‡ Ann. & Mag. Nat. Hist. 1866, ser. 3, vol. xviii. p. 42.

§ Not only specific, but even generic differences would probably be shown by the soft parts, were they preserved. Carapaces which we are obliged to refer to the one genus, *Bairdia*, may possibly belong to such different groups as *Bythocythere*, *Macrocypris*, *Paracypris*, and *Cytherura*, as defined by the researches of G. S. Brady, G. O. Sars, and others.

Carapace elongately subdeltoid in outline; length in type specimen less than two and a half times the height, in others considerably more than that. Dorsal border arched (in some examples flatly so), with both slopes slightly concave; ventral border straight or faintly incurved. Anterior extremity broad, rounded below, and angulate above; posterior extremity produced and rostrated. Left valve overlaps the right moderately on both borders. Surface smooth. Length $\frac{1}{25}$ to $\frac{1}{14}$ inch.

Fig. 1 represents Sir R. Griffith's original specimen (cleared from the matrix), from which Prof. M'Coy described the species. Fig. 3 is from a very beautiful example in the collection of Mr. John Young. Both it and fig. 6 are relatively longer, flatter in the arching of the dorsal border, and with a more broadly rostrated anterior end than the type specimen. Fig. 5 represents a right valve which is included in this species with some doubt. The posterior extremity is less elevated than in other specimens, and is acutely pointed rather than rostrated, and it has a straight slope on the hinder third of the dorsal border. Still the specimen has more the character of *curta* than of any other species; we refer to it as *B. curta*, var. *terebra*, and notice that it is near the Permian *B. rhomboidea*, Kirkby, Trans. Tyneside N. F.-Club, 1859, vol. iv. pp. 147 & 149.

Fig. 7 represents a variety which we name *bicornis*. Its dorsal border is elevated and flat in the middle region, with deeply excavated anterior and posterior slopes, both of which curve upward to form acutely angular extremities. The extremities make two strong convex curves, meeting at the middle of the ventral border, which is thus sinuated and incurved at the centre; it is rather more protuberant anteriorly than behind. The anterior extremity is thus broad and trenchant, and the posterior acutely and obliquely rostrated. The central portion of the valves rises abruptly from the regions adjoining the ventral border and the ends, which are compressed. The lateral outline of the carapace resembles the shape of a Scythian bow.

Fig. 8, var. *deformis*, is from an example from Steeraway, Salop, that has much in common with the one just noticed; but the slopes of its dorsal margin do not curve upward to acute points as in fig. 7, and the anterior third of the carapace is much more protuberant ventrally. In Mr. Charles Moore's collection.

Localities of Bairdia curta.

In England. *Carboniferous Limestone*: Wyebourne, Cumberland; Settle, Yorkshire; Steeraway, near Wellington, Salop.

In Scotland. *Carboniferous Limestone* (*Upper*): Kennox Water (Douglas) and Wester House (Carluke), both in Lanarkshire.

Carboniferous Limestone (*Lower*): Braidwood (Carluke), Brockley (near Lesmahagow), Shields Farm (East Kilbride), Calderside (South Shiells), all in Lanarkshire; Causland and Fernie Hill (Gilmerton), in Edinburghshire.

In the 'Annals & Mag. N. Hist.' ser. 1, 1847, vol. xx. p. 229,

&c., Prof. M'Coy, writing of the Carboniferous Entomostraca of Australia, refers to *B. curta* as occurring in the Dunvegan shales, together with a form which he recognizes as "*Cythere impressa*," M'Coy (*Beyrichia*?): see Ann. N. H. ser. 3, vol. xviii. p. 44, &c.

2. Bairdia plebeia, Reuss. Plate XXVIII. figs. 9–19.

Bairdia plebeia, Reuss, 1854, Jahresbericht wetterau. Gesellsch. 1854, p. 67, fig. 5.

B. Geinitziana, Richter, 1855, Zeitsch. deut. geol. Ges. vol. vii. p. 530, pl. 26. fig. 12.

B. plebeia, Kirkby, 1858, Annals Nat. Hist. ser. 3, vol. ii. p. 324, pl. x. figs. 1–7.

B. plebeia, Kirkby & Jones, 1859, Trans. Tyneside Nat. Field-Club, vol. iv. pp. 141–146, pl. ix. fig. 7.

Cythere (Bairdia) plebeia, Kirkby, 1861, Quart. Journ. Geol. Soc. vol. xvii. p. 308.

Cythere (Bairdia) plebeia, Kirkby, 1862, Annals of Nat. Hist. ser. 3, vol. x. p. 203, pl. iv. figs. 5–10.

Cythere plebeia, E. E. Schmid, 1867, Neues Jahrbuch, &c. 1867, p. 581, pl. vi. fig. 26 (not figs. 1–25 & 27–45; these are all grouped together at pp. 582 & 588).

Bairdia plebeia, Jones & Kirkby, 1875, Ann. Nat. Hist. ser. 4, vol. xv. p. 56, pl. vi. figs. 6, 7.

B. plebeia, as a Permian species, has been described by both Reuss and ourselves; but we will briefly notice its leading features from Carboniferous specimens.

Subdeltoid in outline, with the valves convex except at the ends, which are compressed; length a little more than twice the height. Dorsal border arched, with the posterior slope always concave, and the anterior slope occasionally so; ventral border straight or slightly incurved. Anterior extremity rounded, most prominent above; posterior extremity rostrated. The right valve strongly overlapped by the left on the dorsal border, and on the centre of the ventral border. Surface smooth; rarely pitted. Length $\frac{1}{25}$ to $\frac{1}{18}$ inch.

Carboniferous specimens of this species present many variations of form. These variations mainly consist of increase in relative length, of sinuation or non-sinuation of the anterior slope, of the tendency of the anterior extremity to become subangulated, and proportionate length and rostration of the posterior extremity.

Fig. 15 is from a Craigenglen specimen, showing a coarsely pitted surface, in which character it resembles *B. ampla*; nevertheless the general form of the carapace is that of *plebeia*.

Figs. 16–18 show a much inflated form from the Carboniferous Limestone of Backwell, near Bristol. The lateral contour and end view of this specimen differ considerably from those of ordinary *B. plebeia*.

B. plebeia appears to have been the prevailing form of the genus during the Upper Palæozoic periods. The following *Localities* are some of those where it has been found:—

In England and Wales. *Yoredale Rocks*: Whorlton and Barnard Castle, in Durham.

Carboniferous Limestone: Weardale, Durham; Wyebourne, Cumberland; Settle, Yorkshire; Great Ormes Head, Caernarvonshire; Backwell and Charterhouse, in Somerset; Weston-super-Mare, Somerset; Brocastle, South Wales.

In Scotland. *Carboniferous Limestone* (*Upper*): Pathhead, Fife; Levenseat Limestone-Pits, Edinburghshire; Gare, Carluke, and Robroystone, in Lanarkshire; Garple Burn (Muirkirk), Williamswood near Cathcart, and Orchard near Pollokshaws, in Renfrewshire; Swindridge and Highfield (Dalry) in Ayrshire.

Carboniferous Limestone (*Lower*): Pitlessie Limeworks, coast near Ardross, and coast east of St. Monans, in Fifeshire; Darcy Quarry, Currielee Limeworks, Magazine Limeworks, Causland, West Mains Farm (Baads), Mount Lothian, Fullarton, Bents, Mansfield, all in Edinburghshire; Prestongrange, East Lothian; Galabraes, Linlithgowshire; Calderside, South Shiells, East Drunnloch, Shield's Farm (East Kilbride), High Blantyre, Brockley (Lesmahagow), Carluke, Brankumhall Quarry, all in Lanarkshire; Corrieburn (Sculliongeur), Craigenglen, Campsie, in Stirlingshire; Broadstone, Howrat (near Beith), Craigie (Kilmarnock), in Ayrshire; Campbeltown, Argyleshire.

Calciferous Sandstone: Coast near Randerstone; coast east of Pittenweem, and coast west of Pittenweem, Fifeshire; Donkin's Quarry, near Ecclefechan, Dumfriesshire.

3. Bairdia Hisingeri, Münster. Plate XXIX. figs. 4–10.

Cythere Hisingeri, Münster, 1830, Jahrbuch für Mineralogie, p. 65.

Bairdia Schaurothiana, Kirkby, 1858, Annals Nat. Hist. ser. 3, vol. ii. p. 329, pl. x. fig 14.

Cythere Schaurothiana, Geinitz, 1861, Dyas, p. 36.

Cythere (*Bairdia*) *Schaurothiana*, Kirkby, 1862, Ann. Nat. Hist. ser. 3, vol. x. p. 203, pl. 4. figs. 1–12.

Bairdia Hisingeri, Jones & Kirkby, 1865, Ann. Nat. Hist. ser. 3, vol. xv. p. 408, pl. xx. fig. 12.

Subrhomboidal in outline; convex: length rather more than twice the height. Dorsal border straight or slightly convex in the middle portion, with an easy slope to the anterior extremity, and an abrupt one to the posterior extremity; ventral border incurved anteriorly, and rounded towards each end. Anterior extremity broad, rounded, and overhanging above; posterior extremity projecting (ram-like), subangulate, or slightly rostrated. The left valve overlaps the right strongly along the dorsal border; also along the ventral border, where a flange projects about the anterior third. Surface smooth. Muscle-spot placed near the centre of the valve, and formed by a central dot, surrounded by eight or more others, all of which are somewhat raised above the surface of a shallow circular excavation. Length $\frac{1}{10}$ inch.

This robust species is distinguished by its great size, rhomboidal form, and abrupt posterior slope—also, in many specimens, by the strong overlap of the left valve, especially on the ventral border, and, in consequence, by a more distinct antero-ventral curve, amounting almost, in some cases, to a blunt angle.

Next to *B. plebeia*, this species is, perhaps, of the most common occurrence in Carboniferous strata. Some of the *Localities* known to us are given below:—

In England and Wales. *Carboniferous Limestone*: River Wansbeck, Northumberland; Wyebourne, Cumberland; Great Ormes Head, Caernarvonshire; Steeraway, Salop; Holwell, Somerset.

In Scotland. *Carboniferous Limestone* (*Upper*): Gillfoot, Carluke, and Kennox Water (Douglas), in Lanarkshire.

Carboniferous Limestone (*Lower*): Mayfield Quarry and Currielee Limeworks (near Dalkeith), West Mains Farm (Baads), Fullarton, Mount Lothian, all in Edinburghshire; Galabraes, White Baulks, North Mine Quarry, in Linlithgowshire; Prestongrange (East Lothian), Hillhead Quarry (Wilsontown), South Shiells, Fullwood (Carluke), Braidwood (Carluke), Brockley (Lesmahagow), in Lanarkshire; Craigenglen, Campsie, Stirlingshire; Craigie (near Kilmarnock) and Howrat (near Dalry) in Ayrshire.

Lower Carboniferous Series: Donkin's Quarry (near Ecclefechan) and Bonshawburnhead Quarry, in Dumfriesshire.

4. Bairdia ampla, Reuss. Plate XXVIII. figs. 20–23; Pl. XXIX. fig. 3; Pl. XXXII. figs. 17, 18.

B. ampla, Reuss, 1854, Jahresb. der wetterau. Ges. p. 68, fig. 7.

B. ampla, 1859, Jones, Trans. Tyneside Field-Club, vol. iv. pp. 162 & 166, pl. xi. figs. 14, 19.

B. ampla, Kirkby, 1861, Quart. Journ. Geol. Soc. vol. xvii. p. 308.

B. ampla, Jones & Kirkby, 1875, Annals Nat. Hist. ser. 4, vol. xv. p. 56, pl. vi. fig. 5.

B. ampla is not of very common occurrence in Carboniferous strata, though examples are found showing the punctate surface-ornament characteristic of the species in the Permian formation. Of the specimens figured, perhaps the valve from Whorlton (Pl. XXIX. fig. 3) is the most typical, having the finely arched dorsal border, with the convex slopes, the broad and evenly rounded anterior extremity, and the nearly straight ventral border of good Permian examples.

The internal cast of a left valve from Wyebourne (fig. 23) shows an impression of the muscle-spot, which is formed of six small spots grouped round a central spot. This cast approaches *B. brevis*, J. & K., in outline, but differs therefrom in its greater relative length.

Localities of B. ampla.

In England. *Yoredale Rocks*: Whorlton, Durham.

Carboniferous Limestone: Wyebourne, Cumberland.

In Scotland. *Carboniferous Limestone* (*Upper*): Levenseat, Edinburghshire.

Carboniferous Limestone (*Lower*): Darcy Quarry (Dalkeith) and Mount Lothian, in Edinburghshire; North Mine Quarry (Linlithgowshire), Hairmyres (East Kilbride), Auchenbeg (Lesmahagow), in Lanarkshire; Dockra (Beith), Craigie (Kilmarnock), in Ayrshire.

Other figures of this species are here given for the purpose of showing the pitted surface that often characterizes well-preserved specimens.

Fig. 17, Pl. XXXII., is from Hairmyres, East Kilbride.

From Blinkbonny Quarry and some other localities we have specimens, collected by the Geological Surveyors of Scotland, showing an irregularly reticulated surface, as depicted in fig. 18, Pl. XXXII. These specimens approach *B. plebeia* in some of its forms; but from that species they differ in having a decidedly convex ventral border, and much greater rotundity of valves, with greater relative length.

5. Bairdia grandis, n. sp. Plate XXIX. figs. 1, 2.

Cythere (*Bairdia*) *plebeia*, Reuss, var. *grandis*, Jones, 1859, Trans. Tyneside Field-Club, vol. iv. p. 162, pl. xi. fig. 13.

From Whorlton and some other localities we have a large form of carapace-valve that well answers to the cast described and figured as *B. plebeia*, var. *grandis*, as above quoted. The carapace reminds us rather more of *B. subdeltoidea*, as to its shape, than *B. plebeia*. Its size, too, and its relatively greater height and less produced posterior extremity, all distinguish it from *B. plebeia*. Hence we raise it to specific rank, and describe it thus:—

Subdeltoid in outline; length less than twice the height. Dorsal border boldly convex, with sinuous anterior and posterior slopes; ventral border straight. Anterior extremity broad, rounded; posterior extremity bluntly pointed. Surface smooth. Length $\frac{1}{12}$ inch.

B. grandis has been found in *Yoredale Rocks* at Whorlton, Durham, and in *Carboniferous Limestone* (*Lower*) at Carluke, Lanarkshire.

6. Bairdia mucronata, Reuss. Plate XXIX. fig. 11.

B. mucronata, Reuss, 1854, Jahresb. wetterau. Ges. p. 67, fig. 6.

B. mucronata, 1855, Richter, Zeitschrift deutsch. geol. Ges. vol. vii. p. 531, pl. 26. figs. 18, 19,

We have a single specimen of a carapace-valve from Whorlton, which corresponds closely with the figure of *B. mucronata* given by Reuss and Richter, except in being somewhat higher—a difference of, perhaps, no moment as to specific relationship. Reuss describes the species as follows:—"Elongately elliptical; rounded in front; running out behind into a long, narrow, compressed flap; upper margin arched; under margin almost straight; surface smooth." This answers very well for our specimen.

In *Yoredale Rocks* at Whorlton, Durham.

7. Bairdia submucronata, n. sp. Plate XXIX. figs. 12–18.

B. mucronata, Reuss, var. *submucronata*, Jones and Kirkby, 1867, Trans. Geol. Soc. of Glasgow, vol. ii. p. 222.

We have specimens from Whorlton and from various localities in Scotland that possess some affinity to *B. mucronata*, but which differ from it in having an elliptical ventral margin, a more symmetrical and less pointed posterior extremity, and a lateral contour which, though convex, is flattened over its central portion. Some of the specimens show a tendency to become subrhomboidal, with a faintly rostrated posterior extremity, and so approach *B. plebeia*. But we are inclined to look upon these specimens as distinct both from the latter species and *B. mucronata*, and describe them as follows:—

Subpyriform or subrhomboidal in outline; greatest height about the anterior third; length about two and a half times the height, or less. Both dorsal and ventral borders convex. Anterior extremity roundly prominent; posterior extremity rather acutely pointed. Lateral contour flatly convex, with the posterior end the most acute. Surface smooth. Length $\frac{1}{25}$ inch.

Localities of B. submucronata.

In England and Wales. In *Yoredale Rocks* at Whorlton, Durham; and in *Carboniferous Limestone* at Great Ormes Head, Caernarvonshire.

In Scotland. *Carboniferous Limestone* (*Upper*): Gare (Carluke) and Robroystone in Lanarkshire; Orchard, near Pollokshaws, in Renfrewshire.

Carboniferous Limestone (*Lower*): Currielee Limeworks, Magazine Limeworks, Mansfield, in Edinburghshire; Corrieburn, Craigenglen (Campsie), and Sculliongeur, in Stirlingshire; Carluke and Brockley in Lanarkshire.

Lower Carboniferous Series: Bonshawburnhead Quarry, Dumfriesshire.

8. Bairdia subelongata, n. sp. Plate XXX. figs. 1–11 & 16.

B. subcylindrica (Münster), Jones & Kirkby, 1867, Trans. Geol. Soc. Glasgow, vol. ii. p. 221.

B. subcylindrica (Münster), Armstrong & Young's Catalogue of Carb. Foss. of Western Scotland (1871).

We have many specimens of a long, narrow form of *Bairdia*, which have much in common with *B. elongata*, Münster, but do not approach near enough to that species (so far as we know it) to permit of absolute identification. This form we describe under the name of *subelongata*.

Elongate; length more than three times the height. Dorsal border straight or very slightly convex; ventral border straight or very slightly concave, and parallel (or nearly so) with the dorsal border. Anterior extremity broadly rounded, evenly so in many cases, but sometimes most prominent above; posterior extremity bluntly pointed, being diagonally truncate, as it were, above and below. Dorsal overlap moderate. Lateral contour about four times as long as wide, flat or flatly convex for a good central third, with pointed ends, the anterior being rather the most acute. Surface smooth. Length $\frac{1}{18}$ inch.

This description applies most exactly to the more typical examples, which are always to be distinguished by their nearly straight backs, regularity of height, and well-rounded anterior ends.

Specimens, however, occur whose backs are decidedly curved, whose height is not so equal throughout, and whose anterior ends lose the normal broadly rounded form of typical examples. Possibly such specimens (figs. 6, 8, 9) may represent a variety; but, as their lateral contour shows little or no variation, we look upon them as not showing too great a divergence from the type of this species.

Other specimens, while retaining the almost straight and parallel borders of the species, possess more pointed posterior extremities, as shown in figs. 7 & 10.

We were once inclined to look upon the examples having a convex dorsal border as probably the same as Münster's *B. subcylindrica*; but that species has the dorsal border more finely arched, a smaller anterior extremity, and a more convex lateral contour than any of the elongate forms of *Bairdia* we are noticing. This will be seen on comparing the latter with figures 14 & 15, which are from a Bavarian example of Münster's species.

Figs. 12, 13, inserted for comparison, represent what we consider to be an elongate form of *B. Hisingeri*, from Campsie.

Localities of B. subelongata.

Wales. In *Carboniferous Limestone*, at Great Ormes Head, Caernarvonshire.

Scotland. *Carboniferous Limestone* (*Upper*): Ravenscraig, near Kirkcaldy, Fifeshire; Levenseat Limestone-pit, Mid Lothian; River Avon, below Kinneil Mill, Linlithgowshire; Garple Burn, near Muirkirk, Ayrshire; Orchard, near Pollokshaws, Renfrewshire; Gare (Carluke), Meikle Earnock Burn, Climpy (Wilsontown), Gillpott (Carluke), Auchenbeg (Lesmahagow), in Lanarkshire.

Carboniferous Limestone (*Lower*): Seafield Tower and Inverteil Quarry near Kirkcaldy, Abden near Kinghorn, Pitlessie Quarries, Wilkinson Quarry near Cupar, Ladedda Quarry near Cupar, Woodtop Quarry (Teasses), St. Monan's, Woodend Quarry near Fordel, Charleston Quarry, in Fifeshire; Brunston Colliery, Blinkbonny Quarry, Darcy Quarry (S.W. of Dalkeith), Magazine Limeworks, Mount Lothian, Baad's Mill, Mansfield, Fullarton, Currielee, in Mid Lothian; Catcraig Land Quarry, near Dunbar, in East Lothian; North Mine Quarry, Galabraes Quarry, in Linlithgowshire; Craigenglen (Campsie), Corrieburn, in Stirlingshire; Carlops Quarry, Whitefield Old Quarry, in Peeblesshire; Calderside Quarry, Boghead (Hamleton), East Drumock, Hillhead Quarry near Wilsontown, Ponfeigh Burn and Craigburn near Douglas, Fulwood and Braidwood (Carluke), Mousewater near Lambcatch, Sheills, Brankumhall Quarry, Brockley near Lesmahagow, High Blantyre, in Lanarkshire; Craigie (near Kilmarnock), Dockra (Beith), in Ayrshire.

Calciferous Sandstone: Billow Ness, Fifeshire.

9. BAIRDIA SUBGRACILIS, Geinitz. Plate XXX. fig. 17.

Bairdia gracilis, Jones (non M'Coy), 1850, in King's Monogr. Perm. Foss. p. 63, pl. 18. fig. 7.

B. gracilis, Reuss, 1854, Jahresb. wetter. Gesellsch. 1854, p. 65, figs. 2 *a*, 2 *b*, 3.

B. gracilis, Richter, 1855, Zeitsch. deut. geol. Ges. vol. vii. p. 530, pl. 26. figs. 16, 17.

Cythere (Bairdia) gracilis (M'Coy?), Jones, 1859, Trans. Tyneside N. F.-Club, vol. iv. p. 163, pl. xi. fig. 15.

Bairdia subgracilis, Geinitz, 1861, 'Dyas,' p. 34, figs. 9*a–c*.

From the "Main Limestone" of the Carluke district we have examples of an elongate *Bairdia* (fig. 17) possessing a more strongly convex dorsal and incurved ventral border than any specimens we have described as belonging to *B. subelongata*. They have altogether a curved outline, the dorsal border being convex and the ventral border concave, with the anterior half of the carapace considerably the larger. The posterior extremity is pointed, and the anterior rounded. These specimens have not the shell well preserved; but, so far as can be judged, they come very near the Permian form, which one of us identified with *B. gracilis*, M'Coy, and which Dr. Geinitz has since named *subgracilis*.

The figures given for this species by Reuss, Richter, and Geinitz differ somewhat among themselves as to the relative proportions of the posterior third of the carapace; but the general shape sufficiently accords throughout to indicate a specific alliance.

10. BAIRDIA BREVIS, Jones & Kirkby. Plate XXXI. figs. 1–8.

B. brevis, J. & K. 1867, Trans. Geol. Soc. Glasgow, vol. ii. p. 221.

B. brevis, J. & K. 1871, Armstrong and Young's Cat. Carb. Foss. of West Scotland, p. 25.

Subrhomboidal; length about half as much again as the height. Dorsal border boldly convex, the posterior slope of the arch being much the deepest and rather concave; ventral border convex in most examples, but in some nearly straight in the centre and rounded towards the ends. Anterior extremity broad, rounded, or subtruncate, most prominent above; posterior extremity rostrated, with the beak usually more or less acute. Lateral contour broadly lenticular, with the greatest width in the centre, which is rather less than half the length. Surface smooth. Length $\frac{1}{25}$ to $\frac{1}{20}$ inch.

The specimens figured show the most important variations of outline. Such variations mainly relate to the amount of inward slope of the anterior extremity, as depicted in figs. 3 & 5, and to the convexity of the ventral border, which, in such examples as are represented by figs. 2 & 3, forms a bold sweep continuous with the inferior slopes of the two extremities, while in others (fig. 5) it is flattened in the centre to nearly a right line.

Compared with its height (about two thirds of the length), this is the shortest species of the genus.

Localities. In England this species has been found in the *Carbo-*

niferous-Limestone series of Wyebourne, Cumberland; Weardale, Durham; Charterhouse, Somerset; and Scremerston, near Berwick-on-Tweed.

In Scotland. *Carboniferous Limestone* (*Upper*): Climpy, Wilsontown, Lanarkshire.

Carboniferous Limestone (*Lower*): Seafield Tower and Inverteil Quarry (near Kirkcaldy), Abden (Kinghorn), Roscobie and Charleston Quarry (near Dunfermline), Ladedda, Wilkinson, and Woodtop Quarries (near Cupar), Pitlessie Quarries, in Fifeshire; Hillhead Quarry (near Cockmuir Bridge), Blinkbonny Quarry, Brunston Colliery, in Mid Lothian; Salton Limeworks, Kidlaw Quarry, Paiston Quarry, Catcraig Land Quarry and Burlage Quarry (near Dunbar), in East-Lothian; Craigenglen (Campsie), Spouthead Burn, in Stirlingshire; Brockley (Lesmahagow), Braidwood (Carluke), in Lanarkshire; Bonshawburnhead Quarry, Dumfriesshire.

11. Bairdia siliquoides, sp. n. Plate XXXI. figs. 9–14.

Siliquiform, or pod-shaped; length from two and a quarter to less than three times the height. Dorsal border almost evenly arched, with the extremities nearly alike, the anterior being rather wider or less acute than the posterior; ventral border convex. Lateral contour plumply lenticular. Surface smooth? Length $\frac{1}{20}$ to $\frac{1}{18}$ inch.

Most of the examples of this species which we have seen were collected by the officers of the Geological Survey of Scotland, from a shale of the Carboniferous-Limestone series, on the River Avon, Linlithgowshire. These specimens are all single valves, and do not show the hingement as well as could be wished. We have one specimen from a thin limestone of the Calciferous-Sandstone series of Fife, with the valves united, but not in such preservation as to display clearly the amount of overlap along the dorsal border. Still we have not much doubt of the species belonging to *Bairdia*; it is a well-characterized form, and comes nearest to the little-known Permian species *Bairdia acuta*, Jones.

Localities.—Scotland. *Carboniferous Limestone* (*Upper*): River Avon, below Kinneil Mill, Linlithgowshire; Kennox Water, Douglas, Lanarkshire.

Calciferous Sandstone: Coast near Randerstone, south of Kingsbarns, Fifeshire.

12. Bairdia amputata, Kirkby. Plate XXXI. figs. 15–18.

Bairdia truncata, Kirkby, 1858, Ann. Nat. Hist. series 3, vol. ii. p. 433, pl. xi. fig. 4.

Cythere amputata, Kirkby, 1859, Trans. Tyneside F. C. vol. iv. pp. 155, 156, & 167, pl. xi. fig. 22.

We have a single specimen from Paiston Quarry, East Lothian, that apparently belongs to the Permian species *Cythere amputata*, Kirkby. But this example is larger and in better condition than any Permian specimens (casts) we have seen; and it shows in the overlap of the right valve by the left, along the dorsal edge, and in the rostrated form of the posterior extremity, that the species is more properly placed with *Bairdia* than *Cythere*.

This Carboniferous specimen is relatively higher and has the dorsal border more angulate than Permian examples. It may be described as follows:—

Elongately subpentagonal; convex: length twice the height, which is greatest at the anterior third, from which point the dorsal border descends in right lines towards each extremity. Anterior extremity broad, truncated inwards; ventral border projecting (flap-like) at the anterior ventral angle, and sloping inwards behind towards the posterior extremity: this end of the valves is bluntly rostrated, the upper slope being deep and abrupt. Lateral contour lenticular; greatest width about the anterior third, and more than one third of the length. Surface smooth. Length $\frac{1}{18}$ inch.

B. amputata is a strongly characterized species. It can always be distinguished by the angularity of its general outline and its abruptly truncate anterior end.

As a Carboniferous species, it has only occurred in the Lower Carboniferous-Limestone shale of Paiston Quarry, East Lothian, where it was found by the officers of the Geological Survey of Scotland.

13. Bairdia præcisa, n. sp. Plate XXXII. figs. 1–6.

Ovately subrhomboidal, compressed; length less than twice the height. Dorsal border strongly convex, with the posterior slope much the deepest; the anterior slope forms an abrupt angle with the anterior extremity, which is broad and obliquely truncate inwards and downwards; ventral border straight; posterior extremity rounded or slightly subangular. The left valve overlaps the right along the whole of its border, most strongly so dorsally and at the antero-dorsal angle. Lateral contour more or less wedge-shaped, the greatest width being at the anterior third. Surface smooth? Length $\frac{1}{22}$ inch.

The specimens on which the preceding description is based were found in a thin limestone of the Calciferous-Sandstone series near Randerstone, Fife. Their outline somewhat resembles a reversed *Leperditia*; their mode of hingement, however, their truncated anterior end, and wedge-like lateral contour show that such likeness is not real.

This species has been met with only at the above-mentioned locality.

14. Bairdia nitida, n. sp. Plate XXXII. figs. 9–12.

Elongately subovate; highest at the anterior third; rounded in front, tapering to a point behind; very convex: length two and a half times the height; width greater than the height. The dorsal border slopes gently downwards from the anterior to beyond the posterior third, whence it descends abruptly to form the posterior extremity; the ventral border is convex. Overlap of the left valve moderate. Lateral contour tumidly lenticular, widest in the centre. Surface smooth. Length $\frac{1}{20}$ inch.

This neat and plump form of carapace has apparently no very near Carboniferous relations. Perhaps it approaches most closely to the mucronate forms of the genus.

The only example which we have found occurred at Anstruther, Fifeshire, in one of the thin limestones of the Calciferous Sandstone, about 3800 feet below the base of the Carboniferous-Limestone series. It was there associated with *Beyrichia subarcuata* and species of *Spirorbis*, *Myalina*, *Macrocheilus* (?), and *Orthoceras*. This, we believe, is the earliest appearance of *Bairdiæ* in Carboniferous strata.

15. Bairdia circumcisa, sp. n. Plate XXXII. figs. 13–16.

Reniform, compressed; length about twice the height. Dorsal border arched; extremities rounded, the anterior being the highest and most blunt; ventral border straight. Dorsal overlap of left valve strong. Lateral contour compressed in the centre, pointed at the ends; width rather over a fourth of the length. Surface smooth. Length $\frac{1}{20}$ inch.

The only example we have seen of this form is slightly injured near the anterior end, as shown in the figures. Its general outline resembles that of *Cythere bilobata*, Münster; but that species is very convex, and has an incurved ventral margin. *Bairdia æqualis*, D'Eichwald, seems to be a related form.

From the *Carboniferous Limestone* (*Lower*) of Whitebaulks Quarry, near Linlithgow. The specimen belongs to the Geological Survey of Scotland.

16. Bairdia, sp.? Plate XXXII. figs. 7, 8.

We have seen in the collection of the Geological Survey of Scotland the curious carapace from the *Carboniferous Limestone* (*Lower*) of Cowden's Quarry, near Dunfermline, Fifeshire, that is represented by figs. 7 & 8, Pl. XXXII. It looks like a very much attenuated relative of *B. præcisa*. It may probably be somewhat malformed; for the postero-ventral region shows traces of injury. Until other examples turn up we forbear doing more than figure it.

Conclusion.

The species of *Bairdia* we have described and figured in this paper are, it is believed, all that have been found in British Carboniferous rocks, with the exception of M'Coy's *B. gracilis*, about which little is known *. Two Bavarian species described by Count Münster (*B. elongata* and *B. subcylindrica*) have not yet occurred in Britain. Neither have four Russian forms described by D'Eichwald †, nor the Australian *B. affinis*, Morris. Including these, there are twenty-three Carboniferous species belonging to the genus.

Seven of these species are found recurrent in the overlying Permian formation; but none of them are known to extend into Mesozoic strata; and, excepting one doubtful instance ‡, none appear to be recurrent from the Devonian or Silurian rocks beneath.

In the following Table we give a list of all the Palæozoic *Bairdiæ* known to us (omitting such as appear to be but varieties or synonyms), with references to figures of the species not noticed in this paper. The Table also shows the occurrence and recurrence of the species in the different subdivisions of the two upper systems of Palæozoic strata.

* See Annals Nat. Hist. ser. 3, vol. xviii. p. 42 (1866).

† See also Ann. N. H. ser. 4, vol. xv. p. 52 (1875).

‡ D'Eichwald refers to *B. curta* as having been found in the Old Red of Russia.

Table of *Palæozoic Species of* Bairdia.

Note.—The species which have no references for Illustrations attached to them are described and figured in the foregoing memoir.	Permian.				Carboniferous.						Devonian.	Silurian.
	Upper Magnes. Limest.	Middle Magnes. Limest.	Lower Magnes. Limest.	Lower Red Sandstone.	Coal-measures.	Millstone-grit.	Carbonif. Limest. (Upper).	Carbonif. Limest. (Middle).	Carbonif. Limest. (Lower).	Lower Carboniferous.		
Permian and Carboniferous.												
1. Bairdia plebeia, *Reuss*	*	*	*	...	...	...	*	...	*	*		
2. B. Hisingeri (*Münster*)	...	*	*	...	...	...	*	...	*	*		
3. B. ampla, *Reuss*	*	...	*	...	...	...	*	...	*			
4. B. Kingii, *Reuss*, Ann. Nat. Hist. ser. 3, vol. ii. pl. x. f. 8.	...	*	*									
5. B. berniciensis, *Kirkby*, loc. cit. f. 15	...	*										
6. B. rhomboidea, *Kirkby*, loc. cit. pl. xi. f. 3	...	*										
7. B. amputata, *Kirkby*	...	*	...	...	...	...	...	...	*			
8. B. subgracilis, *Geinitz*	*	...	...	...	...	...	...	...	*			
9. B. acuta, *Jones*, King's Monogr. Perm. Foss. pl. 18. f. 10	*	*										
10. B. grandis, *Jones*	*	...	...	...	...	...	*					
11. B. mucronata, *Reuss*	...	...	*	...	...	...	*					
12. B. drupacea, *Richter*, Zeitschr. deutsch. geol. Ges. vol. vii. pl. 26. f. 10	...	...	*									
Carboniferous.												
13. B. gracilis, *M'Coy*, Syn. Carb. Foss. Ireland, pl. xxiii. f. 7	...	...	...	...	...	...	...	...	*			
14. B. curta, *M'Coy* †	...	...	...	...	...	...	*	...	*	...	?*	
15. B. submucronata, *Jones & Kirkby*	...	...	...	...	...	...	*	...	*	*		
16. B. brevis, *Jones & Kirkby*	...	...	...	...	...	...	*	...	*	*		
17. B. subcylindrica (*Münster*)	...	...	...	...	...	...	*	...	*			
18. B. elongata (*Münster*), Ann. Nat. Hist. ser. 3, vol. xv. pl. xx. f. 13.	...	...	...	...	...	...	...	...	*			
19. B. subelongata, *Jones & Kirkby*	...	...	...	...	...	...	*	...	*	*		
20. B. siliquoides, *Jones & Kirkby*	...	...	...	...	...	...	*	...	...	*		
21. B. præcisa, *Jones & Kirkby*	...	...	...	...	...	...	...	...	...	*		
22. B. nitida, *Jones & Kirkby*	...	...	...	...	...	...	...	...	...	*		
23. B. circumcisa, *Jones & Kirkby*	...	...	...	...	...	...	...	...	*			
24. B. æqualis, *D'Eichwald*, Lethæa Rossica, livr. 7, pl. lii. f. 6.	...	...	...	...	...	...	...	...	*			
25. B. distracta, *D'Eichwald*, loc. cit. f. 12.	...	...	...	...	...	...	...	...	*			
26. B. Qualeni, *D'Eichwald*, loc. cit. f. 4	...	...	...	...	...	...	...	*				
27. B.? excisa, *D'Eichwald*, loc. cit. f. 8.	...	...	...	...	...	...	...	...	*			
28. B. affinis, *Morris*, in Strzelecki's 'Phys. Descrip. N. S. Wales,' p. 291, pl. 18. f. 10	...	...	...	...	...	...	...	*?				
Silurian.												
29. B. protracta, *D'Eichwald*, loc. cit. f. 19	...	...	...	...	...	...	...	...	...	...	...	*
30. B. Phillipsiana, *Jones & Holl*, Ann. N. H. ser. 4, vol. iii. pl. xiv. f. 7	...	...	...	...	...	...	...	...	...	...	...	*
31. B. Murchisoniana, *Jones & Holl*, loc. cit. vol. ii. pl. vii. f. 9	...	...	...	...	...	...	...	...	...	...	...	*
32. B. Griffithiana, *Jones & Holl*, loc. cit. f. 10	...	...	...	...	...	...	...	...	...	...	...	*
33. B. Salteriana, *Jones & Holl*, loc. cit. f. 11.	...	...	...	...	...	...	...	...	...	...	...	*
34. B.? Browniana, *Jones*, Trans. Geol. Soc. Edinb. vol. ii. p. 321; Geol. Mag. ser. 2, vol. i. p. 511, fig. 1	...	...	...	...	...	...	...	...	...	...	...	*

† Quoted from the Old Red Sandstone of Russia by D'Eichwald, 'Lethæa Rossica,' vol. ii. p. 1338. See Bigsby's 'Thesaurus Devonico-Carboniferus,' p. 26.

EXPLANATION OF THE PLATES.

Plate XXVIII.

(All the specimens are magnified 25 diameters.)

Fig. 1. *Bairdia curta*, M'Coy; left valve of the original specimen, *freed from matrix*. Granard, co. Longford, Ireland. Fig. 2, ventral view of same.

3. *B. curta*; right valve and edge of left valve of a specimen belonging to Mr. John Young. From Brockley, near Lesmahagow. Fig. 4, ventral view of same.
5. *B. curta*, var. *terebra*; single right valve. Wyebourne, Cumberland.
6. *B. curta*; left valve. Settle, Yorkshire.
7. *B. curta*, var. *bicornis*; right valve of a specimen belonging to Mr. James Thomson. From West Broadstone, Ayrshire.
8. *B. curta*, var. *deformis*; right valve. Steeraway, Salop. In Mr. Charles Moore's collection.
9. *Bairdia plebeia*, Reuss; left valve. Newfield Quarry, High Blantyre. Fig. 10, dorsal view; fig. 11, ventral view; and fig. 12, end view of same.
13. *B. plebeia*; left valve. Newfield Quarry.
14. *B. plebeia*; right valve. Craigenglen, Campsie.
15. *B. plebeia*; left valve, showing surface-ornament. Craigenglen.
16. *B. plebeia*; left valve of a gibbose specimen. Backwell, Somerset. Figs. 17 & 18, ventral and end views of the same. In Mr. C. Moore's collection.
19. *B. plebeia*; left valve of a small specimen. Brocastle, South Wales. In Mr. C. Moore's collection.
20. *Bairdia ampla*, Reuss; right valve. Hairmyres, East Kilbride. Figs. 21 & 22, dorsal and end views of the same.
23. *B. ampla*; cast of left valve, showing muscle-spots. Wyebourne, Cumberland.

Plate XXIX.

(All the specimens are magnified 25 diameters.)

Fig. 1. *Bairdia grandis*, n. sp.; left valve. Whorlton, Durham. Fig. 2, dorsal view of same.

3. *Bairdia ampla*, Reuss; left valve. Whorlton.
4. *Bairdia Hisingeri* (Münster); right valve and edge of left valve. Craigenglen, Campsie. Fig. 5, dorsal view; fig. 6, ventral view; fig. 7, anterior view; and fig. 8, posterior view of the same.
9. *B. Hisingeri*; left valve. Craigenglen.
10. *B. Hisingeri*; right valve, with shell partly removed, showing impression of muscle-spot. Craigenglen.
11. *Bairdia mucronata*, Reuss; left valve. Whorlton.
12. *Bairdia submucronata*, n. sp.; left valve. Bonshawburnhead Quarry, Dumfriesshire.
13. *B. submucronata*; left valve. Whorlton.
14. *B. submucronata*; right valve. Craigenglen. Fig. 15, ventral view; fig. 16, dorsal view; and fig. 17, end view of same.
18. *B. submucronata*; right valve. Carluke, Lanarkshire.

Plate XXX.

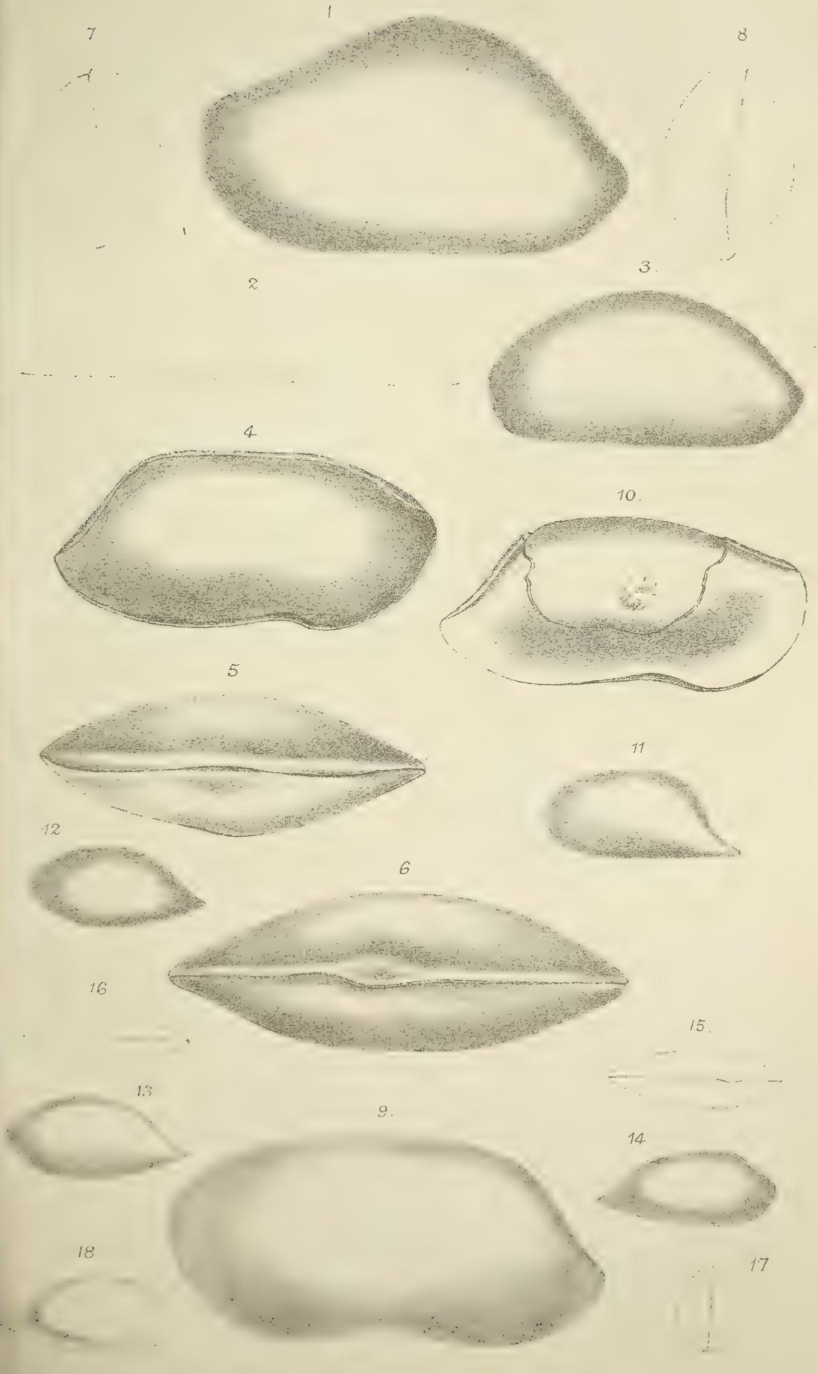
(All the specimens are magnified 25 diameters.)

Fig. 1. *Bairdia subelongata*, n. sp.; left valve. Woodend Quarry, near Fordel, Fife. Fig. 2, dorsal view of the same.

3. *B. subelongata*; right valve. Ladedda Quarry, Fife. Fig. 4, ventral view; fig. 5, end view of the same.

CARBONIFEROUS BAIRDIÆ.

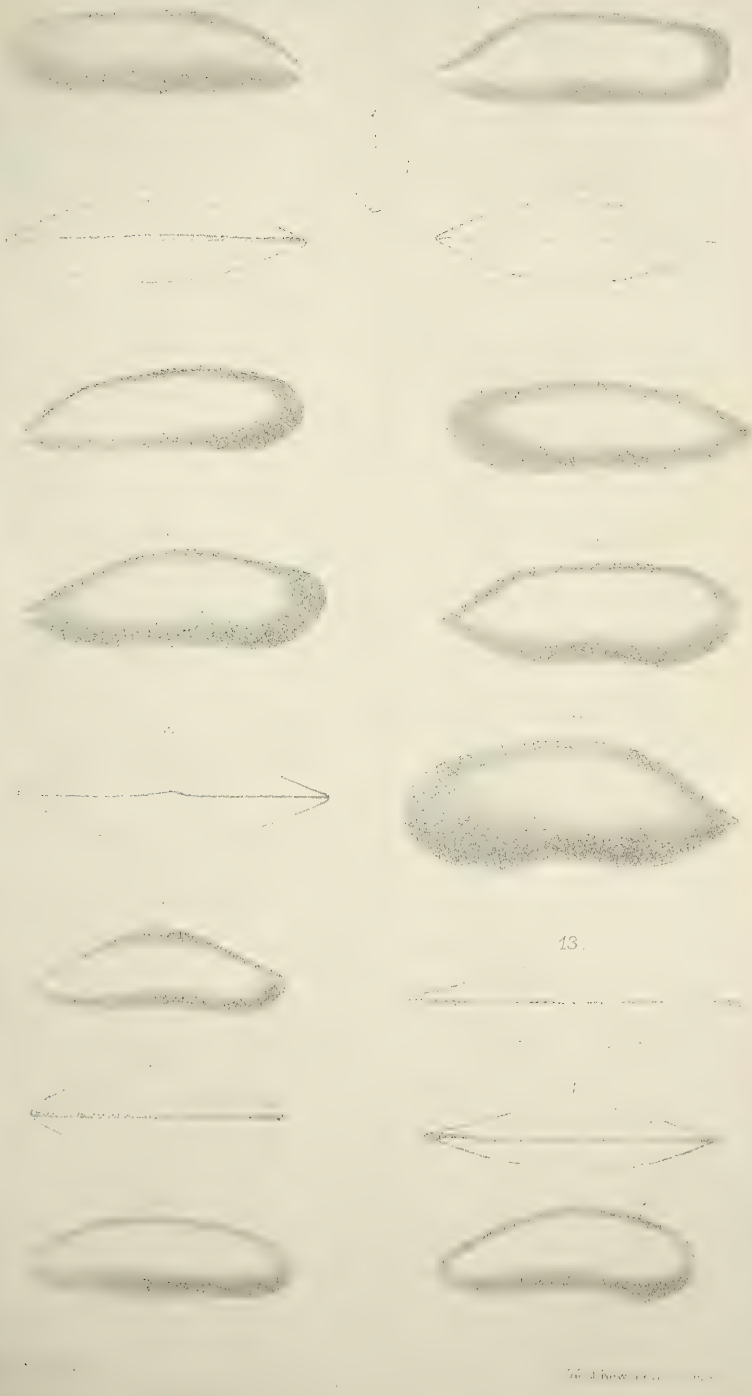
West Newman & Co imp.



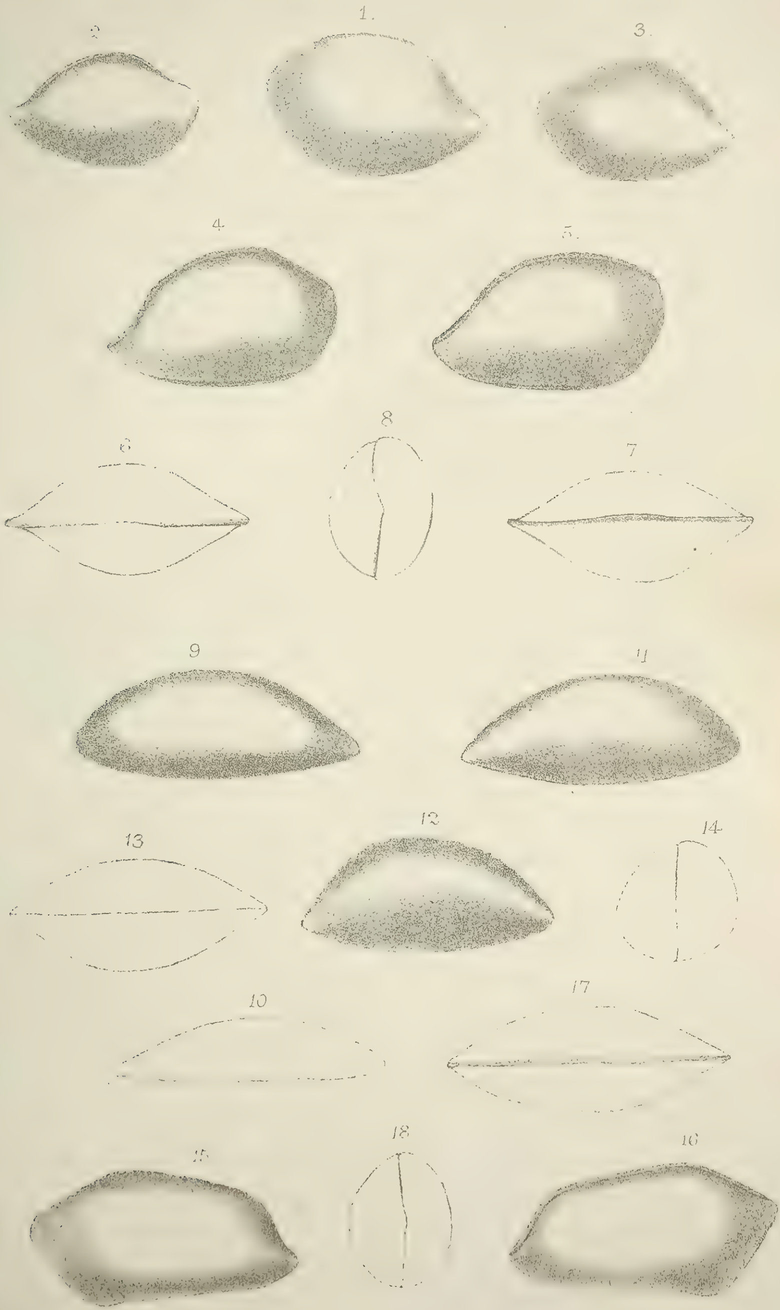
CARBONIFEROUS BAIRDIÆ.

T.R.J. & J.W.K. del.t A.S. Foord lith.

West, Newman & C.o imp.

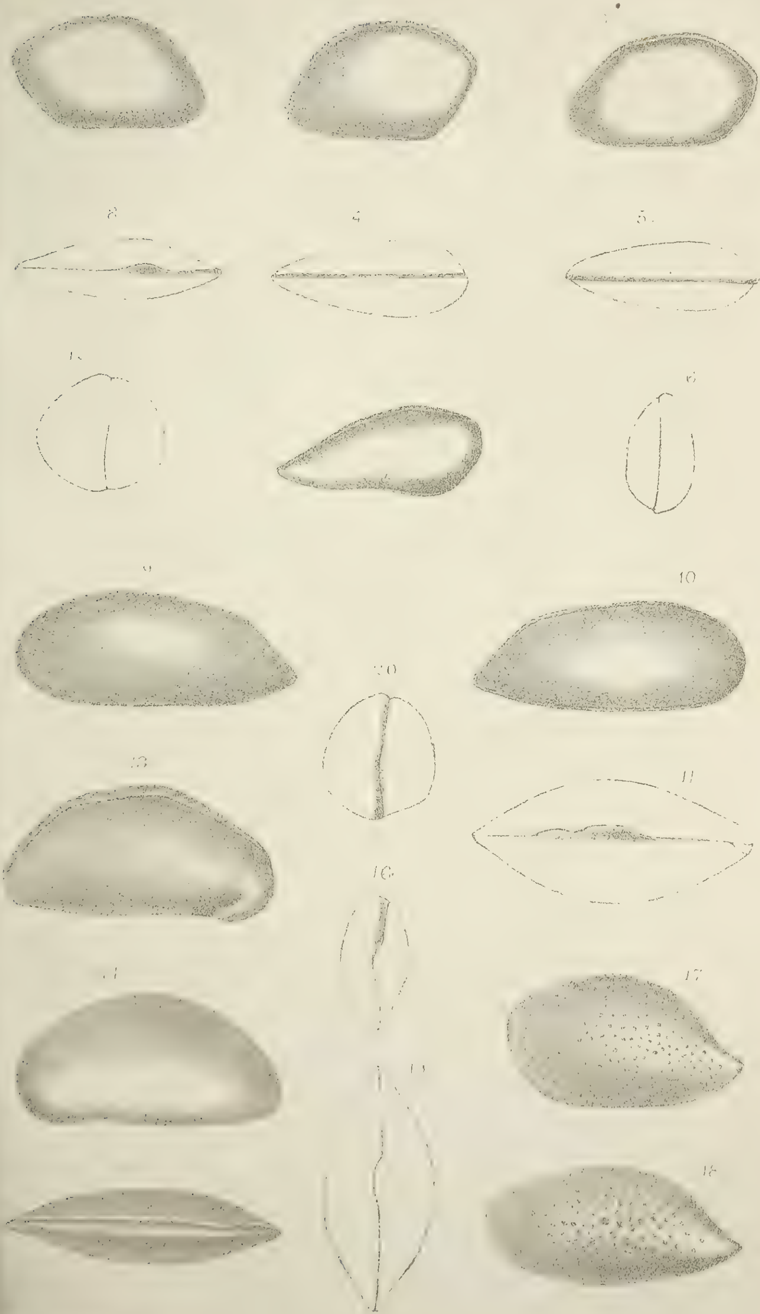


[illegible]BONIFEROUS BAIRDIÆ.



J W K. delt. A.S. Foord lith. West Newman & Co. imp.

CARBONIFEROUS BAIRDIÆ.



J.W.K. ... A.S. Foord. Lith.

West Newman & C° imp

CARBONIFEROUS BAIRDIÆ.

Fig. 6. *B. subelongata*; right valve. Blinkbonny Quarry, Mid Lothian.
7. *B. subelongata*; left valve. Ladedda Quarry,
8. *B. subelongata*; right valve. Paiston Quarry, East Lothian. Fig. 9, ventral view of the same.
10. *B. subelongata*; right valve. Newfield Quarry. Fig. 11, dorsal view of the same.
12. *B. Hisingeri* (Münster), elongate variety; left valve. Craigenglen, Campsie. Fig. 13, dorsal view of the same.
14. *Bairdia subcylindrica* (Münster); right valve of a Bavarian specimen from Tragenau, near Hof. Fig. 15, dorsal view of the same.
16. *B. subelongata*, n. sp.; right valve. Pitlessie, Fifeshire.
17. *Bairdia subgracilis*, Geinitz; right valve. Carluke, Lanarkshire.

Plate XXXI.

(All the specimens are magnified 25 diameters.)

Fig. 1. *Bairdia brevis*, J. & K.; left valve. Kidlaw Quarry, East Lothian.
2. *B. brevis*; right valve. Inverteil Quarry, near Kirkcaldy, Fifeshire.
3. *B. brevis*; left valve. The same locality.
4. *B. brevis*; right valve. Abden, Kinghorn, Fifeshire.
5. *B. brevis*; right valve. East Salton, East Lothian. Fig. 6, dorsal view; fig. 7, ventral view; fig. 8, end view of the same.
9. *Bairdia siliquoides*, n. sp.; left valve. River Avon, near Kinneil Mill, Linlithgowshire. Fig. 10, dorsal view of the same.
11. *B. siliquoides*; right valve. Same locality.
12. *B. siliquoides*; left valve. Randerstone, Fife. Fig. 13, ventral view; fig. 14, end view of the same.
15. *Bairdia amputata*, Kirkby; right valve. Paiston Quarry, East Lothian.
16. *B. amputata*; left valve. Same locality. Fig. 17, dorsal view; fig. 18, end view of the same.

Plate XXXII.

(All the specimens are magnified 25 diameters.)

Fig. 1. *Bairdia præcisa*, n. sp.; left valve. Randerstone, Fifeshire.
2. *B. præcisa*; right valve. Same locality.
3. *B. præcisa*; right valve. Same locality. Fig. 4, ventral view; fig. 5, dorsal view; fig. 6, end view of the same.
7. *Bairdia*, sp; right valve. Cowden's Quarry, Fife. Fig. 8, ventral view of the same.
9. *Bairdia nitida*, n. sp.; left valve. Anstruther, Fife. Fig. 10, right valve; fig. 11, ventral view; fig. 12, end view of the same.
13. *Bairdia circumcisa*, n. sp.; right valve and edge of the left valve. Whitebaulks Quarry, Linlithgowshire. Fig. 14, left valve; fig. 15, dorsal view; fig. 16, end view of the same.
17. *Bairdia ampla*, Reuss; left valve, showing pitted surface. Hairmyres, East Kilbride.
18. *B. ampla*, var.; left valve, showing reticulated surface. Blinkbonny Quarry, Mid Lothian. Fig. 19, ventral view; fig. 20, end view of the same.

45. A Contribution *to* South-American Geology. By George Attwood, Esq., F.G.S., Assoc.Inst.C.E., Mem. Am. Inst. M.E. *With an* Appendix *by the* Rev. Prof. T. G. Bonney, M.A., F.R.S., Sec.G.S. (Read June 25, 1879.)

[Plate XXXIII.]

The paper which I have the honour to present to the Society, entitled "A Contribution to South-American Geology," refers to a tract of country about 150 miles in length, commencing from a small port called Puerto de Tablas on the Orinoco river in the State of Guayana, Venezuela, and taking a south-easterly direction into the interior as far as the Caratal Gold district, as shown on the Map (Pl. XXXIII.).

Mr. Carlos Seigert, a German surveyor who has spent many years in the country, has lent me his notes in relation to the line of country I have surveyed and described; and his observations confirm the map I have compiled. The elevations marked on the section have been computed by the aneroid and mercurial barometers, and they were carefully checked by the boiling-point test made with Casella's hypsometers, as shown in the following Table (p. 583).

After landing at Puerto de Tablas and climbing up the sandbank, large exposures of weathered rock-masses are seen. It is only after a careful examination that the rock is found to be crystalline and of igneous origin. Parallel lines of alteration are so distinct and so regular on the outer surfaces that, until the weathered portions have been broken off and the unaltered rock exposed, it is not possible that a definite conclusion can be arrived at. The rock presents a highly crystalline appearance, and consists chiefly of felspar, with some quartz and a dark green mineral. It contains 64·83 per cent. silica, and 6·80 per cent. iron = protoxide 8·34 per cent., or peroxide 8·84 per cent. The rock may be called a syenite (with microline); but until Prof. Bonney kindly examined my microscopic slides I did not feel certain on the point, especially as I found the amount of silica to be unusually large and more than is generally found in syenites.

On the south bank of the Orinoco river the syenite extends some 50 miles east of the port of Las Tablas, and about 90 miles west, as far as the city of Bolivar, near which place a granitoid rock appears, and further west a true granite.

Having left the river, "the road"* takes a south-easterly direction, and passes over about two miles of tableland, the rocks being syenitic and the same as those found at Las Tablas.

An open plain, called by the natives "sabanah," has then to be crossed, and a change in the rocks occurs. The rock is of a greyish-white colour, and consists of felspar, quartz, mica, and a little oxide of iron; it contains 71·50 per cent. silica, and 2·75 per cent. iron = peroxide 3·57 per cent.

* I call "the road" the course taken by myself from the river to the interior.

Table of Latitudes, Longitudes, and Elevations, to accompany Map and Geological Section (Pl. XXXIII.).

Name of Place.	Latitude N.	Longitude W.	Water boils, ° Fahr.	Temp. of Air.	Elevation by Barometers.	Elevation by Hypsometer.
	° ′	° ′		°	feet.	feet.
Chile Mine; Superintendent's House	7 11	61 58	210·05	83	1020	1044
Peru Mine; New Shaft	7 11	61 57	210·45	80	756	806
Caratal; House of Dr. Rodriguez	7 12	61 55	210·75	84	625	640
Quacipati; small town	7 21	62 01	210·95	84	515	524
Cunuri; farmhouse	7 27	62 06	210·52	91½	...	783
Platanal; farmhouse	7 33	62 08	210·20	91	...	961
Candelaria; farmhouse	7 36	62 19	210·60	78	...	718
*Carichapo del medio; farmhouse	7 39	62 22	210·60	87	...	729
La Florida; farmhouse	7 44	62 27	210·38	93	...	868
Maño Piedra; mountain-pass	7 45	62 29	209·40	90	...	1441
Upata; an old Spanish town	7 52	62 34	209·85	80	...	1165
Alta Gracita; village	7 55	62 36	210·10	86	...	1021
Moyori; mountain-pass	7 59	62 35	209·64	91	...	1298
*Las Corales; farmhouse and stopping-place	8 04	62 38	210·90	83	...	552
Puerto de Tablas; shipping-town, Orinoco river	8 14	62 52	211·90	81		
Callao Mine; Office Callao Company	7 14	61 56	211·00	90	556	502
Potosi; Mining Company's office	7 11	61 59	210·75	84	625	639

* N.B.—The latitudes and longitudes of these places must be taken as approximate, owing to observations not agreeing closely.

The rock may be called a "highly felspathic granite." Leaving the sabanah, which extends about six miles in width, the tropical forest commences and continues until the town of Upata is reached.

About two miles beyond the commencement of the forest a beautiful granitoid rock, full of garnets, takes the place of the felspathic granite. It contains 48·50 per cent. silica, and 11·50 iron=peroxide 14·95 per cent. This rock is found for about 4 miles, and also near a ranch called San Juan. At the crossing of the Upata river rocks of a schistose micaceous character are met with. They are of a white colour with dark specks, and consist of quartz, felspar, and mica. These rocks are then followed to Las Corales (552 feet above sea-level, see Pl. XXXIII.), the road still winding its way through the forest.

At Las Corales a change in the rock is found, and highly felspathic granite again comes in. No change of decided character in the rock is found until the village of Alta Gracita is reached. The rock on the summit of the mountain-pass (of the mountain called Moyori) is found to contain much less mica than at the base of the mountain; but as the rock on the pass is highly weathered, no great attention was paid to the fact. The last-named pass is the highest point in elevation but one found in my section, being 1298 feet above sea-level.

About a quarter of a mile S.E. of Alta Gracita large masses of ferruginous quartzite are met with, and in places they are found to be stratified. Hæmatite and magnetic iron-ores of great purity occupy more than two miles in length. In places pyrrhotite is met with; the bronze-yellow and copper-red colour on the fresh fracture of the mineral is sufficient to distinguish between it and pyrite without the aid of a magnet.

Upon approaching the old Spanish town called Upata, situated on the Upata river (a stream that finds its way into the Orinoco), and 1165 feet above sea-level, a change of rock occurs. The rock is a crystalline one and consists of rather irregularly formed grains of a felspar and a greenish mineral. Prof. Bonney pronounces it to be igneous, and calls it a quartz diorite.

Continuing the journey in a south-easterly direction, the quartz diorite extends about eight miles, when a ferruginous quartzite comes in, and extends for nearly ten miles.

Some stones taken as an average sample were found to contain, by analysis, silica 50 per cent., iron 35·00 per cent.=peroxide 45·50 per cent. For several miles these deposits of hæmatite were found stratified, having a S.E. strike and dipping S.W. at an angle of 70°. Large masses of pure magnetic iron-ore were also found; and a large area comprising from seven to eight miles was found composed of the mixed iron-ores.

On approaching the base of the mountain called Maño Piedra, the quartzite contains but a small quantity of iron, and finally gives way to a belt of about half a mile in width of quartz breccia made up of very coarse angular fragments. The breccia is then replaced by a beautiful granite consisting of pink quartz, mica, and felspar.

The mountain-pass over Maño Piedra is 1441 feet in height. Granite continues for about five miles, when a dike of basalt about one mile in breadth is found on the S.E. side of the mountain. Near the base of the mountain quartz breccia is again met with, and is about two miles in width, and of a similar character to that found at the N.W. base. A schistose granite is now found consisting of white quartz, felspar, and mica. At the farmhouse of La Florida (see Map) a stratum of slate-rock of a reddish colour, moderately weathered, but much altered, crops up, having an east and west strike, and dipping nearly vertical, but having, if any thing, a slight inclination to the south. Near the above is found a large quartz vein, containing pyrite, which is often decomposed. No minerals of value have been found in it so far. Proceeding still in a S.E. direction, the rock is again found to be granite, but having a schistose character. Large veins of quartz resembling reefs are found about every half-mile, and the quartz fragments are scattered to such a great extent over the hills and valleys that travelling, even on foot or on horseback, becomes tedious as well as dangerous. The country is now more open, very few large trees are met with, and but little vegetation is seen.

Granite still continues.

Upon reaching the Carichapo river close to the farmhouse called Candelaria (see Map and section), a belt of coarse slaty rocks about one mile in thickness is found cropping out, having an E. and W. strike and a slight dip to the S. From Candelaria to a farmhouse called Platanal, a distance of about twenty-four miles, a greyish-white granite prevails, and in it are numerous quartz veins. At present none of them have been found to contain any of the precious metals.

For about one half the latter distance the road goes through the forest. Leaving Platanal (961 feet above sea-level) the greyish-white granite is still found, and continues until the farm of Cunuri is reached.

Cunuri is 783 feet above sea-level, and is distant about twelve miles from Platanal. The road has a gradual descent from the latter place over an open rolling country composed of granite, in which barren quartz veins are numerous. Near Cunuri a small belt of mica-schist is found dipping nearly vertical, and having an E. and W. strike. A small belt of gneiss is now met with. Adjoining it is a narrow belt of quartzite of a highly indurated, saccharoidal character.

From Cunuri to the old Jesuit mission village called Quacipati the same greyish-white granite is the predominant rock; but about a quarter of a mile on the N.W. side of the town granite disappears and a fine-grained gneiss takes its place. It contained silica 72·50 per cent. About one mile to the S.E. of Quacipati, granite reappears and continues to the Yuruari river. The Yuruari is one of the main branches of the Essequibo river, which empties itself into the Atlantic Ocean near Georgetown, Demerara (British Guayana). On each side of the river (Yuruari) is found a stratum of coarse slaty rocks, highly ferruginous and much altered. The extent of the same is not over a quarter of a mile in width, and then a rock is found with a green and dullish black crystalline mineral, and carrying a small quantity of iron sulphides. It contains 51·15 per cent. silica. The specimens which I was able to collect are considerably weathered, but the characteristic features are those of gabbro. It consists of saussurite and diallage, and is sometimes coarse-grained, fine-grained, or compact. When polished it has both a slaty and a spotted appearance. Prof. Bonney states that the specimen I sent him for examination "has once been a gabbro."

Within one mile of the Potosi Company's office the gabbro gives way to a greenish-coloured rock, very compact and fine-grained, consisting of felspar, augite, and chlorite, and containing small quantities of magnetic iron, also traces of iron and copper sulphides. The rock has been called a diabase.

To show the effect of weathering and the chemical difference produced in the composition of this rock, I have had three complete analyses made from one stone; and as the three different portions analyzed show distinct lines of alteration, and as they are all from one compact stone, the results have proved of interest.

Three analyses made from one piece of diabase rock found at the Potosi Company's Mines (Spanish Guayana, Venezuela, S. A.), to show the difference in chemical composition between the portions weathered and the portion unaltered.

	Unaltered.	Weathered.	Highly Weathered.
Silica	49·57	41·77	43·46
Alumina	15·37	19·34	18·39
Peroxide of iron	....	13·21	20·43
Protoxide of iron	12·34	4·63	
Protoxide of manganese	traces.	traces.	traces.
Copper	traces.	traces.	traces.
Lime	9·65	4·98	2·37
Magnesia	7·41	5·01	3·46
Potash	0·85	0·69	0·59
Soda	1·99	0·83	0·14
Sulphur	trace.	trace.	trace.
Chlorine	trace.	trace.	trace.
Phosphoric acid	none.	none.	none.
Water (combined)	3·10	7·30	7·95
Water (hygroscopic)	0·17	2·55	3·39
	100·45	100·31	100·18

N.B. The above analyses were made at the Metallurgical Laboratory at the Royal School of Mines, Jermyn Street.

The loss of silica resulting from weathering compared with the stability of alumina shows that silica is much more liable to atmospheric action than alumina.

The iron which exists in rocks contains more oxygen when the rocks have been exposed to the atmosphere, or when they occur near the surface, than when the rocks are found some depth below the surface and sheltered from the weather. The unaltered rock contained 12·34 per cent. of protoxide of iron and no peroxide, whilst the highly weathered contained no protoxide but all peroxide.

Lime shows itself to be readily soluble, the unaltered rock having contained 9·65 per cent. of lime and the highly weathered only 2·37 per cent.

Magnesia also is proved to be readily carried away by the weathering, but not in the same ratio as the lime.

Potash and soda are very sensitive to weathering, but soda much more so than potash.

The quantity of combined as well as the hygroscopic water in the unaltered and the weathered and highly weathered portions proves that rocks contain a larger quantity of water both *combined and uncombined* when they are exposed to the atmosphere than when they are sheltered from its influences.

The diabase rock occupies a large area, and in it are found the gold-producing veins of the Caratal mining-district. The veins are very quartzose and numerous, and all contain gold; but, owing to the present high rate of wages and the great cost of procuring supplies from the Orinoco river, only eight or nine of the richest are now being worked.

The Chile vein is one of the principal ones; and it has been traced about one mile in length. It has a dip of 55° to the south, and an E. and W. strike; it averages in thickness about 4 feet, and is a true fissure vein. The yield of gold at 200 feet in depth gave between five and six ounces of standard gold to the ton (2000 lb.), whilst near the surface it only turned out about one ounce per ton. A large quantity of gold was extracted in the form of nuggets and small grains by washing in wooden bowls (bateas) the alluvial soil in the vicinity of the outcrops. The present yield of gold from the Caratal and Las Pastora mining-districts is about 130,000 ounces per annum; but it is rapidly increasing as the country is becoming more populated.

About 30 miles due west from Potosi a new district has lately been opened; large quantities of gold nuggets have been found close to the surface in the alluvial soil, and gold-bearing veins have been discovered near the washings. The rock is diabase and similar to that of the Caratal district.

Conclusion.—It is a remarkable fact that although quartz veins are found in great numbers all the way from the port of Las Tablas to the Caratal mining-district, yet none of them have so far been found to contain the precious metals, *i. e.* in any appreciable quantity, until the diabase is met with.

All the rocks analyzed show a higher percentage of silica than is generally found.

The independent examination made by Prof. Bonney, from *microscopical sections alone*, as to the character of the rocks agrees closely with the observations made by myself in the field, and also with the analyses previously alluded to.

It is not improbable that many minor details are omitted in my section, considering the difficulties under which the observations were made, my sole object being to explain the general geological features of a comparatively little-known district.

Note on some Rocks *from* South America.

By the Rev. Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

1. (Near Potosi, p. 586.) This rock has been much altered. The following constituents are present:—(*a*) crystalline grains composed of earthy-looking granules and minute, rather fibrous microliths, showing light colour with the two Nicols, being one of the decomposition pseudomorphs after felspar, often called saussurite; (*b*) augite and diallage, more or less converted into hornblende and a chloritic mineral; (*c*) iron peroxide, probably ilmenite; (*d*) a little apatite. The general aspect of the saussuritic grains suggests that the felspar has been plagioclastic. Of the pyroxenic mineral the greater part is altered, being converted into hornblende with strong dichroism and very characteristic cleavage, associated with which are smaller more fibrous forms, some of which are probably varieties of hornblende, others rather more resemble chlorite. Portions of the diallage and augite remain unchanged in many of the grains; both minerals appear to be present. One or two serpentinous-looking aggregates may possibly replace olivine. We may venture to say that the rock has once been a gabbro, in which the pyroxenic constituent has been almost wholly converted into hornblende, as has not seldom happened*.

2. (Quacipati, p. 585.) The ground-mass of the rock consists chiefly of minute grains of quartz, looking as if fused together. In this are scattered many small grains of epidote and scales of mica. Of the latter there appear to be two kinds—one having its darkest tint an olive-green, rather strongly dichroic; the other nearly colourless, and showing brilliant tints with the two Nicols, rather like paragonite; indeed these two types of mica are common in the granitoid gneiss of the St. Gothard. In this ground-mass are several crystalline grains, not very clearly defined in outline, and containing the epidote and mica-granules. One or two rather resemble kyanite; but, as far as I can make out, they are only felspar, and two or three suggest plagioclase. The rock is a metamorphic one, a kind of fine-grained gneiss.

3. (Cunuri, p. 585.) Consists mainly of hornblende grains rather irregular in form, with characteristic cleavage and strong dichroism; but associated with these, and apparently partially replaced by them, is a mineral which, from absence of dichroism and general aspect, more resembles decomposing augite. There are a good many grains of quartz and some of decomposing felspar. The rock appears to be a hornblende schist with but slight traces of foliation.

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 896.

4. (Cunuri, p. 585.) A gneiss, though but little foliated: consists of quartz, felspar, mica, and epidote, with a little sphene, iron peroxide, and a few other microliths. The quartz is rather free from cavities and enclosures, what there are being very minute. The felspar is in rather irregular grains; orthoclase appears to predominate, some showing cross-hatched structure. Several grains of felspar show twinning, by a series of rather faint bands of a darker tint. The mica appears to be biotite. One or two of the microliths may be apatite, others are short belonites of a very pale greenish, almost colourless, mineral (? hornblende); there are also a few specks of a secondary mineral, probably zeolitic. In general microscopic character this rock resembles a slide in my collection from a specimen collected at Godhaven, Disco Island, and its aspect is one which I have often noted in very ancient rocks.

5. (Maño Piedra, p. 585.) A basalt; small crystals of plagioclase and clustered grains of augite, with iron peroxide, mostly ilmenite. I do not see any olivine.

6. (Between Upata and Maño Piedra mountain, p. 584.) A ferriferous quartzite, consisting of subangular grains of rather clear quartz and of opaque iron peroxide, probably magnetite and ilmenite, in proportion of about two to one. Some of the smaller grains of peroxide are included in those of quartz; the larger occupy interstices and are more irregular in form than the latter. A few of the little colourless microliths mentioned above (4) are present in the quartz, as well as some tufted trichites. A fair number of minute cavities are to be seen in the quartz; they seem not to contain any fluid.

7. (Upata, p. 584.) A crystalline rock consisting chiefly of rather irregularly formed grains of a felspar and a greenish mineral. The fomer is generally, if not always, a closely twinned plagioclase, and is remarkable for containing very numerous microliths; these are prismatic in form, resembling prisms of the monoclinic system, but generally a little distorted, so that it is difficult to ascertain the exact shape of the section*; they are, on an average, about ·01 in. in length, and four or five times as long as broad. As a rule, they are arranged parallel to a twinning plane, and so probably lie in the brachydiagonal. The green mineral is rather intermediate in character between augite and hornblende; it is in irregular rounded grains †; in texture it seems intermediate between fibrous or platy and granular, approaching in some respects to epidote; the cleavage is rather imperfect and not very characteristic, on the whole perhaps rather nearer that of augite, and is sometimes platy, rather like diallage. The mineral is very distinctly dichroic, sections roughly basal being pale brown, roughly prismatic pale olive-green; the latter changes little in tint; the former takes almost that of the other section, when the plane of polarization of the transmitted light is changed. This mineral occurs in a slide of eclogite from Eppenreuth in my collection, and

* Similar microliths occur in a felspar in no. 4, and in one in a gneiss from Ceylon in my collection.

† In two or three cases the grains seem to have imperfectly developed angles.

is probably omphacite; irregular grains of iron peroxide are also present, with quartz and a little apatite. Macroscopically this rock closely resembles, and microscopically is almost identical with, one in my collection brought from Holsteinburg in South Greenland by Mr. P. H. Carpenter, and is nearly related to a specimen (locality unknown) given to me by Prof. Rupert Jones. The structure is rather abnormal; but I think it must be an igneous rock, and thus is a variety of quartz-diorite.

8. (Puerto de Tablas, p. 582.) A crystalline rock consisting chiefly of felspar with some quartz and a dark green mineral. The greater part of the slide is very characteristic microcline, with numerous wavy fibres of interbanded albite, as figured by Des Cloiseaux*. Minute enclosures are present, some opacite, some hornblende (?) microliths or opaque belonites, commonly arranged so as to cross at angles of about 60°, and roughly bisected by the albite bands. The green mineral is very dark in colour, fairly strongly dichroic, and shows one very decided cleavage; it seems rather altered, and perhaps is partly replaced by a chloritic mineral; but, though not very characteristic, it is probably hornblende. There are some grains of iron peroxide (some being hæmatite), and ferruginous stains are frequent; also two or three grains of epidote and a little apatite (?). The rock appears to be of igneous origin, and so is a microclinic syenite.

9. (Potosi Mines, p. 586.) Much decomposed, but appear to have consisted of plagioclase felspar, augite, and ilmenite: the felspar is now replaced by a saussuritic mineral; the augite rather decomposed, stained, and replaced by groups of microliths; the ilmenite also much decomposed. The rock evidently has been a fine-grained dolerite, and for convenience may now be roughly grouped with the diabases.

* Zeitschr. deutsch. geol. Gesellsch. (1875), vol. xxvii. p. 956. Not being at the time familiar with the aspect of microcline, I submitted this specimen to T. Davies, Esq., F.G.S. (to whose extensive knowledge of minerals I have so often been indebted), and he pronounced it undoubtedly microcline.

rinoc

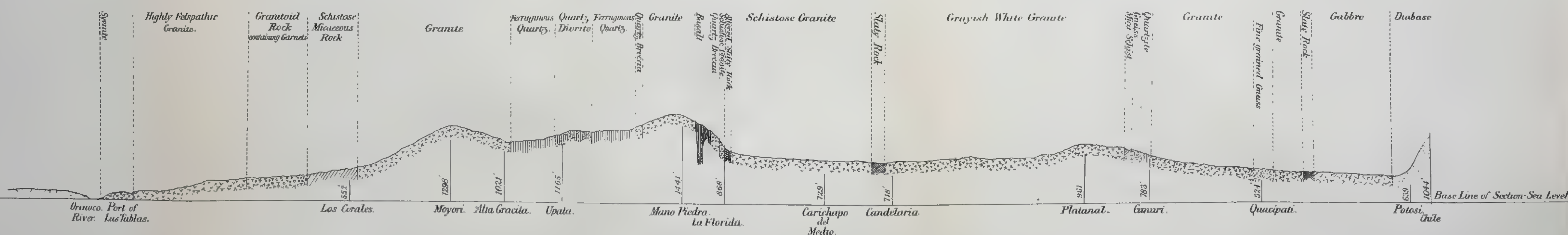
Fig. 1. Map showing the Course of the Orinoco River from Barrancas to the City of Bolivar and the line of section described.

by George Attwood F.G.S. 1878.

N.B. ——————— Line of Section

Fig. 2. Section from the Port of Las Tablas on the Orinoco River to the Caratal Gold District. S.A.

Horizontal Scale 6 miles to 1 Inch
Vertical Scale 1458 feet to 1 Inch.



46. *On the* Dinosauria *of the* Cambridge Greensand. By Professor H. G. Seeley, F.R.S., F.G.S. (Read December 18, 1878.)

[Plates XXXIV., XXXV.]

Introductory Note.

The remains of Dinosaurs were for many years very rarely met with in the Cambridge Upper Greensand; and several important parts of the skeleton have never yet been found. But a considerable collection of more than 500 bones is now preserved in the Woodwardian Museum alone; and since the greater number of these fossils have been discovered in larger or smaller sets of naturally associated remains, each of which is obviously a portion of the skeleton of a single individual, they afford evidence on which it is possible to establish many species which belong to several genera. Occasionally the series of remains is sufficiently large to give grounds for a conjectural reconstruction of the animal; but more frequently the bones are limited to a few caudal vertebræ; and even the larger sets of associated bones come chiefly from the caudal and sacral regions of the vertebral column. With the exception of *Macrurosaurus*, already described*, and also known from a long sequence of large caudal vertebræ, all the remains indicate animals of small or of moderate size, varying between the magnitudes of a sheep and an ox. The majority of the species were characterized by possessing comparatively short tails; though one animal, at least, had a tail in which the vertebræ were more than usually elongated. These remains possess a peculiar interest in being the latest known representatives of the Dinosauria in British geological deposits; and they help to define the limits within which the osteological structure of the order varied and persisted in that organic type.

The literature of British Upper Cretaceous Dinosauria is very scanty. Professor Owen, in 1860, figured in the Palæontographical Society's monograph (2nd Suppl. to *Iguanodon*, pl. vii. figs. 15–17) two Dinosaurian teeth from the Cambridge Greensand, one of which resembled *Hadrosaurus*, while the other was like *Iguanodon*. I have never seen either specimen, and, so far as I am aware, no other Dinosaurian teeth have ever been met with; they were, I believe, the property of Mr. Beddome, of Trinity College, who, when at Cambridge, made considerable collections of vertebrate fossils. These teeth would now be invaluable, because I am not acquainted with any English Greensand skeleton which I should be disposed to identify with either *Iguanodon* or *Hadrosaurus*; and the teeth, without actually pertaining to those genera, may perhaps indicate the directions of the affinities of some of the Cambridge species. The next contribution to knowledge is Professor Huxley's classical paper on *Acanthopholis*, from beds just above the Greensand at Folkestone†.

* Quart. Journ. Geol. Soc. vol. xxxii. p. 440. † Geol. Mag. vol. iv. p. 65.

That brief memoir clearly sets forth the leading characteristics of an armoured genus which is well represented at Cambridge. It may, perhaps, have been that other Dinosaurs were protected by armour undistinguishable from that of *Acanthopholis*, and that some of the Cambridge Dinosaurs were not weighted with these dermal plates. There is, I think, evidence to show that the plates were arranged in some of these species in one median row placed over the neural spines of the vertebræ, with lateral rows of plates, which I infer to have been relatively few and large, and placed somewhat after the manner of the scutes of a Crocodile*, but in the tail and limbs to have conformed to the plan of the land Chelonia.

As doubts have from time to time been expressed as to whether some of the fossils of the Cambridge Greensand might not have been derived from the waste of underlying deposits during its accumulation, and consequent uncertainty has been freely expressed by some writers as to the possibility of bones collected from day to day being naturally associated portions of the remains of one animal, it may perhaps here be useful to state once for all what the evidence is upon which the association of these vertebrate fossils is accepted as a basis for specific and generic characters. Almost every phosphatite digging presents fossils with a mineral character peculiar to the locality, so that a trained observer who has carefully watched these workings for years finds it possible to identify the localities of many specimens on this evidence almost with certainty; and the chances of imposition by wilful deception are small. Then, in the cases of some Plesiosaurs and Ichthyosaurs, I have been present at the workings when associated portions of skeletons have been found, so that I can state from my own knowledge that naturally associated portions of single animals are met with; and often we have had to wait for months for the neck of an animal of which the body has been found, until the overlying rock was removed so that the bones could be collected. The circumstance that private collectors rarely obtain associated sets of bones is explained by the necessity of being on the spot and watching the workings several times a day, so as first to obtain the bones direct from the diggers, and, secondly, to obtain any that the diggers may have overlooked, after the phosphatic nodules have been washed in the mills, when the fossils are detected if they are strong enough to resist attrition. For a long time associated series were limited to portions of one region of the body, because the collector was content with the produce of a single washing; and it was not until Mr. William Farren employed Mr. Pond, an experienced foreman of phosphatite-washers, to devote his whole time to visiting the phosphatite-washings about Cambridge, with the purpose of collecting the whole of the fossil Vertebrata, that it was proved that the bulk of the remains occur as naturally associated

* A brief account of some 376 Dinosaurian bones from the Cambridge Greensand is given in my 'Index to Fossil Remains of Aves, Ornithosauria, and Reptilia,' 1869, pp. xvii, 18–24. The bulk of the remains were then referred to three new species of *Acanthopholis*; and since that date the *Macrurosaurus semnus* has been described and figured in the Journal of this Society.

portions of skeletons of single animals, and that scattered or isolated bones are comparatively rare. It rarely happens that any pit yields more than three or four skeletons. These are almost always of different species; they generally occur at considerable intervals of time; and if an animal happens to lie in the line in which the rock is being worked its remains are collected in a few minutes, while if it is at right angles to the working it will have to be watched for bit by bit as the excavation progresses. In arranging these Dinosaurian and other fossils in the Woodwardian Museum, I have occasionally had to reject an accidental Ichthyosaurian or Plesiosaurian fragment found with a Dinosaur; but I hardly ever remember evidence of two Dinosaurian skeletons being mixed together. And when this has occurred the circumstance could be traced to the fossils having been indiscriminately purchased and mixed by the engineer at the works, or only collected after having been triturated in the mills.

There is no doubt that some of the bones in the Cambridge Greensand have suffered from attrition, and it is probable that the apparently worn condition of the bones has led to the belief that they were derived from some older formation; but not only is a similar fauna unknown in any older formation, but it occurs well developed on this horizon at Gosau, in Austria. Moreover, the bones are much less worn than is often the case with specimens from the Wealden deposits of Sussex; and no one has ever suggested that the Wealden fossils are derivative. And in so far as the Cambridge Greensand specimens are worn, it is probable that the greater part of the abrasion has been produced in the washing-mills at the several diggings after the specimen had been dug out from the bed. In many cases, however, this explanation will not apply; and bones occur which have roughened edges, roughly fractured surfaces, and considerable holes penetrating into their substance. These circumstances led me to institute experiments on the effects of exposure of bones to the air and subsequent maceration as influencing their condition of preservation; and I have found the articular ends especially to suffer from exposure, while under maceration the bones become so brittle that they are fractured with slight movement. In the case of land animals, such as Dinosaurs, both these conditions may well have exercised an influence; and what has hitherto been regarded as evidence of wear seems to me better explained in this way. Many associated bones are decomposed, past all recognition, on the exposed neural surfaces; while the ventral surfaces which rested on the sea-bed yield valuable distinctive characters.

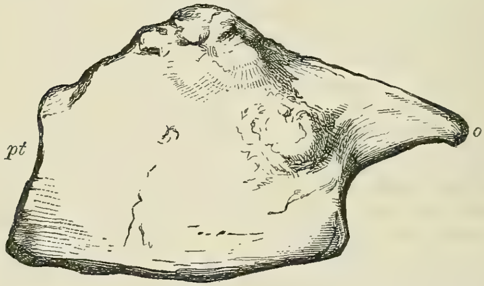
I venture now to submit to the Geological Society some account of the structure, affinities, and systematic position of this Dinosaurian fauna; and I desire to express my grateful sense of the kindness of Prof. Hughes in affording me facilities for studying the Woodwardian Dinosaurs, and my indebtedness to the Council of the Royal Society for assistance in carrying on this investigation. On the present occasion I offer descriptions of a few only of the typical Dinosaurs of the deposit.

Part I.

Note on the axis of a Dinosaur from the Cambridge Greensand, preserved in the Woodwardian Museum of the University of Cambridge (fig. 1).

The more important bones which are absolutely distinctive of the Dinosaurian skeleton, such as the pelvis, astragalus, &c., have not been met with from the Cambridge Greensand; and though there have been obtained from that formation a large number of isolated and associated bones, which belong to several extinct genera, each having more or less in common with the described types of Dinosaurs beyond all question referable to the group, there is probably no bone more characteristic of the order than a badly preserved example of the second cervical vertebra. This solitary specimen is the result of more than a quarter of a century of zealous research,

Fig. 1.—*Axis of* Acanthopholis ?, *nearly nat. size.*



o. Odontoid process.
p. Pedicle of centrum supporting the neural arch, below which are the articulations for the rib.
pt. Posterior articular surface of centrum.

carried on by many collectors under opportunities which have never been surpassed; and therefore, though it only confirms, under certain generic differences, the characters of the axis from the Wealden described by me some time ago*, it seems worthy of a brief memorandum as showing that the Dinosauria retained this typical characteristic to so late a geological period as the Cambridge Upper Greensand.

The state of preservation of the fossil would suggest to me that it was probably found in the neighbourhood of Haslingfield. The neural arch is not preserved, and but little remains of the external hard film of bone; but although this is lost, and the cancellous tissue is almost everywhere exposed, the close resemblance of its form to the centrum of the Wealden axis strongly suggests that this condition is more likely to have resulted from prolonged exposure to the air, or from maceration, coupled perhaps with the action of solvents in the water, than to have been produced by attrition, though the marks of wearing are also observable. Therefore the specimen

* Quart. Journ. Geol. Soc. vol. xxxi. p. 461.

is more valuable as an evidence of form of the centrum than might at first sight appear, obscured though its surface is with small adherent masses of phosphatite, marl, oysters, and the shelly base of a *Gorgonia*-like polypary.

The striking features of the specimen are:—(1) the evidence that the neural arch was supported on pedicles of the centrum (fig. 1, *p*); (2) that the upper tubercle for the rib, usually called a diapophysis, was supported on this pedicle, and not on the neural arch itself; (3) the form of the odontoid process, which is compressed from below upward, and is almost a third of the length of the vertebra; (4) the form of the centrum, which is wide and depressed in front, and narrower, deeper, and subhexagonal behind; (5) the obliquity of the posterior articulation, which extends further backward at its ventral than at its neural border; and (6) the absence of all indications of a separate wedge-bone element beneath the anterior articulation,—the last point being perhaps the most interesting of all, because the Upper-Greensand Ichthyosaurs and Plesiosaurs similarly cease to have this ossification marked either by form or suture in the axis, although it is a characteristic separate element of the skeleton in the species which represent those orders in the older Secondary rocks.

The extreme length of the vertebra is $2\frac{1}{2}$ inches. The length along its neural border is about $2\frac{3}{10}$ inches; but, owing to the excavation of a large vertical space for the atlas below the odontoid process, the length along the ventral surface is only $1\frac{8}{10}$ inch. The neural canal is smooth, relatively large, and excavated in the centrum as a half-cylinder, which is $\frac{8}{10}$ inch wide in the hinder part of the vertebra.

The anterior articulation for the atlas is vertical and subreniform, concavely impressed below the odontoid process, so that its ventral margin was prominent. This concave area is $\frac{8}{10}$ inch wide, and is margined laterally by slight eminences, external to which the bone is again concave. The odontoid process (fig. 1, *o*) is slightly worn at its extremity and on its neural surface, but extends forwards in a broad wedge shape, also compressed from below upwards to some extent. The transverse measurement of the anterior face of the vertebra is $1\frac{1}{2}$ inch, while its vertical measurement, from the neural canal downwards, is $\frac{9}{10}$ inch.

The posterior articulation, as already remarked, is inclined forward (fig. 1, *pt*), is well cupped concavely, is a regular hexagon in outline, and is wider than the part of the centrum anterior to it. Its articular margins are a little worn; but it measured fully an inch from the neural to the ventral surface, and each side of the hexagon was about $\frac{6}{10}$ inch long.

The basal surface appears to have been flat from front to back, though its anterior margin is slightly worn. The articulations for the rib were placed much as in the Wealden specimen already described (Q. J. G. S. vol. xxxi. p. 461), except that in the Greensand fossil they are both relatively rather higher on the side of the centrum, and the parapophysis extends rather nearer to the anterior articular margin.

This specimen may be referred provisionally to Prof Huxley's genus *Acanthopholis*, though there is no certain evidence of its generic determination; its occurrence would justify the anticipation that this type of axis will be found to characterize all Cretaceous Dinosaurs. It is, however, remarkable that in *Zanclodon* the relations of the axis and the centrum of the atlas are entirely Crocodilian, and that the forms of the bones are so absolutely similar to the same elements in a Crocodile as to add a new element to the affinities of the Dinosauria, as indicated by this portion of the vertebral column.

Part II.

On the Vertebral Characters of Acanthopholis horridus, *Huxley*; *from the base of the Chalk Marl near Folkestone* (figs. 2 & 3).

Prof. Huxley's account of the remarkable Cretaceous Dinosaur named *Acanthopholis** is the basis for all future comparisons in estimating the affinities of the allied types which I am about to describe, some of which belong to species of the same genus, and others to genera all more or less nearly related. The most striking of the remains from the Cambridge Greensand are often portions of vertebral columns; and as the vertebræ of *Acanthopholis* have not hitherto been figured, it becomes necessary to add to the original description of the genus some account of these remains, part of which are in the Museum of the Geological Survey, while others are in the British Museum. As these remains were found at the same time they probably belong to one individual. Altogether there are hardly more than six or eight vertebræ, which give characters of the dorsal and early and later caudal portions of the series.

Dorsal Vertebræ.—The dorsal vertebra of *Acanthopholis* was briefly described by Prof. Huxley (Geol. Mag. 1867, vol. iv. p. 66). It is preserved in the Museum of the Geological Survey.

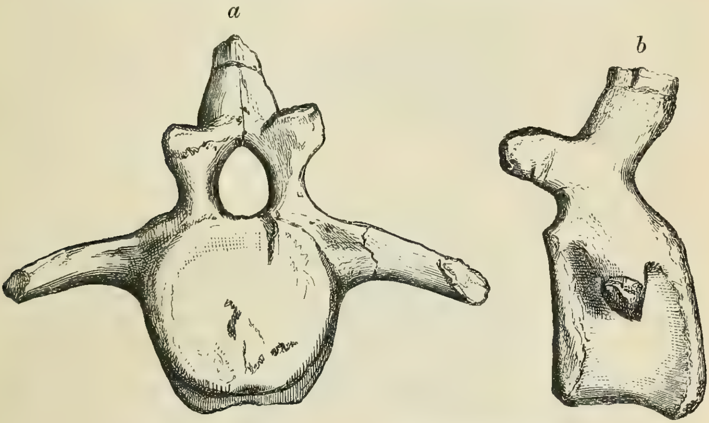
The anterior articular end of the centrum is 2 inches deep from the neural canal to the base, is vertically ovate in outline, $1\frac{9}{10}$ inch wide in the middle, and $1\frac{4}{10}$ inch wide at the upper part below the pedicels for the neural arch. The margin of the centrum is imperfectly preserved, and the flattened face is slightly concave.

The length of the centrum is $2\frac{1}{10}$ inches. The sides and base of the centrum are rounded from above downward. There is a very faint median ridge at the base, making the bone less concave from front to back than at the sides. The width of the middle of the centrum from side to side is $1\frac{9}{10}$ inch, and the width at the base of the neural arch in the middle of the centrum is $1\frac{5}{20}$ inch; the depth from the base of the neural canal to the base of the centrum is $1\frac{6}{10}$ inch. The neural canal is narrow with parallel sides; in front it is $\frac{5}{10}$ inch wide, and causes the centrum to project slightly below it anteriorly. The canal is deeply excavated in the bone. The condition of preservation of the specimen gives no indication of a suture with the neural arch, which probably existed.

* Geol. Mag. 1867, vol. iv. p. 65.

Early Caudal Vertebra (fig. 2).—The early caudal vertebra might be about the third. It has the centrum rather short, with the articular surface subcircular in front, and larger and subquadrate behind. The neural arch is moderate, with the compressed spine directed upward and backward; and the prezygapophyses extend outward in a V-shape, anterior to the face of the centrum. The transverse anchylosed caudal ribs are compressed from above downward, and directed outward and a little downward.

Fig. 2.—*Early Caudal Vertebra of* Acanthopholis horridus, *one half nat. size.* (From a specimen in the British Museum.)



a. Anterior view. *b.* Left lateral view.

The centrum, as in the early caudals of *Scelidosaurus*, has an aspect of leaning obliquely forward, partly owing to the articular surface for the chevron bones causing the posterior articulation of the vertebra to extend below the anterior articular margin, and partly in consequence of a real obliquity, as indicated by the angles made by the articular faces with the neural canal. The margins of the articular faces are apparently worn a little or roughened by decomposition. The antero-posterior measurement of the centrum is $1\frac{6}{10}$ inch below the neural canal, $1\frac{2}{10}$ inch through the middle of the concave articular faces, and nearly $1\frac{7}{10}$ inch towards the inferior visceral margin, so as to suggest a convex curve for the inferior outline of the tail.

The anterior articulation is somewhat markedly concave from above downward, has a thick rough rounded border, and is as nearly as possible circular, with a diameter of about $1\frac{9}{10}$ inch. The posterior articulation is subquadrate, but a little wider than deep, the width being about $2\frac{2}{10}$ inch. The depth from the neural canal to the facets for the chevron bones $1\frac{8}{10}$ inch, and to the base of the centrum rather over 2 inches. The least depth of the centrum from the middle of the neural canal to the middle of the basal visceral surface is $1\frac{8}{10}$ inch. The chevron facets, though prominent, are not clearly defined; a broad median concavity on the basal surface of the centrum may indicate that they were separate. This chevron region is $1\frac{3}{10}$ inch wide, and not more than $\frac{4}{10}$ inch long; it is oblique, looking downward and backward.

The sides of the centrum are somewhat flattened, are obliquely inclined, and converge towards the base, which is about an inch wide, and defined chiefly by the rounded ridges in the line of the chevron bones. The sides are slightly convex from above downward, and moderately concave from front to back.

The transverse processes have their superior surfaces on a level with the base of the neural canal. At their union with the centrum they expand in every direction so as to have a nearly circular base and to spread to the width of the centrum. As preserved, the process is about $1\frac{7}{10}$ inch long. It is compressed from above downward, being twice as wide as deep, and tapers a little outward, being $\frac{7}{10}$ inch wide at the end. The posterior margin is more curved than the anterior margin; and while the superior surface is more flattened from side to side, the inferior surface is the more convex.

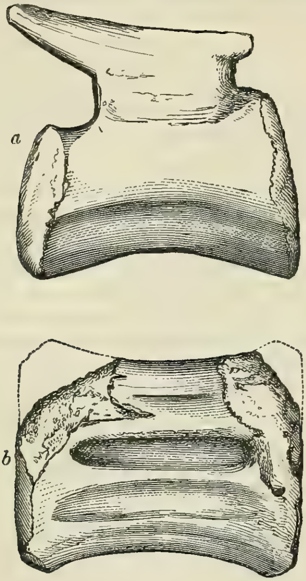
The neural canal is vertically ovate, about $\frac{8}{10}$ inch high and more than $\frac{5}{10}$ inch wide.

The neural arch is moderate, with the neurapophyses compressed from side to side and directed forward, so that the præzygapophyses project anteriorly to the front of the centrum; these processes were strong and subcylindrical; their articular ends appear to have been about $1\frac{8}{10}$ inch apart anteriorly, and to have converged backward in a Λ-shape, being deeply divided in front. Above the zygapophyses, of which the posterior are not preserved, the neural spine is directed obliquely backward, and becomes more compressed from side to side; it is fractured at less than 2 inches above the base of the neural canal, where it appears to be $\frac{8}{10}$ inch long and less than $\frac{5}{10}$ inch wide, and of an almond-outline in section, being sharper in front than behind.

Middle Caudal Vertebræ.—Centrum about $1\frac{1}{2}$ inch long, with the articular ends subcircular, wider than deep, the anterior apparently the larger, but both about $1\frac{2}{10}$ inch deep and wide (fig. 3). There is a rather deep, narrow, concave, median groove (see fig. 3, *b*) on the base of the centrum, about $\frac{3}{20}$ inch wide, which does not enlarge towards the ends. The sides are made subangular by two imperfect lateral ridges (see fig. 3, *a*), of which the lower is but slightly developed, and the upper one has in the middle the rudiment of a transverse process. The neural arch is compressed from side to side, prolonged backward beyond the centrum into a neural spine with parallel superior and inferior margins, more than $\frac{1}{2}$ inch deep and rising $1\frac{2}{10}$ inch above the base of the centrum, and compressed posteriorly from side to side. Anteriorly it is prolonged into two stout zygapophyses, which, as preserved, do not extend in front of the centrum.

The latest caudal vertebra preserved is in the Museum of Practical Geology. It has the centrum $1\frac{11}{20}$ inch long, and the neural arch rather shorter. The articular ends of the centrum are subhexagonal and moderately concave. The depth of the anterior face is rather less than an inch; the width from side to side in the

Fig. 3.—*Middle Caudal Vertebra of* Acanthopholis horridus, *nat. size.* (In the Museum of Practical Geology.)



a. Right lateral view. *b.* From beneath, showing median longitudinal groove.

middle of the centrum is $1\frac{1}{10}$ inch. The upper outline of the neural arch is straight and oblique. The depth from the posterior end of the neural arch to the base of the centrum is $1\frac{9}{20}$ inch, while in front the corresponding measurement is $1\frac{7}{20}$ inch; the width over the anterior zygapophyses is $\frac{11}{20}$ inch. The posterior end of the neural arch (which is imperfectly preserved) tapers. The length of the union between the neural arch and centrum is $\frac{8}{10}$ inch. The ridges on the sides of the centrum are only developed towards the articular ends.

This vertebral column is quite distinct from that of any other genus, though, as indicated by Prof. Huxley, it closely approaches to *Scelidosaurus*. There is a close general correspondence in the form of the dorsal centrum, though in the lower part of the back *Scelidosaurus* appears to have the body of the vertebra more compressed from side to side. The early caudal vertebræ in *Scelidosaurus* are longer, and more oblique, and have the neural spine less inclined backward. The later caudal vertebræ in *Scelidosaurus* are much more elongated than in *Acanthopholis*, have the body more constricted, and have no trace of the inferior median groove or of the lateral ridges of *Acanthopholis*, while the form of the neural arch is altogether different. The basal groove, form of the caudal centrum, and lateral ridges are rather indicative of resemblance to *Iguanodon*. The dermal armour, however, must not be neglected, as suggesting a not improbable and near relationship to *Hylæosaurus*. The Dinosaur from the Gosau beds (Upper Greensand), which Dr. Bunzel refers to *Scelidosaurus*, is closely allied to *Acanthopholis*, though it cannot be included in that genus.

Part III.

On the Skeleton of Anoplosaurus curtonotus, *Seeley, a Dinosaur from the Cambridge Greensand, contained in the Woodwardian Museum of the University of Cambridge.* (Plates XXXIV. & XXXV.)

At the close of the year 1872 Mr. Henry Keeping secured for the Woodwardian Museum, from one of the phosphatite-washings near Reach, an associated series of Dinosaurian bones, which, though indicating an animal of no large size, makes a considerable addition to our knowledge of the Cretaceous modifications of that organic type. In all there are about 77 bones or fragments of bones, which may be referred to under the following osteological headings :—

1. Anterior extremity of left ramus of lower jaw.
2. Five or six centrums of cervical vertebræ.
3. Twelve or thirteen centrums of dorsal vertebræ and fragments of ribs.
4. Six centrums of sacral vertebræ and fragments of sacral ribs.
5. Eight centrums of caudal vertebræ.
6. Four neural arches of vertebræ, chiefly dorsal.
7. Evidence of both coracoids.
8. Proximal end of scapula.
9. Proximal and distal ends of right humerus.
10. Proximal and distal ends of left femur; and other fragments, among which are metatarsal bones, phalanges, and fragments of the left tibia.

All the specimens are more or less broken and worn; they are incrusted with Oysters and *Plicatulæ*; but having lain in the sea where the phosphates were not abundant, are in a pale state of mineralization, and have few adherent masses of phosphate of lime upon them. Like the other Cambridge-Greensand fossils which have come under my notice, they show no signs of being derivative, and appear to me to be of Upper Greensand age.

The Lower Jaw.—The fragment of jaw (Plate XXXV. fig. 1) is $2\frac{3}{8}$ inches long. It is fractured posteriorly, inferiorly, where the inner margin of the bone is thin, and anteriorly, so that it affords no evidence of the nature of the symphysial union of the rami other than that it was very short and narrow. The jaw becomes less deep from behind toward the anterior extremity, as in other Dinosaurs, and teeth were apparently continued almost, if not quite, to the anterior end. The alveolar margin is nearly straight, being but very slightly convex externally, and similarly concave internally. It is compressed from side to side, $\frac{3}{8}$ inch thick posteriorly, and $\frac{5}{16}$ inch thick anteriorly; it may have been vertical. As preserved, the external alveolar wall is higher than the inner wall, and appears always to have been higher. In the length of $2\frac{1}{4}$ inches are the sockets or spaces for thirteen teeth; the sockets appear to have been nearly half an inch deep, and parallel to the inner surface of the jaw, so that the teeth were directed outward. The sockets were apparently nearly circular; but owing to this outward direction they appear as though they were transversely oblong. The inner surface of the jaw is approximately parallel to the outer surface; it consists of two areas—a long flat superior space, the plane of which is twisted a little outward anteriorly, about $\frac{5}{8}$ inch deep, and limited inferiorly by a sharp straight angular ridge; and below this is a channel attenuated anteriorly, the side of which bends under the superior area (see Pl. XXXV. fig. 1 *a*). The thickness of the bone becomes reduced below the ridge, being hardly more than $\frac{1}{8}$ inch thick where fractured along its inferior border, which is directed inward. As preserved, the groove is not more than $1\frac{1}{2}$ inch long, hence the symphysis could not have occupied more than an inch in front of the groove.

Externally the specimen consists of an inferior part, convex from above downward, corresponding to the internal groove, and therefore extending longitudinally from behind forward, bulging out so as to widen the jaw to $\frac{5}{8}$ inch, and dying away in front, where the jaw is moderately convex from the alveolar margin downward. Above this longitudinal inferior convexity the bone is very slightly channelled in length, being slightly concave from above downward. Along this space are several vascular perforations at irregular distances, which become small and more numerous towards the anterior extremity of the specimen. The extreme depth of the fragment as preserved, at the posterior fracture (Pl. XXXV. fig. 1 *a*), is about $1\frac{1}{8}$ inch.

This form of jaw has hitherto been described in no British Dinosaur; but on some future occasion I expect to be able to show that an animal with a similar mandible has left its remains in the Gosau beds of Austria, which are also of Upper Greensand age.

The Vertebral Column.

Cervical Vertebræ.—None of these vertebræ have the neural arches preserved, and all have the margins of the centrums and the tubercle for the rib worn. This gives rise to some uncertainty as to whether the sixth vertebra is not rather a first dorsal, as I incline to believe. The five vertebræ (Plate XXXIV. fig. 1) are similar in size, and measure $7\frac{1}{4}$ inches in length when placed in close succession, without making any allowance for the intervertebral cartilages. The earliest vertebra preserved has the centrum somewhat depressed; but the centrums increase slightly in depth as they succeed each other backward, and decrease slightly in length. The first (fig. 1, I), as preserved, is fully $1\frac{1}{4}$ inch long, with the anterior articular surface worn, so that neither its width nor depth can be given with certainty; though, as widened by the diapophysis, it is obviously wider and does not appear to be so deep as the posterior articular end. The diapophysis is large, and placed low on the side of the centrum just behind the anterior articulation; the transverse width over the diapophyses appears to have been at least $1\frac{3}{8}$ inch. Behind the diapophyses the centrum is constricted regularly, so as to measure 1 inch from side to side. The sides and base are concave (Pl. XXXIV. fig. 1 *a*) from front to back; but the sides have a somewhat vertical aspect and the base a broad and flattened aspect, owing to these regions being separated by slight angles at the margin of the posterior articulation, though the base is moderately convex from side to side, and rounds into the superior lateral regions. The ovate posterior articulation has had its margin rubbed; it is flattened, but moderately concave, much as in Teleosaurs, and is $\frac{15}{16}$ inch deep and $1\frac{1}{8}$ broad, as preserved. The neural arch may have extended the whole length of the centrum; the neural canal is shallow, widened posteriorly, and contains small nutritive foramina in the middle.

The second vertebra preserved (fig. 1, 2) has the base of the centrum more rounded, and consequently the diapophysis appears to be rather higher on the side of the centrum. The centrum is less constricted from side to side behind the diapophyses, the sides of the centrum are more convex in depth, the centrum is shorter, and the articular surfaces appear to be larger. The following are the measurements of the specimen as preserved:—

Along the base of the centrum $1\frac{3}{16}$ inch, less along the neural canal; width over remains of diapophyses $1\frac{3}{8}$ inch; depth of anterior articular face 1 inch; width behind the diapophyses $1\frac{1}{8}$ inch; width of posterior articulation $1\frac{1}{4}$ inch; depth of posterior articulation $1\frac{1}{16}$ inch.

The external margins of the bases for the neural arch are compressed so as only to measure $\frac{15}{16}$ inch from side to side.

In the succeeding cervicals (fig. 1, 3, 4, 5) the differences are slight, except from the increased depth of the centrum, which in the fifth measures $1\frac{1}{8}$ inch deep posteriorly, as preserved. The anterior articulation of the centrum is in all cases nearly flat; but the posterior face is moderately cupped, often with a central depression. The base of the neural canal, too, becomes more deeply channelled; it is impressed in the middle with the nutritive foramina, and the tubercle for the rib rises higher on the side of the centrum. Since the first vertebra preserved is posterior to the axis, this animal must have possessed at least seven cervical vertebræ; but there were probably not more than eight, since not more than one vertebra appears to be missing from between the last cervical and first dorsal of the series.

Dorsal Vertebræ (Pl. XXXIV. fig. 2).—There are thirteen dorsal vertebræ, or vertebræ from between the neck and the sacrum. They appear to be in sequence, and therefore, if the number were similar to that in the Crocodile, the gap between the dorsal and sacral series must be very small. In the Crocodile the series can readily be divided by the relations of the ribs into three groups, comprising, after the eight cervical, three pectoral, seven dorsal, and six postdorsal or lumbar. Nothing corresponding to this division can be recognized in the fossil, because only the centrums of the vertebræ are preserved.

These centrums are exceedingly similar in form, but increase slightly in length as they pass down the back, and when placed together in sequence, with their articular faces in contact, form an upward arch, which is unlike the straight horizontal column of the Crocodile, and suggests, I think, that the body may have been carried in a semi-erect position, as was certainly the condition in so many of the Dinosauria. The form of the centrum, which is well rounded on the underside (fig. 2*a*), is remarkably Teleosaurian. The position of each vertebra in the series is determined by length, size of the articular ends, and shape, width, and degree of excavation of the area which forms part of the neural canal, there being a marked increase in width and depth on nearing the sacrum, while the neural area widens posteriorly on nearing the neck.

The first centrum of the series is fractured transversely, as though by a stroke of the workman's pick, and only the posterior half is preserved. It shows the articular area for the neural arch to be exceedingly broad, and the posterior face of the centrum is very slightly concave, being much less impressed in the middle than in the cervical region. The second dorsal measures $1\frac{2}{10}$ inch from front to back, has an aspect of slight compression from side to side, where it measures 1 inch in the middle of the centrum, becoming a little wider towards the neural arch. The depth of the centrum from the neural canal is $1\frac{3}{20}$ inch. The posterior articular face is almost absolutely flat. The third dorsal is rather better preserved; it measures $1\frac{5}{20}$ inch in length, is rather more flattened at the sides and ends, and has the neuro-central suture so uniform that the back of the vertebra can only be recognized by the nutritive foramina in the neural canal being placed slightly behind the middle line. The fourth dorsal slightly increases in length, and is more compressed below the neuro-central suture, so that the articular faces of the centrum become vertically elongated, measuring, as preserved, $1\frac{3}{10}$ inch in depth and $1\frac{3}{20}$ inch wide. The fifth to the twelfth centrums are about $1\frac{1}{2}$ inch long, and have the sides of the neural canal rather narrower than in the earlier dorsal region, the sides being subparallel, with a slight expansion at both the anterior and posterior ends. The neuro-central suture is slightly convex from back to front, is marked with transverse grooves, as in Teleosaurs, and in the seventh centrum the lateral compression reduces the transverse measurement in the middle of the suture to $\frac{17}{20}$ inch. Towards the end of the dorsal series the articular face of the centrum is more nearly circular, and it becomes flat at one end, and somewhat concave at the other. There is no certain evidence on the matter; but I am inclined to regard the somewhat larger end with the concavity as anterior, on the ground that the neuro-central sutural surface is somewhat wider towards the concave end. Hence there would seem to be an approach towards a procœlous articulation in the lower part of the back, which may be a functional development consequent upon a semierect mode of progression. The last dorsal is much longer in the neural than in the visceral measurement, the extreme length being $1\frac{13}{20}$ inch. There is no important change in the size or form of the articular face. When placed together, end to end, without allowance for intervertebral cartilages, the series of dorsal vertebræ measures 19 inches; but this does not represent the entire length of the dorsal region, because at least one vertebra is missing between the last dorsal and first sacral, and at least one between the first dorsal and last cervical.

Neural Arch.—The most perfect specimen of a dorsal neural arch is figured (Pl. XXXV. fig. 14). It measures $1\frac{11}{20}$ inch from the sutural surface uniting with the centrum, to the slight transverse platform (*a*) from which the compressed neural spine (*e*) rose; though now broken away, the platform was horizontal, small, convex from front to back, concave from side to side, with the outer prolongation notched out posteriorly and directed a little upward. Its anterior border reaches no further forward than the middle of the neurocentral suture. There is the usual strong buttress below this transverse process, compressed from side to side, and terminating in an elevated vertically ovate articulation for the rib (*b*), looking outward and a little upward, $\frac{3}{10}$ inch wide and $\frac{5}{10}$ inch long, above which the buttress is constricted, and below which it widens and disappears. The prezygapophyses are broken away (*d*); but the posterior zygapophyses (*c*) are flat ovate facets looking obliquely downward and outward, converging inferiorly so as almost to unite, but remaining separated by a groove. The arch over the neural canal is remarkably high and narrow.

Dorsal Ribs.—The dorsal ribs are represented by a number of fragments, but none are sufficiently perfect to give any idea of their length. The fragments are all more or less curved. The two specimens figured (Pl. XXXV. figs. 11, 13, 12) give some idea of the difference in size of the specimens and of the typical characters which they present. They are especially remarkable for having the under or visceral surface compressed and the dorsal surface expanded like the crosspiece of a capital T. This would suggest a great development of intercostal muscles, and would have led me to anticipate for the animal some form of dermal armour; but since no trace of armour was found with the remains, the explanation of this form of rib has yet to be discovered.

Sacral Vertebræ (Pl. XXXIV. fig. 3).—The sacral vertebræ, as preserved, are six in number, and the series is apparently complete; but they do not become anchylosed into a sacrum, though the articular surfaces were evidently in intimate juxtaposition. It is impossible to affirm that this condition is proof of the immaturity of the individual, though such a conclusion is natural. As placed together, end to end, the series of vertebræ measures $8\frac{1}{2}$ inches in length. As in the other regions of the vertebral column, there is no trace preserved either of neural arches or of the short sacral ribs in union with the centrums, except the impressed surfaces for their articulation upon the sides of the centrums. In the absence of the usual aids for determining the order of succession of the bones, I have arranged them in sequence by means of the form of the neural canal and the mutual adaptation of the articular surfaces. Like the sacral vertebræ in other Dinosaurs, these centrums are of dissimilar forms, and are unlike the dorsal vertebræ, which all have the visceral surface well rounded, as in Crocodiles.

The first sacral (fig. 3, 1) is $1\frac{6}{10}$ inch long along the neural canal, and about $\frac{1}{10}$ less along the visceral border. The base and sides are flattened, though the sides are moderately concave in length, and slightly convex from above downward, in which direction they converge. The base is defined by well-rounded shoulders, which merge into the sides; it is slightly concave in the middle towards the two ends. The anterior articular surface is much the smaller of the two, is vertical, flattened, slightly concave from above downward, and subquadrate, being wider above than below. From the neural canal to the base is $\frac{9}{10}$ inch. The width of the centrum just below the neural canal is $1\frac{2}{10}$ inch, while the width at the base is about $\frac{7}{10}$ inch. The neural canal is very large, deep, widens rapidly behind, and gives off the first pair of sacral nerves anterior to the posterior articular surface, where the transverse measurement is $1\frac{1}{4}$ inch. In front the neural canal is about $\frac{6}{10}$ inch wide; posterior to the excavations for the sacral nerves the width is probably nearly double. The posterior articulation is angularly crescentic, being concave above in the line of the neural canal; it is $\frac{8}{10}$ inch deep, $1\frac{1}{2}$ inch wide at the upper margins of the neural groove in the centrum, and about $\frac{8}{10}$ inch wide at the base. The surface is flat, but marked with grooves, which radiate towards the sides and base. The length of the wall for attachment of the neural arch is less than an inch; it is compressed from side to side, and increases in width in front. There is no indication of a rib to the ilium having originated from the centrum of this vertebra.

In the second sacral (fig. 3, 2) the centrum attains its greatest width, and the neural canal acquires its largest size; but in form the vertebra is unlike the first, especially being depressed and much broader than long, with a rough parallelism between the convex visceral surface and the concave neural canal. The extreme length of the centrum is $1\frac{13}{20}$ inch; but it is somewhat less in the median line, since the posterior face is concave from side to side. The base is flattened, but rounds into the sides, which slope obliquely outward, more rapidly towards the posterior than towards the anterior end. In front the flat articular face of the centrum is $\frac{8}{10}$ inch deep; it is of subcrescentic outline, extending superiorly up each side of the neural canal, where the horns are $\frac{1}{2}$ inch wide. The posterior articulation is an arc of a large circle, as wide at the sides as in the middle, where it is $\frac{8}{10}$ inch deep. The pedicles for the neural arch reach from the anterior face of the centrum backward $\frac{9}{10}$ inch, and diverge outward; they are $\frac{1}{2}$ inch wide, and narrow posteriorly. They are bounded behind by the large canals for the sacral nerves, larger on the left side than on the right; these canals are directed obliquely forward. Behind and chiefly below these grooves are the large, subcircular facets, $\frac{3}{4}$ inch in diameter, for the sacral ribs, which look outward, backward, and somewhat upward, extending to the posterior articular surface of the centrum, and by their transverse extension making the side of the centrum concave from front to back. The transverse width of the centrum at the notches for the sacral nerves is $1\frac{3}{4}$ inch; the transverse width over the front of the facets for the sacral ribs is about $2\frac{1}{4}$ inches; the width of the neural canal between the pedicles for the neural arch, as preserved, is $1\frac{1}{4}$ inch.

The third sacral vertebra (fig. 3, 3) is smaller, with the centrum similarly depressed, the neural canal almost as large, the anterior intervertebral articular surface convex from side to side, and the posterior articulation similarly concave, the latter being relatively deeper; the length of the centrum in the median line is $1\frac{1}{2}$ inch. The base is flattened, slightly convex in the middle portion, and measures $1\frac{17}{20}$ inch transversely. This great width, like the flattening, results from the fact that the whole of the side is occupied by surfaces for the attachment of sacral ribs. The two pairs of these surfaces are divided by the grooves for the sacral nerve, which are only half as wide as those in the second vertebra; these grooves are $\frac{8}{10}$ inch from the anterior articulation, and are directed outward, a little backward, and vertically downward between the facets for the sacral ribs as a canal $\frac{3}{20}$ inch wide. The anterior of these rib-facets is the larger; it is an inch deep, and not quite so long, being subquadrate; the surfaces look outward, forward, and very slightly upward, and extend to the anterior articular surface of the centrum. The posterior facet is fully as deep, but not more than half an inch in length; it extends back to the posterior articulation, and looks outward and backward. The greatest transverse measurement is 2 inches at the middle of the centrum. The neural arch appears to have been attached to both the anterior and posterior ends of the centrum by pedicles, which are coextensive with the length of the facets for the sacral ribs. The superior and inferior margins of the articular faces of both ends of the centrum are subparallel, about $\frac{8}{10}$ inch deep; but the anterior articulation has the greater transverse measurement, and increases in depth a little towards its lateral limits. The width of the neural canal, as preserved, is $1\frac{1}{10}$ inch, but becomes less posteriorly.

The fourth sacral vertebra (fig. 3, 4) has greatly decreased in size. There is a vertical elevated ridge in the middle of the anterior articular surface of the centrum, on each side of which the flattened surfaces are slightly concave; the outline of the articulation is reniform, it is more than $\frac{8}{10}$ inch deep, and was about $1\frac{3}{10}$ inch wide. The under surface of the centrum has a conspicuous rounded median ridge, most marked posteriorly, and on each side the halves of the base are flattened and converge inferiorly. The posterior articular surface of the centrum is relatively narrow (because there is only one pair of facets for sacral ribs, and they are immediately behind the anterior articulation); it is $\frac{9}{10}$ inch deep in the middle, and $1\frac{7}{20}$ inch wide at the upper third; the surface is concave from side to side, and most impressed in the upper part of the middle line. The neural canal widens in its hinder third, where it gives off a pair of sacral nerves, which are directed slightly backward as they pass out. The anterior lateral facets for the sacral ribs are large, extend back behind the middle line of the centrum, and were directed forward and outward. The neural canal again becomes narrower behind than it was in front.

In the fifth sacral vertebra (fig. 3, 5) the centrum reverts very much to the form and proportions of an early dorsal, being compressed at the sides, having the base well rounded, and the margins of the articular surfaces well elevated. It is $1\frac{1}{4}$ inch long, and has the body of the vertebra relatively deep in proportion to the width. The anterior articulation is half an oval, with a prominent tubercle below the neural canal, and on each side of this tubercle is a depression; the surface is otherwise flattened, but slightly convex from side to side; it is $\frac{9}{10}$ inch deep in the middle, and about $1\frac{2}{10}$ inch wide in the upper third. The posterior articulation is more nearly subquadrate; it is rather deeper, about as wide, is flattened, but concavely impressed in the median line below the neural canal. The facet for the sacral rib is small, and limited to the upper third of the side of the centrum. The neural canal has now become much smaller than in the first sacral, and the nerves are given off very high up, more than $1\frac{2}{10}$ inch from the base of the posterior articulation, and hardly more than a quarter of an inch anterior to it.

The sixth and last sacral centrum (fig. 3, 6) approximates in characters to an early caudal; but the neural canal is more deeply excavated than in the caudal region, while the large size of the attachment for the neural arch and the form of the anterior articulation show it to be sacral. It is $1\frac{2}{10}$ inch long in the line of the neural canal, and less in the basal measurement. The anterior articulation is less than an inch deep, and is widened transversely by the large facet for the sacral rib to about $1\frac{2}{10}$ inch, but the transverse measurement over those facets is $1\frac{6}{10}$ inch. Below the neural canal, which is only $\frac{3}{10}$ inch wide in front at the base, is a prominent tubercle, with a concavity on each side, as in the fifth vertebra, below which the surface is similarly marked with slight grooves, such as are usually seen in cartilaginous surfaces between which there is no motion. The posterior surface is more nearly circular, and measures more than an inch in depth and $1\frac{3}{10}$ inch wide; in its centre is an elevated tubercle, as usual in caudal vertebræ, and around this the surface is concave and marked with faint concentric lines. The base of the centrum is well rounded, but its sides are pinched in concavely below the facet for the last sacral rib; this facet appears to have been transversely elongated and to have looked outward. The attachment of the neural arch appears to have extended the whole length of the centrum, and to have been wider than in any of the other sacral vertebræ.

This sacrum gives evidence of only four sacral ribs (Pl. XXXIV. fig. 4). The first, attached between the second and third centrums, and the second, between the third and fourth centrums, were massive, the former being $1\frac{1}{2}$ inch in diameter at its origin and the latter rather less. These were the true sacral elements, and would correspond to the sacrum of the Crocodile or Teleosaur. The third and fourth sacral ribs are small; the former is given off from the fifth, and the latter from the sixth sacral vertebra. The great enlargement of the neural canal in the sacral region, where it becomes much wider than the entire diameter of a dorsal centrum, and the absence of any corresponding pectoral enlargement is strongly suggestive, not only that the hind limbs were relatively more developed than the fore limbs, but that progression was carried on by means of the hind limbs; and the slight increase in size of the centrums from the neck to the sacrum would support such a conclusion.

Caudal Vertebræ (Pl XXXIV. fig. 5).—The eight caudal vertebræ, when placed together in close succession, measure $8\frac{1}{2}$ inches in length, and when so placed arrange themselves in a curve, which has the convex side downward, while the dorsal and sacral regions form a curve in the opposite direction; and this curve of the tail appears to be correlated with the elevation of the root of the tail well above the ground.

Each centrum is just over an inch long, the last of the series being of the same absolute length as the first, though the vertical and transverse measurements have become greatly reduced. The first caudal of the series exactly corresponds in size with the posterior articular face of the last sacral vertebra.

The anterior face of the second centrum is flattened, but slightly concave, is of subcircular outline, nearly $1\frac{2}{10}$ inch wide and nearly $1\frac{1}{10}$ inch deep. The posterior face (fig. 5 *a*) is subtriangular, owing to the sides converging inferiorly and terminating in the oblique facet for the chevron bone, which is more than half an inch wide, and rounds upward into the intervertebral articular surface. This surface is $1\frac{1}{10}$ inch wide in its upper third, and nearly $1\frac{2}{10}$ deep to the base of the chevron articulation: it is much more concave than the anterior articulation, and the depression is similarly deepest just above a slight mamillate eminence in the centre of the intervertebral surface. The antero-posterior measurement of the centrum is 1 inch. The base of the neural arch has come away on the left side, leaving a large pit $\frac{3}{4}$ inch long and $\frac{4}{10}$ inch wide. On the right side the pedicle has remained attached, and shows that from this broad base a small compressed lamina ascended, directed inward, to form the arch over the neural canal. At the sides of the centrum are, on each side, an ovate facet more than half an inch long and of less depth, placed midway between the anterior and posterior articular faces of the vertebra. These facets gave attachment to the transverse processes or caudal ribs; they have an elevated border, and the upper fourth is formed by the pedicle of the neural arch, while the remainder of the facet is on the upper part of the side of the centrum. In subsequent vertebræ this facet decreases in size, descends a little in position, and is placed nearer to the posterior end of the centrum. The sides of the centrum converge inferiorly towards a flattened narrow base, which is about $\frac{4}{10}$ inch wide, and owes its existence and imperfect definition to the chevron bone attached to the base of the posterior articular surface. The ventral surface of the first centrum is considerably more convex from side to side. In the sixth caudal the width and depth of the centrum are about an inch; the antero-posterior extent of the narrow lamina of the neural arch is $\frac{9}{20}$ inch; the transverse process appears to be short, thick, and directed a little backward. The base is better defined by an obscure angular ridge, and midway on the side, below the transverse process, is another angular ridge. The articular ends of the centrum are more concave than in the earlier vertebræ. The first six vertebræ (fig. 5) are in natural sequence; then the series is broken by the loss of probably four vertebræ. The remaining two centrums preserved were followed by at least four more, so that the tail may have included at least sixteen vertebræ, and have measured at least as many inches.

The last centrum preserved has the anterior face $\frac{19}{20}$ inch wide and $\frac{15}{20}$ inch deep, with the outline flattened above and convex below. The posterior face is $\frac{9}{10}$ inch wide and $\frac{8}{10}$ inch deep. There is an indication of division in the chevron facets. The underside of the centrum becomes rounded, and the size of the transverse process, still high on the side, is reduced to a mere tubercle. The neural canal is narrow and slightly channelled in the centrum, and the base of the small neural arch was less than $\frac{4}{10}$ inch long.

The Scapular Arch.

Coracoids.—The right coracoid is only preserved in a fragment, but the left is fairly perfect (Pl. XXXV. fig. 2). It was an expanded subquadrate bone of the usual pattern, thick at the articular surfaces for the humerus and scapula, and thin at the two other edges, the anterior and upper of which is broken. The underside of the bone is concave, the upperside gently convex. It is $3\frac{4}{10}$ inches wide from the scapular to the inferior margin. The surface to which the scapula was attached (fig. 2, *b*) is convex in length, as preserved, and imperfectly ossified. It measures about $1\frac{1}{2}$ inch in length, is $1\frac{1}{10}$ inch thick at the junction with the humeral surface, and becomes compressed as it ascends. The humeral surface (fig. 2, *a*) is subquadrate, $1\frac{2}{10}$ inch long, and of about the same thickness; it is smooth, truncating the bone transversely, and nearly flat. Below the humeral articulation the bone is emarginate on the external surface, and the emargination resembles the appearance that would be produced by drawing the thumb over the angle of a plastic substance. The portion of the anterior border which looks downward is $2\frac{1}{2}$ inches long, as preserved, and thin, thickest at the corner nearest the humerus, and becoming attenuated as it ascends. The other upperside, which is somewhat broken, is about $2\frac{1}{4}$ inches long. The coracoid foramen is placed about the middle of the scapular margin, and extends obliquely inward, upward, and backward; it is about $\frac{3}{10}$ inch in diameter, and penetrates into the scapular margin as it emerges on the inner side of the bone.

Scapula.—The scapula is known from an important fragment, comprising the articular end of the right side of the bone (Pl. XXXV. fig. 3). It is imperfectly preserved at the anterior border, but is 3 inches wide. The humeral surface (*a*) is flat, $1\frac{1}{4}$ inch long, and about as wide; it is rounded posteriorly, and convex on the inner surface from side to side. The coracoid surface (*c*) is divided into two portions, and is somewhat compressed from side to side. The inner surface of the bone is concave from above downward. The posterior outline is moderately concave, while the anterior outline is more concave, rounding distally into a convex outline, which is partially broken away. The specimen is $3\frac{1}{2}$ inches long, and, where fractured, the ascending shaft is $1\frac{1}{2}$ inch wide, $\frac{9}{10}$ thick, and more compressed on the inner than on the outer margin. The distinctive feature of the bone which separates it from other scapulæ is the development towards the humeral side of a massive quadrate spinous process (fig. 3, *b*), which increases the thickness of the bone to $2\frac{1}{4}$ inches. It is $\frac{19}{20}$ inch wide, margined posteriorly by a sharp ridge, anteriorly by a rounded ridge, is rounded inferiorly almost as perfectly as a pulley surface, and flattened externally till it merges, after about 2 inches, in the free end of the scapula. It extends to within about half an inch of the humeral articulation, and is directed obliquely forward across the bone.

The Fore Limb.

Humerus.—Only the right humerus is preserved (Pl. XXXV. figs. 4, 5). It has been fractured by a blow from a digger's pick, which has removed the middle portion of the shaft and broken away the radial crest. The distal articular end is imperfect, owing to decomposition of the bone before fossilization, and its decayed surface, like the body of the shaft, is overgrown with *Plicatulæ*. The humerus is larger than might have been anticipated in an animal otherwise giving indications of a semierect position. It was probably not less than 9 inches in length, evidently possessed a long and compressed radial crest, which reached at least halfway along the bone, had the proximal end massive and the distal end fairly expanded, while the lower part of the shaft was constricted in the usual manner. As preserved, the specimen at the proximal end (fig. 4) is nearly flat on the ventral surface, with the slightest indication of concavity from side to side. The extreme width from side to side is rather less than 3 inches, as preserved; but the bone was somewhat wider, since no part of the radial crest is preserved, though its limit is indicated by a slight reflection downward of the margin of the fragment at the fracture (fig. 4, *a*). The radial crest appears proximally to have been about half an inch thick, and to have extended to within about three fourths of an inch of the proximal end of the bone. It is separated from the articular head by an oblique region, which is somewhat compressed, less than 1 inch long, a little concave in length, and rounded from side to side. The head of the bone (fig. 4, *b*) is subovate, but the margins of the articular surface are a little worn or decayed. It is slightly convex in its long diameter, from the ulnar to the radial side, which measures about $1\frac{9}{10}$ inch, and rather more convex from the dorsal to the ventral side, where it measures about $1\frac{6}{10}$ inch. Its margin bulges convexly on the dorsal aspect, but not so markedly as in some other Dinosaurian types, such as *Hadrosaurus*; it is even less than in the humerus attributed to *Hylæosaurus*, and is perhaps more nearly like *Scelidosaurus*, though the resemblance would appear to be closer to another and undescribed Dinosaurian genus from the Lias. The proximal articular surface is smooth, though marked by irregular shallow grooves, which may indicate that it possessed a terminal articular cartilage, though developed to a less extent than in the Ceteosaurians of the Lower Secondary rocks. Towards the ulnar side the articular surface becomes narrow and prolonged, like the stalk of a fig (fig. 4, *c*); but this portion is inclined at an angle of about 45°. It is nearly flat in its long measurement, which is more than an inch, and slightly rounded in its narrow measurement, which appears to have been less than three quarters of an inch. It gives an extreme length of articular surface to the head of about $1\frac{7}{10}$ inch. Externally the ulnar margin is well rounded from side to side, about $\frac{6}{10}$ inch thick, and by its compression forms on the dorsal surface a concave longitudinal channel, which descends some little distance on that aspect of the bone. Below the articular head of the bone the shaft is convex from side to side, but becomes rapidly compressed, so that 2 inches below the articular surface its thickness is scarcely 1 inch. The fragment is unfortunately only about 2 inches long; it shows indications of the lateral margins rapidly converging, is marked on the dense external layer with longitudinal striæ, and shows at the fractured end fine cancellous tissue, but no trace of a medullary cavity.

Distal end.—The distal end (fig. 5) apparently formed an angle with the proximal end in the usual way, so far as can be judged by comparison of the proximal and distal fractured surfaces of the humerus. The distal fragment is $4\frac{1}{2}$ inches long, and at its proximal end has a subtriangular section, measuring nearly $1\frac{1}{2}$ inch in the greatest long diameter, from the ulnar to the radial sides, and about 1 inch in the greatest short diameter, which is towards the ulnar side from back to front. It will thus be seen that the bone is compressed towards the lower radial margin, and the strong crest which is there indicated is the distal termination of the radial crest. The long axis of this section is at an angle of about 45° to the axis of the distal articulation. The ventral side is here flattened, but has a slight indication of a longitudinal concavity. The dorsal aspect is divided into two areas by a rounded angular bend, that of the ulnar side is the shorter and less convex. The shaft continues to decrease in thickness towards the distal end, where it measures, just above and between the condyles, $\frac{9}{10}$ inch, and it more rapidly increases in width, though, from the radial condyle being broken away, it is impossible to state accurately what the width was, though it could not have been less than 3 inches.

Metacarpal bone.—This small well-preserved specimen I am inclined to regard as the fifth or outer metacarpal of the left fore limb. It is $1\frac{4}{10}$ inch long, and has the proximal articulation subtriangular, $\frac{9}{10}$ inch wide and $\frac{8}{10}$ inch deep, with the apex of the triangle below. The articular surface is nearly flat, but slightly oblique, as shown in the figure (Pl. XXXV. fig. 9).

The bone is compressed from above downward, $\frac{6}{10}$ inch wide in the middle of the shaft and $\frac{4}{10}$ inch deep. It terminates distally in an oblong surface, which is convex from above downward and from within outward, and has the upper outer corner rounded away. The surface is fully $\frac{8}{10}$ inch long and $\frac{6}{10}$ inch deep.

The Hind Limb.

The Femur (Pl. XXXV. fig. 6) is very imperfectly preserved, having been considerably fractured by the workmen. A portion of the proximal end is preserved, which is about $3\frac{1}{4}$ inches long, and displays a small piece of the outermost part of the proximal articulation (*a*), showing it to have been comparatively smooth and slightly convex from front to back, in which direction the measurement was rather more than 1 inch. The bone was flattened behind, but was not flattened on the external aspect at the proximal end. Here it is convex from within outward, and also rounds into the posterior surface. In front there is a strong proximal trochanter (fig. 6, *b*), somewhat of the type seen in *Iguanodon*, but more compressed; it is closely adherent to the shaft without being anchylosed to it. The cleft on the posterior side is more marked than on the anterior side, and extends for $1\frac{3}{4}$ inch below the proximal articular surface. This trochanter is broken away in its upper part, but its base is $\frac{7}{10}$ inch wide and nearly $\frac{3}{10}$ inch thick. The inner half of the proximal end of the bone is broken away.

The distal end is represented by a small portion of the shaft, also of a left femur, and therefore presumably the same bone. It is from just above the distal condyles, and shows on the posterior surface the usual groove between the condyles, which is placed, as usual, nearer to the inner than to the outer side of the bone. The fragment, which is only $1\frac{1}{2}$ inch long, is 2 inches wide at the distal end, and the greatest antero-posterior measurement is $1\frac{3}{20}$ inch, while in the condylar groove (fig. 7, *a*) the measurement is $\frac{17}{20}$ inch. The front is flattened, with a slight tendency to a median longitudinal depression. The inner side is slightly flatter than the outer side; but both are well rounded, and round into the two halves of the posterior surface. There is no indication of any expansion of the bone at the distal end, and it is improbable that the strong external muscular process seen in some genera was here developed.

The bone had a large medullary cavity; it is dense at its circumference, and finely cellular internally. I estimate the length of this femur to have been about 12 inches. Its distinctive features are the compression and position of the proximal trochanter. Its imperfect preservation renders comparison with other types at present difficult.

The Tibia.—The left tibia is represented by two fragments of the shaft, which give no indications of the forms of either the proximal or distal articular ends. The distal end decayed before fossilization, but the proximal end and middle of the shaft appear to have perished under blows from the diggers' picks. Proximally the larger fragment is triangular, being flattened behind and obliquely compressed from side to side so as to form a strong cnemial crest, which is directed outward in front of the proximal end of the fibula. The oblique inner and anterior surface of the bone is flattened. The external or fibular side (Pl. XXXV. fig. 8, *a*) is gently channelled from front to back. The width of the fragment, as preserved, from side to side posteriorly is $1\frac{3}{20}$ inch, from front to back at the external border $1\frac{3}{10}$ inch, and from the cnemial crest to the inner posterior border $1\frac{6}{10}$ inch. The two posterior angles of the bone are rounded, and the cnemial crest, which is gently concave in the outline of its length, becomes more compressed proximally.

The distal fragment becomes flattened in front and convex from side to side behind, with the fibular side flattened and front inner margin angular. The bone curves a little forward towards the distal end. Its measurement from side to side is reduced to $\frac{8}{10}$ inch, and from back to front to $\frac{13}{20}$ inch. The medullary cavity is very large; its wall is thinner in front than elsewhere.

The tibia was more slender than might have been expected, and appears to have been of about one fourth the size of the tibia of *Hadrosaurus* figured by Leidy. It closely resembles in form the same element of the skeleton in some Dinosaurs from Gosau.

Metatarsus.—The metatarsus is represented by the proximal halves of three bones somewhat rubbed, and a distal end of another. The fractures show them to have had medullary cavities; but they are too imperfect for description. There is also a phalange (Pl. XXXV. fig. 10).

Part IV.

On the Axial Skeleton of Eucercosaurus tanyspondylus, *Seeley, a Dinosaur from the Cambridge Greensand, preserved in the Woodwardian Museum of the University of Cambridge* (figs. 4 & 5, pp. 616, 620).

Introduction.

The remains of a large land-animal, for the reception of which it becomes necessary to institute the genus *Eucercosaurus*, are limited to an associated series of nineteen vertebræ and a neural arch, obtained from one of the more recently opened workings in the Upper Greensand, at Trumpington, near Cambridge. The state of preservation is not very satisfactory, the bones being often incrusted with phosphate of lime, and several of them considerably decomposed, as the consequence of long maceration. Some of them have also been a little worn, and a few broken, during their discovery, by the picks of the excavators.

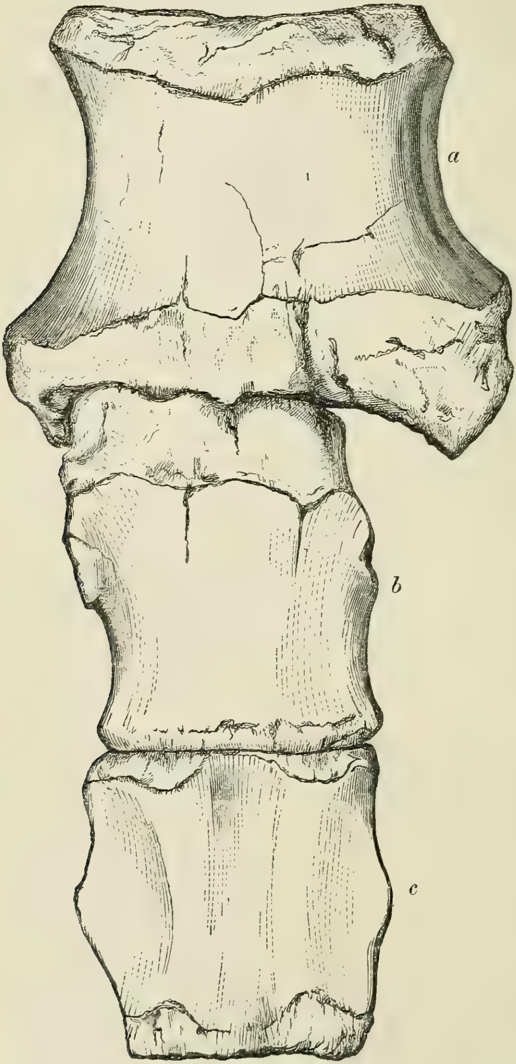
There is no indication of the skull or neck; but both may be inferred to have been small, since the four dorsal vertebræ preserved show a considerable and decreasing difference in size towards the neck. At first sight there may seem to be just a possibility that the eighth vertebra may not belong to the same animal; but against that suggestion is the evidence of similarity of form and similar condition of preservation.

I am led, by the forms of the vertebræ, to anticipate that the animal carried itself in a more or less erect position, supported on the hind limbs, and that, following the usual osteological law exemplified in the vertebral column of man, the growth of the lower dorsal region was in proportion to the increase of pressure consequent upon its having to support the number of vertebræ above it. No single centrum is well preserved in this dorsal region of the body; but the neuro-central suture is marked by transverse ridges, and the underside of the centrum in the earlier part of the series is characterized by an angular or squeezed condition of the visceral aspect. This pinched appearance becomes lost as the series is traced backward, and in place of the inferior keel a well-rounded visceral surface is developed. The neural arch preserved is strong, but not high; the transverse processes are given out horizontally from it, and the ribs may have been articulated to them exclusively. The sacral region is represented by three vertebræ, but of such forms as to suggest that there were probably five or six; and the tail, represented by twelve vertebræ, presents the unusual condition of the vertebræ becoming elongated as they pass downward in the series. The chevron bones, as indicated by facets for them, were at first unusually large; but where the centrum has developed the hexagonal outline, which it afterwards attains when more elongated, the chevron bones must have been small, since no definite facets for them can be seen on the slightly rubbed articular ends. It is mainly on the evidence which this specimen gives of a strong sacrum and a long tail, such as could have acted as a balance to the weight of the anterior part of the body, that I am disposed to affirm the erect or semierect position of this Trumpington Dinosaur. The modifications which the vertebral column in consequence presents are of a type met with in no other Dinosaurian genus from the Cambridge Greensand. There is no approximation towards any of the typical American Dinosaurs, and there may be some uncertainty as to its relative position in the Dinosaurian order; but it is probably affiliated to the Iguanodont family. Yet the ridges which give the remarkable compressed hexagonal aspect throughout the vertebræ of the tail are so far similar to the ridges on the short caudal vertebræ of *Acanthopholis*, as to suggest that the difference of form may be mainly a functional development consequent upon the different ways in which the bodies of the animals were carried.

Dorsal Vertebræ.—The first three vertebræ are from the early part of the dorsal region. The centrum of the earliest preserved is about $1\frac{6}{10}$ inch long. The anterior articular face is broken, and the posterior articular face is nearly flat, without a central depression. It is $1\frac{1}{2}$ inch wide and $1\frac{4}{10}$ inch deep to the worn visceral keel. Its outline was subtriangular. The sides of the centrum are concave from back to front, moderately convex from above downward as usual, and terminate in a sharp keel on the visceral surface. The greatest width of the centrum in the middle just below the neuro-central suture is $1\frac{2}{10}$ inch. The attachment of the neural arch was wide, $\frac{13}{20}$ inch, and is marked by somewhat irregular grooves subparallel to the articular ends. The second vertebra is of the same length, has the articular surfaces more or less incrusted with phosphatic matrix, and differs chiefly in having the sides of the centrum more inflated, so that the articular ends have a rounder lateral outline, and in having the visceral keel, which is about $\frac{4}{10}$ inch wide in the middle, defined by a groove on each side. What I take to be the posterior articular face of the centrum is decidedly concave. Both of these specimens appear to have suffered from rubbing in the mill at the washing from which they were obtained. Several vertebræ are missing between the second and the third of the series preserved. The third centrum is $1\frac{7}{10}$ inch long dorsally, and rather less at the visceral margin, showing that the back was probably arched convexly. The sides of the centrum are much more inflated, and the visceral keel has disappeared from the middle of the base of the centrum, though it is still indicated by strong rugosities at the two ends. The side of the centrum adjacent to the articular ends continues this rugose condition round the side by means of short wavy ridges. The visceral surface was somewhat rubbed before fossilization; but the articular ends, as preserved, are nearly circular. The anterior face is $1\frac{9}{20}$ inch deep, slightly cupped, with a central boss. The posterior face is $1\frac{6}{10}$ inch wide, moderately cupped, but without any central elevation. The articular margins are a little worn, but appear to have been rounded. Again, several vertebræ are missing between the third and fourth. All trace of the visceral keel has now disappeared, and the centrum has again become slightly deeper than wide, and has a somewhat compressed aspect at the sides, owing to its depth. The rugose marks for ligamentous attachment are relatively stronger and longer than in the earlier vertebræ. There is a small nutritive foramen more than a third down the side and intermediate between the two ends. Similar foramina occur in the previously described vertebræ. This centrum is $1\frac{8}{10}$ inch long on the neural surface, and apparently less on the visceral surface, though one end of the specimen had decomposed from maceration before it was fossilized. The articular ends are slightly concave, and the posterior end is nearly 2 inches deep and $1\frac{17}{20}$ inch wide, as preserved. The lines of the neuro-central suture are nearly obliterated by decomposition, but the least width of the centrum in the middle is $1\frac{6}{10}$ inch.

Sacrum.—Of the sacrum three vertebræ are preserved. They so far closely correspond with sacral vertebræ of *Anoplosaurus* as strongly to suggest that in this genus also there were at least six elements in the sacrum. The two bones, which have the forms of second and third vertebræ (fig. 4, *a*, *b*, p. 616), fit together by natural surfaces, and show that the sacral elements were in the closest possible bony union, short of anchylosis, the coadapted intercentral surfaces being irregular. There is, however, some difficulty in adapting the third sacral vertebra to the articular surface of the fourth (?) (*c*); so that it would seem more probable that another vertebra should have been introduced between them. But the anterior end of the fourth (?) centrum was destroyed by decomposition before fossilization, and the posterior surface is partly destroyed by fracturage since it was exhumed. And when the three centrums are placed together in sequence resting on the visceral surfaces as they probably lay on the sea-bed, the whole of the neural surfaces are seen to be so much decomposed that the vertebral form is scarcely recognizable.

Fig. 4.—*Three Sacral Vertebræ of* Eucercosaurus tanyspondylus, *nat. size.*



The vertebra which from its resemblance to the fourth sacral of *Anoplosaurus* (fig. 4, *c*) I regard as holding that place in the series measures rather more than $1\frac{7}{10}$ inch in length, and has a broad shallow channel on the median part of the visceral surface, deeper, however, than in *Anoplosaurus*. This is bounded laterally by two broad well-rounded ridges, into which it merges, and which terminate inferiorly the comparatively flat sides of the centrum. At what I take to be the anterior end these ridges are a little more divergent than at the posterior end. The base of the centrum has no sharply defined border, but is about $\frac{9}{10}$ inch wide at the articular ends. What remains of the sides of the centrum is only sufficient to show that these were moderately concave from front to back, and comparatively flat and divergent from below upward. Only a small fragment of the neural canal is preserved, enough to show that the depth from this surface to the base of the centrum towards the middle of the vertebra was about $1\frac{1}{4}$ inch. The sides appear to have diverged outward anteriorly, as though to give attachment to small sacral ribs; but behind the indication of this anterior inflation, of which there is no trace in *Anoplosaurus*, there appears to have been a broad rounded prolongation of the side upward towards the neural canal, as though for the passage of an intervertebral nerve. There is nothing to indicate the deep excavation of the centrum for the expansion of the spinal cord in the sacral region; but only evidence that the vertebral nerve, when given off, was prolonged downward instead of upward. The small fragment of neural surface is flat.

The centrum which corresponds best in form with the second sacral of *Anoplosaurus* (fig. 4, *a*) has become naturally fractured and enlarged before fossilization, as a consequence of maceration and absorption of phosphatic material. It is broad and deep, expanded at the posterior end, but with the base and sides so well rounded as to form about two thirds of a circle. The anterior end, which is roughened from decomposition and the natural rugoseness of the articular face, is vertically semiovate, being, as preserved, $2\frac{1}{10}$ inches wide below the neural canal, and $1\frac{7}{10}$ inch deep. The posterior end widens as though to give attachment to strong sacral ribs, and measures from side to side nearly $2\frac{7}{10}$ inches, while as preserved it is only $1\frac{1}{2}$ inch deep; hence the crumpled irregular articular face is transversely subreniform. The indications of the neural surface are comparatively flat, widening posteriorly, and widest just in front of the sacral ribs, where it may be presumed that sacral nerves were given off.

Of the third sacral element (fig. 4, *b*) nothing remains but the basal portion of the centrum. It is $1\frac{19}{20}$ inch long, $1\frac{4}{10}$ inch wide posteriorly at the sides, which are flat and vertical, and rounded into the nearly flat base, which is slightly concave from front to back and slightly convex from side to side. On a level with the base, at the anterior ends of the sides, are large facets fully an inch long for sacral ribs. The articular ends appear to have the same rugged faces noticed in the preceding sacral element.

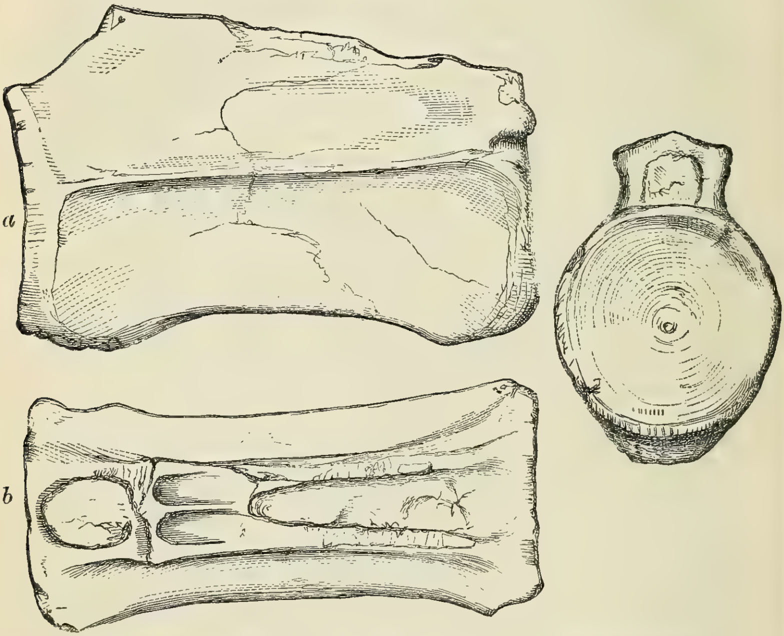
Caudal Vertebræ (fig. 5, p. 620).—The tail appears to have comprised three types of vertebræ. Of the earliest caudal there is one, of the middle caudal four vertebræ, and of the later caudal region five. To these I have added provisionally two later caudals in the same condition of mineralization and of similar size, also from the Trumpington pit, which show exactly the same characters, but were found subsequently.

The first caudal is distinguished by a short deep centrum with a rounded visceral surface, flattened articular ends, no chevron bones, small neural arch, and apparently poorly developed transverse processes, which are abraded. The centrum is about $1\frac{1}{2}$ inch long, less along the neural canal and more at the inferior border. The articular face is $1\frac{1}{2}$ inch deep in front, and, as preserved, of the same width, though originally wider. A transverse depression runs across it in the middle so as to divide the surface into superior and inferior portions meeting at a slight angle. The neural canal appears to have been about $\frac{1}{2}$ inch in diameter. The neural arch, as preserved, extends the whole length of the centrum, is depressed in front, and appears to have been fractured at its upper and hinder prolongation. All trace of the transverse process is removed by abrasion; it was given off on a level with the base of the neural canal.

The four middle caudal vertebræ successively increase in length, have the sides of the centrum compressed, and the base narrow and rounded, largely encroached upon by the facets for the chevron bones. These vertebræ have strong transverse processes given off, so as to extend outward and a little forward. These transverse processes are flattened and apparently hollow, like the rest of the neural arch, and perhaps the body of the centrum. They rapidly become small, and in the fourth are reduced to transverse ridges which are already below the level of the neural canal. The first centrum, as preserved, is $1\frac{19}{20}$ inch long. The posterior articular face of the centrum is decomposed, and the anterior face obscured with matrix; but the facet for the chevron bone is a large equilateral triangular area with rounded angles, about $\frac{8}{10}$ inch long. The space is concave, as though the bone had decomposed; but the decomposition does not extend onto the rounded articular margin of the centrum. The depth of the centrum from the base of the neural canal is rather less than $1\frac{1}{2}$ inch. The space between the two facets for the chevron bones on the base of the centrum is less than $\frac{6}{10}$ inch long. The transverse process is about $\frac{2}{10}$ inch thick and $\frac{8}{10}$ inch wide, 1 inch from inner border of the neural canal; it is directed slightly upward, and its hinder margin inclines forward. The sides of the centrum are flattened, though slightly convex from above downward, and fairly concave from side to side. In the next caudal the centrum is 2 inches long at the base. The posterior articular surface is flat and subtriangular, $1\frac{1}{4}$ inch broad and about the same depth, with straight converging sides, which are truncated inferiorly by the large facet for the chevron bone, which is nearly $\frac{7}{10}$ inch long. The transverse processes are more nearly horizontal, but are broken abruptly; the neural arch appears to have the laminæ very thin. The following vertebra, which is the eleventh of the whole series, is fully $2\frac{1}{10}$ inches long. The anterior facet for the chevron bone is not decomposed, and presents a flat oblique surface. The flattened ends of the centrum are slightly concave. The base, instead of being narrow and rounded, now begins to be defined by two slight parallel ridges.

The twelfth vertebra is about $2\frac{1}{4}$ inches long. Here the neural arch is much more elongated, and the centrum less deep, so that the transverse-process ridge, which extends the whole length of the vertebra and is slightly convex in length, divides the side into two subequal regions, of which the lower is chiefly formed by the centrum, and the upper by the neural arch. The articular ends are subcircular, rather wider than deep, and moderately cupped concavely. The articular face is about $1\frac{2}{10}$ inch in diameter. Several vertebræ are here missing, and the remainder of the series from 13th to 19th have an elongated prismatic form. Those numbered 16 and 17 are the specimens which were brought to the Museum on a separate occasion from the others. All these vertebræ agree in every thing except length, relative development of the facet for the chevron bones, and preservation. All have the articular face of the centrum subcircular and concavely cupped. The sides are divided by a median ridge into two areas on each side, of which the upper pair are rather the smaller and more deeply excavated. At the base there is a narrow, slightly channelled region defined by parallel sides; and a similar region, somewhat wider and shorter, runs along the upper surface of the neural arch, so that the vertebræ have a compressed hexagonal aspect. The 13th is rather over $3\frac{1}{2}$ inches long; the 14th $2\frac{6}{10}$ inches long. The 15th (imperfect) shows the anterior end of the neural arch, but is not sufficiently well preserved to show whether the zygapophyses interlocked. The 16th vertebra (fig. 5, p. 620) is nearly $3\frac{7}{10}$ inches long, and is the best preserved in this region. It has the anterior face of the centrum subhexagonal, but with the upper pair of lateral elements shorter than the lower pair, $1\frac{1}{4}$ inch wide at the outer angle, and about as deep to the rounded surface, where a chevron bone may still have been attached. The posterior articular face is of the same size. The extreme depth of the centrum in front is $1\frac{4}{10}$ inch. The median ridge on the side of the centrum is concave in length, so that the diameter of the bone in the middle of the ridge is 1 inch. The lateral spaces above and below this ridge are $\frac{8}{10}$ of an inch high in the middle of the centrum; the narrow base is less than $\frac{1}{4}$ inch wide. The width of the neural arch posteriorly is about $\frac{1}{2}$ inch; along it in the superior median line runs a slight ridge. The neural arch has a more pinched aspect than the part of the centrum below the median lateral ridges. The 17th vertebra is $2\frac{3}{4}$ inches long; it shows that the chevron bones still exist, but that the articular faces of the centrum have become slightly smaller, though hardly more deeply cupped. The 18th and 19th vertebræ are represented by fragments which add nothing to our knowledge beyond showing that the central part of the centrum was either hollow or occupied by a spongy tissue of the most delicate character. Throughout the whole of these specimens the external surface is remarkably dense, and seems to have resisted decomposition to an unusual degree; while the cartilaginous surfaces have more frequently suffered

Fig. 5.—*Sixteenth Caudal Vertebra of* Eucercosaurus tanyspondylus, *two thirds nat. size.*



a. Left lateral view. *b.* Superior view. *c.* Anterior view.

decay. The isolated neural arch is much invested with phosphate of lime, but does not differ essentially from the neural arch attached to an early caudal vertebra, except that the transverse processes and platform are above the level of the neural canal. This proves the arch to be either cervical or dorsal. The indications of the facets of the zygapophyses show that the centrum was probably $1\frac{7}{10}$ inch long, so that the arch would correspond in size with the third dorsal vertebra described. The posterior zygapophyses measure 1 inch transversely, and are notched out to a moderate extent posteriorly; the facets are small and look obliquely downward and outward. The anterior facets are broken away, but appear to have been limited laterally by remarkable tubercles. The transverse processes were compressed concavely, notched out in front of the posterior zygapophyses, and extending outward from the vertical laminæ of the neural arch, which are imperfectly preserved. The transverse processes, like the neural spine, are fractured.

All the parts which are most characteristic of the Dinosaurian genera, such as the bones of the extremities, the pelvic and pectoral arches, and the teeth, are unfortunately wanting. We are hence compelled to rely on the forms of the vertebral centrums in estimating the affinities of this genus; and there are very few genera in which associated sets of vertebræ from the several regions of the body enable one to make a satisfactory comparison.

No other Dinosaurian genus known to me has the tail-vertebræ so hexagonal, compressed, and elongated as in *Eucercosaurus*. Perhaps the tail of *Hylæosaurus* is least dissimilar, and the compressed visceral side of the earlier dorsal centrums may probably be taken to indicate an affinity towards the Iguanodont family.

Part V.

On the Skeleton of Syngonosaurus macrocercus, *Seeley, a Dinosaur from the Cambridge Greensand, preserved in the Woodwardian Museum of the University of Cambridge* (figs. 6–8, pp. 424–626).

Introduction.

Syngonosaurus is founded upon a series of nineteen vertebræ, which represent the neck, back, sacrum, and tail; and in some respects these vertebræ offer evidence of affiliation to several Dinosaurian types, especially to *Eucercosaurus*. The early dorsal vertebræ, however, are remarkably compressed from side to side, not merely at the base, but throughout the body; and ossification has progressed so far that, notwithstanding the somewhat battered condition in which the remains are preserved, the neural arches are constantly united to the centrums. In the lower dorsal region the compressed condition of the centrum is only recognized in the great vertical depth of the bone. The ridge on the visceral surface gradually disappears, till it is represented by a mere tubercle below the anterior and posterior articular ends. The ridge, however, reappears in the sacrum, where the depth of the centrum becomes greatly diminished, in the usual manner. The caudal vertebræ at first had centrums with the articular faces oblique, slightly procœlous, and in close juxtaposition, indicating the tail to have been stiff. The chevron bones formed a single large facet, which appears to have obliquely truncated the lower half of the posterior face. The facet is represented by a sutural surface, probably indicating that these bones were large as well as firmly adherent. Ten vertebræ are preserved from the back, four from the sacrum, and five from the earlier part of the tail. These tail-vertebræ have the centrum much compressed from side to side below the transverse processes; but the visceral surface, though narrow, is well rounded. The other associated bones are imperfect fragments of a metatarsus badly preserved; and in the absence of better evidence of their pertaining to this vertebral column, I do not feel that they can be satisfactory evidence of the extremities. There are eleven pieces of dermal armour, large elongated plates, some of which appear to have been symmetrical and median, others to have been placed laterally. Each plate has a sharp elevated ridge. But there is no positive evidence that the armour was found with the bones. The circumstance was not stated when the collection was purchased by the University; but after the remains were exhibited in the Woodwardian Museum, Mr. W. Farren mentioned to me that both sets of bones came to him at the same time and from the same washing, and might therefore perhaps have been associated portions of one animal. This species was indicated in my 'Index' 1869, pp. xvii & 24, as *Acanthopholis macrocercus*.

The Vertebral Column.—The vertebral column steadily enlarges from the neck to the lower part of the back. In the earlier dorsal region the articular faces of the centrums are slightly concave; but in the lower part of the back they are flat at both ends. In the early part of the tail the articulation appears to indicate a stiff condition; but in the lower part of the tail the articular faces are fairly concave. Notwithstanding the worn state of the specimens, they all agree so perfectly in character, and are so different from any other remains that have been found, that no doubt can be entertained as to their being portions of a single animal. It is impossible to tell how much of the abrasion was produced in the washing-mill, and how much before fossilization; but as the bones show evidence of fracture and decomposition, it is probable that much of the worn appearance which they present has resulted from decay consequent upon maceration and exposure of the upturned surfaces.

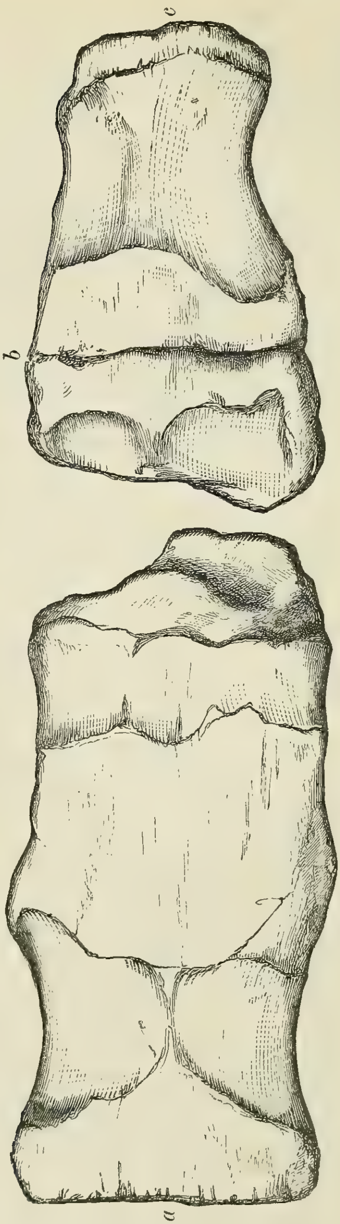
Cervical Vertebra.—Although this specimen is sufficient to give important characters of the cervical region, it has neither articular end preserved, and shows but little of the neural arch. The centrum was about $1\frac{6}{10}$ inch long and $1\frac{2}{20}$ inch deep. It is compressed from side to side, and has the base narrow and rounded. The neural arch is defined from the centrum by a deep groove; below this groove and behind the upper part of the anterior articular face is an indication of the large tubercle for the rib, which must have been fully half an inch in diameter. The posterior articular face of the centrum was triangular. The platform of the neural arch reached to a height above the base of the centrum of $2\frac{2}{10}$ inches. The transverse process for the upper head of the rib was directed outward and forward; it is fractured, and is there $\frac{1}{2}$ inch deep. The neural canal was large, and nearly 1 inch high.

Dorsal Vertebræ.—The next four vertebræ belong to the early dorsal region; they differ from the cervical chiefly in being a little larger, wanting the tubercle for the rib-articulation, and in the increasing depth and width of the centrum. The neural arch also, which is partly preserved in three out of the four, is directed more obviously outward. But all these vertebræ have the same compressed centrum, with comparatively flattened sides, converging to a narrow rounded base and subtriangular articular terminal ends. When the neural arch is broken away, it is seen to have united with the centrum by rugose transverse ridges, arranged on a facet which extends the length of the centrum, and looks obliquely outward and upward. The length of the centrum in this region varies between $1\frac{1}{2}$ inch and $1\frac{7}{10}$ inch. The articular ends widen at the upper margin from little more than 1 inch to $1\frac{4}{10}$ inch, and the depth is about $1\frac{4}{10}$ inch. The sides are slightly concave from back to front, and their curve is prolonged upward, continuous with the neural arch, which is always distinguished by the deep groove already referred to. The succeeding four belong to the lower dorsal region; in them the centrum increases in size and depth, and its side becomes rather more convex. It still retains the basal ridge, which becomes sharper, and sometimes disappears, being marked by a tubercle at each end. In the earliest of these four vertebræ, the height from the base of the centrum to the platform of the neural arch is rather more than $2\frac{1}{2}$ inches, and the length of the centrum is $1\frac{3}{4}$ inch, while its depth from the neural canal is about $1\frac{4}{10}$ inch. In the largest and, apparently, last or last but one of the four, the width of the centrum at the anterior articular face, as preserved, is $1\frac{8}{10}$ inch, while the depth of the centrum is about the same. From the decreasing height of the neural arch this vertebra may be supposed to be near to the sacral region. It is $1\frac{8}{10}$ inch long in the dorsal measurement, and less ventrally. The height to the platform of the neural arch from the middle of the base is $2\frac{3}{4}$ inches.

The transverse processes are about $\frac{1}{2}$ inch thick, but are fractured. The neural spine and zygapophyses are also broken away, but the zygapophyses look inward as well as upward. The ninth dorsal vertebra differs so much from those with which it is associated, and recalls so strongly the dorsal region of *Acanthopholis*, that I am inclined to regard it as having become accidentally mixed with the other remains. It is in the same state of mineralization, but is much longer, had a perfectly rounded base, was most compressed below the neural arch, and had circular articular ends, with a central pit, so that I feel no doubt that it ought not to be included in the definition of *Syngonosaurus*.

Sacrum.—The sacrum (fig. 6, p. 624) has lost the neural arches, and consists, as preserved, of two portions, each of which includes parts of two vertebræ, so that there were certainly no fewer than four, and may have been more. The last dorsal described corresponds in size and character with the first sacral of the larger fragment, which has a similar flat, subtriangular, articular end (fig. 6, *a*), which is $1\frac{7}{10}$ inch broad at the upper part, as preserved. The sides are convex from above downward, and meet in a sharp keel in the middle of the base. The suture between the first and second vertebra is entirely obliterated. The depth from the neural canal to the middle of the base is $1\frac{1}{2}$ inch; in the second vertebra it becomes reduced to $1\frac{1}{4}$ inch. The fragment is $3\frac{6}{10}$ inches long, which I estimate to be within a tenth of an inch of the length of two vertebræ. The base of the second vertebra is much more convex than that of the first, and the median keel is all but obliterated. The width of the centrum in the middle is rather less than $1\frac{1}{2}$ inch in the first sacral vertebra, and somewhat more in the second. The state of preservation is such that there are

Fig. 6.—*Sacral Vertebræ of* Syngonosaurus macrocercus, *ventral aspect, nat. size.*

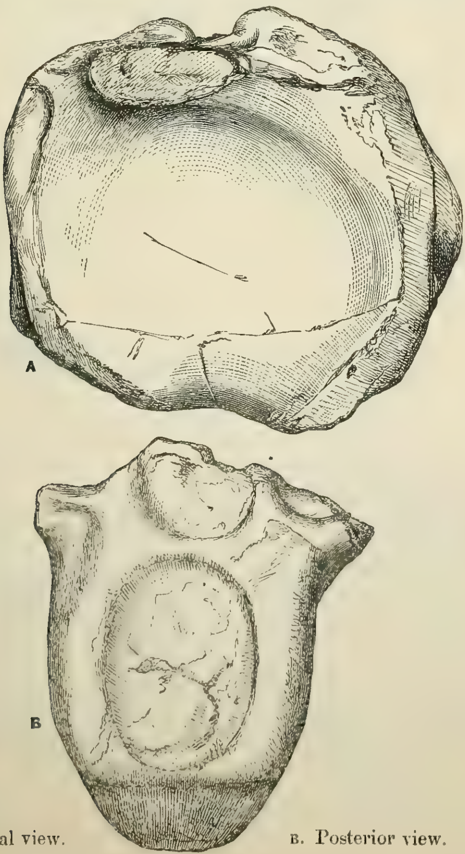


a. Anterior articular surface of first sacral preserved.
b. Suture between third (?) and fourth (?) sacral vertebræ.
c. Posterior articular surface of fourth (?) sacral vertebra.

no indications of facets for the attachment of sacral ribs, unless they be in the fractured and decomposed sides of the second sacral element. The other sacral fragment is smaller, and consists of the hinder portion of a vertebra with a flattened underside, which unites by a visible suture (fig. 6, *b*) with the fourth sacral, which is $1\frac{7}{10}$ inch long. At the junction of these two vertebræ there is laterally a large flattened surface of $1\frac{1}{4}$ inch, and extended to the bases of the centrums, to which one of the principal sacral ribs was obviously attached. The fourth sacral is very narrow, measuring only 1 inch from side to side in the middle, and having well-rounded sides and a rounded base. Neither vertebra shows any portion of the neural canal; and the posterior face of the fourth, which seems to have become separated from the sacral vertebra next succeeding, was flat, small, subcircular, and hardly more than 1 inch in diameter (fig. 6, *c*).

Caudal Vertebræ.—The five caudal vertebræ are not consecutive. The two earliest (fig. 7) have the centrums with oblique articular

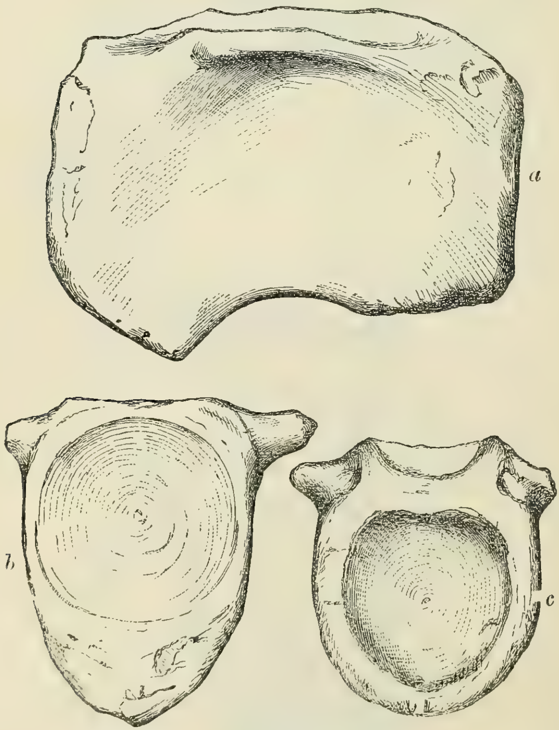
Fig. 7.—*Second Caudal Vertebra of* Syngonosaurus macrocercus, *nat. size.*



A. Right lateral view. B. Posterior view.

surfaces, which in front are cupped and behind are flattened. The angle of inclination of the articular faces is about 55°. The length of the centrum along the neural canal is fully 2 inches. The margins of the articular faces are worn. The centrum is compressed from side to side, and at the base the sides round together. The transverse process is given off on a level with the base of the neural canal as usual, but is broken, and only a small fragment of the neural arch is preserved, so as to arch over the spinal cord in front, forming a foramen about $\frac{6}{10}$ inch in diameter. Above the transverse process the neural arch is somewhat pinched in, as is the centrum below. The depth from the neural canal to the base of the centrum is about $1\frac{8}{10}$ inch; the width from side to side is about $1\frac{4}{10}$ inch. The base of the articulation posteriorly is truncated by an oblique triangular facet for the chevron bone; but it is uncertain whether this condition also marks the anterior facet. A vertebra is probably missing from between the second caudal and the third; for the third, fourth, and fifth become rather more elongated, the third (fig. 8) measuring $2\frac{4}{10}$ inches long. It is more compressed from side to

Fig. 8.—*Third Caudal Vertebra of* Syngonosaurus macrocercus, *nat. size.*



a. Right lateral view. *b.* Posterior view. *c.* Anterior view.

side below the transverse process, has a narrower rounded base, and terminates at each end in a large subcircular concave cup, which is $1\frac{2}{10}$ inch in diameter; below this, at the posterior end, is a large shield-shaped, subtriangular, rugose facet for the chevron bone, which is $\frac{9}{10}$ inch deep and fully 1 inch wide. The measurement from the neural canal to the base of this facet is $1\frac{7}{10}$ inch.

Except that they are longer, these vertebræ recall closely the forms of some of the earlier caudal vertebræ of *Eucercosaurus*; but the shape which was there seen to be characteristic of one or two vertebræ only, here seems to extend throughout the series; and though the centrum has in the last caudal preserved become reduced to little more than half the depth of the earliest, there is no indication of changing character, and the transverse process remains strong. The resemblance is close as far as it goes; but in the sacrum and dorsal regions the character is quite different, and *Eucercosaurus* has neither the compression of the body of the centrum nor the sharp keel, except in the earliest dorsal preserved. These points of resemblance indicate close affinity, but do not suggest generic identity.

Bones of the Extremities.—With this vertebral column were found four metatarsal bones. They are rather more than half the size of the complete metapodium which I figured in the 'Annals of Natural History' for November 1871, and regarded as probably pertaining to the fore limb. The first left metatarsal is fairly perfect, $2\frac{4}{10}$ inches long, $1\frac{3}{20}$ inch wide proximally, and $1\frac{8}{10}$ inch deep at the proximal end, which is imperfectly preserved. Its sides are concave, and it widens distally to $1\frac{9}{10}$ inch, where the articular face is concave from side to side, well rounded from above downwards, and about $\frac{9}{10}$ inch deep. The other three are the proximal ends of the second, third, and fourth metatarsal bones. When the four are placed together they measure rather over 5 inches from side to side, which is a greater width of foot than I should have anticipated for *Syngonosaurus*; but, in the absence of the larger bones of the hind limb, it is impossible to affirm or deny their claim to belong to this animal. There are also two phalanges which, from their shortness, may be first and second: but these also are so large, relatively to the metatarsus, as to suggest doubt as to their natural association with them. The first is $2\frac{6}{10}$ inches wide and $1\frac{8}{10}$ inch deep at the proximal end; it is $2\frac{1}{10}$ inches long and $1\frac{1}{2}$ inch thick. The second phalange is $2\frac{1}{10}$ inches wide and $1\frac{3}{10}$ inch deep at the proximal end, is $1\frac{3}{10}$ inch long, and is compressed towards the distal end, so as to be there less than an inch thick. The indication of the fore limb is limited to the proximal end of the humerus; but the greater part of the bone is lost. The proximal end of the right humerus is not quite perfect on the radial side, but is $2\frac{6}{10}$ inches wide and $1\frac{6}{10}$ inch deep over the middle of the head. The ulnar side of the head is modified after the pattern of the crocodile, and a sharp ridge is prolonged down the two inches preserved of the ulnar side of the bone, which is compressed. The whole proximal part of the shaft rapidly becomes compressed distally, and as rapidly narrows from side to side; the articular head shows the characteristic Dinosaurian convexity on the middle of the dorsal surface, but appears to be less concave than usual on the ventral aspect. Some doubt may well attach to the association of this bone with the vertebral column.

There are twelve subovate pieces of dermal armour reputed associated with the skeleton. They vary from $2\frac{1}{2}$ to $3\frac{1}{2}$ inches in length, are about 2 inches wide, and have a strong elevated angular crest and fold running down the length of the plates, which have the lateral halves a little concave. The margins are thin and show no signs of overlapping, except at the posterior ends; and the external surface is roughened, with an irregular pitted appearance, similar to that seen in *Acanthopholis* and *Scelidosaurus*. The dermal surface is usually smooth and concave; but one symmetrical plate has the under surface deeply excavated, evidently for a muscle, and may therefore be inferred to be one placed over the neural spine of a vertebra; it is, however, in a slightly different state of mineralization, and possibly may not belong to the series. It must remain for the present an unsettled question whether *Syngonosaurus* was really armoured, though the probabilities lean in that direction. The only existing reptiles in which dermal armour of the pattern found among the Dinosaurs is met with are the Chelonians; and in that order, both on the limbs and tail, dermal bones, covered with a horny sheath, are found, which differ from those of Dinosaurs chiefly in size.

Part VI.

On the Dorsal and Caudal Vertebræ of Acanthopholis stereocercus, *Seeley, a Dinosaur from the Cambridge Greensand, preserved in the Woodwardian Museum of the University of Cambridge; with some notice of a second species of* Anoplosaurus *collected with these remains.*

Among the smaller series of Dinosaurian bones collected for the Woodwardian Museum by Mr. W. Farren, is a collection of twelve vertebræ and a fragment of a dermal spine, which were catalogued in my Index to Aves, Ornith. and Rept. 1869, pp. xvii and 24, as *Acanthopholis stereocercus*. Looking at the specimens anew, I have no doubt that the remains are not all referable to one species. The first, which is in bad preservation, is a cervical; it has, apparently, got into the washing-mill and become worn. It is so far similar to *Anoplosaurus* as to suggest that it really belongs to the neck of a second species of that genus. The next two are dorsal; then follows a postsacral of remarkable form, which is succeeded by an early caudal. The next three caudal vertebræ I do not now regard as pertaining to the same species, and separate them as belonging to a second and undescribed species of *Anoplosaurus*. They want the median groove on the base of the centrum, which is characteristic of the caudals of *Acanthopholis*, and in all essential characters they have the general facies of caudal vertebræ of *Anoplosaurus*; but differ from the species already described in the vertebræ being of relatively much greater length, and distinguished by carrying the neural canal in a deep groove in the centrum. The remaining three vertebræ present the characters of *Acanthopholis*, and may well have belonged to the same animal as the preceding five bones.

Dorsal Vertebræ.—The two dorsal vertebræ present the characters already described in dorsals of *Acanthopholis* and *Anoplosaurus*, but have the articular faces of the centrums more deeply concave than in any form hitherto described. It may therefore be enough to say that the dorsal measurement in both is a little greater than the visceral measurement; that the aspect is Teleosaurian, slightly compressed, and well rounded on the base. There are several small nutritive foramina in the middle of the side. The neural canal is a long groove with parallel sides, and its width is less than the width of the lateral surfaces from which the pedicle for the neural arch is broken away. The better-preserved and slightly longer of the two vertebræ is $1\frac{17}{20}$ inch in extreme length, has the posterior articular face $1\frac{1}{2}$ inch deep and rather narrower, while the anterior articular face is nearly circular, with the measurement of $1\frac{1}{2}$ inch. The greatest compression of the centrum from side to side, where its transverse measurement is 1 inch, is below the neural canal.

Postdorsal.—A bone which I am disposed to regard as a last lumbar or, more probably, postsacral vertebra, is distinguished by a large neural canal, and a centrum which is oblong and defined by six sides. The body of the vertebra is $1\frac{7}{10}$ inch long, with a flattened base, flattened sides, and subquadrate articular ends. The anterior end, as preserved, is $1\frac{2}{10}$ inch deep and more than $1\frac{1}{2}$ inch wide. The posterior face is somewhat smaller; both are concave surfaces, with a somewhat large obscure central boss. The base at each end is $1\frac{2}{10}$ inch wide, and about $\frac{9}{10}$ inch wide in the middle. There is no indication of its lateral ridges being connected with facets for chevron bones; the sides are similarly gently concave from back to front, and show a thickened mass at the base of the neural arch, as though a slight transverse process might have there originated, or a facet existed for a small osseous attachment. It is impossible from the fractured fragments of the pedicle of the neural arch to judge what the characters of that portion of the vertebra were. The least width of the neural canal in the middle is $\frac{13}{20}$ inch.

The early caudal vertebra is in good preservation and shows unusual characters. The neural arch is anchylosed to the centrum, the short transverse processes are well indicated, and the facets for the chevron bones are unusually large for this genus, and divided from each other. The centrum is $1\frac{11}{20}$ inch long dorsally, $1\frac{1}{2}$ inch long ventrally. The transverse processes are short, vertically compressed, rather oblique, and placed posteriorly on the upper third of the centrum; they measure from front to back about $\frac{6}{10}$ inch at their bases. Below these transverse processes, the sides of the centrum, which are flattened, converge towards the visceral surface; but the base can only be defined at the articular ends by the width of the facets for the chevron bones, which is rather less than an inch, because the middle of the base is occupied by a deep groove, more than $\frac{1}{4}$ inch wide, which is boat-shaped, tapering away between the chevron facets. These facets are convex from front to back, and each is slightly concave from side to side; they round into the articular ends of the centrum, and are markedly distinct from each other at the posterior end, where they are longest. The length of the base of the centrum, between the anterior and posterior pairs of facets, is $\frac{13}{20}$ of an inch. Above the transverse process is a pair of short strong ridges, developed at the posterior end, which are horizontal and just above the base of the neural canal. The neural arch is small, narrow, and depressed; its posterior end was removed by fracture, but anteriorly it is less than $\frac{1}{2}$ inch wide, and the extreme measurement, from its summit, as preserved, to the base of the centrum is $1\frac{8}{10}$ inch. The articular faces of the centrum are subhexagonal, and somewhat deeply impressed in the centre, especially the anterior face, which is $1\frac{2}{10}$ inch high and $1\frac{4}{10}$ inch wide. While the posterior face is not quite so high, it is a little wider, and is less markedly hexagonal, owing to the influence of the transverse processes in developing an angle on the upper third of the side.

The next vertebra preserved is from a much lower position in the tail; it has essentially the same type of character, and measures $1\frac{9}{20}$ inch in length along the neural canal, but is so much smaller in vertical and transverse measurements, that the anterior face is barely an inch wide and almost $\frac{17}{20}$ inch in greatest depth. The posterior face has the same depth, and may have been a little wider. The articular faces are moderately concave, subhexagonal, and prolonged downwards into articular facets for the chevron bones, which are larger behind than in front. They are divided by a deep narrow groove, which runs along the middle of the base. On the middle of each side is a blunt somewhat rounded ridge, which helps to give the centrum its hexagonal aspect by dividing the side into two subequal regions, two of which converge downwards, and the other two converge upwards. Below these ridges, and nearer to the basal ridges, are two other moderately developed longitudinal ridges; and above also, on a level with the neural canal, are two more short ridges, sufficiently elevated to give a channelled, pinched appearance to the base of the neural arch, since another ridge runs along that region on each side. The neural arch is small, and its pedicle, $\frac{7}{10}$ inch long, is placed nearer to the anterior than to the posterior end, as in *Acanthopholis horridus*. The neural arch has a median ridge, which rises a little as it extends backwards; the arch is fractured, both at the anterior and posterior ends, and the neural canal is small. The height from the middle of the base of the centrum to the middle of the neural arch is $1\frac{3}{20}$ inch. The next vertebra shows all these characters, except that the neural arch is broken away, and indicates that the channel for the spinal cord was slightly excavated in the centrum. The lateral spaces between the ridges are also rather more concave. The length of this centrum is nearly $1\frac{2}{10}$ inch; the width of the articular face is fully $\frac{8}{10}$ inch. The last vertebra of the series is $\frac{9}{10}$ inch long. It, too, has lost the neural arch, and has the articular ends more deeply excavated and much wider than high. From the relatively small size of the base, its outline is subpentagonal. The neural canal is very small, and the arch absent from the posterior third.

In instituting the species on these remains, I rely on the four vertebræ last described for its type, without in any way doubting the natural association of the dorsal vertebræ with these caudal elements. Still, as three caudal vertebræ of *Anoplosaurus* had become accidentally mixed with them, and the cervical vertebra belongs to that genus also, it seems to me unsafe to attribute the dorsal vertebræ unreservedly to *Acanthopholis*, although we know that that region of the body presents no essential difference from the same region in *Anoplosaurus*. As compared with the tail of the type species, *Acanthopholis horridus*, Huxley, this species is distinguished by having the middle caudals much more robust, with a deeper basal groove and strongly developed facets for the chevron bones, while the neural arch is bounded by lateral ridges, which are absent in the type species. The later caudals are relatively more robust than in the type, and distinguished by progressively decreasing in length, by retaining well-developed chevron facets to the last, and by having the neural arch less developed and defined by a deep groove at its base.

Anoplosaurus major.

The Cervical Vertebra.—I have already suggested the possibility of this centrum pertaining to a second and larger species of *Anoplosaurus*. The centrum is depressed and broad in front, and leans obliquely forward, more so at the posterior than at the anterior articular surface. This condition would probably suggest that the neck was carried in an upraised position. The base of the centrum is $1\frac{1}{2}$ inch long, while the neural canal was somewhat less. The base is flattened, apparently with a slight median ridge, but is slightly convex from side to side, and the base makes about a right angle with the nearly vertical lateral spaces behind the articular tubercle for the rib. The vertebra measures from side to side $1\frac{1}{10}$ inch, but the width over the tubercles, as preserved, is $1\frac{9}{10}$ inch. The tubercles are on the middle of the side of the centrum, close to the anterior articulation, and are about $\frac{1}{2}$ inch in diameter. Immediately behind the tubercles the centrum has a pinched aspect. The anterior face is transversely ovate, 1 inch deep, as preserved, but the underside is a little worn; it is moderately cupped, and was about $1\frac{1}{2}$ inch wide. The posterior articular surface is somewhat deeply cupped, $1\frac{3}{20}$ inch in depth and $1\frac{3}{10}$ inch wide. The neural canal is very wide, being $\frac{7}{10}$ inch in diameter. The bases of the laminæ of the neural arch are compressed, and extend along the length of the centrum; they appear to be confluent with the centrum, and show no certain indication of suture.

Although the caudal vertebræ which indicate the second species of

Anoplosaurus are not such as one would choose for the foundation of a new species, they differ from *Anoplosaurus curtonotus* in the absence of the basal ridges, which causes the base to be flattened, and in having flat sides, which are only broken by the tubercle which represents the transverse process, and which, prolonged into a ridge, divides the side into two areas. The facets for the chevron bones were so small that they have become obliterated by the wear to which the specimens have been subjected, and appear to have only marked the posterior ends. The best-preserved specimen has the centrum slightly oblique, $1\frac{6}{10}$ inch long, with the articular ends hexagonal, the posterior end being nearly $1\frac{4}{10}$ inch wide, $1\frac{1}{10}$ inch deep. The other two vertebræ are $\frac{1}{10}$ of an inch longer, and the faint ridges of the base and sides are less developed; so that the species is distinguished from the type of the genus by the more elongated form of vertebræ, and by retaining the two basal angles after the transverse tubercular process had disappeared, as well as by the deep excavation of the neural canal in the centrum, and by the presumably larger size of the adult animal. It may be a convenience, pending the discovery of better materials, to indicate this species as *Anoplosaurus major*.

A small fragment of a nearly smooth dermal plate, probably referable to the *Acanthopholis*, was collected with these remains, but is too imperfect to yield any useful characters.

Part VII.

On a small series of Caudal Vertebræ of a Dinosaur from the Cambridge Greensand (Acanthopholis eucercus, *Seeley*), *contained in the Woodwardian Museum of the University of Cambridge.*

This note is founded on the small assemblage of six caudal vertebræ catalogued in my 'Index to the Secondary Reptiles in the Woodwardian Museum,' as Series vi. (p. 24). They indicate a close resemblance to the tail-vertebræ of *Acanthopholis horridus*, Huxley, but differ in the more elongated form and more constricted condition of the centrum, in the somewhat different development of ridges upon the side of the centrum, in the rapid diminution in length of the centrums, which in the type species remain all of about the same length, and in the greater size of the bones now described, which appear to indicate a rather larger species. The collection was purchased by the University from Mr. Farren; and I see no reason to doubt his statement that the vertebræ were found associated, and form part of the skeleton of one individual.

The earliest specimen preserved is an early caudal. It is robust, about $2\frac{1}{4}$ inches long, and $1\frac{7}{10}$ inch deep in the anterior articular face, which is subcircular and fairly concave; the posterior articulation is broken, but was subhexagonal, not so deep in vertical measurement, and similarly cupped. The body of the vertebra is subcylindrical, with six more or less marked longitudinal ridges, two on the base, slight and rounded, separated by an interspace of less than half an inch, which interspace is a slightly impressed median channel, most marked towards the two ends of the centrum.

The sides of the vertebra are well rounded; but at the upper third, behind the middle of the centrum, is another pair of longitudinal ridges, which become produced into very short transverse processes, compressed from above downwards, and imperfectly preserved; the third pair of ridges are those which form the bases of the neural arch, between which and the transverse processes the upper part of the side of the centrum is concave. These pedicles, from which the neural arch is broken away, are compressed from side to side, diverge a little as they extend backwards, reach to near the anterior margin, and extend backwards for about $1\frac{2}{10}$ inch. The outside transverse measurement of these ridges in front is $\frac{8}{10}$ inch, behind it is about $1\frac{2}{10}$ inch.

Several vertebræ appear to be missing between the centrum described and the second of the series, which has unfortunately been fractured longitudinally and vertically, so that it is little more than half a centrum. The fracture shows the bony tissue to be arranged in short, irregular, parallel longitudinal laminæ, about $\frac{1}{16}$ of an inch apart. The centrum is longer along the ventral than the neural surface, the superior measurement being less than 2 inches, and the inferior measurement about $2\frac{1}{4}$ inches, indicating that the tail was curved in an opposite direction to the back, as might be expected. The anterior articulation is much wider than deep, the vertical depth being $1\frac{1}{2}$ inch, and the outline reniform, since the neural canal impresses the centrum concavely. The posterior articulation is much more deeply excavated above; the antero-posterior measurement through the middle of the articular faces is $1\frac{7}{10}$ inch. The greatest vertical measurement ($1\frac{8}{10}$ inch), from the hinder ridge of the neural arch to the facet for the chevron bone, is about equal to the greatest transverse measurement in the upper third of the centrum.

The subcylindrical centrum, which enlarges towards the two ends, is modified hexagonally by eight longitudinal ridges, two on the base, faint and parallel, becoming strong posteriorly, where they terminate in the oblique facets for the chevron bone. The side of the centrum below the neural arch is divided into three regions by two moderately elevated longitudinal ridges: the lower region is flat, and measures $\frac{8}{10}$ inch from above downwards; the middle region is slightly concave and about half as wide; while the upper region is more concave, and has a depth of $\frac{6}{10}$ inch. The upper of these lateral ridges becomes prolonged outward behind the middle line into a slight vertically compressed transverse process. The neural canal is still large, but the arch is smaller; its pedicles are very slight, are on the inside of the neural ridges, and only measure about $\frac{8}{10}$ inch in length.

The third vertebra of the series has the centrum $2\frac{1}{10}$ inches long on the inferior margin, and is smaller in all measurements. The transverse tubercle has now disappeared, and the lateral ridges are obscure. The ridges which terminate in the facets for the chevron bone are well developed posteriorly, and terminate in two distinct surfaces, which look obliquely downwards and backwards. The neural arch is small, and extends to within half an inch of the anterior articulation; it has no trace of a neural spine or lateral process.

The fourth vertebra is much smaller and more constricted. It is fully 2 inches long. The transverse measurement in the posterior articulation is $1\frac{4}{10}$ inch, while the depth is about an inch. The outline is subtriangular, and the cup is deeply excavated. There appears to be only one chevron facet; and, though larger posteriorly, a similar small facet also impresses the anterior articulation. This surface is flat, broadest in the upper part, but not so deep as broad. The least transverse measurement in the middle of the centrum is 1 inch. A median lateral ridge on the side of the centrum is well marked; above it the side of the centrum is concave in both measurements; below it the side of the centrum is convex vertically in the middle part. The neural arch is very small, and is margined at its base by ridges, which appear to mark its junction with the centrum. The vertical measurement through the vertebra from the neural canal to the base is $\frac{8}{10}$ inch just behind the neural arch.

The fifth vertebra is $1\frac{6}{10}$ inch long, and distorted by the development of the chevron element only on the left side. Normally, the centrum would be hexagonal, with a median longitudinal ridge on the side. The width in front, about $1\frac{1}{10}$ inch, is considerably more than the depth; posteriorly the measurements are less. The neural arch is small and compressed, with its upper margin horizontal.

The sixth vertebra is as long as the fifth, and has the facet for the hypapophysis developed in front and behind; but the ridges are absent from the middle of the underside of the centrum. The lateral ridges, on the other hand, are greatly developed and nearly parallel to each other; this gives the centrum a depressed appearance. The anterior articular face is the wider, while the posterior face is the deeper, being more than $\frac{8}{10}$ inch deep, the anterior face being fully $\frac{6}{10}$. The neural canal is still about $\frac{1}{4}$ inch wide.

Conclusions concerning the classification and organization of these Dinosaurs may conveniently be deferred until the whole of the remains have been described and figured; but these and other studies strongly enforce a conviction that the Dinosauria are far more nearly related to the Triassic and older Secondary Crocodilia than the evidence of their affinities hitherto adduced would have prepared us to anticipate.

EXPLANATION OF THE PLATES.

All the figures are of the natural size.

PLATE XXXIV.

The vertebral column of *Anoplosaurus curtonotus.*

Fig. 1. Left lateral aspect of third to seventh cervical centrums, showing how the bodies of the vertebræ increase in depth from before backward, and indicating at the upper anterior corner of each an attachment for a cervical rib.

1 *a.* Visceral aspect of third (?) cervical vertebra, showing flattened and rounded under surface, and expansion towards the anterior end.

Fig. 2. Left lateral aspect of fourteenth to eighteenth centrums of the series, showing the somewhat compressed appearance of upper parts of the bodies of the last five dorsal vertebræ.

2 *a*. Visceral aspect of the last dorsal vertebra, No. 18.

2 *b*. Posterior (?) articular end of the same centrum, No. 18.

3. The sacrum, showing the neural or superior surface, and giving evidence of the great expansion of the spinal cord in the region of the second and third sacral vertebræ. The outlets for the escape of the sacral nerves at the sides of the centrum are best seen in the first three vertebræ.

4. Dorsal surface of vertebral end of a sacral rib, showing the massive end for attachment to the sides of the centrums of the second and third vertebræ. Its worn upper surface gave attachment to the neural arch.

5. Left lateral aspect of a sequence of six early caudal vertebræ numbered 25 to 30, showing decreasing depth of the centrum posteriorly, and diminishing size in the surface for the attachment of the sacral rib which remains in union with the 30th vertebra. The chevron facet, *c*, also diminishes in size.

5 *a*. Posterior articular surface and facet for the chevron bone of the vertebra No. 26.

PLATE XXXV.

Fig. 1. Internal aspect of anterior end of the left ramus of the lower jaw, showing the broken inferior border and the imperfectly preserved sockets for the teeth on the superior border.

1 *a*. Outline of the fractured posterior end of the same specimen.

2. External aspect of left coracoid, showing the coracoid foramen, and (*a*) articular surface for the humerus, and (*b*) the surface for union with the scapula. The broken superior margin of the bone is also shown.

3. External surface of proximal end of right scapula, showing the constricted upper part of the bone, (*a*) the articular element in the glenoid cavity for the humerus, (*b*) the greatly elevated spine, and (*c*) the compressed articular surface for the coracoid.

4. Superior surface of proximal articular end of right humerus, showing (*a*) the fractured radial side of the bone, (*b*) the articular head, and (*c*) the extension of the proximal articulation onto the compressed ulnar border.

5. Distal portion of the same bone with only a minute trace of the distal articular surface. It shows the widening outline of the distal end, but not the radial crest, which is concealed behind the bone.

6. External aspect of proximal end of left femur, showing (*a*) the curved proximal articular surface, and (*b*) the proximal styloid anterior trochanter, which is fractured proximally.

7. Outline of the distal end of the shaft of tne same bone, showing (*a*) the intercondylar groove on the inferior surface.

8. External or fibular-posterior aspect of two portions of the shaft of the left tibia, showing (*a*) the groove behind the cnemial crest in which the fibula was carried.

9. Probably the metacarpal bone of the fifth digit, superior aspect, left foot.

10. Phalange, probably of the fore limb.

11. Lateral view of proximal end of a dorsal rib, showing the compressed vertical condition of the bone and its flattened superior surface. These characters are also shown in fig. 13, which gives the outline of the fractured end of the bone.

12. Transverse section of another dorsal rib, showing the expanded upper surface widened as though to carry dermal armour.

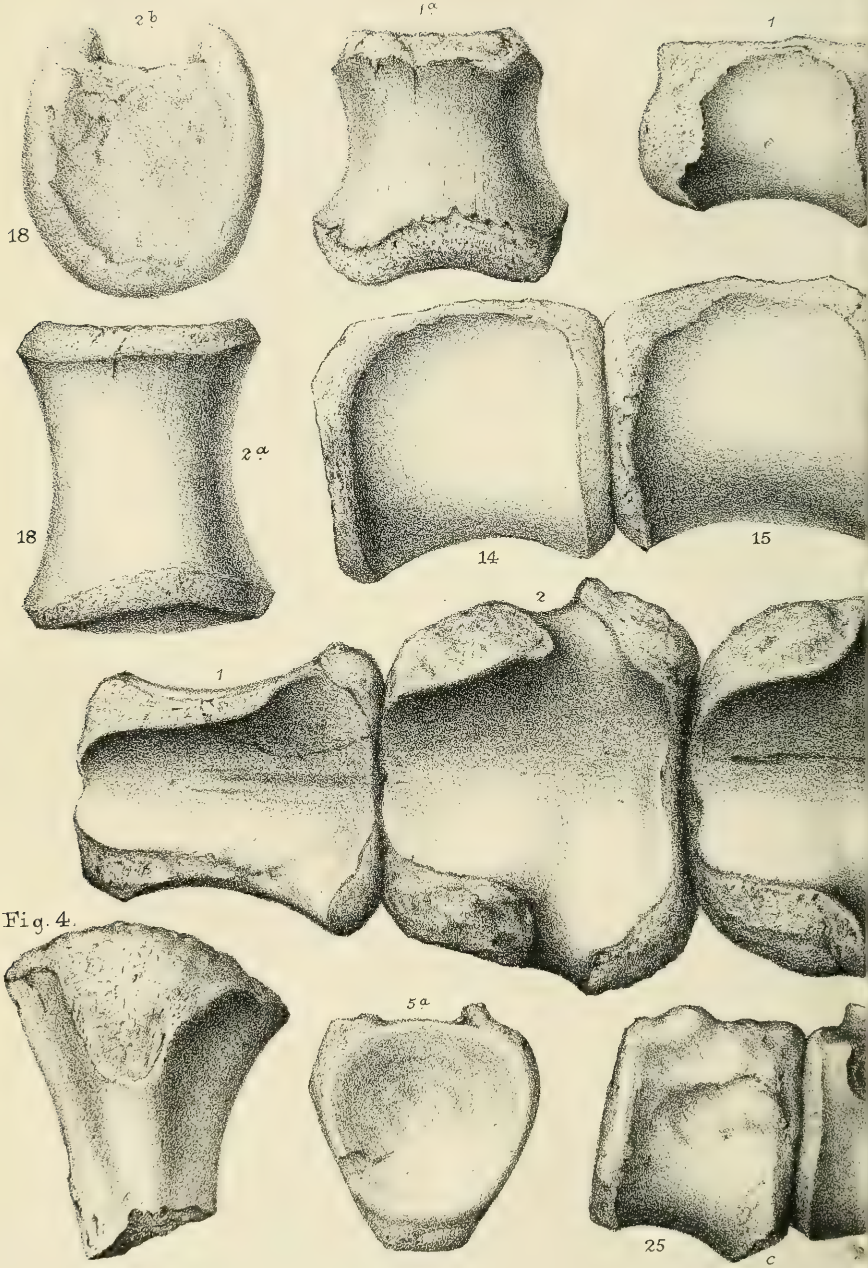
14. Right lateral aspect of neural arch of dorsal vertebra, showing (*a*) the fractured base of the transverse platform, (*b*) the lower articular surface for the dorsal rib, (*c*) postzygapophysis, (*d*) fractured prezygapophysis, (*e*) fractured base of neural spine, (*f*) articular surface for union with the centrum.

Discussion.

Mr. Charlesworth dwelt on the importance of practical experiments on the effects of exposure and maceration on bones, such as those carried out by the author of this paper.

Mr. Hulke bore testimony to the great value of Prof. Seeley's researches; but said he always felt doubt on the safety of putting together the *disjecta membra* obtained by diggers and coprolite-washers. He also expressed doubt as to the generic distinctness of *Anoplosaurus* and *Acanthopholis*. Of the truly Dinosaurian character of most of the specimens brought forward by the author of the paper there was no doubt whatever.

Prof. Seeley was aware of the difficulty of dealing with such specimens, but had given his reasons for associating the scattered bones laid before the Society.



C. Berjeau lith.

ANOPLOSAURU

Fig. 1.

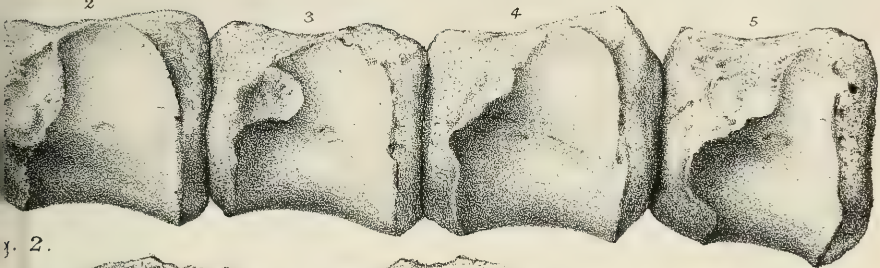


Fig. 2.

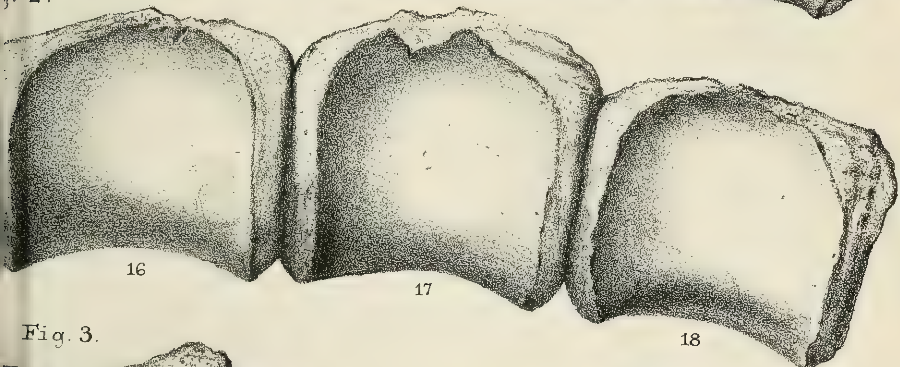


Fig. 3.

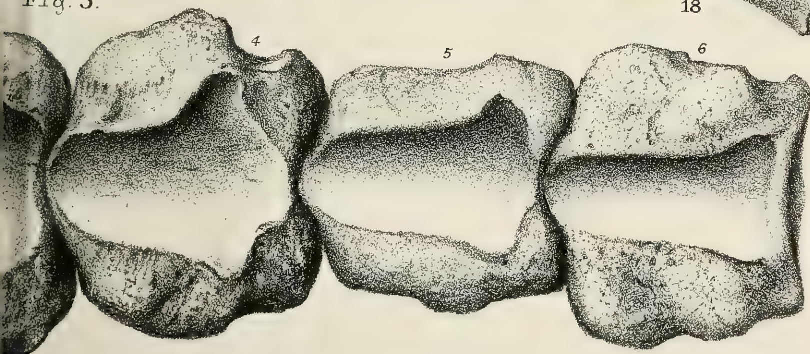
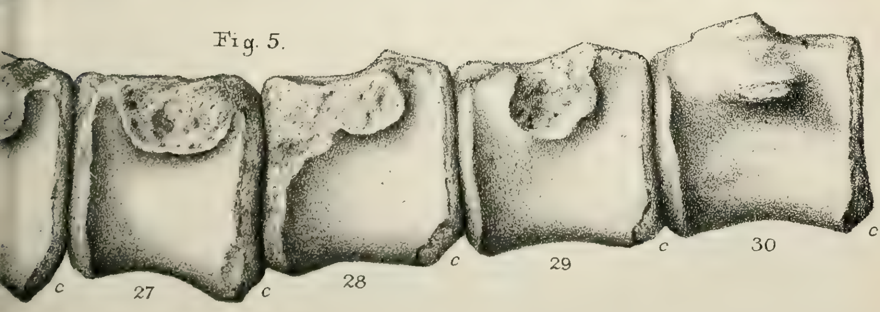
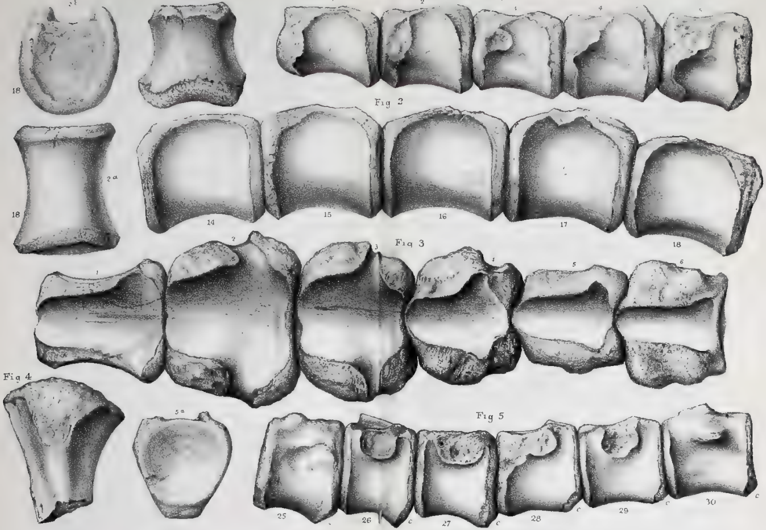


Fig. 5.



Mintern Bros. imp.

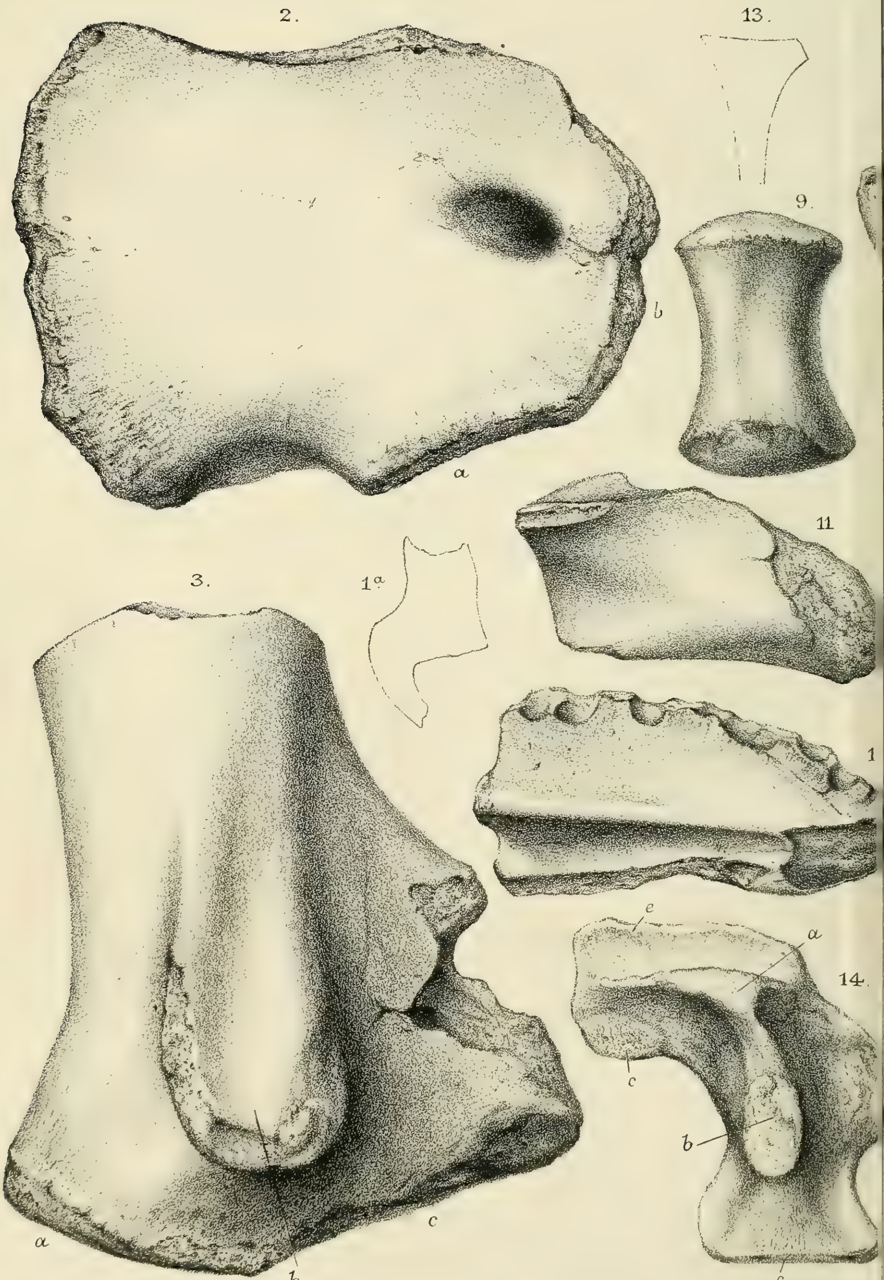
CURTONOTUS.



C Berjeau lith

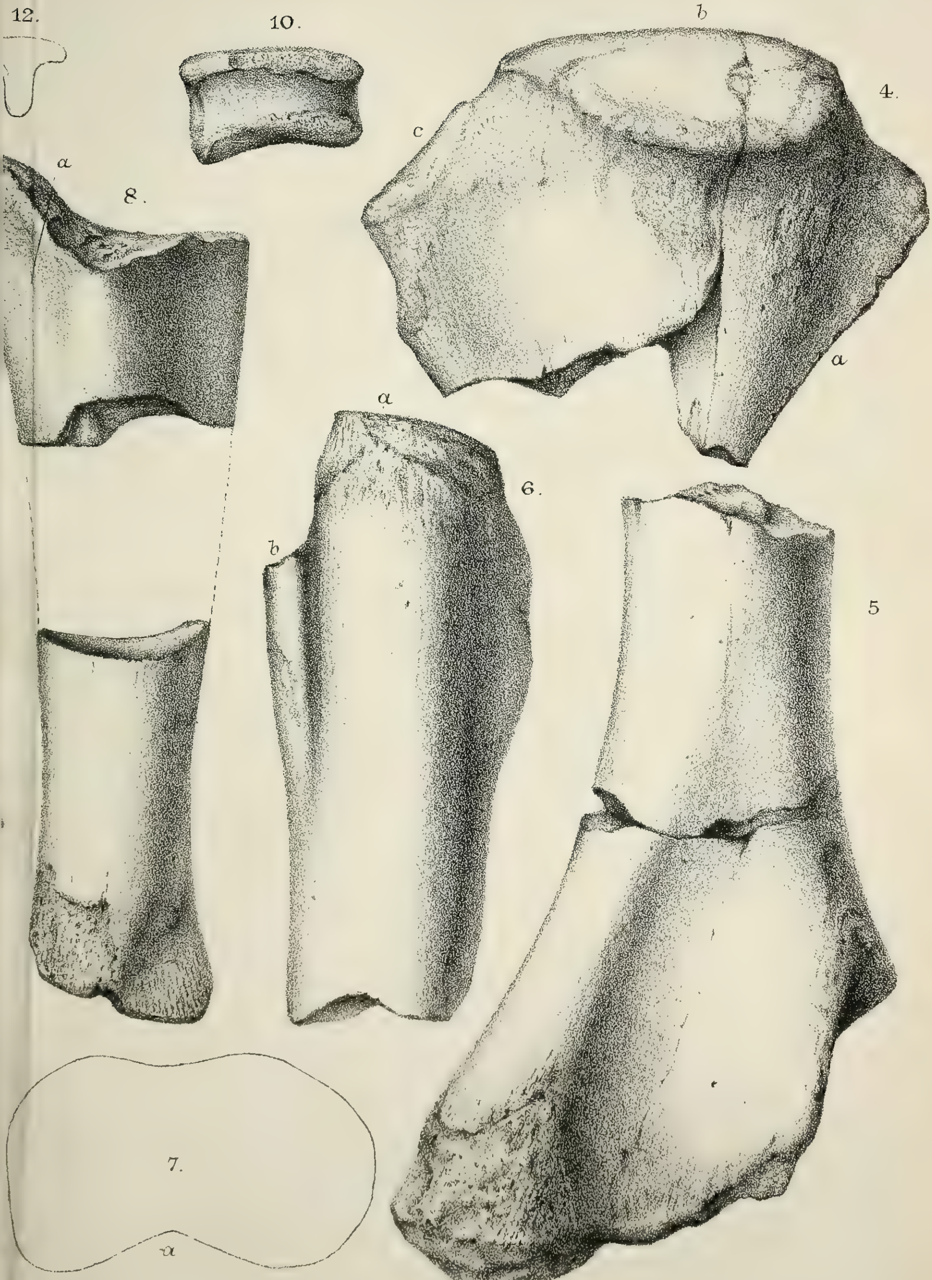
Mintern Bros imp

ANOPLOSAURUS CURTONOTUS



C. Berjeau lith.

ANOPLO SAU



CURTONOTUS.

Mintern Bros. imp.

C. Berjeau lith.

ANOPLOSAURUS CURTONOTUS.

Mintern Bros. imp.

47. *On the* Diorites *of the* Warwickshire Coal-field.

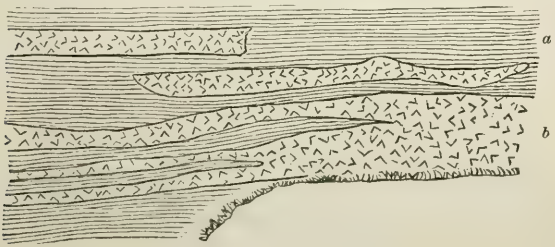
By S. Allport, Esq., F.G.S. (Read June 25, 1879.)

In a paper communicated to the Geological Society, and published in the 30th volume of the 'Quarterly Journal,' I briefly described the microscopical structure and composition of the various masses of igneous rocks which occur in the Carboniferous strata of the Midland Counties, with the exception of those found in the Warwickshire Coal-field. I now propose to complete the series with a short account of the only hornblendic rocks to be found among them.

Although they form but a small group they are of considerable interest, as some of them present remarkable varieties of structure, and others a mineral constitution which distinguishes them from any British rocks hitherto examined.

The geology of the Warwickshire Coal-field has been described in the Memoir of the Survey published in explanation of sheet lxiii. S.W.; and a reference to that map will show that the rocks now to be described are restricted to the district between Atherstone and the village of Marston Jabet, about two miles south of Nuneaton, and also that the several bands and larger masses occur only in the lower unproductive beds of the Coal-measures and in the underlying Millstone Grit. Although the sheets usually run very regularly between the beds of shale they are clearly intrusive, as they sometimes pass from lower to higher beds, and have invariably altered the shales in contact with their upper and under surfaces. The junction of the eruptive and sedimentary rocks may be seen in several clear sections. In a quarry in Purley Park, about a mile south of Atherstone, there is a good exposure of both rocks; at first sight they appear to be interbedded, but in one place there is a wedge-shaped band of shale enclosed in one of the sheets of trap. A still more interesting example may be seen in the railway-cutting near Chilvers Coton, where there are no less than ten alternations of the two rocks (see fig.). Although the geological period of the

Diorite intrusive in Carboniferous Shales in Railway-cutting near Chilvers Coton.



a. Shales. *b*. Diorite.

intrusion cannot be precisely determined, it is at least certain that it was previous to the deposition of the Triassic rocks, for in an old quarry near Marston Jabet the Lower Keuper sandstone lies horizontally on the upturned edges of the Carboniferous shales and included trap.

The Microscopic Structure of the Warwickshire Diorites.

An examination of numerous specimens from the different masses shows clearly that, as a group, these rocks must be regarded as diorites, the characteristic constituents being a triclinic felspar and hornblende; these two minerals together with magnetite and apatite are invariably present, and in addition a little orthoclase is seldom absent. Although many of the specimens examined are ordinary diorites, there are occasionally such wide departures from the normal type, that, from a mineralogical point of view, some of them must clearly be classed with rocks not hitherto observed among the older eruptive series. On the whole, it would perhaps be difficult to point to a group of rocks presenting more interesting varieties of composition and texture, or which afford more instructive examples of extensive alteration.

Quarry near Marston Jabet.—A finely crystalline specimen, very like a basalt in external appearance, contains an immense number of small hornblende crystals in a felspathic base, both minerals being nearly or quite unaltered. The clear brown crystals of hornblende are unusually well developed, and as they lie in all directions a single thin slice affords many excellent transverse and longitudinal sections of the prism. One rarely meets with an augitic or hornblendic rock containing such an assemblage of well-formed crystals. They are thickly set in a clear matrix of triclinic felspar, and interspersed among them are rather numerous grains of magnetite, with here and there a few needles of apatite. The only indication of alteration is a little calcite in the matrix; no other minerals are present.

The three following specimens, selected from a number collected in the same quarry as the last, may be taken to represent the more general character of the rocks of the district; and they possess a special interest, as they afford excellent examples of successive stages of alteration. The first example is rather coarsely crystalline in texture, and the original constituents are very well preserved; the plagioclase is generally clear, and exhibits well its characteristic twin striation. The hornblende is of a clear brown colour, for the most part quite unaltered, and presents its ordinary optical and physical characters; it is much fissured, and occasionally contains so many cavities that the crystals are little more than skeletons; it also encloses many grains of magnetite, and the latter are also rather thickly disseminated through the mass. Long hexagonal needles of apatite are rather abundant; and, lastly, there was a glassy or felsitic ground-mass in which the crystallized constituents were set. This ground-mass has been much altered, and now consists of a fine granular substance, partly serpentinous in character, with here and there a little calcite.

The second example is quite similar in texture to the first; the felspar, still easily recognizable as triclinic, is far from clear, having been partially converted into a grey pulverulent substance. The hornblende occurs in various stages of alteration; some crystals are but slightly attacked, while others are to a considerable extent converted into a pale green serpentinous substance. The alteration has followed the cleavage-lines and fractures, and has also invaded the substance of the crystals on each side; while the numerous cavities just mentioned are also filled by the same substance. In a single slice there may be seen almost every degree of change from a slight marginal erosion to a mere skeleton of the original. Of the latter, however, some little is always left; and whether the alteration be little or great the original crystalline forms are perfectly preserved. In the third specimen the alteration has proceeded still further, the whole of the hornblende crystals having been completely converted into pale green pseudomorphs; they were originally rather large and well developed, and their forms are still perfectly sharp and distinct. The felspar is here quite turbid and opaque, and the interstitial ground-mass is represented by calcite.

It may here be well to observe that the importance of a series of specimens like those just described can hardly be overestimated; in fact a collection of specimens in various stages of alteration is absolutely essential for any one who wishes to acquire an accurate knowledge of the older rocks; and it fortunately happens that a diligent search will very frequently supply the requisite materials for study. Among the older rocks, which have been quarried to some extent, it is generally possible to obtain specimens in every stage of alteration; and a careful study of such examples frequently renders it easy to determine the former presence (in other rocks) of minerals whose original composition and appearance may have been entirely changed. In other words, it will be found that many pseudomorphs possess characteristic microscopic features which render their recognition easy to an experienced and cautious observer. I venture to urge this point, as there is no more promising field for microscopic research; it is one which has, however, been treated with comparative neglect, and even the very existence of extensive pseudomorphic changes has not long since been denied by at least one writer of eminence.

Diorite containing Augite and Olivine.

Purley Park, near Atherstone.—A portion of the mass in this locality is in an excellent state of preservation; it is a greyish-black rock, distinctly crystalline in texture, and in external appearance closely resembles a fine-grained dolerite.

A thin slice exhibits under the microscope a mass of plagioclase crystals with a few of orthoclase; among these are scattered numerous small crystals of brown hornblende, many crystals and grains of clear yellowish augite, many grains of magnetite, a few needles of apatite, and several pseudomorphs after olivine. There is also a matrix in which the original constituents are set, but whether glassy or felsitic in its original state, there is no evidence to show; it has undergone a considerable amount of alteration, and now consists generally of a pale green serpentinous substance frequently accompanied by calcite. In several instances the usual forms of the augite crystals are perfectly well seen, some of them being twins; they exhibit no trace of dichroism when examined without the analyzer in the same way as the hornblende; and as well-formed crystals of both minerals occur in a single slice, their crystallographic and optical characters may be observed side by side. The augite appears to be very irregularly distributed throughout the mass of the rock; for in some slices it is almost as abundant as the hornblende, while in others it is nearly or even quite absent. It is slightly altered here and there, but never resembles uralite, the altered parts having merely a turbid grey aspect, like that observed in many of the dolerites.

Having given special attention to the various kinds of pseudomorphs after olivine, I had no difficulty in detecting their presence in several of these rocks; the discovery was, however, so entirely unexpected that, after cutting many slices, it was no small satisfaction to meet with a thoroughly characteristic form of the crystal. Some of these pseudomorphs consist exclusively of calcite, while in others the central parts are filled with viridite; they thus correspond in every way with many observed in the more highly altered dolerites described on a former occasion*. In some slices the pseudomorphs are very numerous and are generally larger than the crystals of augite or hornblende; they nearly all contain a few grains of magnetite, but never any other of the original constituents. The fissured condition of the unaltered crystals is also clearly indicated by the veins so familiar to those who have studied this mineral in the older dolerites. These and other features described in the paper just referred to are so thoroughly characteristic, that there is no room for doubt as to the former presence of olivine in these rocks.

There is also present in some quantity another mineral of which it will be well to speak less positively. It is quite colourless and occasionally clear, though it generally contains more or less of a fine dust which gives it a cloudy appearance, especially round the margins. Some of the sections are hexagonal, others rectangular; the former are dark between crossed Nicols, while the latter are coloured, though the tints are not brilliant. The crystals certainly belong to the hexagonal system, and are larger and stouter than the ordinary needles of apatite, many of which also occur in these rocks; it is possible, I think, that they may be nepheline. Against this

* S. Allport, "On Carboniferous Dolerites," Quart. Journ. Geol. Soc. vol. xxx. p. 542.

view there is, of course, the difficulty of an easily decomposed mineral like nepheline having remained unaltered from Palæozoic times; but, on the other hand, it should be remembered that olivine presents a similar difficulty, yet has nevertheless been frequently preserved unchanged throughout the same enormous periods.

Two of the secondary constituents have already been mentioned, namely calcite and viridite, or a serpentinous substance; to these may be added an orthorhombic zeolite which fills small cavities with long radiated lamellar crystals; they are clear and colourless, but exhibit brilliant colours in polarized light.

Quarry close to Atherstone.—In this mass the hornblende is also accompanied by a considerable quantity of very pale brown augite; the crystals are well formed and among them are several twins. The felspar is highly altered, but a few crystals may be recognized as triclinic. In two slices examined there were no pseudomorphs after olivine.

Railway-cutting, Chilvers Coton.—This is an excellent locality for collecting well-marked varieties of the intrusive rocks. On the west side there is a light-coloured mass composed chiefly of pink felspar, with rather long prisms of altered hornblende scattered through it. Another variety is of a dark green colour, and consists almost entirely of hornblende in comparatively large crystals. Between these extremes there may be found several intermediate varieties. Microscopic examination of these rocks affords no additional fact of importance.

Conclusion.

It appears from the preceding investigation that the intrusive rocks of the Warwickshire coal-field are for the most part ordinary diorites, but that they also occasionally present remarkable variations from the normal type.

The varieties described appear, however, to be strictly local; and in all of them the predominant and characteristic constituents are a triclinic felspar and hornblende, together with a little magnetite and apatite; a glassy or felsitic matrix is also nearly always present.

Hornblendic rocks containing augite and olivine have not been previously found in these islands, nor, I believe, elsewhere, except among rocks of Tertiary or later age. They appear, moreover, to be rather rare everywhere, a few only having been observed among the hornblende and augite andesites* or the Bohemian basalts described by Bořický†.

It is now certain that rocks of precisely similar composition were erupted during the later Palæozoic period; how much earlier remains to be seen. The existence of these rocks may therefore be regarded as additional evidence against the singular notion, apparently held by many, that the products of volcanic action were in some unaccount-

* Zirkel, Lehrbuch der Petrographie, vol. ii. p. 222.

† Basaltgesteine Böhmens, pp. 137, 138.

able way suddenly changed about the commencement of the Tertiary period.

It may be observed in conclusion that these Warwickshire rocks differ greatly from the neighbouring syenites of Leicestershire, recently described by Professor Bonney*, with which I am also well acquainted. In the latter the prevailing felspar is orthoclase, and quartz is always present; epidote is also a very common secondary constituent. I have detected no trace of either quartz or epidote in the diorites, and orthoclase invariably occupies a very subordinate position.

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 225.

48. *The* Precambrian Rocks *of* Shropshire.—Part I. By C. Callaway, Esq., M.A., D.Sc. Lond., F.G.S. *With* Notes *on the* Microscopic Structure *of some of the* Rocks, by Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S. (Read June 11, 1879.)

Contents.

Introduction.

In a paper communicated to this Society on March 21st, 1877, entitled "On a new Area of Upper Cambrian Rocks in South Shropshire"*, I intimated that certain volcanic rocks associated with the shale in question, which had been usually regarded as eruptive greenstones, were for the most part composed of bedded material; but details were deferred.

Mr. S. Allport, in a paper "On certain Ancient Devitrified Pitchstones and Perlites from the Lower Silurian District of Shropshire"†, read before this Society in May 1877‡, announces the same conclusion from entirely independent observations, devoting his attention, however, chiefly to the chemical and microscopic side of the question, and arriving at the very important conclusion that these (so-called) Lower Silurian pitchstones and perlites are identical in character with the most modern volcanic rocks.

In June 1878, I read to this Society a paper on "The Quartzites of Shropshire"§, in which I gave several sections across the Wrekin volcanic chain, and assumed that the bedded rocks of which it is mainly composed were of Precambrian age.

Messrs. Hill and Bonney, in their second paper "On the Precarboniferous rocks of Charnwood Forest" ||, infer the same conclusion

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 652. † *Ibid.* vol. xxxiii. p. 449.

‡ Both Mr. Allport and myself had contemporaneously announced this fact to the Birmingham Natural History Society, and he informs me that it was known to him nine years ago.

§ Quart. Journ. Geol. Soc. vol. xxxiv. p. 754. || *Ibid.* vol. xxxiv. p. 236.

from my determination of the (at least) Upper Cambrian age of the quartzites which flank the Wrekin axis.

It is proposed in the present paper to describe the lithological and stratigraphical character of these rocks, and to state in full the evidence for their Precambrian age. In a subsequent communication an attempt will be made to trace the physical history of this Precambrian mountain-chain, to describe the association of the bedded rocks with subsequent eruptive greenstones, and to correlate the Precambrian groups of Shropshire with other known formations. The recent recognition by the author of the Lilleshall Precambrian rocks on the eastern flank of the Malvern Hills*, and of the Malvern schistose types at the base of the Wrekin series, has an important bearing on the last inquiry; but details are, for the present, reserved.

I have to acknowledge my great obligation to Prof. Bonney, F.R.S., for his invaluable and willing aid in working out some difficult points in lithology. Mr. Allport's paper on the Wrekin, already referred to, has also been of great assistance.

A. Physical Geography of the Wrekin and Caer Caradoc Chain.

In Shropshire, this chain of hills is twenty-nine miles in length from N.E. to S.W.; but, if we include in it the elevations west of Kington, in Herefordshire and Radnorshire, which are probably in part composed of rocks of the same series, the line will reach nearly fifty miles. These hills do not form an unbroken range, but are here and there separated by broad intervals of comparatively level ground. The more typical forms are triangular in transverse section, and semilunar viewed from the N.W. or S.E., the greater length lying in the general direction of the chain. They are easily distinguished from the round-backed elevations of the Longmynd on the N.W., and from the ridges of the Caradoc Sandstone on the S.E., by their abrupt slopes and conical forms. They constitute a median axis, on each side of which run several parallel ridges with their escarpments facing towards it. On the west is the Longmynd range, succeeded at a distance of six miles by the abrupt edge of the Stiper Stones. On the east appear in succession the parallel elevations of Hoar Edge, the Chatwall ridge, and, at a greater distance, the sharp escarpment of Wenlock Edge, overtopped by the less angular and less regular ridge of the Aymestry Limestone. Most of the flanking ranges lie in comparatively unbroken straight lines, and fall down steeply on the side looking towards the Precambrian axis; while the axial rocks themselves present a cone or boss at intervals only, and slope abruptly and evenly to both south-east and north-west.

The following are the principal elevations, commencing at the north-east end of the chain :—

* Messrs. Hill and Bonney, Quart. Journ. Geol. Soc. vol. xxxiv. p. 237, note §, also recognize a second Precambrian group at Malvern.

a. *The Wrekin Group.* Lilleshall Hill, Ercal, Lawrence Hill, the Wrekin, Primrose Hill.
b. *Caer Caradoc Group.* The Lawley, Caer Caradoc, the Ragleth, Hope Bowdler Hill.
c. *Horderley Group.*
d. *Kington Group.*

B. Lithological and Stratigraphical Characters of the Rocks.

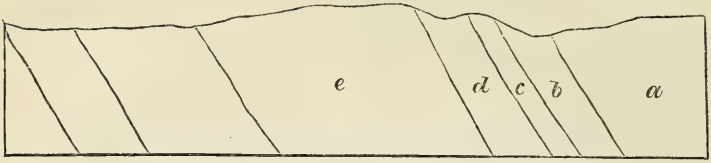
1. *Lilleshall Hill.*

This elevation is coloured on the survey map as "altered Caradoc," with a central boss of "greenstone." I have seen no trace of greenstone or any other intrusive rock in the hill. The supposed Caradoc is of Precambrian age.

Details.—At the S.W. end, in the road just below the village, is a hornstone of dark grey colour mottled with red. This is overlain, in a small opening immediately to the S.W. of the large quarry, by a grey thin-bedded ashy slate, with oval steatitic blotches on the planes of lamination, dipping N. 10° W. at 23°. In the great quarry there is a fine exposure of similar strata, much altered. Felspathic and steatitic matter are separated in the decomposition, and give in places a beautifully variegated appearance to the rock, pink and green colours predominating. Here and there the felspar has segregated in clusters and layers of red crystals. Some of the ashy beds are white and less altered. The general dip is N.N.W. at 30°. At the N.E. end of the quarry there is an interesting junction of the softer beds with an overlying hornstone. The latter is very hard and compact, approaching a hornstone; while the former, in immediate contact with it, is so soft as to be easily scratched by the nail. In this place the ashy rock is very ferruginous, the iron peroxide separating in little round nests. The beds dip at 40°. The hornstone cannot be far from the horizon of a massive hornstone band which stands out as a craggy boss crowning the hill, and is probably the "greenstone" of the Survey. N.E. of the summit, we have a repetition of grey ashy beds, dipping N. 10° W. at from 40° to 50°, succeeded by a felspathic breccia, composed of fragments of Wrekin rhyolite in a grey matrix. Some of the fragments show the characteristic banded structure. Breccias are abundant on the S.E. slope. The highest beds, clearly exposed in a long section at the N.E. end of the hill consist of alternations of ashy beds and hornstones, similar to those described, as represented in fig. 1.

In this section the ashy bands are very clearly separated from the hornstones. The beds *b* and *d*, for example, each about 10 feet thick, are soft and ferruginous, and have been excavated by weathering to a considerable depth; while the band *c*, 5 feet thick, composed of hornstone precisely similar to the rock at the N.E. end of the great S.W. quarry, stands out like a sharp wall.

Fig. 1.—*Section across N.E. end of Lilleshall Hill.*



a, c, e. Hornstone. *b, d.* Ash.

In a series of rocks from Charnwood Forest I have observed a slate which suggests, though it is quite distinguishable from, the grey slate S.W. of the large quarry. Prof. Bonney has also noticed this resemblance.

On the N.W. side of Lilleshall Hill are faulted beds of Bunter Sandstone; and on the S.E. the Hollybush Sandstone is thrown down. On the N.E. the axis of the ridge is prolonged under the Carboniferous Limestone, which is bent into an arch by the subsequent elevation of the Precambrian axis. To the S.W., a S.W. line of fault, Bunter Sandstone against Coal-measures, connects Lilleshall Hill with the Wrekin, and the axis is undoubtedly continued under the younger formations.

Summary.—A S.S.W. ridge, composed of alternations of hornstone and ashy slates and shales, with felspathic agglomerates in the middle. Average dip of 40° to N.N.W. Minimum thickness 1500 feet. Bounded by two nearly parallel faults, converging at each end, Bunter Sandstone being thrown down on the N.W., Hollybush Sandstone on the S.E.

2. *The Ercal* (figs. 4 & 5, p. 650).

Details.—On the N.W. slope of this hill, just overlooking the town of Wellington, is a large quarry, distinguishable for miles by the colour of the bright red felspathic rock of which the exposure chiefly consists. Near the surface this rock is divided by very close joints, and it is easily shovelled away as gravel. It forms a broad zone, striking E. and W. across the face of the quarry. It is underlain by a grey or greenish-white rock, forming a zone parallel to the upper red band for the entire breadth of the section. The dip of the red rock is apparently to the S., that is, opposite to the prevalent dip of the Wrekin chain. Following this rock from the N.E. end of the Ercal, just above the quarry, along the ridge to the S.W., we come in about half a mile to a sudden change. The red rock abruptly gives place to a compact felstone, dipping N.N.W. at 50°, which is exposed in a buttress which supports the ridge on the N.W., and still more conspicuously in the broken crags at the S.W. end of the hill.

It might, at first sight, seem as if the Ercal were composed of beds lying in a synclinal; but the great difference between the rocks at the opposite ends appears to negative this supposition. I believe that the ridge is cut across by a fault. This view is supported by the abrupt change in lithological characters. At the point of junction the ridge is cut into by a ravine on the N.W. slope. The felstone spur forms one side (S.W.) of the hollow, and on its N.E. curve the red rock breaks up through the soil.

The red rock is granitoid in character and probably of clastic origin. (See Note B, p. 664.) Its rectilinear junction with the grey rock seems to negative the supposition of an amorphous mass.

The grey band is uncrystalline, much jointed, and very variable in colour and hardness. To the naked eye, it looks very much like a tuff, containing fragments of the characteristic Wrekin rhyolite, some of which are distinctly banded. Some of the included bits are rounded, like pebbles. Prof. Bonney is, however, clearly of opinion that this singular rock is simply another form of the Wrekin rhyolite intrusive in the red rock. (Note A, p. 663.) This revelation by the microscope is very interesting and important, and will be a great aid in correlation.

Along the S.E. flank of the hill strike the thick beds of quartzite, succeeded by the Hollybush Sandstone and the Shineton Shales, described in previous papers *. The quartzite probably holds the same position on the N.W. of the axis, but exposures are very scanty.

Summary.—A S.W. ridge composed of a bedded granitoid rock dipping southerly, and underlain by eruptive Wrekin rhyolite, at the N.E. end, and of grey and brown felstones with a N. dip for the remainder of its length, the two series being separated by a fault, the ridge being flanked by quartzite on the N.W., and by quartzite, followed by Cambrian strata, on the S.E.

3. *Lawrence Hill* (figs. 2, 4, 5).

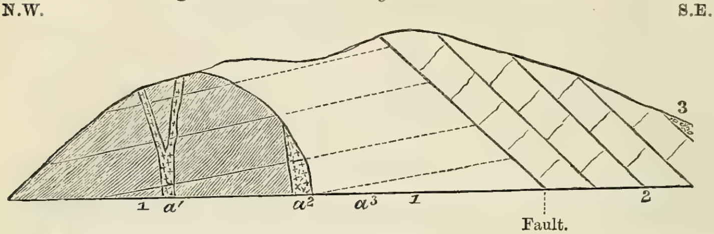
Details.—The north-east end is composed of felstones similar to the opposite crags of the Ercal, and felstone may be traced all along the crest of the hill till we reach the edge of the great quarry, which exposes a considerable part of a transverse section of the chain. It was this magnificent exposure which first convinced me of the erroneous interpretation of the Survey. This supposed eruptive greenstone consists of felspathic tuff †, clearly bedded, and dipping north at 50°. The true bedding is much obscured by jointing, but it may be made out most satisfactorily by following beds to the right or left. Continuity of texture is thus as clear a proof of stratification as continuity of mineral composition in ordinary sedimentary rocks. The bands vary from a fine-grained ash to a breccia or a conglomerate. Even hand specimens sometimes distinctly show alternations of fine and coarse bands. In addition to this evidence of stratification, the seams separating beds and the exposed surfaces of the beds themselves are clearly visible. The coarser bands contain fragments of pitchstone and of felstone, the

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 652, and vol. xxxiv. p. 754.

† Described by Mr. S. Allport, Quart. Journ. Geol. Soc. vol. xxxiii. p. 458.

latter sometimes displaying the characteristic banding of some of the Wrekin felstones. Fig. 2 shows the structure of the chain at this point.

Fig. 2.—*Section through Lawrence Hill.*



1. Bedded Precambrian tuff, dipping north.
2. Quartzite.
3. Hollybush Sandstone.

a^1, a^2, a^3. Dolerite dykes. The position only of a^3 is indicated, and only so much of a^2 as is actually exposed is drawn.

The shaded portion represents the strata exposed in the quarry. The continuation of the bedding beyond the quarry is indicated by the broken lines. The beds plunge into the face of the quarry obliquely, so that the section is taken at an acute angle with the dip, and the true dip is not shown. The dyke a^1 is well exposed, and, in its lower part, stands out like a wall. The dolerite is fine-grained, and may be called basalt. It is considerably altered, calcite being deposited in the cracks, and the tuff in the vicinity of the dyke has also undergone more than its usual alteration. The changes in both cases I conceive to be due to the infiltration of carbonated waters subsequently to the injection of the basalt, the dislocation allowing passage to the water more freely than the unbroken strata. The altered tuff in proximity to the Lawrence-Hill dyke contains greenish matter, apparently some form of magnesian silicate, one of the commonest products of wet chemical decomposition. The surface of the dyke in contact with the tuff is minutely jointed into rectangular prisms an inch or two square, and lying with their long diameters at right angles to the bounding surface. I have detected two of these dykes, apparently a^2 and a^3, on the Wrekin side of the ravine, in the road up to the cottage, and striking towards a mass of dolerite which protrudes at the surface within half a mile to the south-west in the summit ridge of the Wrekin.

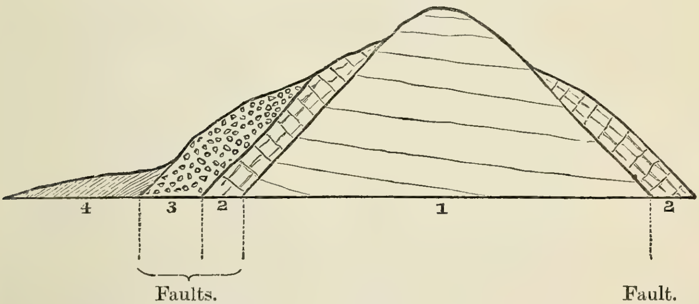
Fig. 2 also shows that on the south-east the tuff is overlain at a considerable angle by beds of quartzite, the former dipping north, the latter south-east. The quartzite is succeeded by the Hollybush Sandstone, and the Hollybush Sandstone by the Tremadoc Shales of Shineton. The planes separating all four formations from each other are probably strike-faults. The quartzite also occurs, but inconspicuously, on the north-west side of Lawrence Hill, dip undetermined.

Summary.—A south-west ridge, composed mainly of felstone, but displaying at the south-west end a considerable thickness of altered felspathic tuff, dipping north at 50°, and cut through by three basaltic dykes, which strike towards a mass of dolerite in the Wrekin. The ridge is flanked by quartzite on both sides, the beds on the south-east being succeeded by the Hollybush Sandstone and the Shineton Shales.

4. *The Wrekin* (figs. 3, 4, 5).

Details.—At the north-east end of the hill, opposite the great quarry in Lawrence Hill, there are numerous exposures of dark grey and reddish tuff, similar to the Lawrence-Hill series. In a large opening at the foot of the ascent, the tuff beds are pushed out into a rounded anticlinal spur. This contortion appears to be due to the intrusion of the mass of dolerite to which reference has been made. Two of the three Lawrence-Hill dykes are also visible on this side of the ravine; and it is evident that both the contortion and the dykes are due to the same cause. Between this point and the dolerite mass the tuffs are somewhat disturbed, the dip being pushed round to 20° west of north. Near the cottage the tuff is a breccia, which is sometimes conglomeratic, the pebbles consisting of felstone, pitchstone, and less frequently of quartz. The subjoined section shows the lie of the tuffs which compose the north-east end of the Wrekin, with their relation to the flanking deposits.

Fig. 3.—*Section across the Wrekin, north-east end.*



Scale about 8 inches to 1 mile.

1. Bedded Precambrian volcanic tuff, dipping north.
2. Quartzite (probably Precambrian).
3. Hollybush Sandstone.
4. Shineton Shales (Tremadoc).

Ascending the hill above the cottage, we reach a round bare hump, the exposed apex of the greenstone mass*. It is composed of dark green dolerite, which in some parts is agglomeratic, in others amygdaloidal, with nuclei of calcite. In its colour, state of decomposition, and in all other respects this rock resembles the dykes of Lawrence-Hill quarry, with which it is undoubtedly connected. It would appear to have been an ancient volcanic vent. It is the only greenstone found in the entire Wrekin chain †.

* First noticed by Mr. Allport in the paper to which reference has been made.

† I have since detected greenstone at the S.W. end.

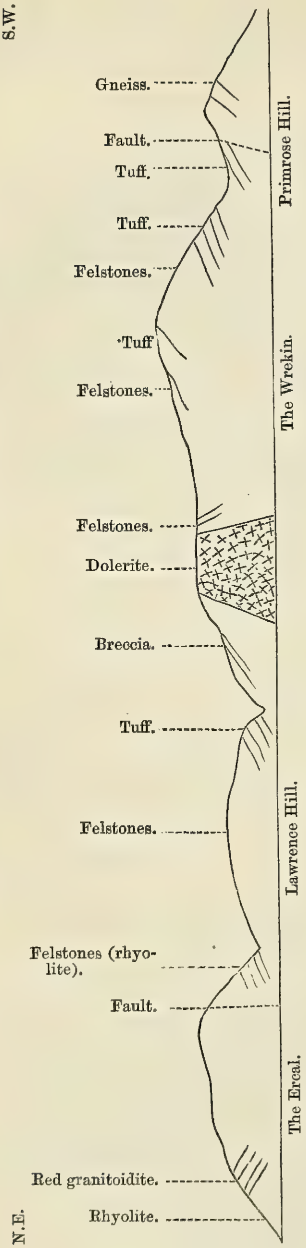


Fig. 4.—*Longitudinal Section of the Wrekin Chain.* (Scale $2\frac{1}{4}$ in. to 1 mile.)

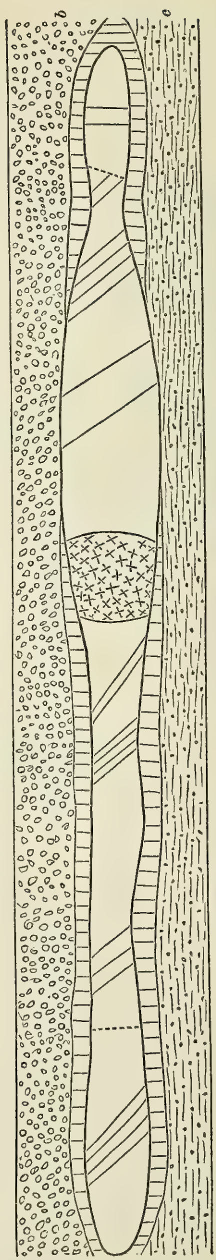


Fig. 5.—*Ground-plan of the same, the Dips in fig. 4 being converted into Strikes.*

a. Quartzite. *b.* Hollybush Sandstone. *c.* Trias.

Following the ridge to the south-west, we come to a reddish felstone, the dip of which has been locally reversed by the disruptive greenstone. This rock is continued for some distance. In places it is clearly banded into laminæ of various colours, an alternation of dark chocolate with buff bands being the commonest variety. The laminæ are sometimes contorted like the gnarled wood of an ancient oak.

These Precambrian lavas are underlain near the summit by a greyish agglomerate, with fragments of brown felstone. The dip is northerly.

At the summit and for some distance beyond is a considerable exposure of reddish and chocolate-coloured felstone.

In the middle of the south-west slope, with the normal east and west strike, is a dark coarse tuff, undistinguishable in appearance from the beds near the cottage at the north-east end.

Below the tuff we come to a compact red felsitic rock, underlain, in the saddle between the Wrekin and Primrose Hill, by typical agglomerate.

Relations of the Wrekin axis to the flanking deposits.

The volcanic rocks of the chain are fringed by quartzites *, which in every observed case (with one exception) dip away from the axis at an average of 45°. The exception is on the north-west side of the ravine, between the Ercal and Lawrence Hill, where the beds are nearly vertical, the dip being towards the axis. The base of the quartzite is brecciated, and the junction is evidently a fault. Towards the base the quartzite contains rounded fragments of banded felstone, similar to some of the Wrekin felstones. The quartz rock is clearly younger than the axial rocks, and has been thrust up and thrown off on every side by the upheaval of a rigid wedge of the older series. Under the summit on each side, as shown in fig. 5, the quartzite appears to be absent; and it is presumed that the crest of the Wrekin was an island in the Precambrian ocean, and by its partial denudation furnished the felstone fragments imbedded in the quartzite. On the north-west the Bunter Sandstone is faulted down against the quartzite. On the south-east, the quartzite is succeeded by the Hollybush Sandstone, and the Hollybush Sandstone by the Tremadoc shales of Shineton, the junctions in both cases being parallel lines of fault.

Figs. 4 & 5 will illustrate the series just described. Fig. 4 is a longitudinal section through the chain from end to end. The dips are not fully filled in, only those being indicated which are ascertained with reasonable certainty. The quantity of dip cannot be shown, the section, as in the transverse section, fig. 3, being taken at an acute angle with the dip. The underground extension of the dolerite neck is, of course, hypothetical; it should be represented, if the space permitted, as sending off three dykes to the north-east. Fig. 5 is more instructive, since the true direction of the strikes is shown, and the relations of the flanking formations are indicated.

* Described in Quart. Journ. Geol. Soc. vol. xxxiv. p. 754.

Summary.—The Wrekin is a S.W. ridge, composed of alternations of bedded felspathic lavas and tuffs, with an average dip of 40° to the N. and a little to the W. of N., broken through and disturbed in one place by a mass of greenstone sending off dykes to the N.E., and flanked on both sides by quartzites, which on the S.E. are succeeded by the Hollybush Sandstone and the Shineton Shales.

5. *Primrose Hill.*

The Wrekin tuff is continued through the saddle connecting this spur with the Wrekin mass, and appears on the northern slope near the summit. The chief part of the hill is composed of rocks of an entirely different type. On the S.W. slope, about twenty yards below the top, crops out a band of schistose rock dipping to the N.E. at 55°. It is a very quartzose granulite, the quartz being sometimes quartzite, and the felspar is like the red variety in the Ercal quarry. It is very irregular in composition, passing frequently into hornblendic gneiss, and sometimes approximating to a quartzite with a little red felspar. The W. and S.W. slopes are occupied with granitoidite *, which appears to Prof. Bonney and myself identical with the red rock of the Ercal (Note C). On the N.W. side crop out numerous exposures of a compact rock, which Prof. Bonney has determined to be clastic and similar to hornstone. Some eruptive rocks break out in a few places. Amongst these I have observed a diorite, undistinguishable from a specimen in my collection from Malvern; and Prof. Bonney confirms this view (Note C, p. 665). Some of the granitoidite also is of the Malvern type, showing the red felspar and the small nests of mica, sometimes in a decomposed state, characteristic of the granitic type which I have from the Wych and the North Hill. In both localities there is also the same tendency to pass into hornblendic rock. The strike of the beds is also the same. On the whole, I have no hesitation in identifying the Primrose-Hill rocks with the Malvernian system. Further attempts at correlation are postponed to a future paper. The Wrekin tuffs are in contact with the older schists N.E. of the summit of Primrose Hill, and the plane of separation is undoubtedly a fault. The discordance of strike between the two groups suggests a considerable unconformity.

6. *The Wrockwardine mass.*

Details.—The prevailing rocks of this area are purple and green felstones and breccias. At the village of Wrockwardine, green is the predominant colour. In one or two spots a greenish dolerite, highly decomposed and containing free calcite, has pushed its way up to the surface. In the lane leading from the village towards Cluddley are several exposures of rock like hornstone, and on a knoll to the E. of this road are purple felstones, whose clearly developed banding shows a S.W. strike with a prevailing S.E. dip.

* I adopt this term from Prof. Bonney, Quart. Journ. Geol. Soc. vol. xxxv. p. 322, note *.

At Flax-Hill quarry, S.W. of Wrockwardine, the purple-banded felstones are highly spherulitic. A dyke of earthy rock, a decomposed greenstone, throws off the lavas towards the S.W. The felstone is continued for some distance to the S.W., and is seen at Leaton, one mile S.W. of Wrockwardine.

At about one mile S.S.W. of Wrockwardine, midway between Burcot and the old turnpike on the Shrewsbury road, some very interesting rocks are exposed. They are very hard and compact, approaching hornstone in texture and fracture, but are clearly fragmental. The contained fragments are green and purple felstone, the purple variety being sometimes banded. They vary in size from a pin's head to a pigeon's egg. Their shape is irregular, their outlines being sometimes well defined, but often shading off into the matrix, which is frequently as compact as hornstone. This rock has seemed to me to favour the clastic origin of hornstone. The beds have a high dip to the W. Associated with this breccia is a compact fine-grained rock, to which also Prof. Bonney assigns a fragmental origin (Note 2, p. 666). Underlying these strata, in the field to the E., is purple felstone (Note 1, p. 666).

At Lea Rock, about half a mile W. of the last spot, are the banded felstones or altered perlites described by Mr. Allport in the Journal of this Society *. Nuclei of quartz, chalcedony, and agate give the rock a peculiar spotted aspect. The nuclei sometimes open out into geodes lined with quartz crystals.

The induration which these and other rocks of the Wrekin area have undergone is due, I conceive, not to intense heat (for the rock, when in contact with intrusive masses, by no means displays greater hardness), but to the chemical action of infiltrated waters at perhaps very low temperatures. The dissolving power of water is well seen in some of the banded felstones, free silica being dissolved out and deposited in lines of minute quartz crystals along the lines of lamination. I have also noticed in the quartzites that weathered surfaces constantly display a coating of recrystallized quartz. The dissolved silica may well have acted as the cement to the flinty hornstones and breccias.

Summary.—A low rounded elevation, trending S.W., composed of purple and green felstones and hornstones, with some highly indurated agglomerates, and broken through at intervals by greenstone. Bedding not very clear, but a general S.W. strike, agreeing with the strike of the mass, but discordant to the usual strike of the Wrekin chain.

7. *Charlton-Hill area.*

Details.—Charlton Hill is an inconspicuous oblong elevation, three quarters of a mile from N. to S. and half a mile from E. to W. The northern half is composed of tuff of the Lawrence-Hill type. This passes down towards the S. into a massive bed of conglomerate (Note 3,

* Vol. xxxiii. p. 454.

p. 667) striking across the centre of the hill from E. to W., and dipping to the N., that is, with the normal dip and strike of the Salop Precambrian rocks. The contained pebbles are well rounded; they consist of quartzite, quartz, gneiss, mica-schist, red felspar, and granitoid rock. This assemblage strongly suggests derivation from the Malvernian series represented at Primrose Hill*. The matrix is apparently ash. This bed is indisputably a subaqueous formation; it appears to be on the same horizon as the tuffs of the Wrekin. Following this conglomerate along the strike to the E., it is seen to end abruptly against a reddish felspathic rock, probably intrusive.

Below the conglomerate, and occupying the south end of the hill, is a rock which I have observed in no other Shropshire locality. It is a mass of porphyritic felstone, composed of crystals of red and green felspar in a dark green matrix. The hill at this point is flanked by quartzite.

There is a fine exposure of Precambrian rock in the road S.E. of Charlton Hill. In the upper part is a compact red felstone; below this are beds of greenish claystone, with gritty bands, made up of small rounded fragments similar to the pebbles of the chief conglomerate, the prevailing constituents being quartz and a red felspar. These seams of grit have all the appearance of derivation from the same land as the conglomerate, but from a greater distance, the pebbles being much smaller and being more exclusively composed of the less destructible rocks. A little lower down the road is an instructive junction of the older Precambrian beds with the overlying quartzite, which dips S.S.E. at 60°.

In a small boss to the S. of Charlton Hill is an indurated tuff of the ordinary Wrekin type, associated with gritty beds. Quartzite dips away to the south.

Summary.—Conglomerates, grits, claystones, and tuffs, with a general dip to the N.; felstone, sometimes porphyritic; quartzites dipping away from bosses of the older series in all directions.

8. *District between the Wrekin and the Lawley.*

The two areas are connected by a south-west line of fault. On this line igneous rocks are exposed at two points. The first is in a cutting on the Severn Valley Railway, near Cound Cottage, about a mile south-west of Dryton Bank. The rock is a dark brownish-green fine-grained dolerite, with amygdaloids of calcite. The other spot is a mile and a half further to the south-west, where a small quarry has been opened, on the opposite side of the ravine from the great sandstone-quarry of Cound Moor. Here also the rock is a greenstone; but it is more coarsely crystallized, the felspar and the augite (or hornblende) being readily distinguishable. Higher up on

* In this conglomerate I have made out eighteen varieties, more than half of which I have recently recognized in Anglesey.—C. C., Sept. 1879.

the slope of the hill this greenstone is overlain by beds of Caradoc sandstone.

9. *The Lawley.*

Details.—The centre of the hill is a mass of greenstone. At the summit is a dark-green basalt. On the north-west slope the rock is coarsely crystalline, and is very similar to the greenstone opposite Cound-Moor quarry. The crystals of white felspar imbedded in a dark-green matrix give the rock a speckled appearance. In parts, where the greenstone is decomposed, mica and cubic iron pyrites are seen. Following the ridge towards the north-east from the summit we come, above Yew-Tree House, to a grey felspathic breccia, which is continued for some distance to the north-east extremity, where coarse tuff, striking east and west in bands across the ridge, is broken through by black basalt. At the south-west end a red felsitic rock occurs.

The Lawley is bounded by faults on both sides. On the west lie the Coal-measures of Leebotwood; on the east runs a parallel valley excavated in Shineton Shales. At the south-west end quartzites are seen dipping away from the hill, and lapping round for some distance to the east and north-east. Just below the quartzite at Cowley Farm, where the ridge breaks down into the ravine to the south-west, is a small exposure of grey grit with Caradoc fossils. The strange position of these beds will be perceived when it is observed that this fragment is separated from the Caradoc escarpment of Hoar Edge by an intervening ravine hollowed out in upper Cambrian rocks (Shineton Shales).

Summary.—A south-west ridge, composed of an intrusive mass of greenstone, with Precambrian tuffs and felstones at each end, lapped round by quartzites on the south-west and south, and bounded by faults on all sides.

10. *Caer Caradoc.*

Details.—The N.E. spur, called Little Caradoc, is mainly composed of intrusive rock. At the north-eastern extremity is a mass of greenstone extending for several hundred yards along the ridge; it is large-grained, the plagioclase prisms sometimes reaching nearly an inch, and is strongly distinguished from every other greenstone in the district. Resting on it to the S.W. are some slaty beds of a flinty texture; they are of slight thickness, and are disturbed by the intrusion of the greenstone. The remainder of Little Caradoc is chiefly composed of fine-grained greenstone.

In the neck uniting this spur with Caer Caradoc proper the greenstone is highly altered; it is spotted with spherical concretions of radiated epidote. In some of the nuclei calcite is crystallized with the epidote. A similar rock extends for some distance along the ridge towards the summit. Quartz is sometimes substituted for the calcite in the amygdaloids.

The structure of the main mass is very varied. At the summit, where the remains of an ancient camp are visible, is a light-coloured reddish felspathic rock, apparently a felstone, mottled with minute geodes of quartz, which is sometimes coated with viridite. The geodes show a tendency to lie in parallel planes, as if they had originally been air-bubbles in a lava-flow. To the S.W. of the summit greenstone breaks out in the centre of the ridge, and keeps to the crest of the hill for some distance, being flanked on each side by grey felspathic rocks. Then the grey rock occupies the entire saddle, but greenstone soon reappears, and forms the axis of the range for a quarter of a mile, with the grey rocks, as before, on each side. An isolated boss of greenstone also breaks out on the S.E. slope. Towards the S.W. end of the range is a very interesting series of bedded rocks, clearly dipping to the N.E., that is, at right angles to the trend of the ridge; they are undoubtedly fragmental and most distinctly stratified. Some of the beds are very thin. In some spots several varieties occur in a thickness of a yard. The common rocks are a coarse ashy shale, a coarse grit made of crystals of red felspar with grains of quartz, a similar grit with the fragments imbedded in a dark matrix (Note 4, p. 667), a felspathic breccia, and a compact felspathic rock with a flinty fracture. In one place I detected a thin band of quartzite, the only instance of the occurrence of that rock in the older Precambrian strata of the district. The Caer Caradoc range terminates with a mass of greenstone, which occupies the south-western slope, and by its intrusion has increased the dip of the overlying beds.

On the Survey map this mountain is coloured as altered Caradoc, with four masses of intrusive greenstone irregularly arranged. The position of these intrusions, as well as the description of the bedded rocks, requires some modification. There are more than four eruptive masses, and they are generally arranged in a linear manner along the crest of the ridge.

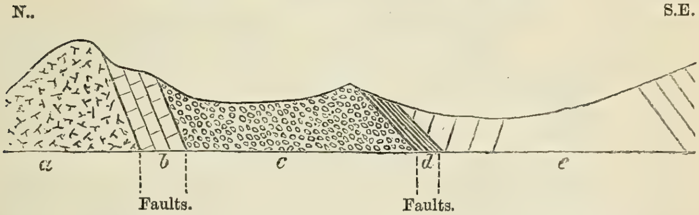
The strikes in this range have been greatly disturbed by the greenstones. Wherever bedding can be made out in proximity to eruptive rock, the dip is away from the intrusive mass. On the whole it is probable that the original strike was in accordance with the prevailing E. & W. strike of the axial series. At the S.W. end, for example, where the bedding is most distinct, the dip is N.E.; but it is evident that if the intrusive boss which has disturbed the beds at that point did not exist, the dip would have been more northerly.

Caer Caradoc, like the Wrekin, is a wedge of consolidated Precambrian rock, thrust up through younger beds, and is consequently bounded by faults on all sides. In the Survey map, Wenlock strata are faulted down against the N.W. side of the ridge. This is quite correct as regards a part of the distance; but this Wenlock wedge has been carried by the surveyors too far to the S.W. Towards the S.W. end of the hill the fault brings down against the axial rocks the slates of the Longmynd group, with their usual dip to the N.N.W. at a very high angle. On the S.E. side of the ridge the relations of the flanking strata are very complicated. At Little Caradoc the axial rocks are overlain by high-dipping quartzite, succeeded by Hollybush Sandstone and Shineton Shales, with Caradoc

Sandstone plunging towards the latter. Fig 6 illustrates this arrangement.

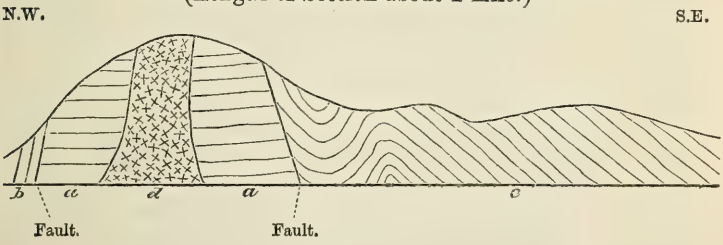
I believe the junctions of these flanking rocks to be faults in each case, the masses being sliced out of more extensive formations. These slices rapidly thin out towards the south-west, so that Caradoc sandstones gradually approach the axis, and, under the summit of the hill, they rest against it. Fig. 7 represents the relations of the flanking rocks at the south-west end of the mountain.

Fig. 6.—*Section across Little Caradoc and valley to the South-east.*
(Length of Section about half a mile.)



a. Greenstone of Little Caradoc. *b.* Quartzite. *c.* Hollybush Sandstone.
d. Tremadoc (Shineton Shales). *e.* Caradoc.

Fig. 7.—*Section across Caer Caradoc towards its South-west end.*
(Length of Section about 1 mile.)



a. Precambrian Rocks. *b.* Longmynd Slates.
c. Caradoc Sandstone. *d.* Intrusive Dolerite.

Summary.—Caer Caradoc is a wedge of rock limited by faults striking S.W., composed of felspathic grits, felstones, ashy shales, and indurated claystones, which are locally disturbed by several protrusions of greenstone arranged in a line along the axis. On the N.W. the hill is bounded partly by Wenlock limestone and shale, and partly by Longmynd slates; on the S.E. by quartzite, succeeded by Hollybush Sandstone and Tremadoc Shales at the N.E. end, and by contorted Caradoc Sandstone for the remainder of the length.

11. *Helmeth Hill.*

This low narrow ridge continues the line of Caer Caradoc for a short distance to the S.W. A green felspathic rock is seen at one spot on the S.E. slope.

12. *Hazler Hill.*

A greenish breccia occurs at the north-east end, near the road to Church Stretton. A similar rock is seen at the south-western extremity, where it is associated with a dark compact felstone. Here sets in a mass of greenstone, which forms the crest of the low ridge connecting Hazler with Ragleth. This rock is well seen in a quarry at the side of the road. In places it is spotted with amygdaloids of calcite.

13. *Hope Bowdler and Cardington range.*

Details.—At the most westerly summit, called the Gaer Stones, the prevailing rock is grey, earthy, rather compact claystone. A similar material also occurs as the matrix of a grey breccia. On the slope to the E. of the crest is a rough grit of red felspar and quartz fragments, the former predominating.

Following along the ridge to the E., we come next to Hope-Bowdler Hill. Here also the rock is for the most part fragmental. Several varieties of breccia occur, the fragments being of quartz and felspar, and the matrix presenting a very ashy appearance. This breccia thins out towards the E.

On the southern slopes of Cardington Hill, at a lower horizon than the clastic beds, is a fine development of green and purple felstone, the latter predominating. This rock is magnificently exposed in the crags overhanging the gorge which runs up from near Woodgate into the heart of the ridge. It is compact in texture, with scattered felspar crystals, and is banded and spotted with darker colours (Note 5, p. 667). It is limited below by a bed of grit to be shortly described; and, as there are no signs of disturbance either above or below, I infer that it is not intrusive. In the mouth of the ravine, the Survey has assigned to the purple felstone a dip towards the S.; but I am by no means certain that the alleged bedding is not due to jointing. Towards the E. this felstone band approaches nearer and nearer to the overlying quartzite of the Sharp Stones through the thinning out of the breccia.

To the S.W. of this gorge, on the farm of Woodgate, is one of the clearest sections of the entire Precambrian series. The succession, taken in ascending order, is as follows:—

(1) Grey felspathic grit, much kaolinized; 7 to 8 feet.
(2) Purplish felstone, compact, with small felspar crystals disseminated, weathering white at surface; 15 feet.
(3) Speckled grit (Note 6, p. 668), composed of grains of white felspar kaolinized, of small crystals of red felspar, and of green chlorite (?) in scales (which sometimes display a striated "slickenside" surface), and disseminated through the mass; very small rounded pebbles occasionally occur; the white and green minerals form alternating laminæ; barium sulphate is seen in small nests and veins: 20 feet.
(4) Purple felstone, passing up into the mass previously described.

The section displays a very clear dip to the N. at 80°.

About half a mile to the E. of Woodgate, near the farm of Underhurst, is an exposure of a granitoid rock, not unlike the imperfect granite of Primrose Hill, but containing more chlorite.

On the W. side of the main axis, where the Cardington promontory springs from the side of the chain, Longmynd slates (coloured "Caradoc" by the Survey) are faulted down against the Precambrian rocks of Helmeth and Hazler Hills. On the east, the spur projects into an area of Caradoc Sandstone. Near the village of Cardington, the rocks just described are overlain by bedded quartzite, forming the Sharp-Stone ridge, and dipping N. at a high angle with a strike of half a mile. The older series and the quartz rock together form the promontory, which is surrounded, except at its neck, by Caradoc Sandstone with its normal S.W. strike.

Summary.—A great spur, with an E. and W. strike, projecting from the E. side of the main chain at Hazler Hill, composed of breccias and grits in the upper part, underlain by massive felstone with alternations of altered grit and felstones below, and red granitoidite at the base, the whole dipping at a high angle to the N., thrusting up quartzite in front, and being surrounded by Caradoc Sandstone with its usual S.W. strike. Longmynd slates faulted down against the W. flank of the main ridge.

14. *Ragleth Hill.*

Details.—This elevation is coloured on the Survey Map as altered Caradoc, with a linear mass of "greenstone" running about halfway along the crest from the N.E. end. This "greenstone" has no existence, the ridge being occupied by a compact greenish-grey claystone, which also makes up the chief mass of the north-easterly half of the mountain. On the S.E. slope, midway between each end, are beds of thinly laminated greenish fine-grained slate, very similar to ordinary Longmynd slate, and displaying the normal dip (W.N.W.) of that formation. This coincidence of dip is apparently due to a local protrusion of a highly altered greenstone which breaks out of the side of the hill at this point. The slaty beds are overlain by compact reddish felstone. At a little distance to the W., similar slate is interstratified with a coarse felspathic grit with a few grains of quartz. Towards the south-west end the grit appears with an E. and W. strike, associated with a grey compact claystone (Note 7, p. 668). Alternations of slaty and brecciated bands are seen. At the extreme S.W. end is a fine-grained grey claystone in thin beds dipping at a high angle to the N.N.E. A little to the west of this spot is a knob of dolerite, containing much free calcite, and breaking to the surface at about the line of fault between the Cambrian and Precambrian rocks. This protrusion appears to have produced the deviation in the strike of the claystone from the normal E. and W. direction.

Caradoc rocks bound the S.E. side with a faulted junction; they also lap round the S.W. end, where they dip to the S. They are underlain by a coarse conglomerate with a S.W. dip. This rock is chiefly made up of pebbles of quartz, and contains flakes of silvery mica, apparently due to subsequent alteration.

In the N.W. side of the hill, the fault brings down Longmynd strata against the Precambrian axis. The slates which rest against Hazler Hill are continued for about one third of the length of the Ragleth, when they suddenly give place to the purplish felspathic sandstones which lie in force to the S.W. The relations of these subdivisions of the Longmynd series are not yet fully known, and do not concern our present purpose.

Summary.—A S.W. ridge composed of claystones and felspathic grits; a W.N.W. dip, due to a greenstone protrusion on the S.E. side, and a N.N.E. dip at the S.W. end, with another greenstone mass a short distance to the W.; Caradoc rocks faulted against the S.E. side and lapping round the S.W. end; Longmynd slates and sandstones faulted down on the W.N.W.

15. *Wartle-Knoll Group.*

East of the farm named Carwood is a small conical knob composed of brownish felstone full of closely approximated joints (Note 8, p. 668). Wartle Knoll, a loftier elevation, is chiefly made up, especially in the centre, of a breccia of quartz and felsitic fragments. Felspathic rocks of an obscure character are found on the slopes. The Carwood mass is coloured as Caradoc by the Survey. Its position on the S.W. axis, together with its resemblance to some of the Precambrian volcanic series, renders its Precambrian age almost certain. Wartle Knoll rises up through Longmynd strata, and is coloured as such on the Map; but on the whole it resembles Precambrian rather than Cambrian rock.

The Precambrian axis is evidently continued under the purple Longmynd sandstones of Hopesay Common, and underlies an anticlinal of Caradoc rocks at Corston, two miles S.W. of Wartle Knoll.

16. *Kington Group.*

Hanter Hill is composed of gabbro on the E. side and dolerite at the summit. On its N.E. slope is a small exposure of a grey granitoid rock (Note 9, p. 668).

Stanner Rock contains similar dolerite and gabbro. In about the centre of the ridge is a grey compact felstone. At the N.E. end is a dark grey grit with obscure E. and W. bedding, and near it to the S. is a quartzose breccia. In the same locality is seen a greyish granitoid rock, similar to the specimen at Hanter Hill. The structure of this ridge suggests that of the Lawley.

I refer this group with hesitation to the Precambrian period. The rocks are brought up on the same axis of upheaval, but the lithological resemblances are not at present very decisive. The greenstones are, of course, eruptive and posterior.

C. Evidence for Precambrian Age.

1. *Stratigraphical.*

It will be sufficient to collect a few of the facts detailed in the previous sections.

On the S.E. side of the Wrekin the proof is very clear. The axial rocks, striking W.S.W., are overlain by quartzites striking to the S.W. The quartzites are succeeded by the Hollybush Sandstone, and the Hollybush Sandstone by the Shineton Shales (Tremadoc). The Hollybush must thus be of, at least, Upper Cambrian age; the quartzites must be of, at least, Lower Cambrian age (they are probably Precambrian), and the volcanic series must be Precambrian. The discordance between the axial and the flanking rocks will be still more evident when the dips are compared. The volcanic series dips N.N.W., while the quartzites dip S.E. A greater unconformity could hardly be imagined. These relations are expressed in figs. 2, 3, and 5.

In Caer Caradoc the sections are still more satisfactory. Undoubted Lower Cambrian rocks, the Longmynd series, are brought down against the N.W. side of the axis, the discordance of strike between the two formations approaching a right angle, the Precambrian beds dipping northerly, the Longmynd slates westerly (see fig. 7). These Lower Cambrian rocks probably hold the same relation to the axis on its N.W. side as far to the N.E. as Wrockwardine, or even to Lilleshall, being masked by a thin covering of Carboniferous strata at the N.W. base of the Lawley, and by Triassic deposits in the Wellington district.

The Wrekin and Caer Caradoc chain is the axis of a great anticlinal. The formations dip away on both sides, and their dip is determined by the upheaval of the Precambrian nucleus. But the axial rocks themselves do not share in the anticlinal arrangement, being wedges of stratified rock thrust up, after consolidation, between parallel faults. This peculiar method of mountain formation is paralleled in the Malvern chain and in the Dimetians of St. Davids. I have elsewhere * described this structure as "plagioclinal."

2. *From included fragments.*

In the middle of the Longmynd series of Haughmond Hill, near Shrewsbury, is a great bed of conglomerate †, coloured "greenstone" on the Survey Map. It commences a hundred yards or so E. of the Castle, and runs in an unbroken line for more than a mile to the N.N.E. Its superior hardness gives it in some places a somewhat mural appearance. It is made up of rounded pebbles cemented in an ashy-looking matrix. Amongst the pebbles I recognize a grey

* Geol. Mag., May 1879.

† I have already used this argument in the 'Popular Science Review,' January 1879.

hornstone, like one of the Lilleshall rocks, and a chocolate felstone with a few scattered prisms of felspar, very similar to some of the Wrockwardine types. This conglomerate shades off gradually, both above and below, into the ordinary Longmynd sandstones. There is little doubt that this band has been derived from the series described.

I have already mentioned that on the N.W. flank of the Ragleth and further to the S.W., the Longmynd series is represented by a felspathic sandstone. This rock is chiefly made up of quartz and a red felspar, and it is highly probable that it has been produced by the degradation of the granitoid series.

In my paper "On the Quartzites of Shropshire" (Q. J. G. S. xxxiv. p. 760), I state that "towards its base the quartz-rock contains fragments derived from the older series, consisting of small rounded or unrounded pieces of felstone greatly decomposed, but in some cases showing distinctly the banded structure characteristic of some of the Wrekin felstones." As the quartzite is of (at least) Lower Cambrian age, the felstone must be Precambrian. Professor Bonney has examined some of these specimens, and he quite confirms my previous opinion (Note D, p. 666).

General Summary.

1. The axial chain of hills in South Shropshire must be removed from the category of intrusive greenstones, and regarded as built up of bedded rocks broken through by later basic eruptions.

2. The chain is flanked by various formations from the Lower Cambrian to the Trias. Some of the flanking deposits, which are of (at least) Lower Cambrian age, are partially or wholly derived from the axial rocks. By the double test of stratigraphical position and included fragments the bedded part of the chain is thus shown to be of Precambrian age.

3. The lithology of the chain is very varied. (1) Metamorphic rocks of Malvernian (the author) or Dimetian (Professor Bonney) type. (2) Volcanic (Mr. Allport, Professor Bonney, and the author). (3) Sedimentary, as conglomerate, grit, claystone, and shale.

4. The separate masses composing the chain are wedges of the solidified crust thrust up through younger deposits between great parallel S.W. faults. The structure of the ridges is plagioclinal (the strikes being across the axis), and their direction is determined by the faults.

Notes on the Microscopic Structure *of some* Shropshire Rocks.

By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

At Ercal Hill, to the north of the Rhyolites of the Wrekin, so admirably described by Mr. S. Allport*, is a mass of reddish granitoid

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 449, &c.

rock. Microscopic examination of a slide of this caused me to suspect that it was not a true granite, even before the investigation of Dr. Callaway's specimens and our joint visits to the locality. Besides the granitoid rock, there is seen, in the lower portion of a large pit, a compact greyish rock; both these have here been very fully examined with the following results:—

(A) *Compact type.*—Five specimens in all have been examined, three from different parts of the greyish mass forming the lower portion of the pit, two from its upper left-hand corner, where the rock has a redder colour and a very fragmental aspect. As regards the first three, under the microscope they possess in common far more resemblance to the rhyolites described by Mr. S. Allport than one would suspect from their macroscopic aspect *. All, seen by transmitted light, have a more or less glassy aspect, and with crossing Nicols exhibit the usual devitrified structure. For the details of this I content myself with referring to Mr. Allport's descriptions, and will merely call attention to the structural variations in each specimen.

(1) A compact buff-grey rock from the base of the quarry ("fairly typical, very jointy"—C. C.). This exhibits a great number of somewhat faintly defined crystallites of a rather curved or wavy form, such as are figured by Zirkel in the S.E. corner of figure 4, plate viii. "Microscopical Petrography" (U.S. Geol. Explor. of Fortieth Parallel), which give slight indications of a fluidal arrangement: and there are numerous minute filmy brown patches of what may be an iron mica, both isolated and in clusters, associated with a fibrous mineral showing with crossed Nicols a bright golden colour; minute fibres of the same are disseminated over the slide. The white specks visible in the rock are probably decomposed felspar; the only one, however, on the slide shows spherulitic structure towards the exterior, and may be simply a fragment of glass. There are one or two included fragment-like bits containing much opacite †.

(2) A dull green rock, marbled or spotted with pinkish buff, from the upper part of the mass. General character fairly similar to last, except that in parts a fluidal structure is more conspicuous, and there are abrupt changes in the microlithic structure, with comparatively sharp lines of division, as is common in glassy rocks; cracks traverse the slide, filled now with microlithic minerals, chiefly quartz; some of the spots, as in the last, are probably fragments in a slightly different condition.

(3) A marbled dull greenish and pale-red rock, also from the upper part of the grey mass ("taken from a place where there is a marked concentric spheroidal jointing"—C. C.).

Parts of this slide exhibit a beautiful perlitic structure; other

* The marked difference in colour is due to the fact that the normal Wrekin rocks are full of desseminated opacite and rich red ferrite, while in these from the Ercal the corresponding mineral is a pale-brown ferrite.

† This pseudo-clastic character, the result, doubtless, of motion after partial consolidation, is not uncommon in glassy rocks. Mr. Allport has given me a most interesting example of it from the other part of the Wrekin.

parts groups of spherulites, with radial structure, some being about ·03 inch in diameter.

To avoid repetition it is enough to refer to Mr. Allport's descriptions and plate (*loc. cit.* pl. xx.)*.

(4) and (5) are taken from the upper part of the pit on the left-hand side. They are much redder in colour than the others, are more like the granitoid rock, and have a very fragmental aspect. A glance, however, at the slides under the microscope shows that they exhibit the usual aspect of a devitrified glass, with a rather brecciated structure, of the character already described, both specimens showing indications of fluidal structure. In the one this is very clear; in the other, more or less perfectly developed spherulitic structure in frequent. After a careful study of these various slides, and comparison of them with my collection from other parts of this district, I have no hesitation in asserting that the compact rock of this pit is only the Wrekin rhyolite somewhat altered by various subsequent chemical changes, and that it must be regarded as intrusive in the granitoid rock.

(B) *Granitoid type.*—Of this I have had five slides prepared from specimens taken from various parts, from the lowest to the highest exposures. All may be described as consisting mainly of quartz and felspar, with a little iron peroxide (species uncertain) and a very small quantity of chlorite (?). The quartz contains many very minute enclosures; the felspar is rather decomposed, and stained with ferrite; orthoclase and plagioclase (? oligoclase) are both common; and there is much cross-hatching and interbanding visible. Some grains rather resemble microcline. Indications of graphic structure, especially on a minute scale, are not rare. As regards the specimens from the middle part of the mass, I cannot venture to express a positive opinion; they are very like a variety of granite, and yet there is a something, impossible to express in words, which reminds me rather of the granitoidites of the "Dimetian" series in Wales than of true granitic rocks. The specimens, however, from the bottom part of the mass (as may even be seen by the unaided eye) are certainly clastic. Rather rounded fragments, consisting of quartz and felspar, often exhibiting a minute graphic structure, are imbedded in a matrix containing smaller fragments of quartz, often distinctly angular, and of felspar; the matrix also appears to be composed of these two minerals, in an extremely fine state of division, but often showing an approach to graphic structure. One of two explanations is alone possible: either the granitoid rock has been crushed *in situ* (owing probably to the intrusion of the rhyolite); or we have here a quartz-felspar grit, which, though highly metamorphosed (the more finely divided constituents having crystallized *in situ*), still retains traces of its original structure.

After the best consideration which I can give to the question, I

* I believe this is the first time that perlitic structure has been noted at the Wrekin. Mr. Allport's specimens were all from Lea Rock, where spherulitic structure also is much more common. I have since found specimens in this Ercal pit showing to the unaided eye very distinct spherulitic structure.

incline to the former view. But whether this rock be a granite or a granitoidite (and I believe it the latter), there can be no doubt that it is far older than the rhyolite, and thus we may regard it as, in general terms, a representative of the "Dimetian" series.

(C) A very similar rock occurs at Primrose Hill, just S. of the Wrekin. Two specimens collected by Dr. Callaway, labelled "summit" and "N.W. slope halfway up," in mineral constituents and general character so closely resemble the Ercal rock, that we need not hesitate to class them as belonging to the same series. The former, in structure, is similar to the specimens from the middle part of the Ercal granitoidite; the latter exhibits a clastic structure very distinctly in parts of the slide; so that here also we must suppose a most exceptional case of local crushing or admit a clastic origin.

Gneiss, Primrose Hill.—The slide was cut from a specimen whose banded structure showed even to the unaided eye that it was a gneiss. Microscopical examination proves it to be a most characteristic example: it consists of irregular quartz grains with the interstices often occupied by a granular mineral (of a dull yellowish colour with transmitted light, and rather brilliant tints with crossing Nicols), probably a secondary product and possibly epidote, with felspar, mica, and a greenish chloritic mineral. There is the usual tendency on the part of the different constituents to collect in bands. The rock is not very rich in felspar; some of this is very characteristic microcline. The mica is colourless with transmitted light, and shows very brilliant tints with the Nicols. The green mineral rather resembles chlorite than hornblende.

Gneiss, Primrose Hill.—The specimen was selected as an example of one of the less obviously gneissic varieties. Under the microscope, however, its structure is clearly that of a metamorphic rock. As might be expected from the darker aspect of the specimen, it is poorer in quartz than the last, and has much of a chloritic mineral, not, I think, hornblende, though perhaps replacing it, also some decomposed felspar and a good deal of the epidote-like mineral named above, probably replacing felspar.

Two other specimens from the N.W. side, near the top, are very different. One is a compact dull greenish rock of rather brecciated aspect, the other a cherty-looking rock of a brownish-buff tint. The former appears to consist of rather angular fragments of felspar, with some quartz of variable size, imbedded in an earthy-looking matrix, often dark with opacite, and with some chlorite—a rock of clastic origin, though considerably altered. The other is even more distinctly fragmental; the matrix is earthy-looking and not quite so dark as the other, occupying a larger part of the slide. The fragments, as before, are quartz and felspar; and many of them show a minute graphic or fibrous structure, as exhibited in the above-described specimens, suggesting these as the source whence their materials have been derived.

The specimen labelled "halfway up" is a very different rock. It is of igneous origin, rather finely crystalline, consisting of felspar and hornblende, both rather decomposed, with a little iron peroxide and chlorite. The felspar is mainly plagioclastic; but some crystals resemble orthoclase. It is possible that the hornblende may be of secondary origin; but the rock can now only be defined as a diorite. It is not unlike one of the "traps" from Malvern in my collection.

(D) *The Quartzites.*—The first specimen, from "near the cottage on the Wrekin," and thus from quite the lower part of the quartzite series, contains numerous rather angular fragments, some $\frac{1}{3}''$ long, of a material like decomposed pumice. Microscopic examination shows that the rock consists of well-rounded quartz-grains and fragments of varying size, some rounded, but most rather angular, of a rather decomposed rhyolitic rock, doubtless that of the Wrekin. One fragment still exhibits perlitic structure. There is but little cementing material, and this appears to be quartz. The quartz-grains are pretty full of very minute enclosures, and bear a strong resemblance to those of the granitoid rock described above.

There is a point of general interest in this rock worth noting, namely, that the quartz "cement," which is obviously of secondary formation, is often deposited so as to form one crystal with that in a grain (proved, of course, by their giving the same tint with crossing Nicols). The boundary of the grain, however, is clearly shown by the cessation of enclosures, from which this secondary quartz is remarkably free.

The second specimen is from "section S.E. of Charlton Hill." It consists of similar quartz in smaller grains, and finer fragments (often almost triturated and acting as cement) of a rock which appears to be rhyolite. The third specimen, "W. of Rushton, N.W. of Wrekin," is rather coarser than this; of the presence of the rhyolitic rock here, though in smaller grains than in the first, there can be no doubt: some of the quartz is very full of enclosures. Magnified about 70 diameters, they appear as dusky specks, about 200; some remain opaque, but most prove to be cavities of variable form, in the larger of which I sometimes detect very minute bubbles, but cannot distinguish any in the smaller. Some of the grains themselves exhibit a compound structure, as if derived from an older quartzite.

(1) *East Field, near Burcot.*—A glassy-looking rock, with wavy irregular lines of opacite and ferrite, indicating a fluidal structure, and occasional well-preserved felspar crystals, with rather broken edges. Both orthoclase and plagioclase can be recognized; with crossed Nicols a minute cryptocrystalline structure is visible, a considerable part of the slide being dark. The basis has once been glassy, and, so far as can be ascertained, a portion yet remains undevitrified. The rock appears to an old rhyolite of the Wrekin type.

(2) *Burcot, Wrockwardine.*—The microscopic structure of this rock comes rather near to that of no. 5, and it is not without hesitation that I place this among the sedimentary. The mineral composition, however, is, I expect, not very different. Parts of it with crossed Nicols show a very similar structure; but the aspect of this

is more distinctly fragmental, and the bands of ferrite and opacite, with which occasionally occur slightly larger fragments of felspar and quartz, give the rock, as in the hand specimen, the appearance of one banded by deposition rather than by flow. It might be formed of the finest dust of such volcanoes as produced the Wrekin rhyolites, or by the denudation of such rocks.

(3) *Charlton Hill.*—This rock consists of well-rounded fragments in a matrix which resembles a mixture of decomposed felspar and chlorite. Among the fragments I recognize the following varieties:—(*a*) a fragment of very typical granitoidite with characteristic quartz, finely banded plagioclase, and a mica (? paragonite); also one or two smaller fragments, possibly of the same rock; (*b*) a rock apparently consisting of decomposed felspar and chlorite, in general appearance rather like diabase, probably a schist; (*c*) a rather schistose fragmental rock, consisting of quartz, chlorite, and decomposed felspar; (*d*) a rock having a fine granular ground-mass, with some viridite pseudomorphs, some nests of quartz, with viridite and (?) epidote, origin doubtful, but probably clastic; (*e*) a quartzite; (*f*) a quartzose rock, consisting of long angular quartz fragments in a rather fibrous fine-grained matrix, containing probably a little of a chloritic mineral.

(4) *Caradoc.*—This rock is undoubtedly clastic, though at first sight it resembles, to the eye, a fine-grained granite. The fragments are more or less rounded and about equal in size; they compose the greater part of the rock, the interstices being occupied with a finely granular rather earthy-looking matrix. Quartz predominates among the fragments; it contains the dusky-looking enclosures, which show an approach to a linear arrangement rather characteristic of the older rocks both here and in Wales; there is a fair amount of felspar, much of it orthoclase, showing sometimes a cross-hatched structure (? a little microcline), and some plagioclase. Some of the felspar is very full of enclosures; we find also fragments of a brown glassy-looking rock, some of which show fluidal or spherulitic structure, and closely resemble the Wrekin rhyolite. There is a good deal of scattered ferrite and opacite, with microliths of chlorite, epidote, and apatite (?). The appearance of the slide induces me to believe that its material has been derived from the rhyolitic and granitoid Wrekin rocks.

(5) *Hope Bowdler.*—A base, apparently glassy, but rendered almost opaque by ferrite staining, and crowded with acicular felspar microliths. Several larger crystals of felspar are scattered about the slide, both plagioclase and orthoclase being, as usual, recognizable; they are very full of microlithic products, ferrite, minute enclosures of dark glass (?), &c., also a few grains of a greenish mineral, probably decomposed augite or hornblende. One crystal shows the characteristic cross section of the former; needles of apatite are sometimes associated with these. There are, as usual, larger grains of iron peroxide. The slide exhibits numerous darker patches with well-defined rounded outline; these seem to correspond in all respects with the rest of the slide, except that they are coloured by a black, instead of a brownish peroxide of iron.

(6) *Woodgate quarry.*—Rolled and subangular fragments of quartz, decomposed felspar, grit, and rhyolite or mudstone. There is also a large quantity of a streaky chloritic mineral, and many of the fragments appear to be stained with ferrite. Parts of the slide present some resemblance to organic structure, such as sponge-spicules; but, after repeated examination, I believe that they are rhyolitic fragments with crystallites of the form mentioned above (p. 663).

(7) *S.W. slope of Ragleth.*—This rock, which, macroscopically, appears to be a compact yellowish-grey mudstone with a few lighter spots, exhibits under the microscope a minute confusedly granular structure, being apparently composed of fine felspathic mud, stained with ferrite, in patches more or less irregular and containing a fair amount of opacite. Some rather acicular doubly refracting microliths may be of secondary origin, as are the felspathic (?) infiltrations of a crack. There is nothing characteristic about the rock, which might be of any age from Silurian downwards.

(8) *E. of Carwood*—This rock is a good deal decomposed; it appears to have undergone some brecciation *in situ*, and to have been recemented, quartz and epidote occurring in the cracks. It might be a decomposed rhyolite with a faintly marked flow-structure, or it might be an altered mudstone, the detritus of a rhyolite. I hesitatingly incline to the former identification.

(9) *N.E. of Hanter Hill.*—The specimen consists of quartz, felspar, a little of a chloritic mineral (probably replacing hornblende or biotite), and ferrite. The quartz is full of minute enclosures, which give it, in parts, a dirty aspect. These, on applying a high power, appear opaque, being probably earthy or ferruginous; others, however, are transparent,—whether cavities or microliths of some mineral I cannot with certainty determine; some show a very minute black speck, as if they were nearly full of a fluid. The felspar is much decomposed; probably it is chiefly orthoclase, but the characteristic banding of plagioclase is also visible. The rock is evidently of fragmental origin, one part of the slide showing many small grains and rather a different structure from the rest; but it has been a good deal altered, and in general aspect recalls specimens of the granitoid Dimetian rocks which I have examined.

West Field, Burcot.—A rhyolitic agglomerate, apparently wholly composed of volcanic material. Some of the larger fragments exhibit different varieties of fluidal structure, and one shows excellent perlitic structure.

Lilleshall.—Two specimens, collected by myself about two years since, have been examined; one (from the top crag on the S. flank of the ridge) is a rhyolitic agglomerate, like, but rather more decomposed than, those at the Wrekin described by Mr. Allport*. The other is a rhyolite (devitrified) with rather obscure indications of spherulitic structure. It occurs just S. of the monument, and is probably part of a small *coulée*; but its relations to the other rocks are not very clear.

As the result of the investigations above described, I should con-

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 458.

clude, from microscopic evidence alone, irrespective of that obtained in the field, that the granitoid series was much older than the other rocks, and that materials from it, together with fragments from the rhyolitic series, had been worked up into several of the later clastic rocks. It is remarkable that we find here in Salop, as in Caernavonshire, a metamorphic group and a felsitic group (with considerable similarity in each case) in apparent sequence, yet with marked difference in age. Some of the Primrose-Hill specimens also rather resemble certain other rocks recently described by Dr. Hicks, more especially from St. Davids *, and by him grouped with the Welsh quartz-felsites under the name Arvonian.

Discussion.

Dr. Hicks spoke of the extreme interest of the paper, and the confirmation it furnished of the views he had already expressed. He thought that probably at least three groups would be found in this region also. It was also interesting as showing that the granitoid series had a different strike to that overlying it.

Prof. Hughes wished to ask if the stratigraphical relations of the rhyolite and the granitoid rock had been observed in the field, or were only inferred from microscopic examination; and whether the discordant strike had been observed on the same side of the fault.

Prof. Bonney said the rhyolite was clearly intrusive in the granitoid series; and mentioned some points of interest connected with the microscopic examination of the rocks, which he had described in an appendix to Dr. Callaway's paper.

Dr. Callaway said that he had only been able at two or three places to see the granitoid and rhyolitic rocks in contact, and in all cases they seemed to be separated by faults; but there could be no doubt that the granitoid was the older. He had not at present been able to recognize more than two series.

* Quart. Journ. Geol. Soc. vol. xxxv. p. 285.

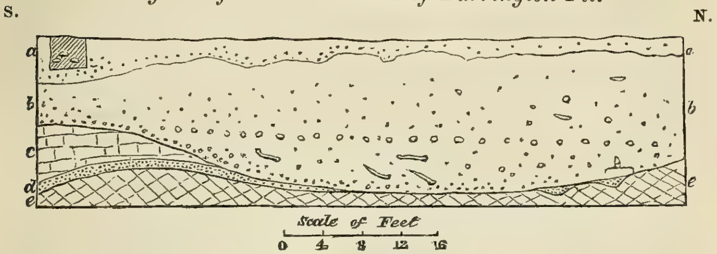
49. *On a* Mammaliferous Deposit *at* Barrington, *near* Cambridge. By Rev. O. Fisher, M.A., F.G.S. (Read June 11, 1879.)

During the latter part of the summer of 1878 I heard from Mr. Griffith, of Christ's College, Cambridge, that large bones were being met with in a "coprolite-pit" at Barrington, on land belonging to Trinity College. Accompanying him there, we found the workmen had reserved for him fragments of three canines of a Hippopotamus, with some of the molars, a tooth of Rhinoceros, and other specimens. Further discoveries were made; and in September, when the work had been discontinued for harvest, I went there with two friends, and, armed with no tool better than a knife, obtained an excellent specimen of an incisor of the Hippopotamus. Upon this I advised Mr. Keeping, of the Woodwardian Museum, to get permission to commence a regular search for fossils, which, term not having commenced, and the Professor being in the country, he took upon himself the responsibility of doing, and through the kindness of Messrs. Smith and Badcock, the lessees of the coprolite-works, began a systematic exploration of the deposit. This was carried on after the Professor's return under his authority, and has been rewarded with great success.

The locality is easily recognized upon the Ordnance Map as being just south of where the final *n* in the word Barrington is printed. It is on the edge of a nearly level tract of ground at the foot of the hill between Haslingfield and Barrington, at an elevation of about 20 feet above the alluvial ground of the present stream of the Rhee. This tract of ground does not, however, form quite a flat terrace, but falls again very gradually northward towards the small streamlet, which, lower down, is crossed by the road near the church. The streamlet is not marked in the Ordnance Map, which wrongly represents the slope of the hill as extending to the lane which leads to the pit. The pit is nearly on the highest part of this tract; and consequently the bone-bearing deposit does not belong to the existing drainage-system, but, though at only a small altitude, may be still considered a high-level gravel.

The exposed section at present extends from north to south about 70 yards. The "coprolites" have been obtained in the deepest part at 22 feet. The section presents a superficial covering of soil and fine gravelly "trail," which, in the southern half, rests immediately on disintegrated chalk-marl; but towards the centre of the pit a thin bed of coarse gravelly silt with large pebbles comes in (see fig., p. 671), dipping slightly towards the north, and when it has descended to about 8 feet from the surface it rather suddenly expands downwards, forming a mass of grey gravelly silt, with many large stones towards the bottom, some of which may weigh from twelve to sixteen pounds. Above the stony bed the material is without large pebbles, otherwise of a similar character. Throughout these silty gravels bones and shells occur. Mr. Keeping carried his work a few feet further north beyond where the "coprolite-bed" runs out, and the base of the silt has there begun to rise.

Diagram of the northern end of Barrington Pit.



a. Trail of fine gravel in which are pits with ashes and bones.
b. Grey gravelly silt with bones and shells. *c.* Chalk-marl.
d. Greensand with "coprolites" (*i. e.* phosphatic nodules).
e. Gault.

There is another smaller coprolite-pit, not yet quite filled up, lying a few yards to the south-west of the present one. It exhibits a little similar stony and gravelly silt, but in patches only, and not *in situ* as deposited, but forming pockets of "trail" with festoon-like arrangement and the axes of the pebbles not horizontal. Those remnants still existing in the "trail" in this southern pit, as well as the manner in which the deposit occurs in the first pit, show that the gravel is a portion of a more extended mass, of which the upper parts have been denuded away.

[Since this paper was read a similar deposit, equally rich in bones, was laid open for a short time half a mile further up the valley, opposite to the blacksmith's shop on the Green.]

The materials of which the bone-bearing deposit consists are peculiar. The matrix is a grey sand with a slight admixture of clay. The pebbles consist of flint in subangular pieces of no great size, sometimes ochreous, sometimes grey, sometimes black. These are not rounded, but have their surfaces worn, polished, and the angles rubbed off. There are rolled lumps of chalk-marl and a considerable admixture of "coprolites," as might be expected, seeing that the coprolite-bed is abraded by the deposit itself. The remaining pebbles are well-rounded pieces of crystalline rocks, consisting of quartz, quartzite, syenite, jasper, and trap. These old rocks contribute a large part of the pebbles, so that the material cannot be called a flint-gravel, in that it appears to consist of the least destructible parts of the Boulder-clay, mixed with materials from the Chalk-Marl and Greensand.

There are splinters of bone worn smooth at their fractured edges; but most of the bones and teeth are scarcely abraded at all, though not often associated. There seems, however, to be reason to think that portions of the same individuals have also occurred in proximity, although mixed up with fragments of others. Thus one might find, one after another, bones of a *Bos*, but among them a tooth of *Hyæna* or tusk of *Hippopotamus*. In some instances it is clear that the ligaments had not decayed when the limbs subsided. Thus my son exhumed an entire set of associated bones of a hind limb of *Bos primigenius*.

What we have here, then, appears to have been a deposit in a deep hole of a stream, where it swept round against the south side of the hill. This stream was probably no other than the present one called the Rhee, and drained the same district then as now. This district is occupied by the Lower Chalk, the Gault, and the Boulder-clay; it contains none of the Upper Chalk within its area, nor any observed beds of flint-gravel. Accordingly we find the materials of the deposit to be such only as those rocks would supply, consisting as it does almost entirely of the débris of the Boulder-clay. That it is newer than the Boulder-clay is also shown by its lying beneath a hill which is capped by a thin tabular bed of that clay. There appear to be very few remnants of the Oolitic rocks among the pebbles, except a few fragments of *Gryphæa*. The pebbles are, for the most part, not at all decomposed, as those are which one now picks up in the neighbouring ploughed fields, and the glacial scratches are well preserved. This would lead to the inference that the river flowed between rather deep banks of Boulder-clay, abrading much at a depth beyond the reach of atmospheric influences.

Some peculiar circumstances must have caused so considerable an accumulation of bones. Probably the carcasses, inflated with the gases of decomposition, were detained here and there in the stream by quiet eddies, such as usually occupy deep holes in the elbows of a stream when the water is not in flood. The prevalent south-westerly winds would also assist in detaining any floating body in such situations*.

Taking departure from the pit, and crossing the valley from north to south, towards Foxton railway-station, the levels give:—

	yards
From mammalian deposit to hedge, level	77
From hedge to northern branch of stream, descent of 20 feet	100
From northern branch of stream to middle do., level	120
From middle stream to southern do., level	134
From southern do. to a point about halfway between the angle of the road and Foxton station, rise of 20 feet	220
	651

At this point we are again upon the level of the mammalian deposit. There are at the present time two sections open in this interval where coprolites have been dug. One is in the level alluvial ground just south of the middle stream. Here a low-level fine river-

* There is a remarkable deposit of bones beneath the row of houses called "The Terrace" at Walton-on-the-Naze, in Essex. At this place the sea is encroaching on what was probably the eastern corner of a sheet of water occupying the same general position that "Walton Creek" now holds. The writer's opinion is, that the accumulation of carcasses at this place was caused by the south-west winds blowing nearly every thing that floated on the southern portion of this sheet of water to this particular part of its shore.

gravel is seen, well washed, with many small bean-shaped calcareous pebbles wholly soluble in acid. No shells were seen in it. The other section is given by a coprolite-pit in work, north of the corner of the road, not quite on so high a level as the Barrington pit, where there are shallow pocket-like patches of a fine flint-gravel; but they have not the appearance of a river-gravel, but rather of a trail or denudation gravel. Towards the station, however, the surface of the ploughed ground gives indications of a subsoil of flinty gravel, and there have been extensive pits of flint-gravel on the north side of the railway between Foxton and Shepreth stations. These pits are not far from on a level with the Barrington deposit, certainly not lower. We find, then, that the terrace-gravel of the same, or nearly the same, level on the south side of the alluvium of the present rivercourse consists of quite different materials from that under consideration on the north. The cause may probably be that the former occupy a line of drainage from the south, as may be seen by a small stream crossed by the railway between Foxton and Shepreth, in which direction lies the chalk escarpment, with its beds of flint and of capping flint-gravels. Whether these Foxton gravel-beds are of the same age as the Barrington deposit is a point on which I have no other evidence to offer; but the circumstance referred to may seem to remove any difficulty arising from their different composition. I have from these Foxton gravels what I believe to be a portion of a flint implement of the rudest type, similar to one which I have from Brandon Hill, given me by Dr. J. Evans, and to a portion of another which I found myself in a railway-cutting at Broomhill, near Brandon.

The shells which have been found at Barrington do not render much assistance towards fixing the age of the deposit. Though abundant enough, the species are few, and the number of strictly aquatic shells remarkably limited. By far the most abundant kind is *Helix fasciolata* (or *caperata*); *Helix virgata* is also common; *Helix nemoralis* also occurs, but is rare. The aquatic species are *Succinea* (?) *oblonga*, *Limnæa palustris* (one specimen), and *Pisidium amnicum*. This is a meagre list. No specimens or fragments of *Unio* or *Cyrena* have been met with.

The Mammalia hitherto discovered at Barrington are:—

1. Homo, probably (by a worked flint).
2. Ursus spelæus.
3. Meles taxus.
4. Hyæna spelæa.
5. Felis spelæa.
6. Cervus megaceros.
7. —— elaphus.
8. Cervus (? species).
9. Bos primigenius.
10. Bison priscus.
11. Hippopotamus major.
12. Rhinoceros leptorhinus.
13. Elephas antiquus.
14. Elephas primigenius.

CATALOGUE OF REMAINS OF ABOVE.

(2.) 1 canine, 1 portion of humerus, 1 metatarsus.
(3.) 1 ulna.
(4.) 1 skull and part of mandible, 1 detached tooth, 1 vertebra, 1 scapula, 1 rib, 2 metatarsals.
(5.) 1 portion of radius.

(6.) 6 portions of antlers, 1 fragment of mandible.
(7.) 1 brow-antler, 1 base and burr, 1 tibia.
(8.) 1 astragalus and broken end of tibia, probably of a young animal. It is larger than Roebuck, but much smaller than Red Deer.
(9.) 1 fragment of skull, which fell to pieces, 1 horn-core preserved (3 feet long on the outer curve, and 1 foot 5 inches round the base), 33 vertebræ, 1 fragment of pelvis, 1 fragment of femur, 10 tibiæ, 9 calcanea, 10 astragali, 1 complete hind limb, 5 metatarsals, 4 portions of scapulæ, 9 fragmentary or complete humeri, 1 radius and ulna attached, 10 portions of radii, 4 ulnæ (olecranon portions), 9 metacarpals (belonging to two or three species of *Bos*), 26 detached bones of feet.
(10.) 4 horn-cores. (Probably some of the bones in the last list may belong to *Bison.*)
(11.) At least two individuals; one probably entire. 1 skull (fragments of), 4 pieces of jaws, 15 molars and a few fragments, 10 canines (or pieces of), 9 incisors (or pieces of), 24 vertebræ, several caudal belonging to a series, 2 pelves (portions of), 2 kneecaps, 4 femora (portions of), 2 tibiæ, 2 calcanea, 1 astragalus, 4 humeri (or portions of), 2 radius and ulna, 8 detached bones of feet.
(12.) Probably five individuals. 19 molar teeth and some fragments, 1 back of skull, 3 vertebræ, 1 fragment of femur, 1 kneecap, 1 tibia, 6 portions of humerus, 5 radii, 3 ulnæ, 13 detached bones of feet.
(13.) 4 molars of two individuals.
(14.) 1 portion of a molar was found, which the author saw, and believed to have belonged to *E. primigenius.* It fell to pieces.

There are likewise a few bones of birds hitherto undetermined. There is no river-deposit mentioned in Prof. Dawkins's paper on British Postglacial mammals*, which is credited with so large a number of species, except Fisherton, where the number is likewise fourteen. The assemblage, however, is not the same.

The specimens have been compared at the University Museum of Comparative Anatomy, and determined by Mr. Tawney, who has labelled and catalogued the whole of them. There is a fine skull of *Hyæna*, which would have been perfect had it not been broken off by the pickaxe just behind the canines; it belonged to an adult, but not aged, individual. A magnificent pair of horn-cores of the *Bos primigenius* were found, with the forehead attached; but unfortunately the horn-cores were so decayed and permeated with mud that only one of them could be saved. The most remarkable fact observed was the abundance of the bones and teeth of the *Hippopotamus*, also abundant at the "Green." Some very fine specimens of the tusks have been, with much labour, built up out of the very numerous fragments into which they fell when removed. Four teeth of *Elephas antiquus* had been previously obtained in another pit in the same field, at a short distance up the course of the old stream, and were presented to the Museum by Mr. F. W. Smith. Mr. Griffith also gave his specimens. I saw only one tooth of Elephant in our working; it was so decayed that it could not be brought home. I believe it belonged to *E. primigenius.* Had I known at the time that the other specimens belonged to *E. antiquus* I should have examined it more closely.

Only one worked flint was found. It is of an oval form, extremely small, being about an inch and a half long by an inch wide. It is

* Quart. Journ. Geol. Soc. vol. xxv. p. 192.

thick for its size. Mr. Keeping picked it up out of the débris, but did not notice having dug it out. I have myself little doubt about its belonging to the deposit. It is of a blackish hue, polished, with white porcellanous mottling, and has specks of botryoidal limestone adhering to it; all which characters mark many of the flint fragments in the silt.

The area excavated for the large collection was about 14 yards from north to south, by about 6 yards from east to west.

If we compare the above list of Mammalia with that given by Mr. Jukes-Browne* for Barnwell, we find the following species common to Barrington and Barnwell:—

Homo (by Mr. Griffith's "hache")†.	Hippopotamus major.
Ursus spelæus.	Rhinoceros leptorhinus ‡.
Felis spelæa.	Elephas antiquus.
Cervus megaceros.	—— primigenius (?).
Bos primigenius.	

At Barnwell, but absent from Barrington, *Equus fossilis.*

It is observable that a small undetermined *Cervus* is mentioned also at Barnwell.

It will be seen, then, that the Mammalia belong to the same group at these two localities. We have, however, at Barrington neither of the distinctive shells *Cyrena fluminalis* and *Unio litoralis.* The absence of either, or both, of these might be accidental; for it is only in places, even at Barnwell, that they are found; but I think the greater distance from the sea would be sufficient to account for the absence of the *Cyrena.* On the evidence I am disposed to correlate this deposit with that of Barnwell.

Let us compare the conclusions which have been drawn from an examination of this deposit with those arrived at by Mr. A. J. Jukes-Browne respecting the age of the valley of the Rhee, which he thinks of a later age than any of the other tributary valleys of the Cam. If I understand him rightly, he considers the gravel at Barnwell, which is about seven miles below Barrington, to be the oldest "terrace"-gravel in the district; for he does not apply that term to the still older "Observatory" gravel. And he thinks it "possible" (p. 68) that the gravels about Foulmire and Foxton were deposited about the same time as those about Barnwell and Trumpington; but he says that, "on the whole, it seems likely that they belong to a somewhat later period."

As to the age of the Foxton and Foulmire gravels, if the two are to be regarded as contemporary (upon which point I have no opinion to offer), the argument from equality of level is rather in favour of the Foxton gravel being of the same age as that of Barrington. But the deposit at Barrington is, in my opinion, due to the ancient Rhee, and it contains a mammalian fauna similar to that of Barnwell, certainly an ancient one; and consequently the Rhee must still occupy a very ancient line of drainage. The absence from it of

* 'The Post-tertiary Deposits of Cambridgeshire,' 1876, p. 64.

† Geol. Mag. dec. ii. vol. v. p. 400; figured in Camb. Ant. Soc. vol. iv. p. 177, pl. A.

‡ The Barnwell specimens in the Museum properly belong to this species.

decided flint gravels, which are so conspicuous in the other tributary valleys, may be probably accounted for, as I have said, by the paucity of materials out of which such gravels could be formed; so that I doubt whether, from that circumstance, any conclusion can be drawn that this valley is more modern than the others.

The measurements referred to in the table of levels show three different levels, of which records still remain, at which the Rhee has run. Starting from the present stream, we find the next older level to have been lower than the present one; it is marked by the lowest-level fine river-gravel in a pit sunk through the present alluvium. The deposit next older than that is the mammalian gravel of Barrington. There may have been deposits of intermediate age, of which no records are left, unless the flint gravel of Foxton be such an intermediate gravel.

If we go lower down the river to Cambridge we find three gravel-levels; the highest and oldest the Barnwell gravel, the next lower the Chesterton gravel, the next the gravel beneath Jesus College and Midsummer Common, which I recollect being formerly largely extracted. These are all noted in Mr. Griffith's section*.

Now I think there can be no doubt that a considerable spread of gravel marks a *stationary* level, or pause in the eroding action of a river in deepening its channel. Gravel is deposited when the river is occupied in meandering from side to side of the valley; and whenever an elbow of the stream reaches the side of the valley, it undermines it and widens the valley at that point. But when the valley is in process of being deepened, the river confines itself more closely to its course, and any gravels which it may then deposit are rearranged during the next stationary period. To what, then, are these stationary periods due, if such there be? It seems that they must be due to alterations in the relative level of sea and land. This is clearly put by Prof. Powell in his Report on the Exploration of the Colorado River, p. 203†. He says, "we may consider the level of the sea to be a grand base-level, below which dry lands cannot be eroded; but we may also have for local and temporary purposes other base levels of erosion, which are the levels of the beds of the principal streams which carry away the products of erosion."

I would inquire, then, can we find any records of marine base-levels corresponding to these river-terraces? It is obvious from the silting up of our estuaries, such as the Fens, and the clean gravels to be found below the bottoms of our present streams, that the present sea-level is not so low as it was at a not very distant period. Now we have an indication of such a former lower level of the sea in the submarine forests. Thus we may account for the low gravels beneath our present alluvium.

The high-level gravels, on the other hand, simply intimate that the fall of the stream at the place where they were deposited was not, at the time, *too* great, and not *so* great as it became afterwards, when they were cut through. The former condition may have been

* *Loc. cit.*

† Published at Washington, 1875.

fulfilled in two ways—(1) the coast may have been more distant at the time when the stream ran at its higher level; (2) the sea may have stood at a higher level upon the present, or nearly the present, coast. Of the two it is most probable that the condition which allowed of the deposition of the terrace-gravels was the former, under which a lesser gradient may have coexisted with even higher land; for it is generally believed that this island then formed part of the continent of Europe; and the Pleistocene mammalian remains constantly dredged off our east coast point in the same direction.

But not only must the sea-coast have been further off, but the land must have been also higher, not merely less denuded down, but physically lifted up in relation to the sea-level; or, what amounts to the same thing, the sea must have been lower. Otherwise we cannot account for deposits on the sea-level, and even below high-water mark, such as occur at Clacton and at Walton-on-the-Naze, and on the dredging-grounds in Essex—the former being, according to Prof. Dawkins, one of "the first terms of the Postglacial series," the latter having nothing to separate it from a somewhat early postglacial deposit.

If this supposition is correct it will rather militate against the opinion of Prof. Seeley, which is referred to by Mr. Jukes-Browne, that the marine gravel of March is of the age of the Barnwell gravels. The coast at the time the latter were deposited ought to have been more distant than March is.

As regards the climate at the period of the Barrington deposit, the occurrence of *Elephas antiquus* and *Hippopotamus* point to a somewhat warm climate. The Elephants and Rhinoceros being the same as at Lexden, in Essex, and the gravel terrace of about the same altitude, it is likely the gravels are of the same age. At that place the remains of beetles, which are abundant, have been attributed by Mr. Wollaston to a warm climate*, probably Mediterranean. The *Unio* and *Cyrena* of Barnwell have a like significance; and *Helix nemoralis* is impatient of great cold.

We learn, then, that there was an interval since the Glacial period (for there is no question that both Barrington and Lexden deposits are Postglacial) when the climate of this island was somewhat warmer than it is at present. There are indications in the disappearance of *Elephas antiquus* and *Rhinoceros leptorhinus*, as well as of *Cyrena fluminalis* and *Unio litoralis*, that it became afterwards colder, and probably colder than it is now; and my own belief is that a still colder period supervened, which is evidenced by the mechanical accumulation of that drift covering which I have denominated "trail"†.

* Quart. Journ. Geol. Soc. vol. xix. p. 400.

† *Ibid.* vol. xxii. p. 554.

(For the Discussion on this paper, see p. 734.)

50. *On some* Superficial Deposits *in the* Neighbourhood *of* Evesham. By the Rev. A. H. Winnington Ingram, M.A., F.G.S. (Read June 25, 1879.)

Subsequently to the late Mr. T. G. B. Lloyd's paper on the superficial deposits of the Vale of Evesham being written, the gravels of the lower series on Green Hill near Evesham have been extensively opened, and disclosed flints of about the weight of 10 lbs. These are so very perfect and unworn by water, presenting generally the same appearance as if they had just been taken from the matrix of the chalk, that floating ice seems to be the most probable agency which brought them to their present elevation, about 120 feet above the level of the Avon. An abundant deposit of flints of the same size and character occurs near Moreton-in-Marsh ; and a large block of chalk was discovered in the railway-cutting at Aston Magna. So it is reasonable to conclude that the flints of Green Hill, some of which present glacial marks, were conveyed by shore-ice down the vale of Moreton, through the depression in the Cotswolds forming at that time what might be called the Straits of Mickleton, to the position which they now occupy. A thin layer of fawn-coloured clay resting on a slight stratum of subangular pebbles, at the base of excavations for brick-earth at Bengeworth, well merits the attention of geologists ; it and the sand immediately above have yielded entire heads and horns of *Bos primigenius* and *Bison priscus*, antlers of *Cervus tarandus*, and many unwaterworn shank and other bones of large mammals. From the same clay a fine tusk of a *Hippopotamus* has come to light. Above this mammaliferous seam of clay rest 20 feet of sand and loam, containing numerous uninjured and unopened specimens of *Unio ovalis*. This formation is, at its surface, about 60 feet above the level, and half a mile from the present channel of the Avon, and appears to have been laid down in a tranquil backwater or reach in the stream which then flowed with a greater volume of water during the season when the deep snow was melting, or in some early pluvial period. On the opposite bank of the river, at Evesham, about a quarter of a mile from its modern course, occurs a formation of similar character and depth ; and the clay there has contributed, in a well sunk through the sand interspersed with river-shells, an antler of a Reindeer. The discovery of a tusk of the *Hippopotamus* points to the fluviatile origin of the clay ; and most likely the River-horse was a denizen of the great stream at the period when the carcasses of Reindeer floated down it on ice, which, stranded and melting, left their bones in the sediment to excite the speculation of geologists of our day.

51. *On a* Section *of* Boulder-clay *and* Gravels *near* Ballygalley Head, *and an* Inquiry *as to the proper* Classification *of the* Irish Drift. By T. Mellard Reade, Esq., C.E., F.G.S., F.R.I.B.A. (Read June 25, 1879.)

At a point in the road along the west coast of Ireland, between Larne and Cushendall and near Ballygalley Head, is a gravel-pit giving a section which may help to determine the classification of the Irish Drift.

The exposed face is, as nearly as I could judge, about 30 feet high, the pit being cut into a grass-covered slope lying against the hilly ground which mostly flanks the coast-road landward.

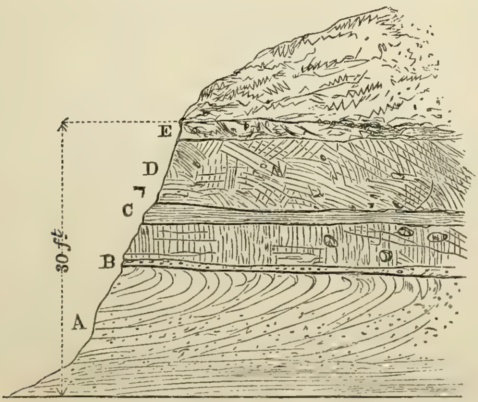
The following is a sketch which I took on the spot last autumn; and although I did not measure the thickness of the beds, it may be relied upon as giving their proportionate disposition.

The base of the excavation (A) is formed by a bed of current-bedded gravel containing shells and shell fragments. The actual base of the bed is not disclosed, so it is impossible to say how thick it is, or whether it rests on a Boulder-clay or on the natural rock.

It is capped by a perfectly straight and nearly level bed of sand, about 4 inches thick (B), on which rest irregularly disposed masses of clay and sand containing boulders, and above this a band of red clay, C, which is again overlain by a mass of unstratified Boulder-clay, D, the surface of which is covered by a bed of subaerial detritus, E, forming the subsoil of the grassy slope.

Coming fresh from Lancashire, where some geologists, following

Section in Gravel-pit near Ballygalley Head.



A. Current-bedded gravel with shells. B. Sand. C. Red Clay.
D. Unstratified Boulder-clay. E. Subaerial detritus.

Prof. Hull's lead, divide the Drift into three parts (viz. Lower Boulder-clay, Middle Drift or Interglacial Gravels, and Upper Boulder-clay), I was much struck by the section. If it had occurred in Lancashire there is no doubt it would at once have been set down as a very good example of the "Interglacial Gravels" and "Upper Boulder-clay."

I had not many minutes to examine the section, but I picked up during the time I was there a few of the shells and shell fragments. These I submitted to Mr. R. D. Darbishire, F.G.S., of Manchester, who has determined the following species:—*Astarte elliptica*, *A. compressa*, *Leda pernula*, *Mactra elliptica*, *Natica*, and *Mytilus*.

On comparing these with my list of shells from the Boulder-clay about Liverpool*, I find that during several years' close search *Astarte compressa* only occurred in great rarity in the numerous localities I examined; and according to Mr. Darbishire's list it is "very rare" at Blackpool. *Astarte elliptica* was frequent in some localities and rare in others. *Leda pernula*, supposed to be a typical arctic shell, was very rare in the localities where it was found.

There is thus, according to shell-evidence, nothing to give an "Interglacial" character to these gravels as compared with either the so-called Upper or Lower Boulder-clays of the north-west of England. My opinion has long been against this tripartite classification, and I have pointed out more than once that it rests upon no intelligible basis†. The examination of the Irish Drift still further confirms me in the opinion that the marine Boulder-clays of the north-west of England and Ireland are but phases of one long sequence of events uninterrupted by changes of climate.

Prof. Hull has applied the same classification of "Lower Boulder-clay," "Middle Sands and Gravels," and "Upper Boulder-clay" to the Drift of Ireland‡. It is quite evident, however, if the Boulder-clays of Galway Bay, as represented by the sections at Blake Hill, and the Fermoy valley in county Clare on the opposite coast, as well as the innumerable islands of Drift in Clew Bay, are members of the "Lower Boulder-clay," it is quite a different thing from the Lower Boulder-clay of Lancashire. The latter is marine, the former contains no evidences whatever of marine conditions.

On the north shores of Belfast Lough, beneath the celebrated raised beach, are to be seen sections of a Boulder-clay that corresponds in appearance with the marine Boulder-clays of the north-west of England. Large glaciated blocks of travelled stone, some of which I could have matched with erratics taken out of the Bootle Dock excavations, are to be seen on the beach washed out of the low cliffs of purple Boulder-clay, which is evidently, as in Cheshire and Lancashire, largely reconstructed from the Triassic Marls. I did not notice any shell-fragments in the Belfast Boulder-clay; but my time was limited, and in Lancashire it often requires close examination to detect them.

* Quart. Journ. Geol. Soc. vol. xxx. p. 27.

† See Geol. Mag. dec. 2, vol. iv. pp. 38, 39.

‡ Physical Geology and Geography of Ireland, pp. 79–95.

The Boulder-clay of Galway and Clew Bays is, on the contrary, made up almost wholly of triturated limestone,—so much so that it is even now a loosely consolidated limestone and stands in vertical cliffs. Imbedded in it are blocks of limestone and granite—one of the latter, at Galway, now on the beach, being from Moycullen and containing about 1600 cubic feet of stone. But neither here nor in Clew Bay, nor elsewhere in Ireland where the same kind of drift occurs, could I see on the contained stones those splendidly planed and grooved surfaces which distinguish most of the largest and smallest stones of the Lancashire Drift. The material and its imbedded stones are all distinctly local.

The explanation of these distinctions I propose to defer until I publish Part II. of the "Drift Beds of the North-west of England," having written this short description of the Irish Drift for record as well as to elicit, if possible, further information.

52. Further Observations *on the* Pre-Cambrian Rocks *of* Caernarvon. By Prof. T. McKenny Hughes, M.A., F.G.S. (Read May 14, 1879.)

[Plate XXXVI.]

On a former occasion (Quart. Journ. Geol. Soc. vol. xxxiv. p. 137) I offered a sketch of the Pre-Cambrian rocks which form the long ridge stretching from Bangor to Caernarvon. The classification I adopted was in descending order:—

i. *The Volcanic series,* consisting of volcanic fragmentary ejectamenta, agglomerates, ash-beds, and slates, occurring near Bangor, and referred to as *Bangor beds.*
ii. *The Felsitic series,* consisting chiefly of quartz felsites, and probably also of volcanic origin, occurring near Llanddeiniolen and Dinorwig, and now referred to as the *Dinorwig beds.*
iii. *The Granitoid series,* occurring near Caernarvon, and referred to as the *Caernarvon beds.*

Endeavouring to correlate these groups with the divisions proposed by Dr. Hicks, I considered that the lowest group included less than the Dimetian, from which I proposed to cut off every thing above the brecciated bed below Bryngarn, on the left of the valley running down from St. David's to Porthclais. The upper group I divided into two. I do not know how far Dr. Hicks, in the modified classification recently offered to the British Association (Report, 1878, Trans. Sect. p. 536), adopts the above threefold classification. I considered that there was no unconformity visible between the groups, whether we accepted the brackets drawn by Dr. Hicks or those which I proposed.

Since this paper was first sent in much additional information has been brought forward by Professor Bonney, Dr. Hicks, and Mr. Houghton, in communications made to the Society, Feb. 5, 1879. A threefold division was adopted; but the authors disagreed entirely with the views I had expressed of the structure of the districts as regarded dips, strikes, faults, and the sequence of rocks, and affirmed the existence of a visible unconformity between the groups *.

I shall now describe the rocks of the district in ascending order.

I. *The Caernarvon Beds* (= Dimetian in part).

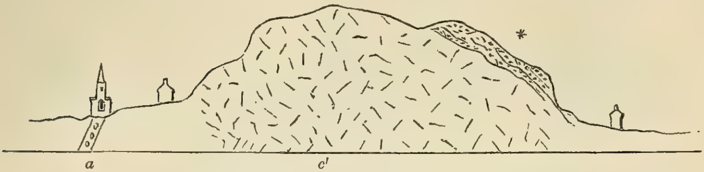
ii. Upper Caernarvon = Crug Beds.
i. Lower Caernarvon = Twt-Hill Beds.

I. i. *The Twt-Hill Beds.*

The coarse crystalline rock of Twt Hill is exposed over a small area on Twt Hill and in quarries along the north side of it. In a

* Having gone over the ground again with my friend Mr. Tawney, I am able to offer a fuller description of the district, and to bring forward much additional evidence on those points respecting which there has been a difference of opinion.

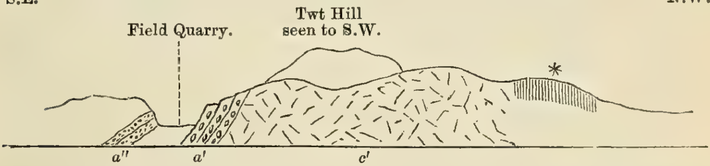
Fig. 1.—*Section of Twt Hill, Caernarvon.*



a. Cambrian Conglomerate. *c'*. Lower Caernarvon beds.
* Beds of quartzite and divisional planes suggestive of bedding.

quarry in the first field on the N.E. of the hill, which we shall refer to as the Twt-Hill Field quarry, it is seen flanked on the S.E. by sandstone, grit, and conglomerate (see figs. 1 & 2). It is thrown back

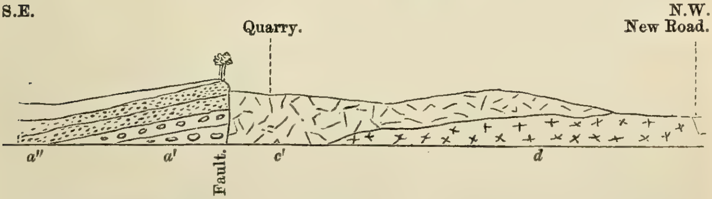
Fig. 2.—*Section N.E. of Twt Hill, Caernarvon.*



a''. Sandstones. *a'*. Conglomerates. } Cambrian. *c'*. Lower Caernarvon beds. * Felsite, with platy structure.

by a small fault crossing the ridge N.E. of Twt Hill, with a downthrow on the E., so that it is found in the quarry by the highest new road above Yscuborwen with the same grit and conglomerate on its

Fig. 3.—*Section in Quarry above Yscuborwen, Caernarvon.*

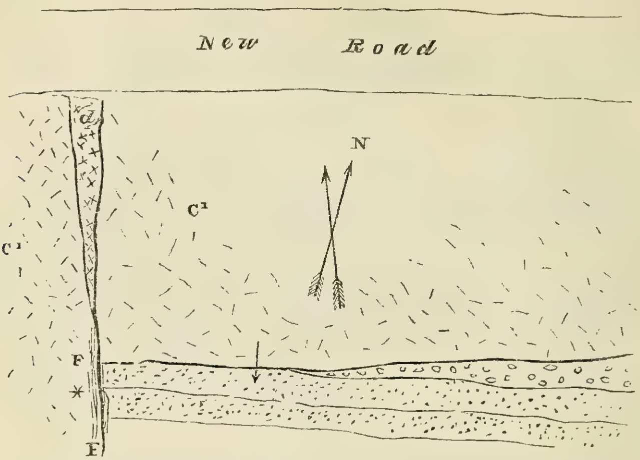


a''. Sandstone and grit. *a'*. Conglomerate. } Cambrian. *c'*. Lower Caernarvon beds. *d*. Greenstone.

S.E. flank (see fig. 3). This fault coincides with a greenstone dyke running S. 20° E. and seen in the quarry; and there is also seen in the same quarry another fault running up to the S. end of the dyke (fig. 4), nearly at right angles to it, and dropping the grit a little on the S.

The coarser variety of the Twt-Hill rock has been largely quarried behind Llysmeirion and Richmond Hill, and is again seen about half

Fig. 4.—*Plan of Quarry above Yscuborwen, Caernarvon.*



a''. Sandstone and grit. } Cambrian. c'. Lower Caernarvon beds.
a'. Conglomerate. d. Greenstone. F. Faults.
* Rock much jointed and veined in continuation of direction of dyke.

a mile E.S.E. of Llanfairisgaer, where it forms a rugged boss in a field N.W. of Bryn. This rock is a coarse crystalline aggregate of quartz and felspar, or, as Professor Ramsay has described it, is like a granite with no mica. In Anglesey a similar rock passes into a granitoid rock with mica. It is doubtful whether any specimen taken from the heart of this mass has exhibited clear evidence of a fragmental origin. There are many systems of divisional planes, and sometimes one set and sometimes another come into prominence from their regularity and persistency.

In the quarries on the N. side of Twt Hill the most bed-like planes turn over to the N., or a little W. of N., as if dragged down to the fault which brings on the Carboniferous rocks. In the N. corner of the Twt-Hill Field quarry (fig. 5) there is a band of decomposing grey felspathic rock, full of more or less regularly developed doubly terminated quartz crystals, similar to those found by Mr. Tawney in the rocks of St. David's; and in this a band, from two to eighteen inches thick, of hard close-textured siliceous rock, which thickens rapidly to the east, with an inclination of about 30° N.N.E. It is somewhat interrupted along joints, so as to suggest that it may not represent original bedding, but may be due to a kind of indigenous vein-structure. On the other hand, this interruption of the continuity of the mass at a joint is not at all conclusive against its being a bed of sedimentary origin with any one who has observed the irregular and interrupted manner in which the grits and quartzites of Anglesey are thrust in among the crumpled schists with which they are associated.

Fig. 5.—*North-east end of Field Quarry, Twt Hill, Caernarvon.*

S.W. N.E.

c'. Lower Caernarvon beds.
* Bed of fine-grained quartzose rock.

On the two bosses which occur N. and N.E. of Twt Hill there is a brownish or yellowish-pink felsite, generally showing a platy structure. This should be distinguished from the Twt-Hill rock. In the large quarries on the N.W., facing the Straits, there is an altered grit. If the more obvious divisional planes represent bedding, these dip in a northerly direction, and are the highest beds there seen; they would necessarily be thrown back out of sight by the fault seen in the roadside quarry, fig. 3.

Close to the great fault which brings on the Carboniferous rocks near Tycoch there is a crystalline grey felspathic rock, much crushed and traversed by slickensides, the surfaces of some of which are glossy, black, and anthracitic-looking. This rock probably belongs to some part of the Caernarvon series.

I. ii. *Crug Beds.*

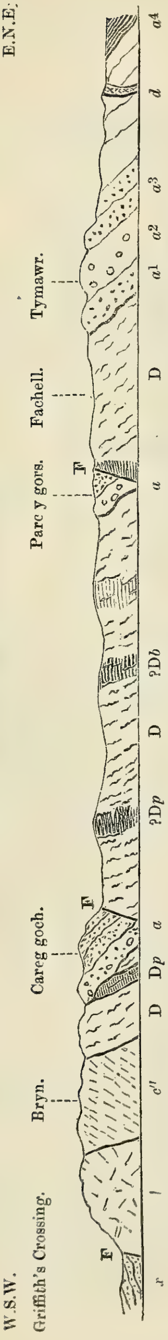
On the S.E. side of the ridge we find strong proof that a group of beds, somewhat similar to the Twt-Hill rock in essential characters, but finer, alternates with felsite-like rocks or passes into them; and though nothing like dip can be made out in them, the strike, as followed along the ridge (see map, Pl. XXXVI.), from about half a mile N.E. of Pengwrach to the brow of the hill above Dinorwig station, shows that they run nearly with the trend of the hill, with perhaps a little more north in them, and generally somewhat dragged over towards the fault along the Carboniferous beds.

On the boss N.W. of Pengwrach we find on the N.W. side crystalline beds, like the finer portions of the Twt-Hill group; and on the S.E. side of the same boss a felsite-like rock. A precisely similar boss occurs close to Crug, with a coarser rock on the N.W. and a felsite-like rock on the S.E. In the road between the two places rock of the coarser variety is exposed.

In the field N.W. of Bryn finer and coarser varieties of the same kind of rock are exposed in bosses projecting through the soil, while immediately over the wall on the N.W. the coarse granitoid rock of Twt Hill is seen. A grey crystalline felspathic rock much seamed by quartz veins forms the most prominent point in this field on the N.E. of the house.

Still further on to the N.E. in the same line, in the lower part of the little valley which runs down from below Tynymaes to about half a mile E.N.E. of Plas Llanfair, there are alternations of beds of finer and coarser crystalline rock, which must be referred to this group. One pink bed we find again, almost identical in character,

Fig. 6.—*Section near Llanddeiniolen.*



x. Carboniferous.

a. Cambrian { a^4. Black slates. a^3. Sandstone and grit. a^2. Conglomerate. a^1. Grit.

D. Dinorwig beds (Felsitic series) { p. Purple felsite. b. Brecciiform beds.

c''. Crug group. c'. Twt-Hill beds. } Caernarvon beds.

d. Dyke.

F. Faults.

in the same strike on the brow of the hill above the station at Port Dinorwig. Here it occurs between grey felspathic rocks; and these can hardly be distinguished from parts of the great mass of felsites which occupy almost all the high ground above Port Dinorwig, and, repeated by faults, stretch away to Llanddeiniolen on the S.E. and Brithdir and Beulah Chapel on the N.E.

II. *Dinorwig Beds* (=Felsitic series).

The next series consists chiefly of great masses of grey quartz felsite. No distinct bedding can be made out in any section; but the strike can be inferred, in the lower part of the series, from the manner in which the rock occurs with reference to the boundary of the underlying formation, and more clearly by following certain beds of marked character in the middle and upper part. It is seen with a subordinate purple bed near Tanyperthi, on the S. of which it is overlapped by a set of grits very similar to some of those which flank the Twt-Hill beds at Caernarvon (see map, Pl. XXXVI.). It projects at intervals all along the ridge to near Brithdir, and then can be followed on the other side of the Bangor road to the fault N.E. as far as Beulah Chapel.

A fault runs S.W. and N.E. under Careg goch W. of Llanddeiniolen, dropping the grits on the N.W.; and passing between Cefn and Tanyrwylfa, crosses the valley near the dyke under Tynycoed, repeats a great part of the felsitic series by bringing them up again on the S.E., and so runs into the Bangor-road fault N. of Brithdir.

This repeated mass of felsites is overlapped near Llanddeiniolen by grits and conglomerates, which can be traced at intervals to the Bangor road N.E. of Brithdir (see map and fig. 6).

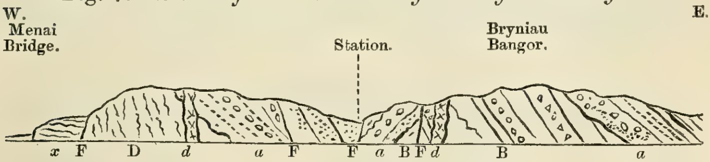
On the mass S. of Brithdir a purple bed is seen near Garth; and this seems to be developed to the N.E. into the Brithdir rock, which is a red quartziferous felspar porphyry. To the S.W. of this, running parallel to it, is a mass of purple brecciated rock seen in the ravine near Y Ganol, and running by Cae Cerig to the E. of Brithdir till it is lost under the overlapping grits and conglomerates.

A similar sequence of beds can be made out in the mass on the W. of the Careg-goch fault. A purplish bed of quartz felsite is seen trending N.E. near Tanyperthi; and at Pantyfallenfach a purple brecciiform felspar porphyry can be traced for some distance with a similar strike. These are probably equivalents of the Brithdir porphyry and Brithdir breccia respectively, thrown back by the Careg-goch fault (see section, fig. 6).

III. *Bangor Beds* (=Volcanic series).

The ground N.E. and E. of Brithdir is much disturbed, and I have not worked out the details; but the sequence is clear further to the N.E., and by reference to it the leading features of the rest of that district can be made out. The volcanic beds are well exposed

Fig. 7.—*Section from Menai Bridge to Bryniau Bangor.*



x. Carboniferous. *a*. Cambrian.
B. Bangor Beds (Volcanic series, agglomerates, &c.).
D. Dinorwig Beds (Felsitic series). *d*. Dykes. F. Faults.

on Bryniau Bangor, from the W. shaft of the tunnel to near the path above the station, and are seen, as already elsewhere described, to consist of hornstones, fine green banded slates, and agglomerates, including fragments of rock precisely similar to the beds among which the agglomerates occur. They contain also small faults and contorted broken-up beds, lying between others apparently undisturbed. From such indications we may infer that we have here a volcanic series, consisting chiefly, in this part, of fragmentary ejectamenta. Following the bands across their edges in descending order, we come to purplish somewhat felsitic-looking rocks; and it is not improbable that we have here traces of small later lava-streams, of which the earlier greater flows are preserved in the underlying Dinorwig beds.

If the Brithdir and Pantyfallen brecciated rocks are lava-flows, owing their brecciiform appearance to half-molten fragments in the lava, they would have to be bracketed with the Dinorwig beds; and this ejection, with imperfect fusion, would seem to indicate the commencement of the conditions under which the Bangor beds were accumulated, in which the fragments appear to have been thrown out unmelted, forming great masses of agglomerate and ash.

We must therefore consider the lowest of the Bangor beds visible in that area to be the coarse brecciated conglomerate seen near Careg Hwfa, immediately S.E. of the purple grits. This conglomerate is very conspicuous with its large pebbles of green felspathic rock weathering milk-white. The dip of the volcanic beds is very clear, averaging about 55° S.E.; and as we follow them along their strike to the N.E. we find them disappearing under the Cambrian conglomerates and grits, which can be traced lapping round the end of the hill from near Minfford to below the Mount.

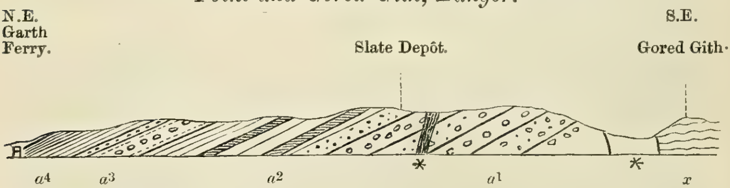
So it will be seen, first, that all the older groups run parallel to one another between Caernarvon and Bangor, the strike nearly coinciding with the trend of the hills, with a little more north in it, and dragged down towards the great faults here and there.

Secondly, that a connected though variable series, consisting of grits and conglomerates, flanks them on the S.E., and folds round the north-eastern end of the several masses into which the range is cut up by valleys, overlapping in turn each of the four groups into which the older rocks have been divided, and changing their character somewhat according to the rocks on which they rest and from which they were principally derived. These grits and conglomerates I refer to the base of the Cambrian, and I now propose to trace them more in detail.

Cambrian.

We find them well developed on the shore S.W. of Garth Point, where there is the following section:—

Fig. 8.—*Section seen along Shore of Menai Straits between Garth Point and Gored Gith, Bangor.*



x. Carboniferous.
a^4. Even-bedded mudstones and finer sandstones.
a^3. Coarse grit, with lines and beds of quartz and jasper pebbles.
a^2. Pale mudstone, with subordinate purple beds, especially in lower part.
a^1. Coarse conglomerate. * Broken faulted ground.

Sandy mudstones with subordinate purple beds are seen here and there in road-cuttings and elsewhere on the hill above, and the conglomerate can be traced obliquely up the hill-side. It crops out below Menai View, runs across from that to near Friddodd, and is exposed in a large quarry near Plas Lodwig. It is seen, well scored by glacial striæ, in the road that leads from Friddodd towards Belmont. Probably one of the faults seen on the shore near Gored Gith cuts it off on the S.W., and it is thrown forward by the Bangor-road faults into the city, where it appears again below the Mount, from which it can be traced at intervals across the end of the hill by the E. shaft of the tunnel, and S. and S.W. to Nant Gwtherin.

The area of two square miles lying S.W. of Bangor is a difficult bit of mapping, from the number of faults and dykes, and the partial metamorphosis accompanying them; but the beds can be pretty well identified. I think the district could be satisfactorily worked out, especially if we had six-inch maps.

Felsites occupy the whole area between the Carboniferous fault and the Trawscanol fault as far N.E. as Penychwynfa. Cambrian grits cross the road near Beulah Chapel, and are seen in the small road-cutting in the field opposite the entrance to Belmont. Here also there is a greenstone dyke exposed, and on the E. side of it, close to the gate, the conglomerate occurs. To the E. pale mudstones are seen along the road from the George Hotel to Bangor, and near the four road ends by the "f" of Gosphwysfa. E. of this the conglomerates are repeated as described above, being seen almost uninterruptedly running from Gored Gith to Plas Lodwig. On the S.E. side of the Trawscanol fault Cambrian grit crops out along the top of the ridge by Bryn Adda, and then we have the interruption of a dyke running along the lane from S. of Maesmawr to the lower Bangor road.

A short distance S.W. of this, by the "dd" of Tafarnnewydd, a red grit and fine conglomerate, like the Careg-Hwfa beds, come to the surface, and are quarried in places.

Along the roadside by Tyddyndu sandstones and mudstones are seen traversed by a dyke which comes behind Coedty. These beds dip at a high angle (50° and 60°) to the N.E., and must be cut off from the felsites of Cilmelyn by the Trawscanol fault.

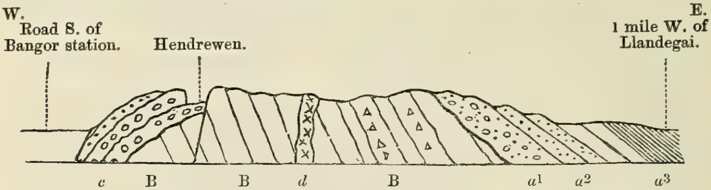
There are some hornstones and baked-looking banded slates on the rugged hill near the "w" of Tafarnnewydd, which at first sight I should be inclined to throw in with the Bangor group; but I have not worked out that bit, and there are beds very like them caught in along the dykes S.E. of the conglomerate of Tymawr near Llanddeiniolen, and these may either be Cambrian, altered by the Coedty dyke, or be older rocks faulted in.

The actual base of the conglomerate and grit I have not seen in this part of the district. Fig. 8 shows the section near Garth Point, and fig. 9 those made out on either side of Bryniau Bangor.

The conglomerate is less conspicuous, and the coarse grit more so, as we trace the series to the S.W. The conglomerate consists of large pebbles, almost all of which are fragments of felsite with a few of quartzite. The grit is generally a tolerably pure siliceous rock with but little felspathic matter. The conglomerate is generally weathered to a considerable depth. It is much decomposed to the bottom of all ordinary quarries; but some fragments brought up the shaft, probably from the same bed deep down, are of tough purplish rock, containing pebbles of felsite similar to those in the more weathered conglomerate.

It is not, however, found to be so much decomposed as we follow it towards Caernarvon. In the quarry at Hendrewen, where

Fig. 9.—*Section from road near Glan Adda, ¼ mile S.W. of Bangor Station, due E. across Bryniau.* (Length of Section 1 mile.)



a^3. Black and grey banded flaggy shales.
a^2. Sandstones and grits. } Cambrian.
a^1. Conglomerate.
B. Volcanic series, Bangor beds. *d.* Dyke.

it is seen to be dropped by a small fault against the Bangor beds to the N.W. flank of the Bryniau ridge, it consists of a very tough grit and irregular conglomerate, the conglomerate in places being very coarse; one pebble was over a foot in longest diameter. It is here traversed by a dyke, near which it is slightly altered. These beds can be followed, dipping in a N. and N.W. direction, to near Tairffynnon, W. of which place the Bangor beds crop out below them. They can be traced along the N. side of the valley towards Perfeddgoed, and crossing the valley, which probably coincides with faulted ground, we can trace similar purplish conglomerate and grit up the road to Wern, and here and there E. of Brithdir, across the road N.E. of Cae Cerig, and beyond the rough land of Rhosfawr. We find bosses of grey coarse grit on one side and of felsite on the other over the hill to Fachell. There we have a fine series of sections, from which the E.N.E. part of fig. 6 has been drawn. The grits associated with the conglomerate are sometimes purplish where the conglomerate is purple, as near the Poorhouse on the Bangor road, but sometimes grey or yellowish, even when the conglomerate is purple. Generally the grits underlying the conglomerate are grey and yellow, as near Wern and Fachell.

About a quarter of a mile N.E. of Fachell, in a large quarry by the road opposite Tymawr, the conglomerate is well seen. Its general colour is purple, and on closer examination it is seen to be composed of pebbles of great variety, from a grey or salmon-pink quartz felsite to a bright porphyry, in which red crystals of felspar shine in a black matrix. This conglomerate is followed by the usual Cambrian grits, sandstones, and mudstones, which are found a little further on much troubled by a great greenstone dyke.

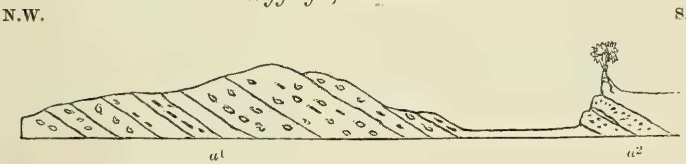
A fault which causes the smashed rock seen along the road by Fachell throws back the Cambrian to the W. of Llanddeiniolen. S. of this fault, near the church, black and grey banded flaggy shales occur, like those seen in a similar position E. of Bryniau

Bangor; and W. of these, grits and purplish sandy shales crop out in the road and quarry near the Rectory. These are probably all above the conglomerate.

Coarse grits, like those near Fachell, occur along the S.E. flank of the hill for about three quarters of a mile near Careg goch, and are quarried here and there. They dip at about 30° to 40° S.S.E. and E.S.E. I take these to be the base of the Cambrian, here irregularly and unconformably lying upon the felsites, and thrown back from the grits of Fachell by the same fault which repeats the Brithdir beds at Pantyfallen and Tanyperthi.

Two miles further to the S.W. we find the grits and conglomerates flanking the Caernarvon beds on the S.E. sides of the ridge. They are first exposed in a small disused quarry, in a field on the top of the hill between Yscuborwen and Tygwyn, where they are seen dipping 45° to 48° S.S.E. and S. 30° E. (fig. 10). The conglomerate

Fig. 10.—*Section in Quarry on top of hill between Yscuborwen and Tygwyn, Caernarvon.*



a^2. Tough sandstone and grit.
a^1. Grit and conglomerate, with quartz, quartzite, lydian stone, jasper, mica-schist, &c.

consists chiefly of white quartz, among which pebbles of blood-red jasper are conspicuous, and less commonly fragments of mica-schists three or four inches in longer diameter. The conglomerates pass under tough grey grits and sandstone, which crop out under the hedge all along the opposite side of the quarry, as shown in fig. 10, which is drawn not quite at right angles to the strike, and therefore shows a somewhat lower angle than true dip.

Less than half a mile S.W. of this a quarry is being worked close to the road recently constructed towards the top of the hill, near some new villas. In this a somewhat similar but finer conglomerate is seen faulted against the Twt-Hill rock, and passing with a dip of about 15° under very tough grey grit weathering yellowish (figs. 3 and 4). The dyke fault, with a downthrow on the N.E., now throws the grits and conglomerates forward to the S.; and they are next seen in the quarry illustrated by fig. 2, resting on the Twt-Hill rock at an angle of about 65°, and dipping under grits and somewhat flaggy sandstones seen in the S. corner of the quarry. The conglomerate has been cut back to the Twt-Hill rock, leaving patches adhering in places, owing partly to the irregularity of the base, and giving the appearance of alternations of Twt-Hill rock and conglomerate, dipping a little to the E. or W. of S. The true dip is seen, however, at the S.W. end of the quarry, and the long face of rock fronting the S.E. is very nearly the bedding-plane.

The conglomerate is much like that seen in the quarry shown in fig. 10, except that almost all the pebbles are white quartz. It is exceedingly tough. The finer portions are much like the upper conglomerate seen at Garth Point (see fig. 8, a^3), and also resemble some of the conglomerate in the Hendrewen quarry (see fig. 9).

The overlying beds consist of a grey grit and micaceous purple flaggy sandstone. This is much weathered, and it is not clear how far the colour may be due to weathering.

The conglomerate is again seen on the S.E. of Twt Hill in front of the new church. The dip was not clear, but it appeared to be S.E. (fig. 1).

Thus we find the conglomerate and grit, which must all be referred to the base of the Cambrian, flanking the Pre-Cambrian rocks all the way from Twt Hill, Caernarvon, to Garth Point, Bangor, dropped in and repeated by faults here and there, and lapping round the ends of all the principal masses of which the range is made up.

The character of the beds varies according to the rocks on which they rest, and from which they were principally derived. Near Caernarvon the conglomerate contains chiefly quartz; near Llanddeiniolen it is composed of pebbles of felsitic rocks in a fine matrix, also like felsitic rock. Near Bangor, though the pebbles seem to be chiefly derived from felsitic rocks, the matrix, especially those portions which are furthest from the felsitic rocks, is often a grit, and generally is much more open and porous, probably being largely derived from the clastic volcanic series; and this accounts for that portion of the conglomerate being most decomposed.

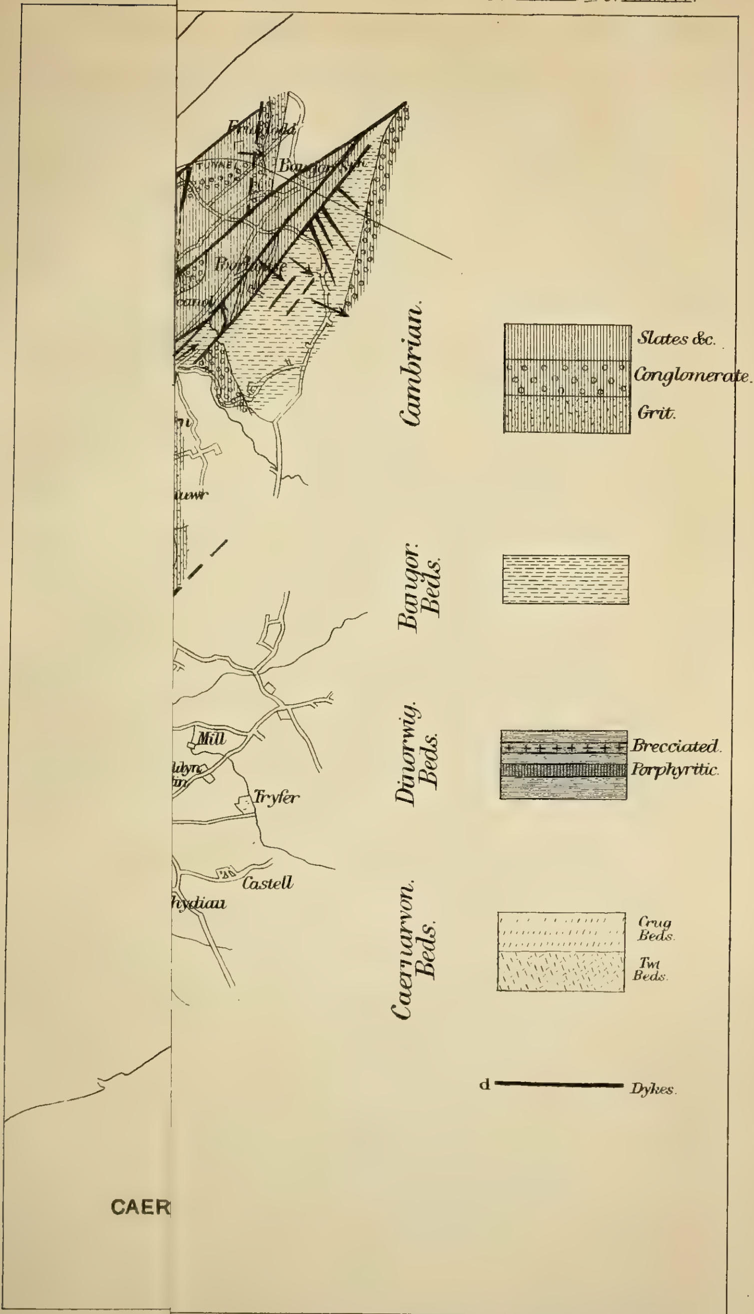
DESCRIPTION OF PLATE XXXVI.

Map of the district between Bangor and Caernarvon.

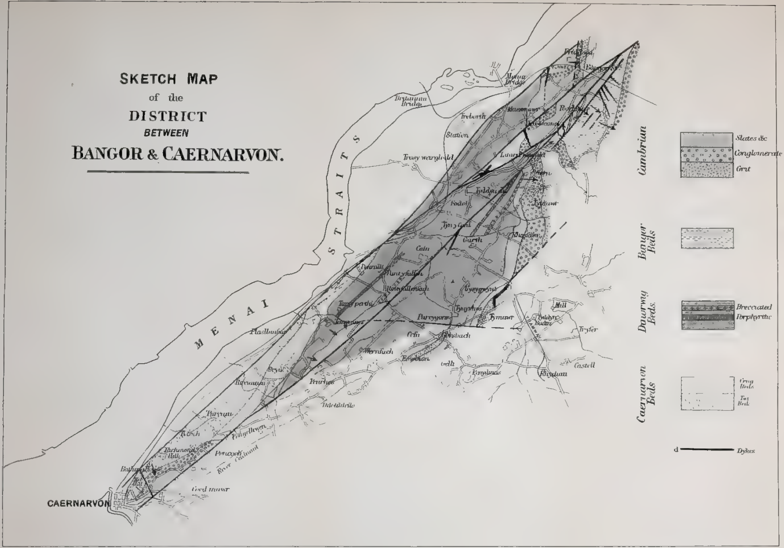
Discussion.

Dr. Hicks remarked that the points of difference between himself and the author of this paper were now very small, as it was quite clear that the author had abandoned the theory in which he attributed an igneous origin to the Dimetian (Twt-Hill) series; and he hailed the appearance of this memoir also as showing that Prof. Hughes was gradually coming round to his views, and accepting his threefold division of the Pre-Cambrian rocks.

Mr. Tawney stated that the specimen alluded to by Dr. Hicks as from a mineral vein was from a bed in the quarry near Twt Hill (admitted by every one who had been there to be a conglomerate); the only question was as to its age. Concerning this, two fairly divergent opinions were before us, viz. one recorded by Prof. Bonney, that it was a bed in the metamorphic Twt series; the other by Prof. Hughes, that it was lying unconformably against the



Dangerfield. Lith. 22. Bedford St. Covent Garden.



Dancerfield Lith 22 Bedford St Covent Garden

Twt-Hill series, and was of Cambrian age; the speaker inclined at present to the latter view.

Prof. Bonney observed that he had not committed himself to more than two series, and that the views which he had stated in his paper had been founded not only on field-work but also on the microscope. With regard to the minor points in Prof. Hughes's paper, he thought there was no doubt evidence of fragmental structure in rock from the heart of the Twt-Hill mass; he did not think that colour was of much importance in the classification of felsite; and he thought that the district N.E. and E. of Brithdir, which Prof. Hughes said he had not worked out, was the most important part. He thought that evidence, both in the field and with the microscope, showed the beds of the Tairffynnon district to be very different from the true Cambrian conglomerate; and that the grit from Fachell to Beulah Chapel was altogether different from that at Careg goch—the former being a felsite-grit, little altered, the latter a quartzite. Lastly, he maintained that the conglomerates in the grit near Twt Hill were totally different from the Cambrian conglomerate, were much more highly altered, were in true sequence with the beds below, and, so far, older than the Cambrian conglomerate.

Prof. Hughes pointed out that Dr. Hicks had mistaken his views. In reply to Prof. Bonney he stated that he thought that the importance of working out a true sequence among the beds was so great as to warrant him in carefully studying that and the effect of faults. He had not neglected the microscopic characters of the rocks, and slices of all the more doubtful or important rocks were on the table; but his chief reliance had been placed on the behaviour of the great masses in the field.

53. *On the* Silurian Rocks *of the Valley of the* Clwyd.

By Prof. T. M'Kenny Hughes, M.A., F.G.S. (Read May 14, 1879.)

In the following paper I offer a preliminary sketch of the Silurian rocks of the southern and western part of the Valley of the Clwyd, and an attempt to correlate the details with the sequence established elsewhere.

In the northern part of the district flaggy shales with subordinate more sandy beds occur; and though fossils are abundant at various horizons, I could not detect any group so marked that I could easily trace it across the country in the limited time at my deposal, while the endless rolls and folds made it difficult to determine, even within short distances, which were higher and which lower beds. A full list of the fossils of Llansannan from "beds above the Denbigh grits" is given by Salter, Mem. Geol. Survey, vol. iii.; but I think it will be found that there are two horizons, both well up in the Denbigh beds, at which Grits occur, and that the Llansannan fossiliferous beds occur between them.

At Pontyrddol, a little over three miles W.S.W. of St. Asaph, I procured the following fossils in a black and grey flaggy sandy shale:—*Petraia* sp., Encrinite stems, *Atrypa reticularis*, *Chonetes lata*, *Leptæna minima* ?, *Orthis elegantula*, *Orthis*, sp. (var. of *elegantula*), *Rhynchonella navicula*, *Spirifera elevata*, *Strophomena depressa*, *Pterinea retroflexa*.

On Moel Fodia, about three miles to the south, the beds are very fossiliferous; I obtained the following from various small openings near the top of the hill:—

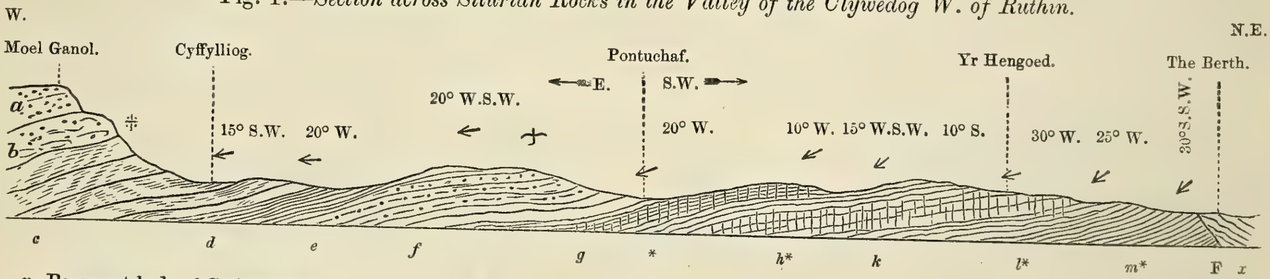
List of fossils from Upper Denbigh Flags of Moel Fodia, Denbigh.

Cliona prisca.
Nebulipora (Monticulipora).
Favosites fibrosus, *Goldf.*
Crinoid stems.
Lichas, sp.
Atrypa reticularis, *Linn.* ?, var. with fine lines.
Meristella, sp.
Rhynchonella navicula, *Sow.*
—— nucula, *Sow.*
Orthis elegantula, *Dalm.*
Spirifera crispa, *His.*
—— elevata, *Dalm.*
Strophomena funiculata, *M'Coy.*
—— depressa, *Dalm.*
Leptæna transversalis, *Dalm.*
Cardiola interrupta, *Brod.*
Cucullella antiqua, *Sow.*
Pterinea tenuistriata, *M'Coy.*
—— imbricata, n. sp.
Cyrtoceras.
Orthoceras primævum, *Forbes.*

West of Denbigh similar beds can be followed rolling into the hills, the Encrinite flags of Nantglyn being apparently pretty high in the series. South of Llanrhaiadr and of Llywesog even-bedded banded flaggy shales are seen at intervals here and there all the way up to the gritty sandstones of Ffriddfawr; and in the next valley there is a very clear descending section from Caregygath, near Moel Ganol, by Cyffylliog along the Clywedog into the Vale of Clwyd.

On the top of Ffriddfawr (see fig. 1) opposite Moel Ganol we find a pale grey sandy mudstone, massive were it not for cleavage, with the bedding generally obscure. Under this are grey tough beds of

Fig. 1.—*Section across Silurian Rocks in the Valley of the Clywedog W. of Ruthin.*



x. Basement-beds of Carboniferous.

a. Greywacke, grey gritty sandstones. *b.* Grey concretionary sandstones, with concentric structure.	Denbigh and Coniston Grit.
c. Passage-beds not clearly seen. *d.* Dark, even-bedded, banded, sandy mudstones. *e.* Massive grey banded sandstone. *f.* Pale sandy mudstones.	Denbigh and Coniston Flags.
g. Rab and flaggy shales. *h.* Fossiliferous flaggy beds. *k.* Bedding less clear. *l.* Fossiliferous flaggy beds. *m.* ,, ,,	Denbigh and Coniston Flags.

F. Fault.
* Fossils.

sandstone a few inches thick in dark grey shale. Some concretionary masses are marked by bands of colour due to infiltration from joint-surfaces like the Whetstones of Moughton in Yorkshire, but they are not red in the Ffriddfawr rock. The shale weathers into a fine rab. Below these are tough, grey, thin-bedded, wavy, banded, concretionary mudstones, full of holes such as are sometimes left by the decomposing out of fossils like *Nebulipora*. Encrinites occur in the concretions. There is nothing very distinctive about these beds; but they agree very well in all their characters with the base of the Coniston Grit. We find now a clearer section; and after crossing near Cyffylliog alternations of paler and darker banded sandy mudstone and grey sandstones, agreeing very well in character with the passage-beds from Coniston Grit to Coniston Flags, we come, near Pontuchaf, to fossiliferous flags with subordinate thicker and more sandy beds.

These can be seen in descending section along the sides of the valley, and in the bed of the stream to near Berth, where they are cut off by a fault which brings the basement beds of the Carboniferous against them on the E.

Measuring from the base of the grits near Cyffylliog, there must be about 4000 feet of beds to be referred to this group. Fossils occur at the various horizons indicated on the section.

In the cutting N. of Hengoed I observed the following:—

Encrinite stems.
Monograptus, sp.
Atrypa reticularis, *Linn.*
Rhynchonella navicula, *Sow.*
Rhynchonella nucula, *Sow.*
——, sp.
Cardiola interrupta, *Brod.*
Orthoceras primævum, *Forbes.*

At Pontuchaf the following occur:—

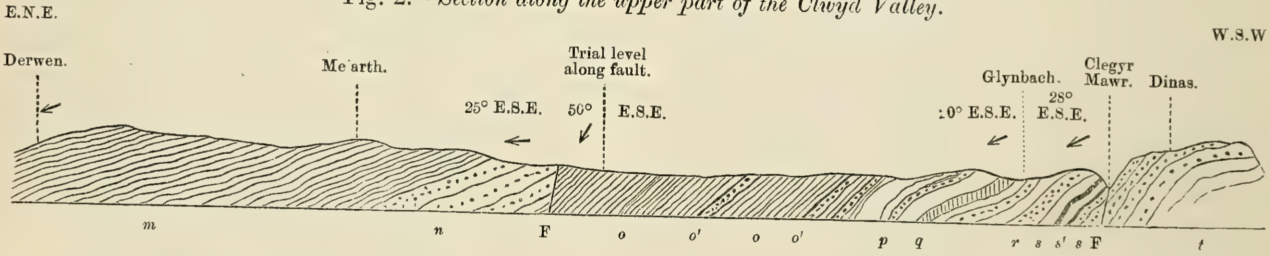
Monticulipora, probably the "Cushion-like coral" of *Salter.*
Encrinite stems.
Atrypa reticularis, *Linn.*
Chonetes lata, *Von Buch.*
Orthis elegantula, *Dalm.*
Orthis, sp. (var. of *O. elegantula*).
Rhynchonella navicula, *Sow.*
—— nucula, *Sow.*
——, sp.
Strophomena depressa, *Dalm.*
Orthoceras primævum, *Forbes.*

From the valley of the Clywedog (see fig. 1) the flags can be traced S.W. to the upper waters of the Clwyd in a generally descending section as they turn up on the S., till on Garwfynydd we come to tough grey gritty sandstones cropping out from below the flags, and forming a marked feature across the country. Below these grits, which are probably on the horizon of the Penyglog Grits of Corwen, and the Austwick Grits of Yorkshire, there are more flags, passing down into pale slates, which rest on grey gritty sandstones with wavy bands in parts. These last appear to be the equivalents of the Corwen Grit*. They are well seen about $\frac{1}{2}$ mile S. of Bod Renail, where they are the cause of a series of small waterfalls.

After some curves, as if in a struggle to run into the Dee by Bettws y Gwerfilgoch, the Clwyd is turned back and, making an angle of about 70° with its former course, crosses the same series of beds again, and running over the Corwen Grits under the old camp

* Quart. Journ. Geol. Soc. vol. xxxiii. p. 207.

Fig. 2.—*Section along the upper part of the Clwyd Valley.*



m. Even-bedded banded flaggy shales.
n. Sandstone.
o. Flaggy shales, with
o', subordinate beds of sandstone.
} Coniston Flags and Denbigh Grits.

p. Wavy banded sandstone.
q. Pale slates with darker beds.
r. Sandstone passing down into pale pasty mudstone.
s. Pale slates with black bands (*s'*) 2–6 ins. thick with *Graptolites*.
} Pale slates and Graptolitic mudstones.

t. Sandstones = Corwen Grits.

F. Fault.

called Dinas, gets on to the Denbigh Flags less than a mile W.S.W. of Derwen Station (see fig. 2).

The succession is better seen here than in the Bod Renail section. To describe the beds, as in the case of fig. 1, in descending order, at Derwen Station we have the Denbigh Flags, the equivalent of *m* in fig. 1. These can be followed along the hill-side and river-bed by Meiarth, dipping on an average about 20° to 30° E.S.E.

About $\frac{1}{4}$ mile W. of Meiarth gritty sandstones similar to those on Garwfynydd crop out. They are thrown down to the level of the stream by a small fault along which a trial has been made for lead. In the flags immediately W. of the fault I found *Mongraptus vomerinus*. These flags have several subordinate beds of sandstone, especially in the lower part where they pass into the pale slates.

The pale slates are well seen in the banks of the Clwyd near Glynbach, and in the little stream-course running down from Clegyrmawr, a considerable way below the position assigned to them on the Survey map. They consist of alternations of light-grey wavy banded sandstones and pale pasty and sandy mudstones with darker bands. In the lower part there are black bands from 2″ to 6″ thick containing a group of Graptolites, which, with the exception of *Monograptus colonus*, are common forms in the Graptolithic mudstones of the Lake-district.

The Graptolites I found were:—

Monograptus convolutus, *His.*	Monograptus tenuis, *Portl.*
—— triangularis, *Harkn.*	—— colonus, *Barr.*

The Corwen Grit comes out from below the pale slates and occupies all the high ground to the W. A small fault crosses the Clegyrmawr stream obliquely, and has been followed for lead, which seems to occur principally, if not exclusively, where the sandstones are faulted together. The workings do not appear to have pierced beds older than the Corwen Grits; and in the waste rock carried out of the level I found an obscure head of an *Illænus*.

On the whole, therefore, it seems clear that we have here a basement series for the Silurian corresponding in all its details to the base of the Silurian made out in Yorkshire and Westmoreland; and that here also, as near Corwen, some of what has been included in the Bala must now be referred to the May-Hill Sandstone and higher beds.

54. *On the* Geological Age *of the* Rocks *forming the* Southern Highlands *of* Ireland, *generally known as* "The Dingle Beds" *and* "Glengariff Grits *and* Slates" (*Jukes*). By Professor Edward Hull, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Ireland. (Read April 9, 1879.)

Contents.

I. Introduction.

The geological age of the formations which rise into the highest elevation in the South of Ireland, and form the central masses of the promontories which jut out far into the Atlantic in the counties of Kerry and Cork, has been long a subject of controversy. They have been referred by successive authors to the Silurian, Devonian, and Old Red Sandstone periods. While I would refrain from speaking dogmatically on a question which may be incapable of absolute demonstration, I wish to place before the Society the reasons which have induced me to agree with those who have referred these beds to the Upper Silurian age. Before proceeding to the discussion of those points which seem to me to bear directly upon the question at issue, I will briefly notice the views expressed by previous authors on the subject.

*Views of Previous Authors.**

1838. In this year Mr. Charles W. Hamilton, in a paper entitled "An Outline of the Geology of part of the County of Kerry"†, described the coast sections of the Dingle promontory, noticing the beds with Silurian fossils and the overlying slates and grits, and

* A fuller account of these views than that here presented was drawn up by the author, but by order of the Council it has been curtailed.

† Journ. Geol. Soc. Dubl. vol. i. (1838).

identified them with the rocks which form the Reeks and Glengariff ranges.

1838. Mr. Thomas Weaver, in a memoir "On the Geological Relations of the South of Ireland"*, described the rocks forming the mountains of Cork and Kerry under the old name of "Greywacke and slate of the Transition series."

1839. Sir Richard Griffith, in presenting his Geological map of Ireland to the Geological Society of Dublin, also read a paper on the principle of colouring adopted in the above map, and on the geological structure of the South of Ireland†, in which he refers to the discovery of numerous Silurian fossils in beds in the Dingle promontory, notices the discordant superposition of the Old Red Sandstone on the clayslate of Dingle, and expresses the opinion that "eventually the greater part, if not the whole, of the schistose rocks of the counties of Cork and Kerry" will prove to be Silurian.

1845. Mr. C. W. Hamilton, in a paper "On the Rocks in the neighbourhood of Killarney"‡, contended, in opposition to Sir R. Griffith, that those of the Killarney and Dingle mountains are not Silurian but of Devonian age. To this paper Sir Richard replied in the same year§; and in 1855, in the seconde dition of his geological map of Ireland, the beds forming the western portion of the Dingle promontory, and the mountainous tracts of Kerry and Cork, are coloured and lettered as "Silurian," and described as "chloritic or brownish-grey quartzite or agglomerate, occasionally alternating with green and purple slate."

1856–7. Prof. Haughton ||, Prof. J. Beete Jukes, and Mr. Salter¶ discussed the classification of the Devonian and Carboniferous rocks, the latter authors contending for the collocation of the Yellow Sandstone with *Knorria dichotoma*, *Anodon Jukesii*, &c. with the upper part of the Old Red Sandstone. In 1857, also, Mr. G. V. Du Noyer gave a minute description of the rocks of the Killarney district**, and assumed the purple and green slates and grits to be of Lower Old Red Sandstone age.

1858. Sir Richard Griffith again took up the question in his "Notes on the Stratigraphical Relations of the Sedimentary Rocks of the South of Ireland"††, in which he indicates that the base of the Old Red Sandstone may be recognized in the Dingle promontory with the same unconformity to the underlying rocks as in other districts examined, but that the beds with Upper Silurian fossils at the extreme west of the promontory pass up directly into the "Glengariff grits;" and, considering the discordancy between these and the Old Red Sandstone, he had no longer any hesitation in regarding the Glengariff beds as belonging to the Silurian system. These opinions are supported by Mr. J. Kelly in a paper "On the Graywacke Rocks of Ireland as compared with those of England"‡‡.

* Trans. Geol. Soc. 2nd ser. vol. v. (1840).
† Journ. Geol. Soc. Dubl. vol. ii. p. 78 (1843).
‡ *Ibid.* vol. iii. p. 134 (1845).
§ *Ibid.* vol. iii. p. 150.
|| *Ibid.* vol. vi. p. 227 (1856).
¶ *Ibid.* vol. vii. p. 63 (1857).
** *Ibid.* vol. vii. p. 97.
†† *Ibid.* vol. viii. p. 2 (1858).
‡‡ *Ibid.* vol. viii. p. 251 (1858).

1867. Prof. Jukes, in a paper comparing the rocks of the South-west of Ireland with those of Devonshire, admits that the Dingle beds seem to be physically more connected with the Upper Silurian than with the Old Red Sandstone*.

In this year also Sir Roderick Murchison, in the fourth edition of 'Siluria' (p. 178), after describing the conformable upward passage of the Dingle beds with Silurian fossils into the "Glengariff grits and schists," maintains that the latter represent "those slates and grits which in Germany, Belgium, and North Devon form the lowest portion of the Devonian system."

In the maps and explanatory Memoirs of the Geological Survey of Ireland the "Glengariff grits and slates," which are the representatives of the "Dingle beds," are coloured and described as Old Red Sandstone; but in the Dingle promontory these beds are separated from the Old Red Sandstone, and are coloured reddish brown. This is explained by Prof. Jukes to be due to the fact that while the boundary line of the "Dingle beds" is quite distinct in the Dingle promontory, it was found impossible to draw any corresponding line elsewhere. He "therefore thought it best not to prejudge the question."

II. Reexamination of the Sections.

From the above abstracts and notices of authors it will be seen that the opinions regarding the age of the Glengariff grit and slate series are various. We might almost say "*quot homines tot sententiæ.*" All are agreed that the beds form a group intermediate between Old Red Sandstone above and Upper Silurian beds below; by some authorities they are classed with the Upper Silurian, by others with the Devonian, by others with the Lower Old Red Sandstone. Be it recollected, however, that as far back as 1839 the late Sir Richard Griffith expressed his opinion that this series, together with the subjacent fossiliferous Silurian beds, would eventually prove to be of Silurian age. This view he subsequently illustrated and enforced; and Prof. Jukes admits that "theoretically it is the better of the two" alternatives between Silurian and Old Red Sandstone. I have never been able to understand exactly why it has been departed from by other observers. For myself, I not only concur in this view upon the grounds which he has advanced, but I hope to be able to adduce in this paper evidence additional to any yet offered in its favour.

The question having been confessedly left an open one by my predecessor, and subject to further investigation, I obtained the permission of the Directer-General to reexamine the sections in Kerry and Cork likely to throw light upon it; and in company with Messrs. J. O'Kelly, Senior Geologist, and Mr. A. M'Henry, Assistant Geologist, I made a tour of the district during the month of September 1878.

We first visited the sections in the Dingle promontory†, then

* Journ. Roy. Geol. Soc. Irel. vol. i. p. 105 (1867).

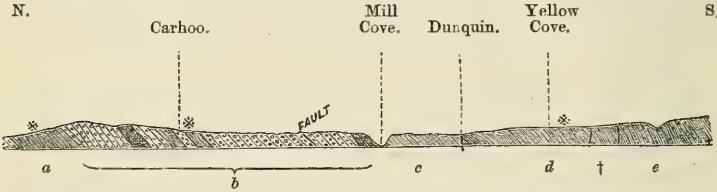
† In this first district Mr. M'Henry was my only companion, as Mr. O'Kelly did not join us till we reached Killarney.

those in the neighbourhood of Killarney, next those of Kenmare, and lastly those south of Glengariff. I shall briefly describe the results of our examination of these districts in the order above named. A detailed description will be unnecessary, so much having already been written on the subject by authors already quoted, as well as by the officers of the Survey.

a. *Dingle Section.* (Figs. 1 & 2.)

The whole series is admirably laid open in the coast cliffs extending from Sybil Point to Slea Head, a distance of six miles. The bottom beds are probably of Llandovery age, upon which follow representatives of the Wenlock and Ludlow beds as far as Clogher Bay. Owing, doubtless, to a large fault, these beds are repeated to the south of Clogher Head, where they form a section of a dome

Fig. 1.—*Section along the Western Coast of Dingle Promontory, showing the connexion of the Dingle Beds with the fossiliferous Silurian below.*



a. Slates &c. with fossils (Wenlock).
b. Beds of volcanic ash and lapilli, with felstone and bands of slate.
c. Purple slate and brecciated beds.
d. Fine-grained purple grits and slates, passing up into grey and yellow slates and calcareous sandstones with Ludlow and Wenlock fossils.
e. Grey and brown and purple slates and concretionary sandstones.
* Fossiliferous localities. † Supposed base of Dingle beds.

or inversion, as represented on the horizontal section prepared by Mr. Du Noyer. Nevertheless from Carrigcarn, opposite Carhoo, southwards there is an unbroken section commencing with the representatives of the Wenlock beds up into the Glengariff grits of Mount Eagle and Slea Head, which strike across the intervening sound into Great Blasket Island. This section, which has been very carefully measured and observed, shows a thickness of about 10,000 feet of strata, and is as follows, adopting the designation of the beds as given by the Geological Survey :—

Section in Dingle Promontory.
(Beds in descending order.)

Old Red Sandstone and Conglomerate resting discordantly on several of the underlying beds (Sybil Head, Kinard Hill, Bull's Head, &c.).

"Dingle beds."
1. Red and purple slates of Ventry and Dingle Harbour, surmounted by conglomerate of Parkmore.
2. *Glengariff grits.*—Hard massive greenish and purple grits, sometimes pebbly, and containing flaggy and ripple-marked beds.
3. Purple and greyish slates with bands of grit interstratified.

"Passage-beds." (Murchison.)	Greenish-grey fine-grained grits with bands of slate resting on grey, brown, and purple slates and concretionary sandstones.
"Croaghmarin beds." (Ludlow?) (About 1000 feet.)	Grey, purple, and brown rough slates (cleavage and dip coincident). Purple and grey slates passing down into brownish and greyish cleaved slates and calcareous grits with fossils, *Atrypa reticularis*, *Pentamerus Knightii*, *Rhynchonella furcata*, *Strophomena depressa*, *Orthoceras annulatum*, &c.*
"Ferriter's Cove beds." (Dunquin Bay.) (Wenlock.)	Fine-grained yellowish grits and sharp slates, with grey shales and brown fossiliferous sandstones, passing down into fine-grained purple grits and slates, weathering with cavities, with a base of purple brecciated beds†.
Volcanic Series.	Beds of purplish ash, lapilli, and agglomerate, sometimes finely laminated and traversed by cleavage-planes; with these are several beds of slate.
"Smerwick beds." (Smerwick Harbour.) 2000 feet.	Purplish, brown, green, and yellow sandstones and flags with bright red shales. No fossils, possibly of "Llandovery" age.

The above section exhibits not only a gradual passage from the unfossiliferous "Dingle beds" into Upper Silurians, but an intercalation of these beds themselves throughout a thickness of 1500 or 2000 feet. The purple slates and grits shown in the section from Dunquin Inlet southwards, and lying well below the fossiliferous beds, are in no way different from the purple slates and grits which lie above the highest fossiliferous band. So much is this the case that, for some time, these beds were classed by Mr. Du Noyer with "the Dingle beds" until the discovery of the fossiliferous band above them, when the boundary was shifted further up. It is quite open, however, to any one to say that the one view is as correct as the other, and that the uppermost known fossiliferous band in the "Croaghmarin beds" is to be included in the "Dingle series."

Another section, showing the passage from "the Dingle beds" into the fossiliferous Silurians, is shown on the northern or western flanks of Mount Eagle, in a brook-course which descends towards Dunquin National School. The section is as follows (beds in descending order):—

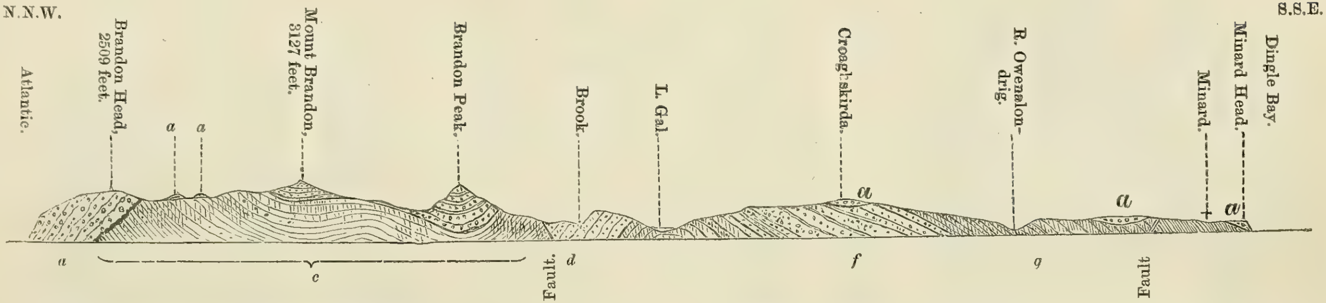
Dingle and Passage-beds.	1. Purple rough slates, with bands of greenish grit. Several hundred feet in thickness. 2. Thin-bedded light-brown sandstones. 5 feet. 3. Evenly-bedded bluish-green and purple flagstones and tiles. 20 feet. 4. Yellowish fine-grained sandstones, micaceous, weathering yellow or brown. 25 feet.
Upper Silurian beds.	5. Beds not seen (probably shales). 6. Calcareous grits, weathering brown, with Upper Silurian fossils.

In this section, as in the larger one along the coast, there is no

* Explanation to sheets 160, 161, 171 of the Geol. Survey Maps, p. 13.

† These beds, several hundred feet in thickness, have an exact resemblance to the purple slates of the "Dingle beds," from which they are separated by the fossiliferous "Croaghmarin beds."

Fig. 2.—*Section across the Dingle Promontory from Brandon Head to Minard Head, showing the unconformity of the Old Red Conglomerate to the Upper Silurian and Dingle Beds, &c.* (Scale 1 inch to 1 mile.)



a. Old Red Sandstone and Conglomerate.
c. Wenlock and Ludlow beds: purple cleaved slates and thin grits, surmounted by green grits.
d. Green grits (Glengariff Beds).
e. Probably slates.
f. "Glengariff grits," massive green grits and conglomerates, capped by Old Red Sandstone (*a*).
g. Upper purple slate series.
h. Dark slates (Llandovery? or Lower Silurian).

break or evidence of discordance in the succession of the beds; on the contrary, the change is gradual, with intercalations, and the whole series gives evidence of continuity.

In fine, after a careful observation of the sections near Dunquin, we came away fully impressed with views regarding the relations of these beds similar to those expressed by the late Sir R. Griffith, that the whole series is one and indivisible, and represents the Upper Silurian beds from the base throughout.

Evidence of Age from Fossils.

I have already stated that the uppermost fossiliferous band in the coast-section at Dunquin might be regarded as occurring in "the Dingle series," as the purple slates which underlie it are precisely similar to those which overlie it, and are supposed to belong to the "Dingle series." Except, however, for the presence in the beds of purple slate of remarkable "fucoidal" markings, it must be admitted that the Dingle beds and Glengariff grits and slates are lamentably destitute of fossil forms. It must be recollected, however, that the strata are not favourable to the preservation of such forms, even supposing they once existed; and we have only to refer to some well-known marine formations of similar composition to feel assured that the absence of fossil forms is no argument against the marine origin of the Dingle beds. For example, it is rarely that any traces of fossils are found in the "Bala and Caradoc" grits and slates, which occupy so large an area of the north-east of Ireland. The fossils which occur are sporadic and local, but hundreds of feet of strata may be examined over many square miles without rewarding the search of the collector.

Another very apposite illustration occurs in the case of the "Morte Slates" of the Devonian series, attaining a thickness of from 3000 to 4000 feet in the Devonshire section, and succeeding the highly fossiliferous beds of the "Ilfracombe group." These slates are unfossiliferous; but it is improbable that they have not, like the beds below them, been deposited in the sea. Many other instances might be cited in support of the view that, notwithstanding the absence of marine fossils, the beds we are considering may really be of marine origin. Before, however, we admit that the Dingle beds are really destitute of fossils, let us consider the evidence offered by the Parkmore-Point Conglomerate.

Parkmore-Point Conglomerate.

Amongst the highest beds of the Dingle series there occur some massive conglomerates forming the cliffs at the entrance to Ventry and Dingle harbours, and particularly well laid open at Parkmore Point. The pebbles are large, well rounded, and formed of various kinds of grit, quartz, hornstone, fragments of purple slate (or schist), white ash, vesicular greenstone, and purple fossiliferous limestone, or highly calcareous grit. From some of the pebbles Silurian fossils were determined by Mr. Salter in 1856*.

* "Explanation" of sheets 160, 161 &c., of the Maps of the Geological Survey, p. 24.

Some of these fossils range upwards from the Caradoc or Bala stage; but the majority are solely Upper Silurian forms, ranging from the Llandovery to the Ludlow stages.

On examining the specimens in the collection of the Geological Survey, it appeared to me that the fossiliferous portions of the rock were curiously mixed up with fragments derived from metamorphic strata, such as quartz, mica-schist, &c., with which they could have no connexion. There can be no difficulty in accounting for the presence of such pebbles, as all the rocks older than the Llandovery stage are metamorphosed in the west of Ireland, and they probably formed the land-surfaces of the Upper Silurian period*. But how are we to account for masses of coral, broken shells, and crinoids of Upper Silurian age, in company with such rolled and transported blocks? Many of these fossiliferous masses are angular, friable, and evidently not far removed from their original position. They could not have been derived from the fossiliferous Upper Silurian beds which crop out on the north-west coast, *because these were buried underneath by several thousand feet* of conformable strata. The conclusion, therefore, that I have come to regarding their presence is that they were really formed *in situ*, in immediate proximity to the place where they are found, but have been loosened, drifted, and somewhat broken up by the current-action, which carried the pebbles of older metamorphosed rocks, and strewed them over the sea-bottom.

I may add that the occurrence of this conglomerate is not regarded by Sir R. Griffith as an obstacle to the acceptance of the view of the Silurian age of the "Dingle beds." He remarks, "Cases of derivative rocks sometimes occur in the same continuous series; and such cases are rather to be expected, if we suppose the existence, at points not far distant, of the contemporaneous operation of agencies of denudation and deposition"†. On the whole it is impossible to suppose that these fossiliferous fragments could have come from strata of the Llandovery and Wenlock stages, which were buried under several thousand feet of these same "Dingle beds," both formations being conformable.

b. *Killarney, Kenmare, Sneem, and Glengariff districts.*

That the main mass of the Dingle beds reappears in the promontories of Iveragh, Dunkerron, and Bear, rising into the highest elevations of the south-western highlands, is now universally admitted, and cannot be questioned. The rocks are similar in character, consisting of hard massive green grits, sometimes conglomeratic, surmounted by great beds of purple slate with bands of grit. Whatever, therefore, may be the age of the Dingle beds in the promontory of Dingle, such will it be in the districts of Killarney, Kenmare, and Glengariff.

A difficulty has, however, been experienced by both Griffith and the Geological Surveyors in the attempt to separate these beds from

* See 'Physical Geology and Geography of Ireland,' pp. 21–25.

† Journ. Geol. Soc. Dubl. vol. viii. p. 11.

the Old Red Sandstone in the Kenmare and Glengariff districts. In the Dingle promontory, as has been stated, the Old Red Sandstone is in the highest degree unconformable to the Silurian and "Dingle beds;" but it has been supposed that in the districts south of Dingle Bay, there is a gradual passage from "the Dingle beds" (Glengariff-grit series) up into the Old Red Sandstone and Carboniferous series. On this account it was found impossible to draw a boundary between the Old Red Sandstone and Glengariff-grit series, and the whole is coloured "Old Red Sandstone" on the Survey maps*. Again, in the words of Griffith, the matter is thus stated:—"Here, at the very threshold, we are apparently met with an insurmountable difficulty, and that is, that we actually find the Glengariff grits gradually conforming upwards, not only into the Old Red Sandstone . . . . . but also, as a matter of course, conforming to the plant-beds of the Yellow Sandstone, such as those of the Coomhola or Roughty rivers, as well as to the Carboniferous slate, the Lower and Upper Limestone, and the Coal"†. Certainly, if this "apparently" conformable passage was a reality, it would present a very strange and unusual phenomenon in geological science; for it would amount to this, that within the short distance across Dingle Bay we should have two formations, on one side in the highest degree discordant to one another, and on the other, concordant, and passing insensibly the one into the other. On the first consideration, therefore, the supposition is very improbable, because it may well be questioned if such an amount of disturbance and denudation as took place between the formation of the "Dingle beds" and the Old Red Sandstone could be confined to the narrow space of the Dingle promontory. As a matter of fact, however, I believe the supposition is entirely groundless, and arises from the resemblance which exists between the upper part of the Old Red Sandstone and the upper beds of the "Dingle" or "Glengariff-grit" series.

For the purpose of investigating this question, my colleagues and I visited the sections on both sides of the Roughty river at Kenmare, also at Sneem, which lies about twelve miles west of Kenmare, on the northern shores of Kenmare Bay, and lastly at Glengariff; and we ultimately arrived at the conclusion that at all these points the Lower Carboniferous beds rest directly upon the "Glengariff" or "Dingle beds," *the Old Red Sandstone being altogether absent.* If this be so, there can be no such passage as that supposed; on the contrary, there is a wide *hiatus*, a whole formation being absent at the line of junction. I shall now give a brief account of each of these sections, beginning with those in the neighbourhood of Kenmare.

1. *Kenmare Sections.*—The first is one near Roughty Bridge, about three miles above the village of Kenmare, and on the south bank of the Roughty river. It is of special interest, as it commences in the Carboniferous Limestone, which lies in a narrow trough. The beds dip at high angles, 70°–80°.

The upper portions of the beds underlying the Carboniferous slates

* See *suprà*, note by Prof. Jukes, p. 701.

† Journ. Geol. Soc. Dublin, vol. viii. p. 11.

and grits were considered to be "Upper Old Red Sandstone," but in reality they in no way differ from the beds of the Glengariff-grit and slate series. This view is confirmed by the examination of the beds for several miles on both banks of the river; and we therefore conclude that the Lower Carboniferous beds rest directly on the Glengariff-grit series, the Old Red Sandstone being altogether absent.

Prof. Jukes and Sir R. Murchison have drawn attention to this section as illustrating the rapid thinning of the Lower Carboniferous slate and Coomhola-grit series as compared with their development at Bantry; this explanation seems to me insufficient.

2. *Section between Kenmare and the Suspension Bridge.*—In this section hard green grits and purple slates, characteristically representing the "Glengariff-grit series," immediately underlie the Lower Carboniferous beds, so that there is clearly no space for any of the strata representing the Old Red Sandstone. The purple slates belonging to the upper division of the series are well laid open in the river Sheen, above its confluence with the Roughty.

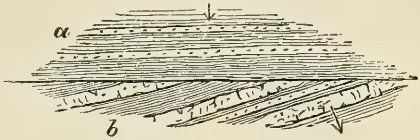
3. *Section at Sneem.*—The sections in the hills to the east of Sneem are remarkable for their continuity through a vast thickness of strata from the Lower Carboniferous beds downwards. At Knockanamadane and Knocknagullion, a thickness of beds of not less than 8000 feet may be traversed bed by bed, maintaining a steady dip towards the S.S.E. at angles of 60°–70°. The beds belonging to the "Glengariff series" consist principally of purple slates with occasionally beds of green grit, and these are overlain by beds which I consider to be Lower Carboniferous. The first section we visited is that laid open in the bed of the Tahilla river, which falls into Coongar Harbour. Commencing at the chapel by Tahilla Bridge, we find ourselves on dark grey and blue slates which yield fossils of Lower Carboniferous age. Below these come olive-grey and greenish grits, sometimes calcareous; and at a distance of about 500 yards above the bridge we arrive at the junction of the Lower Carboniferous with the "Glengariff-grit series," the Old Red Sandstone being evidently absent. At this junction there is some appearance of unconformity between the two formations, several beds of Carboniferous grit apparently terminating obliquely against the purple slates of the "Glengariff series." I here give a section and plan of this very interesting spot (fig. 3), as it thoroughly satisfied us of the complete absence of Old Red Sandstone, and that we had here representatives of formations separated from each other by the wide interval of a whole geological period.

4. Several other sections in the neighbourhood of Sneem go to confirm the view of the entire absence of the Old Red Sandstone; for on descending the mountains towards the coast, you pass over the highly tilted edges of similar beds of purple slate, several thousand feet in thickness, and then reach the grey grits and olive-coloured shales of the Lower Carboniferous series. The notion, therefore, of a passage upwards from the Glengariff beds into the Carboniferous through the Old Red Sandstone seems to have been founded on a miscon-

ception of the relations of the beds, so far, at least, as the valley of the Kenmare river is concerned.

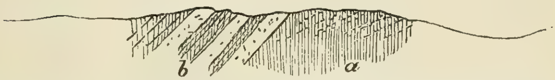
Fig. 3.—*Plan and Section in the Tahilla river near Sneem, showing junction of Carboniferous and Glengariff Beds.*

Plan.



Note.—The obliquity is perhaps slightly exaggerated in the plan.

Section.

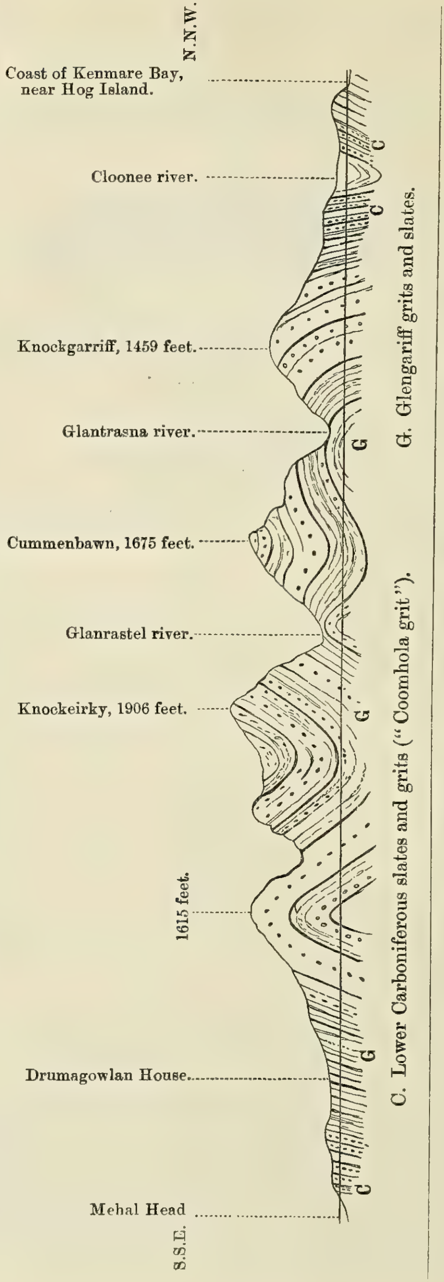


a. Purple slates, cleavage vertical (Glengariff slates), dip uncertain.
b. Hard grey grits, with bands of slate resting with apparent unconformity on the purple slates.

5. *Glengariff Section.*—The rugged promontory which separates Kenmare river from Bantry Bay, and which is deeply indented by Glengariff and Adrigole harbours, falls short of the elevation of the Reeks, but is perhaps not less interesting to the physical geologist than the Reeks themselves, owing to the examples it affords of contortions of strata, atmospheric waste, and glacial erosion. The hard and massive beds of grit, often naked or scantily clothed with herbage, are thrown into several grand folds, and often broken off along scarped and serrated ridges, or isolated pyramidal hills, as represented in the following section (fig. 4). Notwithstanding the apparently complex arrangement of the beds, the general structure of the ridge is that of a crenulated arch, in which the lower beds of grit rise to the surface in the centre, and the upper beds of purple slate occupy the sides, dipping beneath the Carboniferous beds which form the shores of the bays and the sides of the valleys which lead down to them.

Excellent sections, showing the junction of the "Glengariff beds" and the Lower Carboniferous or "Coomhola beds," are shown both along the Bantry and Glengariff road and in the banks of the Coomhola river. Both tell the same tale, namely, the junction of the former with the Carboniferous beds, and consequent absence of representatives of the Old Red Sandstone. On following the section along the Bantry road, we had little difficulty in determining the exact line of division between the two formations, which may be observed near the bend of the road, about 1½ mile S. of Glengariff Church. Here the beds of purple slate and hard coarse green grit of the Glengariff series give place to the olive-green slates and

Fig. 4.—*Section from Mehal Head to Kenmare Bay**. (Horizontal scale, $\frac{1}{2}$ mile to 1 inch; vertical, $1\frac{1}{2}$ mile to 1 inch.)



* Reduced from the "Explanation" to sheets 192 & 199 of the Geological Survey, p. 38.

thin-bedded grits of the Carboniferous. All the beds dip towards the S.S.E. at angles varying from 60°–80°.

6. Not less decisive is the boundary as shown in the fine section of the Coomhola river, which flows into the head of Bantry Bay. This section is described by Professer Jukes in the memoir above quoted. The Coomhola grits, interbedded with grey and black slates with Carboniferous fossils, give place, a few yards north of Coomhola Bridge, to the massive purple grits and slates of the older formation.

Supposed conformity of the Glengariff Series and the Carboniferous Beds.

Considering that in the Dingle promontory the Glengariff-grit series occupies a position of extreme discordancy to the Old Red Sandstone, and therefore to the Carboniferous beds above, there is a *primâ facie* reason for supposing that these formations would be found in a somewhat similar relationship in the region to the south of Dingle Bay. The evidence of this is, however, very small, so much so as to give rise to the impression to which I have already referred, namely, that, as expressed by Prof. Jukes, "from the highest bed of Carboniferous slate as deep down as observation has allowed us to penetrate (into the Glengariff-grit series), is one great and apparently continuous series of sandstones, or gritstones and clay slates"*. It is a common observation how deceptive are such "*apparent*" conformities, because beds which are widely separated in geological time, if they should happen to be similarly placed as regards the horizon, may easily be considered continuous. Whether, if the two sets of beds forming the Glengariff, Kenmare, and Killarney districts were but slightly inclined to the horizon, a clear unconformity would be observable, I am unable to say; it is not improbable. But if beds which are only slightly unconformable to each other are both subjected afterwards to tangential forces, causing them to assume a series of sharp flexures, and to rise to the surface at high angles, as is actually the case, it is clear that the original unconformity, whatever it may have been, will have been so completely superseded by the more recent flexuring that it will be obscured and be incapable of observation unless in transverse sections of great depth. It is thus I account for the apparent conformity of the Carboniferous and the Glengariff grits and slates in the regions now under consideration. The flexuring of the strata along approximately east and west axes after the Carboniferous period has been of so intense a nature as to completely overmaster whatever discordant inclinations may have previously subsisted between the two formations. But whether there is a real or only apparent conformity is a question which cannot affect the relation of the beds or the determination of their geological position; certain I am, in any case, there is not a "continuous series," but, on the contrary, a wide gap in the succession of the beds represented by the absence of the Old Red Sandstone in this district.

I feel satisfied that in this district a whole geological formation —that of the Old Red Sandstone—which in the adjoining districts

* Explanation to sheets 192 & 199, p. 8.

of Cork, Tipperary, and Waterford attains to important vertical dimensions, is entirely absent; consequently there can be no passage from the Glengariff grits and slates into the Carboniferous beds.

Unconformable overlap upon the Glengariff Beds.

A detailed examination of the working maps of the S.W. of Ireland, carried out with the assistance of Mr. A. M'Henry, has developed the following remarkable results bearing upon the past and present relations of the Glengariff series to the Old Red Sandstone and Carboniferous beds, proving beyond question their unconformity here as well as in the Dingle promontory. If we take a series of transverse sections along a line drawn from the extreme S.W. of Cork or Kerry to the N.E. near the border of Cork and Waterford, the following will be found to be the relative positions of these beds, as illustrated by the diagrams (figs. 5–8).

Fig. 5 shows these relations diagrammatically and in plan. It will be observed that at the extreme left, or S.W. direction, in the district of Dunmanus, Bantry, and Glengariff Bays, the Lower Carboniferous slate (1) rests directly upon, or against, the Glengariff beds (5). In the centre the overlap is not so great, as the Yellow Sandstone (2) rests directly upon, or against, the Glengariff beds (5); and at the extreme right or N.E. direction, in the district between Cork and Mallow, the overlap is still less, for the Old Red Sandstone and Conglomerate (3, 4) rests directly upon or against the Glengariff beds. These relations are still further illustrated in the three transverse sections (figs. 6, 7, and 8). Hence it will be observed that while the formations 1, 2, 3, and 4 are everywhere conformable to each other, they are everywhere unconformable to No. 5. There has, therefore, been a deeper depression towards the south-west of the old land-surface formed by the Glengariff beds, or a subsequent greater elevation and denudation towards the north-east after the Carboniferous period. The case of the S.W. of Ireland is somewhat comparable to that of the overlap of the Upper Silurian upon the Cambrian beds from Herefordshire towards the Longmynds*.

Note.—The view of the relations of the beds above given has since been abundantly confirmed by the detailed re-survey of the Cork district by Mr. M'Henry during the past summer (1879).

III. Comparison with Sections in Galway and Mayo.

If any further evidence regarding the age of the Dingle beds than that already adduced were required, it would be found in a comparison with the Upper Silurian rocks on the banks of Killary Harbour in West Galway and Mayo. Here we find precisely similar beds, sufficiently

* As I have endeavoured to show elsewhere (Geol. Mag., Dec. 1878), I believe this region to have been a land-surface or shoal water during the deposition of the marine Devonian beds of Devonshire and the Rhine; nor was it resubmerged till towards the uppermost Devonian period. In this view, I am happy to say, Mr. A. Champernowne concurs (Geol. Mag., March 1879). To this subject I purpose on another occasion to return.

Fig. 5.—*Plan showing the relations of the Glengariff Series, Old Red Sandstone and Carboniferous, in the S.W. of Ireland.*
(Distance about 80 miles.)

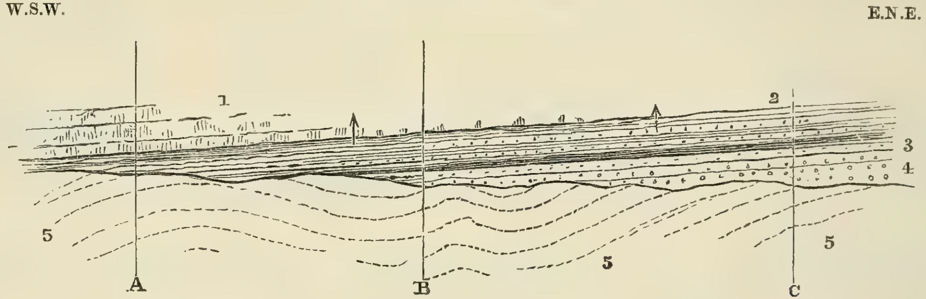


Fig. 6.—*Section at* A (fig. 5).

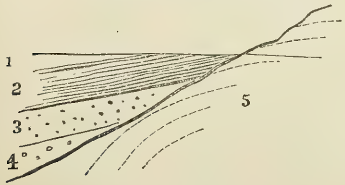


Fig. 7.—*Section at* B (fig. 5).

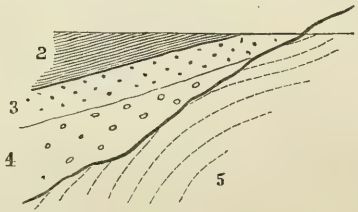
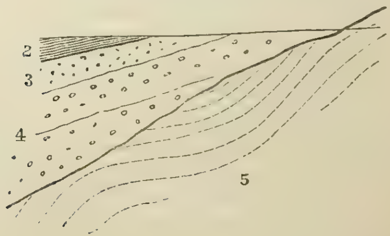


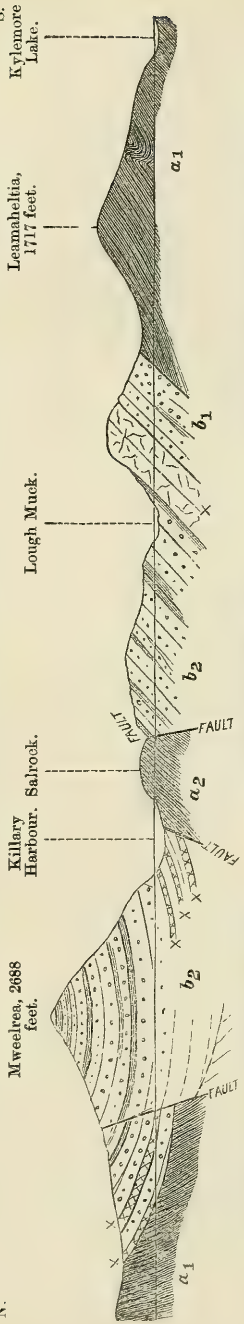
Fig. 8.—*Section at* C (fig. 5).



Conformable Beds:
- 1. Lower Carboniferous slate (and Coomhola grits).
- 2. Kiltorcan Beds (" Yellow Sandstone" of Griffith).
- 3, 4. Old Red Sandstone and Conglomerate.

5. Glengariff grits and slates.

Fig. 9.—*Section across the Killaries, from near L. Cunnel to Kylemore (details omitted).* (Scale 1 inch to 1 mile.)



a_1. Metamorphosed Lower Silurian beds. b_1. Upper Llandovery beds. ×× Contemporaneous felstones and porphyries.
a_2. Unaltered Lower Silurian beds. b_2. Wenlock and Ludlow beds.

fossiliferous to place their age beyond question, and rising into lofty and rugged elevations like those we have been considering in Kerry. Amongst these is Mweelrea, the highest mountain in the west of Ireland, rising 2688 feet from the level of the sea. So similar are the rocks of this district to the "Dingle" or "Glengariff series," that the general description of one set would be applicable to the other.

The Upper Silurian rocks of West Galway and Mayo (fig. 9) consist of a great series of grits and conglomerates, purple and green slates, with beds of conglomerate and limestone towards the base. They contain sheets of felstone porphyry and ash of contemporaneous origin, and are fossiliferous at intervals throughout. These beds, which are of great (but unknown) thickness, comprise the Upper Silurian series from the Llandovery stage upwards into the Wenlock and Ludlow stages; but, as observed by Sir R. I. Murchison, it is impossible in the west of Ireland to separate the Upper Silurian series into those well-marked stages, characterized by beds of limestone and special fossils, which he himself originally recognized in the Silurian region. The Upper Silurian beds rest everywhere discordantly upon a floor of more or less metamorphosed Lower Silurian rocks, filling in old valleys and depressions, and often containing pebbles derived from the older formations. Mr. Kinahan separates the series into divisions, which are probably represented in Dingle and Kerry as under *:—

* Expl. Mem. sheets 93, 94, &c., p. 15 (1878).

Representative beds of the Upper Silurian Series in Kerry and Mayo and Galway.

Kerry (including Dingle).	*West Mayo and Galway.*
3. *Upper Slate Series.*—Bright red and purple slates, forming the shores of Dingle Harbour, also underlying the Lower Carboniferous beds at Sneem, Kenmare, Glengariff, &c. 3000 feet.	3. *Salrock Slate Beds.*—Bright red slates and shales, with bands of grit and one of limestone. *Lingula Symondsii, Pterinæa retroflexa, Trochus multitorquatus.* About 3000 feet.
2. *Glengariff-grit and Ferriter's-Cove Series.*—Massive green grits, sometimes pebbly, with beds of slate (Reeks and Killarney and Glengariff mountains, Great Blasket Island, &c.). The slate series of Dunquin coast, Ferriter's Cove beds, with volcanic ashes and traps, fossils of Wenlock and Ludlow species. About 10,000 feet.	2. *Mweelrea Beds.*—Green and purple grits, conglomerates, with beds of slate and shale. Volcanic ashes and felspathic lavas in the lower beds. Fossils of Wenlock and Ludlow species. 8000 feet.
1. *Smerwick and Sybil-Head Beds.*—Lying at the base of the Dingle section. Purple and brown and green sandstones, flagstones, and shales (no fossils). At Bull's Head, on the slope of Caherconree, Llandovery species have been found, *Favosites alveolaris, Cyathophyllum (Petraia) elongatum, Atrypa hemisphærica,* &c.	1. *Owenduff Series (Upper Llandovery).*—Green and grey grits, sandstones, shales, with brecciated limestone, with volcanic ashes and traps; base generally a conglomerate. Fossils:—*Favosites fibrosus, Cyathophyllum elongatum, Encrinurus punctatus, Illænus Bowmanni, Orthis reversa, Atrypa hemisphærica, Trochus multitorquatus,* &c. About 2000 feet.

From the comparisons above it will be observed that there is no essential difference between the sections in the two districts recorded. In both the fossils are chiefly plentiful in the beds representing the Llandovery and Wenlock series; and if in the upper beds of the Dingle series they are absent or scarce, such is also the case with the Mweelrea beds in Mayo. As regards thickness, both sections are incomplete; but we find in each case a great development of sedimentary strata, surpassing that of their representatives in the Silurian border districts of England and Wales, in which calcareous beds occupy a prominent position. To this feature I propose to return further on.

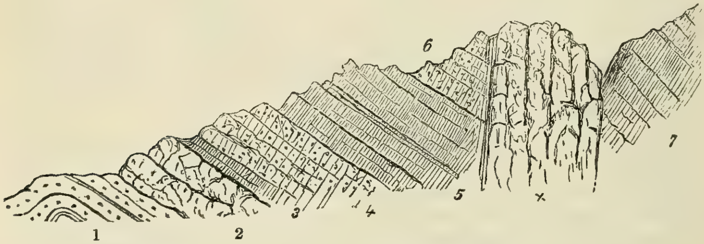
Volcanic Products.—Another feature of resemblance between the beds of the two districts, that of Dingle and Killarney, is the occurrence in both of the products of contemporaneous volcanic action. In the former district these are opened to us along the coast N. of Dunquin Harbour amongst the beds of the Wenlock and Ludlow stage, and on a large scale (fig. 1). They are several hundred feet in thickness, consisting of beds of felspathic ash and lapilli, more or less consolidated, traversed by cleavage-planes and passing from the condition of an agglomerate to that of the finest powder. The general dip corresponds to that of the Silurian beds, being south at 25°–30°; and immediately north of the entrance of Dunquin Harbour or Inlet there occurs a mass of intrusive greenish felstone, about 100 yards across, which may possibly be the consolidated lava filling the throat of the old volcanic vent, from which were blown out the fragmental materials above described.

These volcanic beds reappear along the southern shore of Clogher Bay, and in the adjacent islands, Beginish, Young Island, and Inishvickillane *.

The representative volcanic beds in the region of the Killarney mountains are included in the Glengariff-grit series, and therefore belong to a somewhat later stage than those laid open along the Dingle coast. These beds range through a distance of about ten miles from east to west, entering into the structure of the rugged elevations above Lough Guitane, and the slopes of Mangerton, Carrigwadra, and Killeen, north of the river Clydagh. These volcanic products consist of felstone, felstone porphyry, and beds of ashes and agglomerate, interstratified with the sedimentary slates and grits among which they are enclosed.

One of the principal vents of eruption was situated about a mile south of Lough Guitane, and is represented by the bold and sombre mass of Benaunmore. This rock consists of columnar light green felstone, with crystals of felspar thinly disseminated. It is traversed by several dykes of yellowish and pale pink felstone, and on either side beds of felspathic ash interstratified with the slate of the district. Mr. Du Noyer considers the ash-beds to bear evidence of aqueous deposition†. As illustrating the general character of these volcanic rocks, the following section (fig. 10) made by the writer and Mr. M'Henry on the hills of the Flesk valley, will probably be useful and sufficient. It will be seen, on referring to Fig. 9, that similar volcanic products occur among the Mweelrea beds.

Fig. 10.—*Section of Volcanic Beds in the Hills west of the River Flesk near Lough Athoonyastooka.* (Length of section about 600 yards.)



1. Green grits, &c.
2. Purple felstone porphyry.
3. Purple slate.
4. Beds of fine ash, cleaved.
5. Purple slate.
6. Beds of ash, cleaved.
7. Purple slate.

× Felstone porphyry, either a dyke or a volcanic neck.

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* See Geol. Survey Map, sheet 171, and "Explanation" thereto.

† "Explanation" sheet 184, p. 15. Prof. A. von Lasaulx, who, with Prof. F. Römer, visited this district in 1876, gives a graphic description of these rocks as they occur on the flanks of Mangerton, in 'Aus Irland,' p. 81 *et seq.*

On the supposition that the beds on the flanks of the Killarney range, amongst which we find the volcanic rocks, are higher up in the series than those at the extremity of the Dingle promontory, it would appear that after the volcanic fires had become extinct in the latter district, they broke out in the region to the south, both, however, belonging to the same geological period. Still later (namely, during the epoch of the Carboniferous limestone) there were fresh outbursts of volcanic forces in the adjoining region of the county of Limerick, resulting in the formation of two distinct bands of lava, the lower augitic, the upper felspathic, and separated by a considerable interval of time represented by the formation of many feet of limestone. For examples of such intermittent outbursts in the same region in more recent times, we might refer to the volcanic district of Central France, where, along a tract of country extending for some fifty miles, we find a series of several hundred extinct craters, which were in activity at different periods ranging down from the Miocene into the Pliocene, or possibly even later, and where the older eruptions of Mont Dor and Cantal gave place to those of the Puy and the Vivarais.

Plant-remains.—Besides the "fucoid" markings which are common amongst some of the purple-slate beds throughout the mountains of Cork and Kerry, impressions of plants, belonging probably to the group of vascular cryptogams, have been found in several places, particularly in the mountains of Iveragh and Dunkerron, by the collectors of the Geological Survey. These have been referred by Mr. Baily to the genus *Sagenaria*. Tracks also, probably those of Crustacea, have been discovered, of which specimens are preserved in the collections of the Survey in Dublin. The occurrence of land plants allied to those forms which predominated in the Carboniferous period cannot be regarded as an argument against the view that the beds containing them are referable to the Upper Silurian period, as several instances of a similar kind have been recognized in North America. In this region plant-remains of the genera *Lepidodendron*, *Glyptodendron*, and *Sigillaria* have been found in beds ranging from the base of the Upper Silurian series into the Devonian and Carboniferous *. It is necessary to observe, however, that the specimens of these plants in the collection of the Survey have all the appearance of having been obtained from the Lower Carboniferous beds. The rock is fine greyish-blue grit, unlike that which prevails amongst the Glengariff beds. In either case the occurrence of plants does not, as it seems to me, affect the question of the age of these beds †.

* These have been mentioned by Dr. Dawson, Prof. James Hall, Prof. Lesquereux, Prof. Claypole, and others, and are cited by the last-named observer, in a paper recording a fresh discovery, in Geol. Mag., Dec. 1878.

† Since the above was written, the spots have been re-examined by Mr. Baily, and there seems little doubt of the occurrence of the plants in the Glengariff beds.

IV. Relations of the Upper Silurian Series of the south-west of Ireland to those in the Silurian Region of England.

From what has been said, it will be observed that, along with the late Sir R. Griffith, I regard the great series represented in the Dingle promontory, from the "Sybil (Upper Llandovery) beds" to the highest of the "Dingle beds," as the equivalents of the whole Upper Silurian series of the typical Silurian region bordering the Severn and Wye. Owing to the occurrence of considerable beds of limestone and distinctive characters, both petrological and palæontological, the Upper Silurian series of England and Wales is divisible into well-marked stages, as established by Murchison; such, however, is not the case in the west of Ireland. This has been acknowledged by Sir R. Murchison himself in reference to the district of West Mayo and Galway, and is not less true in reference to the districts of Dingle and Kerry. The remarkable statement by the late Prof. Jukes which I have already referred to, may be regarded as conclusive* on this head; he states that "the Sybil-Head beds, the Smerwick beds, and the Dingle beds are all purple slates and conglomerates of exactly similar general characters, so that it would be impossible to distinguish them." This statement, taken from his notebook as a general conclusion after an examination of the whole section from bottom to top, completely confirms the view I have been advocating in this paper. If we compare the sections in the S.W. of Ireland with those in the typical Silurian region, we shall find the representative strata somewhat as follows:—

Upper Silurian Series of England and Ireland.

England (*Severn and Wye District*).		ft.	*Ireland* (*Kerry*).
Ludlow beds and passage-beds		150	Dingle beds or Glengariff Grits, 10,000 feet.
Lower.	Aymestry Limestone	40	
	Shales, &c.	700	
Wenlock beds.	Wenlock Limestone	280	Ferriter's Cove and Smerwick beds.
	Wenlock Shale, Denbighshire Grits	3000	
	Tarannon Shale	1500	
Upper Llandovery beds.	Upper Llandovery limestone and sandstone	1000	
Upper Silurian beds		6670	

From the above comparisons it will be observed that there is a large accession of materials in the upper portion of the series in the south of Ireland as compared with the representative beds in the south of England and borders of Wales. In both regions the Upper

* This statement was only discovered by Mr. O'Kelly (Oct. 19, 1878) in one of Prof. Jukes's notebooks, dated May 31, 1858, after the above paper was almost written, and is accompanied by a sketch and section intended as "a key to the whole promontory," by which he shows that the fossiliferous Ferriter's Cove beds are in part repeated in the Smerwick beds, owing to an inversion.

Silurian beds are highly discordant to the Lower; and from the absence of these beds in the centre and east of Ireland, where the Lower Silurian beds reach the surface, we may conjecture, after making allowance for denudation, that these districts were land surfaces through a portion at least of the Upper Silurian period. The physical geology of this part of the British Isles is therefore in harmony with that which obtained in the region of Wales, Shropshire, and the borders of the Wye; over this region, as Professor Ramsay has pointed out, the Lower Silurian and Cambrian rocks formed a land surface at the commencement of the Upper Silurian epoch, the extent of which gradually diminished by submergence until it was converted into several islets towards the close of that period*. Possibly this early land surface embraced St. George's Channel, the bordering districts of Waterford, Wexford, and Wicklow, stretching into the centre of Ireland, as around the Galtees, the Silver-mine, and Commeragh mountains we find the Lower Silurian beds overlain directly by the Old Red Sandstone. The Upper Silurian basin must have extended far into the Atlantic, and have been of enormous depth in the region bordering the coast of Kerry, while towards the north it was bounded by the crystalline metamorphosed Lower Silurian rocks, which appear in West Galway and Mayo, and enclose the Upper Silurian trough of the Killaries and Mweelrea.

It is possible that the upper portion of the Glengariff series is newer than the uppermost of the Ludlow beds. The existence of the "Upper Ludlow bone-beds" shows that the border districts of Wales were but slightly submerged at a time when the Upper Glengariff beds may have been deposited in deeper waters. The Upper Glengariff beds may possibly form the connecting links between the Upper Silurian and Lower Devonian series.

V. Relations of the Old Red Sandstone to the Dingle Beds, &c.

Throughout the whole of the south and centre of Ireland the Old Red Sandstone is everywhere unconformable to the rocks on which it reposes, while it passes up by conformable stratification into the Carboniferous series. In the Dingle promontory it rests on various representatives of the Upper Silurian series, from the Llandovery beds upwards, in that highly discordant manner so well described by Griffith and the officers of the Geological Survey, overlapping many thousand feet of strata (see fig. 3). Great indeed have been the terrestrial disturbances and the extent of denudation in this part of Ireland between the epoch of the deposition of the Dingle beds and that of the Old Red Sandstone. At least 12000 feet of strata have in some places been removed during this period. Again, the Old Red Sandstone wraps round the dome-like masses of Lower Silurian beds which rise from beneath the central plain, or sometimes rises into higher elevations, crowning the heights of Galtymore and forming the grand escarpment of the Commeragh mountains. Traced towards the north and east through Waterford and Kilkenny,

* Physical Geology of Great Britain, 5th edit. p. 92.

it becomes attenuated, and ultimately terminates against the flanks of the old granite ridge, where it is conformably overlapped and disappears beneath the Carboniferous Limestone, which, in turn, abuts on the same granitic ridge at Gores Bridge.

Throughout this tract the Old Red Sandstone consists of dull, reddish-brown, rather soft sandstone, often pebbly, and sometimes supported by thick masses of breccia and conglomerate of quartz, jasper, trap, and Lower Silurian grit. The upper beds contain bands of reddish shale, and the whole series attains in Co. Waterford a thickness of about 3200 feet*. The formation, indeed, in its usual condition, bears a strong resemblance to the "Pebble-beds" of the New Red Sandstone of Lancashire and Cheshire; and, on the other hand, has but a faint resemblance to the "Dingle beds" and Glengariff-grit series." The contrast has long ago been pointed out by the late Mr. John Kelly, F.G.S., in the following passage, which I quote in preference to using language of my own:—

"The Old Red Sandstone has two prominent points of character which, in all parts of Ireland, stand out in relief and make it a rock which cannot be mistaken for any other. The first is a thick band of conglomerate at its base, which generally contains quartz, jasper, and other pebbles. The second that this conglomerate always lies unconformably on the inferior rock. The other characteristics are that the lower part of it is usually of a red colour; it passes upwards into yellow; but both are comparatively soft, and easily split for economic use into rudely rectangular blocks, a circumstance quite at variance with, and distinguishing it from, the Silurian grits [meaning Glengariff grits, &c.], which are so much affected by cleavage and so hard, that the blocks are quite refractory under the wedge, hammer, or chisel, and cannot be worked satisfactorily for building-purposes"†.

The upper portion of the formation consists of pale yellow and greenish sandstones and shales, sometimes containing pebbly beds, often rippled and flaggy, and containing remains of plants, freshwater bivalves, and fish, such as *Bothriolepis* (*Dendrodus*), *Coccosteus*, *Pterichthys*, *Glyptolepis elegans*. Palæontologically, this is the most interesting and important member of the whole group, and is, in all probability, the equivalent of that part of the Upper Old Red of Scotland containing the sandstones of Dura Den, with *Holoptychius* and other fishes, to which the Yellow Sandstone of the south of Ireland bears sometimes, curiously enough, a strong resemblance.

Professor Geikie has suggested that the Dingle beds or Glengariff Grits may be the representatives of the "Lower Old Red Sandstone" of Scotland ("Old Red Sandstone of Western Europe," part i. Trans. Roy. Soc. Edinb. 1878). If this be so, then they would be the marine representatives of lacustrine deposits. Both are unconformably overlain by (Upper) Old Red Conglomerate and Sandstone.

* "Explanation" to sheets 167, 168, &c. of the Geol. Survey Maps, p. 15.

† "Extracts" which were intended to be applied to Sir R. Griffith's Geological Map, published in 'Atlantis,' January 1859.

VI. General Conclusions.

From the above considerations, therefore, I am impelled to the conclusion that the great series of green and purple grits, conglomerates, and slates which rise into the highest elevations in the south-west of Ireland are of Upper Silurian age, a conclusion previously arrived at by the late Sir R. Griffith, the late Mr. John Kelly, and other geologists of eminence. Let me now briefly recapitulate the reasons *.

First. These beds form but an upper member of the fossiliferous Upper Silurian series of the Dingle promontory, with which they are connected both by conformity of stratification and similarity in the composition of the beds themselves.

Second. They are overlain, with the most extreme discordancy, by the Old Red Sandstone and Conglomerate, not only in the Dingle promontory, but, as I believe, throughout the south of Ireland, wherever the two formations happen to come together.

Thirdly. These beds are evidently the equivalents of the Upper Silurian series (at least in part) of the region of West Galway and Mayo ("Mweelrea and Salrock beds"), including the rocks on both sides of Killary Harbour, to which they bear a close resemblance.

Fourth. As these beds cannot be of Old Red Sandstone age, neither is it likely they can be the equivalents of the marine Devonian beds of Devonshire, Belgium, and the Rhine. Their place is, in all probability, below these, as I have already hinted. The most natural supposition therefore appears to be that they represent, in a greatly expanded form, the Ludlow series of the west of England and borders of Wales, and form a connecting link between the Upper Silurian and Lower Devonian formations.

Fifth. The absence or scarcity of fossils cannot be regarded as evidence in any way. Fossils are very scarce amongst the upper beds of Mweelrea and Killary Harbour, except in a few localities; but sufficient have been found to enable us to determine the age of the beds which contain them. I have also given reasons for believing that the fossils found in the conglomerate of Parkmore, near Ventry, are really of the age of the beds in which they occur.

Discussion.

Dr. Duncan remarked on the evidence of the occurrence of an enormous interval of time being represented by the great overlap described by the author, and stated that he did not feel disposed, on palæontological evidence, to include the Carboniferous Slate in the Devonian.

* In a paper published in the 'Geological Magazine' for December 1878, I have indicated the probability that the marine Devonian beds (Lynton Slates, Martinhoe beds, and Ilfracombe Limestones) fill up the gap which in Ireland intervenes between the Old Red Sandstone and the uppermost Silurian or Glengariff Grit and Slate series. In which case the "Pickwell-Down Sandstone" would represent the Old Red Sandstone of the south of Ireland.

Dr. Hicks expressed his conviction that the great series of truly metamorphic rocks in Ireland are not of Lower Silurian, but of Pre-Cambrian age. He further stated that a portion of the beds regarded as of Upper Silurian age by the author might belong to the Lower Silurian.

Prof. Ramsay remarked that Devonshire is still partly a *terra incognita* to the geologist, and that as soon as good ordnance maps of the country are produced a completely new geological survey of the country must be made. He had found, both in Westphalia and North America, that strata regarded as Lower Devonian are really Upper Silurian. He regarded the argument of Prof. Hull as nearly convincing. The Lower Old Red Sandstone has not the same relations to the Upper Old Red Sandstone in Ireland that the beds called by the same names in Wales and Scotland have. In the former case the Lower Old Red Sandstone of Prof. Hull is equivalent to the Upper Old Red of Scotland, which lies unconformably on the Lower Old Red of that country. In the Lower Old Red Sandstone of Scotland bands of rock, with Graptolites and Upper Silurian fossils, have been found by Prof. Geikie. He thought that the Upper Old Red Sandstone of Griffith had as much right to be called Carboniferous as Devonian. These points only confirmed the views of Prof. Hull.

Mr. Ussher stated that there is a perfectly conformable series between the Foreland Grits and the Culm-measures of Devonshire. He thought that Devonshire must still be regarded as affording a typical series.

Mr. Jukes-Browne wished to ask a few questions. Prof. Hull's argument appeared to be that, because rocks of a certain character occurring in the Dingle promontory were found to be absent in the Inveragh promontory, it was therefore to be assumed that there must be an unconformity in the latter district as well as in the former; and proofs of an apparent overlap were adduced in support of this. But the evidence brought forward was mainly of a theoretical nature; the explanatory section showing the possible overlap was not supported by any actually observed section in which an overlap was visible. He would like to be assured on what evidence the Glengariff Grits were correlated with the Dingle beds, and why the Upper Old Red Sandstone was banished from the neighbourhood of Sneem and Kenmare, as well as from the head of Bantry Bay, though it was laid down on the maps of the Geological Survey of Ireland and described in the 'Memoirs.'

The succession of rocks in the Dingle district was so different from that in the country south of Dingle Bay, that it was really doubtful whether the two series could be compared.

Few men had gained a greater knowledge of the S.W. of Ireland than the late Mr. Jukes, whose views Prof. Hull had quoted; but Mr. Jukes had not been able to discover any evidence of discordant stratification in the series of rocks referred to.

The Author insisted that in a number of sections the Lower Carboniferous Slate and Upper Old Red Sandstone are seen lying directly upon the Glengariff Grits. In reply to Prof. Ramsay, he stated that Prof. Dewalque had arrived at the conclusion that the marine Devonian beds of Devonshire and Old Red Sandstone of Hereford were different conditions of beds on the same horizon. In reply to Dr. Hicks, he stated that all palæontologists were agreed as to the Upper Silurian age of the beds below the Glengariff Grits; and the Lower Silurian age of the metamorphic rocks is proved by the occurrence in them, when unaltered, of Lower Silurian Graptolites. In reply to Dr. Duncan, he stated that the Carboniferous Slate of Ireland was probably on the same horizon as the Upper Devonian of Devonshire.

55. *Further Discoveries in the* Cresswell Caves. By Prof. Boyd Dawkins, M.A., F.R.S., F.G.S., and the Rev. J. M. Mello, M.A., F.G.S., *with Notes on the* Mammalia *by the former.* (Read June 11, 1879.)

Contents.

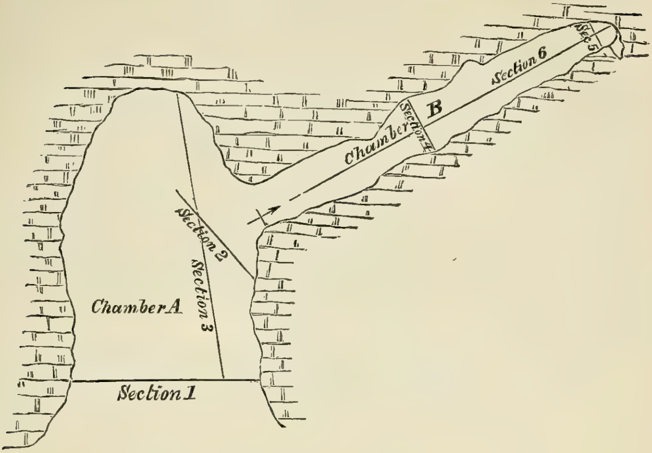
Introduction.

When the exploration of the Robin-Hood and Church-Hole Caves at Cresswell Crags was brought to a close, in 1876, one of the lesser caves remained for further examination, known under the name of Mother Grundy's Parlour, from a certain old gipsy who is said to have chosen it for her home. It had evidently been disturbed by previous diggings, some of which are said to have been carried on by a resident at Cresswell in search of treasure revealed to his wife in a dream ; and this fact, coupled with an unsuccessful trial which we made down as far as the unfossiliferous sand of the other caves, discouraged us from digging it out at that time. We have to thank Mr. John Young for calling our attention to the fact that there still remained in the Cresswell Crags an undiscovered chapter in the history of the cave-fauna of the district. He had purchased a tooth of Hippopotamus in London, which had been obtained from the Cresswell Crags by Messrs. Duffy and Gain, of Tuxford; and as this animal had not been met with in our previous explorations, we resolved to dig out Mother Grundy's Parlour without further delay. Accordingly in November last the exploration was begun, under the careful supervision of Mr. Knight, of Owens College, while we visited the place from time to time to direct the work.

Mother Grundy's Parlour is a shallow semicircular chamber (plan, fig. 1), in a low crag at the eastern extremity of the ravine and on its northern side: it might almost be described as a shallow rock-shelter, being 35 feet deep by 22 feet wide. On its eastern side, near the back (see fig. 1), was a small cavity about 4 feet wide by 2 feet 6 inches high, blocked up to the roof with fragments of rock and earth ; this proved ultimately to be the mouth of chamber B of the ground-plan.

We began the exploration by cutting a trench in the floor on the eastern side of the cavern, and after penetrating through the disturbed soil found that the underlying beds were *in situ*, and contained bones and teeth in considerable abundance.

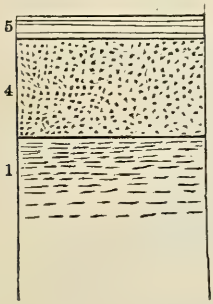
Fig. 1.—*Ground-plan of the Parlour Cave.*
(Scale, $\frac{1}{20}$ inch to 1 foot.)



THE EXPLORATION OF CHAMBER A.

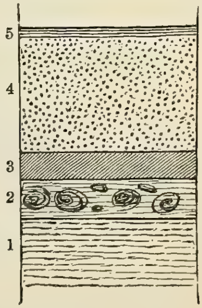
Surface-soil.—The floor was covered with a few inches of dark surface-soil and numerous large blocks of limestone, and contained near the mouth fragments of charcoal, burnt clay and bones, together with a considerable number of flint chips and a few flint flakes.

Fig. 2.—*Section* 1, *in Chamber A* (fig. 1).



	ft.	in.
1. White calcareous sand; no remains	(?)	
4. Red sandy cave-earth, with a few bones	2	6
5. Surface-soil; charcoal and flint implements at base	5	0

Fig. 3.—*Section* 2, *in Chamber A* (fig. 1).



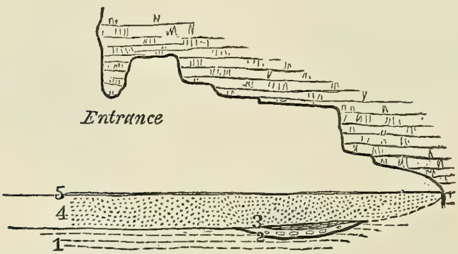
	ft.	in.
1. White calcareous sand; no remains	(?)	
2. Ferruginous yellow and red sand; bones	1	0
3. Red clay; bones	0	6
4. Red sandy cave-earth; bones, &c.	3	0
5. Surface-soil	0	4

This was obviously the equivalent, in point of age, of the superficial layer in the Robin-Hood and Church-Hole caverns (see figs. 2 & 3, No. 5).

Red Sandy Cave-earth.—Below the surface-soil was a bed of light red cave-earth, which, on being followed up towards the mouth of Chamber B, was found to increase in thickness, varying from 3 feet 6 inches opposite the mouth of chamber B to 2 feet 6 inches at the entrance (see figs. 2 & 3, No. 4). The remains of animals were abundant, consisting principally of Bison, Reindeer, Bear, Wolf, Fox, and Hyæna, the coprolites of the last of these animals being very numerous, having been preserved by the dryness of the cavern. In the other caverns, which were wet, they had been crushed out of shape into layers by the repeated trampling of the animals. A few quartzite pebbles, some rudely chipped, were also met with. In the upper parts a few flint flakes were discovered, but they were probably derived from the superficial soil.

Red Clay and Ferruginous Sand.—This stratum near the entrance of the cave rested on the unfossiliferous white sand (see fig. 2), while in figs. 3 & 4, near the entrance of chamber B, two strata were intercalated—a red clay, No. 3, and a highly ferruginous sand, No. 2, which revealed the presence of a fauna hitherto unknown in the Cresswell Caves. In the ferruginous sand, at the point where Section 2 was taken, were the fragments of the skull and other bones of Hippopotamus, together with teeth of *Rhinoceros leptorhinus* of Owen (*R. hemitœchus* of Falconer), along with numerous skulls and jaws of Hyæna and some remains of Bison. It is evident that the skull of a Hippopotamus had been left by the Hyænas in this spot; but unfortunately it had been broken to pieces by the previous diggings which led us to re-examine the cave. The ferruginous sand (No. 2) ultimately proved to be purely local (see fig. 4).

Fig. 4.—*Section* 3, *Chamber A* (fig. 1).
(Scale, $\frac{1}{20}$ inch to 1 foot.)



		ft.	in.
1.	White calcareous sand; no remains		
2.	Ferruginous yellow and red sand; bones	1	0
3.	Red clay; bones, &c.	0	6
4.	Red sandy cave-earth; bones, &c.	3	0
5.	Surface-soil		

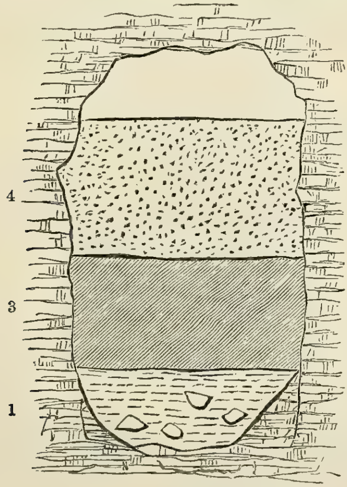
Towards the back of chamber A the strata thinned out rapidly and were so unproductive that we thought it advisable to leave it unexplored, and turn to what proved to be the mouth of Chamber B (fig. 1).

THE EXPLORATION OF CHAMBER B.

The Red Sandy Cave-earth.—The deposits in Chamber B filled it up to the roof, and consisted of the strata previously described, with the exception of the surface-soil (No. 5) and the ferruginous sand (No. 2).

The red sandy cave-earth (see figs. 5, 6, & 7, No. 4) had been disturbed here as in chamber A; it contained bones and teeth of Bison, Reindeer, Hyæna, and Bear. At a distance of 19 feet 6 inches from the entrance, and on the north side, a human skull was met with, in a small recess in the wall, at a depth of 2 feet 9 inches from the surface, here in contact with the roof. Close to it, and above it, were the vertebra of a bison and a quartzite splinter. It is, however, in spite of this evidence, in all probability, as we shall see presently, of a later age than the associated Pleistocene remains.

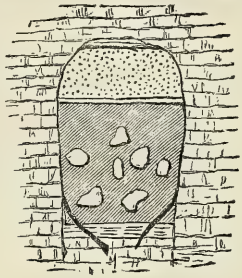
Fig. 5.—*Section* 4, *Chamber B* (fig. 1).



	ft.	in.
1. White calcareous sand; no remains		
3. Red clay; bones, &c.	3	0
4. Red sandy cave-earth; bones, &c.	3	6

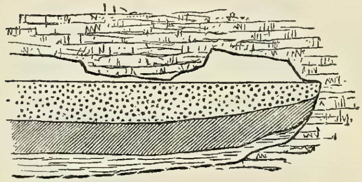
The Red Clay.—The red clay (No. 3) as it passed into chamber B gradually increased in thickness, attaining a maximum of 3 feet 3 inches at the further end. It was very stiff and contained the remains of Hyæna, Bison, Hippopotamus, and *Rhinoceros leptorhinus*, but no implements. It rested immediately on the unfossiliferous white sand (No. 1). At the far end of the chamber blocks of limestone were imbedded in the clay, and between these many bones of Bison were firmly wedged, which were extracted with considerable difficulty. The total thickness of the deposits in chamber B varied from about 9 feet near the entrance to 5 feet at the end (figs. 6 & 7).

Fig. 6.—*Section* 5, *Chamber B* (fig. 1).



	ft.	in.
1. White calcareous sand; no remains		
3. Red clay, with blocks of limestone and bones	3	3
4. Red sandy cave-earth, with bed of sand (2 in.) at base; bones ...	1	8

Fig. 7.—*Section* 6, *Chamber B* (fig. 1).
(Scale, $\frac{1}{20}$ inch to 1 foot.)



1. White calcareous sand.
3. Red clay.
4. Red sandy cave-earth.

Relation of these Deposits to those in the other Caves at Cresswell.

On comparing the above strata with those previously explored in the Cresswell Crags, it is obvious that we must correlate them with the earlier rather than with the later series. The breccia and the upper cave-earth of the Robin-Hood and the Church-Hole caves, with their highly finished suite of palæolithic implements and numerous bones gnawed by hyænas or crushed by man, are conspicuous by their absence. When, however, we compare the red sandy cave-earth, No. 4, of Mother Grundy's Parlour with the red sand underlying the cave-earth in the two above-mentioned caverns, they will be seen to belong to the same stage in the history of the caves of the district. The few rude quartzite tools, and the numerous bones of animals, remarkably perfect and free from the gnawing of hyænas, are to be noted in both. It must, however, be remarked that the horse, so abundantly represented in this stratum in the other caverns, is here only represented by two teeth; while the remains of Bison, very rarely found in the former, are numerous, the vertebræ and horn-cores, so universally eaten by hyænas in the other caves, being here for the most part intact.

The red sandy cave-earth, therefore, represents in this cave the oldest fossiliferous horizon in the others; and the underlying red clay, No. 3, and ferruginous sand, No. 2, are unmistakably to be referred to a still older period, the white sand, No. 1, without fossils being found alike in all the caves of the Cresswell Crags.

Notes on Pleistocene Mammalia.

If the accompaning list of Pleistocene species be examined it will be observed that in the older period of the red clay and ferruginous sand the animals inhabiting the district were very different from those found in the succeeding deposits in this and the other caverns. While the Spotted Hyæna, Fox, Bear, and Bison are common to both, the former is characterized by the presence of the Hippopotamus and leptorhine Rhinoceros, and by the absence of the Horse, Woolly Rhinoceros, and Mammoth, as well as by the absence of traces of Man.

Pleistocene Fauna of Mother Grundy's Parlour.

	Ferruginous Sand.	Red Clay.	Red Sandy Cave-earth.
Palæolithic implements	...	...	*
Spotted Hyæna (var. *H. spelæa*)	*	*	*
Fox (*Canis vulpes*)	...	*	*
Bear (? *ferox*, ? *arctos*)	...	*	*
Bison (*Bison priscus*)	*	*	*
Reindeer (*Cervus tarandus*)	...	...	*
Hippopotamus (*H. major = amphibius*)	*	*	...
Horse (*Equus fossilis*)	...	...	*
Leptorhine Rhinoceros (*R. leptorhinus*, Owen)	*	*	...
Woolly Rhinoceros (*R. tichorhinus*, Pal.)	...	...	*
Elephas	...	...	*

The palæolithic implements in the above list consist of pot-boilers and rude splinters of quartzite, and one imperfect *hache* of ironstone of the 'type Acheulien,' similar to that figured in this Journal from the Robin-Hood Cave (Q. J. G. S. vol. xxxiii. p. 593). The Bear (represented by 17 bones and teeth) probably belongs to the Grizzly species, *U. ferox*, found in the neighbouring caves. The Reindeer is represented by 38, and the Horse by 2, while the Bison and the Hyæna stand at the head of the list with 143 and 114 specimens. The remains of the Elephant, from the upper stratum, are too fragmentary to allow of specific determination.

The Hippopotamus is represented by fragments of skull and the complete molar series of both sides of the upper jaw, one premolar, two upper incisors, all belonging to one individual, a right upper maxillary with the permanent dentition just coming into play and replacing the deciduous series, three lower premolars, a pair of shoulder-blades, and some vertebræ. The remains imply the presence of at least three individuals, in none of which is the adult true molar dentition completed. All are young adults.

The remains of the *Rhinoceros leptorhinus* of Owen consist of thirteen teeth and fragments of teeth which correspond with the specific definition published in the Journal of this Society, 1867 (vol. xxiii. p. 215).

The following measurements, taken in inches at the base of the crown, are uniform with those already published in this Journal, and indicate a slight difference in the proportion of the two upper molars as compared with those from Lexden, Clacton, Grays Thurrock, and Durdham Down (*l. c.* p. 224):—

1. Antero-posterior taken along the outside of crown	1·9	1·95
2. Antero-transverse across the front lobe of tooth	2·32	2·4
3. Postero-transverse across hind lobe of tooth	1·9	2·15

Some of the Rhinoceroses were half-grown calves with the milk-dentition in various stages of wear.

Classificatory Value of Hippopotamus and Leptorhine Rhinoceros.

These two animals are so frequently companions in the caves and river-deposits in Britain, that there is reason for believing that they mark a stage in the zoology of the Pleistocene period. Both are southern species, the Hippopotamus being now confined to Africa, while the leptorhine Rhinoceros is to be viewed also as an extinct species of southern habit. They are associated together in no less than sixteen caverns and river-deposits which I have examined in this country, and are very generally accompanied also by the *Elephas antiquus*. The Hippopotamus is a survival from the fauna of the Pliocene, and is met with in the Preglacial forest-bed of Norfolk, in the Mid-Pleistocene deposits of the Thames valley, the Postglacial strata of Bedford, and the caves of Cefn and Pont Newydd, near St. Asaph. The leptorhine Rhinoceros occurs in the fluviatile strata under the Hessle clay near Burgh in Lincolnshire*, in the brick-earths of the Thames valley, and in the above-mentioned Postglacial caverns. As a rule, these animals are not met with in association with the Mammoth and the Pleistocene stages. They are, however, associated with the Reindeer in the caves of Kirkdale and Victoria in Yorkshire, of Cefn and Pont Newydd in the valley of the Elwy, and in the river-strata of Bedford, Brentford, London, and Peckham. It is therefore evident that they inhabited Britain while the arctic Mammalia were

* I have to thank Mr. Jukes-Browne for this locality.

present in the country, from which fact, coupled with their southern habit, I should feel inclined to consider them characteristic of that period in which the southern animals were living in this country, but were suffering from the competition of arctic invaders driven southwards by the lowering of the temperature—that is to say, in the middle stage of the Pleistocene, as I have defined it in my essay on the "Classification of the Pleistocene Strata by means of the Mammalia"*. It must be further remarked that these two animals were among those which the Palæolithic hunter saw when he arrived in this country, in his expeditions along the valleys now covered by the English Channel and the North Sea. They are found in one cave only in Britain, the cave of Pont Newydd, along with Palæolithic implements, which are fashioned out of quartzite, like those of the red sand in the Cresswell Caves †. They occur also in the Palæolithic river-gravels of Bedford and Peckham, along with implements of the type Acheulien of De Mortillet.

Prehistoric and Historic Mammalia.

The following list (p. 732) represents the principal remains referable to prehistoric and historic times. It differs in no important particular from that of the other caves in the Cresswell Crags, with the exception of the occurrence of fragments of four human skeletons, all belonging to children and youths, and all being found in the red sand. Those discovered in chamber A evidently were deposited in strata which had been disturbed by repeated diggings, and do not belong to the Pleistocene age. In proof of this we may mention that the head of an iron hammer was found by Mr. Knight at the bottom of the red sand.

The skull found in chamber B, also, at a distance of 19 feet 6 in. from the entrance and at a depth of 2 feet 9 in. from the surface, cannot be looked upon as belonging to the age of the red sand, although the passage was completely blocked up in some places, and there were no obvious evidences of disturbance around it. The recent bones belonging to the various animals in the accompanying list, scattered through the red sand, show that it has been disturbed since its deposition, certainly by the burrowing of foxes, rabbits, and badgers, and most probably by the hand of man. The Sheep or Goat, the short-horned Ox, and domestic Pig found in it were unknown in France, Germany, Belgium, or Great Britain in the Pleistocene age, and were introduced by the Neolithic herdsmen into Northern and Western Europe. This skull, therefore, cannot be viewed as a relic of one of the Palæolithic hunters in Derbyshire, but must be referred to their successors in the district.

The two skulls, sufficiently perfect to allow of the shape of the cranium being made out, belong to two types, well known in this

* Quart. Journ. Geol. Soc. vol. xxviii. p. 410.

† The asserted occurrence (Brit. Assoc. Rep., 1878) of traces of Man in the same strata as the leptorhine Rhinoceros and Hippopotamus in the Victoria Cave is founded on an unfortunate mistake.

Prehistoric and Historic Fauna of Mother Grundy's Parlour, 1878.

	Surface-soil and disturbed red sandy Cave-earth.
Human bones and implements	*
Wild Cat (*Felis catus ferus*)	*
Dog (*Canis familiaris*)	*
Fox (*C. vulpes*)	*
Marten (*Mustela martes*)	*
Badger (*Meles taxus*)	*
Stag (*Cervus elaphus*)	*
Roe (*C. capreolus*)	...
Horned Sheep or Goat	*
Celtic Shorthorn (*Bos longifrons*)	*
Pig	*
Hare or Rabbit	*
Rabbit	*

country and on the continent in the Neolithic and succeeding ages. That found in the passage B belongs to the long type (dolichocephali of Thurnam and Huxley, and according to Prof. Morrison Watson is hydrocephalic), while that found in chamber B belongs to the round-headed brachycephali of the same two authors.

The conditions under which the skull in chamber B was discovered were such that it might have been taken to have belonged to one of the Palæolithic inhabitants of the cave, had not the explorations been conducted with all possible vigilance. My experience of cave-exploration compels me to decline to accept any human bones as Palæolithic without the clearest stratigraphical evidence on the point, such as that offered by the human skull found by MM. Lartet and Chaplain Duparc in the cave of Duruthy, Sorde, in the Western Pyrenees. Not only is this evidence wanting in every one of the Palæolithic types from caverns selected by MM. de Quatrefages and Hamy, in their great work 'Crania Ethnica,' now being published, but in the two most important types it points to a contrary conclusion. The long skulls constituting the "type de Cro-Magnon" belong to an interment which is later than the Palæolithic remains in the rock shelter, because they are above them; and the round skulls of the Trou du Frontal are associated with domestic animals and pottery of a kind not uncommon in the Neolithic age. The so-called fossil man of Mentone may be referred to the same date as the polished stone axe found in the cave, and to be seen in the Museum at St. Germain, in 1876. The pottery found with human remains in the caves of Engis, Aurignac, Bruniquel, and Bize is identical with Neolithic pottery, and indicates that the interments are not Palæolithic but Neolithic in date. Pottery and domestic animals were alike unknown in the Palæolithic age.

The long skulls found in the above caves are of the same type as the long skulls referred to the Iberic population of Western Europe in the Neolithic age; and the round skulls cannot be distinguished from the Celtic or cognate Celtic peoples who invaded Europe, also in the Neolithic age, the former being identical with those of the interments in the long barrows, and the latter with those of the round barrows and of the tumuli of the Bronze age in Britain explored by the Rev. W. Greenwell. Both these peoples used caves for sepulchres in Spain, France, and Belgium in the Neolithic age.

From these considerations I find it impossible to follow MM. de Quatrefages and Hamy in their ethnological inferences, which are based on the assumption that in the above cases the human remains belong to Palæolithic men, who lived on in the same area through the stupendous changes which banished some and destroyed other Pleistocene Mammalia—changes in geography and in climate—into the Neolithic age, without, be it remarked, preserving any traces of the art of reproducing animal forms or of the ordinary Palæolithic implements of the men of the caves. I am unable to believe with M. de Quatrefages that any of the present inhabitants of Belgium can be traced as far back as the Palæolithic age, or that they have withstood in their present homes all the changes and invasions which have happened since the Reindeer-hunter camped in the caves of the Lesse. It is to me improbable in itself, and unsupported by satisfactory proof. The few human bones discovered in caves, and of undoubted Palæolithic age, seem to me too fragmentary to offer any satisfactory basis for arriving at any ethnological conclusion as to the Palæolithic races of men in Europe.

General Conclusions.

1. It now remains for us to sum up the results of this inquiry into the Pleistocene strata of the caves of Cresswell Crags. From the preceding pages it will be seen that at the time the red clay and the ferruginous sand were being accumulated in Mother Grundy's Parlour by the action of water, the Hippopotamus and leptorhine Rhinoceros, the Hyæna and the Bison haunted the wooded valleys of the basin of the upper Trent, while we may mark the absence of Palæolithic Man and the Reindeer. Hyænas were abundant, while Horses were absent.

2. Then followed a time, represented in all the caverns by the red sand, when the Mammoth, Woolly Rhinoceros, Horse, and Reindeer haunted the district round Cresswell Crags, and fell a prey sometimes to the hyænas, and at others to the hunter, whose implements of quartzite prove him to belong to the same peoples who have left their implements in the river-deposits.

3. Lastly we have the Palæolithic hunter, represented, in the breccia and upper cave-earth of the Robin-Hood and Church-Hole caves, by flint implements of a higher order, like those found in Solutré (type "Solutrien" of Mortillet), accompanied by implements of bone and antler and the incised figure of a horse, which proves them to have possessed the same artistic faculty of reproducing the forms of animals so remarkable in the frequenters of the caves of the South of France, Switzerland, and Belgium.

The subsequent history of the caves in the prehistoric and historic ages falls more properly within the limits of anthropology than geology, and presents no points of geological interest worthy of being brought before this Society.

Discussion.*

The Chairman (Prof. Prestwich) observed that both communications were of great interest. He believed that this was the first instance of a high-level gravel being described in the neighbourhood to which Mr. Fisher's paper referred. He inquired what was the height of the hill on which the Boulder-clay occurred. The circumstances much resembled those in the Thames valley or near Oxford. In the Somme valley the *Hippopotamus* occurred only in the low-level gravel; here just the reverse. As regarded Prof. Boyd Dawkins's paper, he remarked that the succession also was of great interest; the absence of man from a particular cave, however, would not necessarily prove his absence for the period.

Prof. Hughes stated that the hills bounding the valley referred to by Mr. Fisher formed part of the Chalk-range, which was 200–300 feet high.

Mr. John Evans said that at Barrington there was another satisfactory instance of the Pleistocene Mammalia in beds more recent than the Chalky Boulder-clay, and in a condition showing they could not be *remanié*. He doubted whether the worked flint belonged to the age of the beds. The round stones, he thought, afforded no satisfactory evidence of human use. The materials of the gravel were evidently derived from the glacial drift. At Barnwell a flint implement of the St.-Acheul type had been found.

Mr. R. H. Tiddeman congratulated the authors upon the importance of their discoveries, the succession of the two distinct faunas in the Cave tending to strengthen the views formerly held by Dr. Falconer as to their relative age. The older was almost identical with the Hyæna-bed in the Victoria Cave. He felt bound to challenge the remark of Prof. Dawkins, "that the existence of Man with Hippopotamus in the Victoria Cave was founded on a mistake." He wished to state that the cut bones of Goat were found in the older beds in that Cave, under such circumstances that it was impossible that they could have fallen from the surface, as suggested; for, by the method of careful working adopted, the upper beds had been previously completely removed. Nor was he (Mr. Tiddeman) singular in believing the Goat to have existed in Pleistocene times.

Prof. Seeley said that no river could have occupied the region described by Mr. Fisher, since a slight depression would convert the existing rivulets into estuaries. He thought the gravels were deposited in salt water, and the freshwater shells and bones of land animals had been introduced by small streams. Two or three specimens of Hyæna, in excellent preservation, were found some years since in Quy Fen. He had described, in the Society's Journal, a rib-bone cut by man, found in the Barnwell gravel, which was

* This Discussion relates also to a paper by the Rev. O. Fisher, p. 670.

associated with a similar series of animals to those found at Barrington.

Mr. Callard said that the men who made the carvings on bone were evidently Neolithic, or still more recent, and *Rhinoceros tichorhinus* had survived them; for its remains were found in the stalagmite above them.

Rev. J. Magens Mello stated that he agreed with what Prof. Dawkins had said about the human skulls. One was found in a chamber where it was hardly possible man would have got in the Palæolithic times. He replied to Mr. Callard's remarks about the age of the human race.

Rev. O. Fisher stated that another deposit with similar remains had been found half a mile higher up the valley. The horse, abundant at Barnwell, was absent here at Barrington. He did not think gravels could be deposited in an estuary.

Prof. Boyd Dawkins said the Neolithic races of man could be traced in the present European peoples; but not the Palæolithic. The oldest race was that of the river-bed men, who could not now be identified, and they ranged as far as India. The cavern race might be identified with the Esquimaux. As to the cuts on the bones in the Victoria Cave, some good judges thought they were made by metal tools. The bones were as likely to belong to sheep as to goat. Could it be maintained that domestic animals, such as sheep or goat, were Palæolithic species? So far as Middle and Northern Europe is concerned, they do not appear before the Neolithic period. He believed that in this case they came from a deposit of post-Roman age, where they were abundant.

56. *On the so-called* Midford Sands.

By Prof. J. Buckman, F.G.S., F.L.S. (Read June 25, 1879.)

At the village of Midford, some three miles to the south of Bath, is a fine section of the upper beds of the Inferior Oolite rock, consisting of a cap of oolitic freestones of some 20 feet in thickness, resting upon a mass of sand, of which 25 feet are exposed at the station, and which presents all the features of the sand at Bradford Abbas and Bridport Harbour, as the sands are loose, vary in colour, and present occasional bands of hard compact stone.

From these sands being so well shown at this place, Prof. Phillips was induced to name them, after the village, the "Midford Sands;" and he thus writes upon the section:—

"If we wish to draw a hard limit of mineral deposits, it should probably be between the sand and its calcareous cover (which is often absent); but if we desire to study organic sequence, we shall unite the sands and their shelly cap into a transition group" *.

Now as this "shelly cap" is the one so highly charged with *Cephalopoda* we further quote the following:—

"The 'Cephalopoda-bed,' as Dr. Wright proposes to call the cap limestone of this sandy series, exists where the shells to which it owes its name were specially abundant, or by some natural circumstances were brought together. It is not known in the valleys of the Cherwell or Evenlode, and very partially in any of the branches of the Windrush, Coln, or Churn; but on the western front of the Cotswold cliffs it extends from Cleeve-cloud to Wotton-under-Edge, appears on the Dorsetshire coast near Bridport, and is recognized in France "†.

Mr. Woodward, in his 'Geology of England and Wales,' adopts the name given by Professor Phillips, as follows:—

"Midford is a little hamlet about three miles south of Bath, and it was there that William Smith first studied the Sands, and called them the 'Sand of the Inferior Oolite.'

"They are very well developed at Nailsworth and Frocester, and the names of these places have been locally used to designate the Sands.

"They consist of micaceous yellow sands, with occasional beds of concretionary sandstone or sandy limestone called 'sand bats' or 'sand burrs,' which sometimes contain organic remains; and they are capped by a brown marly iron-shot limestone, one to three feet in thickness, which yields numerous species of Ammonites, Belemnites, and Nautili, whence this bed has been termed by Dr. Wright the 'Cephalopoda-bed'‡, while the series has been termed the 'Ammonite-sands' by Mr. Hull" §.

Now it is the object of this paper to show that Prof. Phillips has

* Geology of Oxford and the Valley of the Thames, p. 118 (1871).
† *Ibid.* p. 119. ‡ "Dr. Wright termed the series Upper Lias Sands."
§ P. 168. Article "Midford Sands."

confounded two beds, in which he has been preceded and followed by the authors quoted.

The Cephalopoda-bed at Midford, Bradford Abbas, Halfway House, and Bridport is situated near the *top* of the Inferior Oolite, while the Cephalopoda-bed of Dr. Wright is situated at the *bottom* of that rock in Gloucestershire, and we have traces of this latter *below* the sands in Dorsetshire.

The so-called Midford Sands are the equivalents of the Ham-Hill building-stone, of the Doulting oolites, of the brown freestones and ragstones of the Cotteswolds, and of the grand sand section at Bridport Harbour.

In the accompanying diagram (fig. 1, p. 738) are placed side by side the Midford section and the Haresfield section.

The detailed section at Midford station is as follows in descending order :—

	ft.	in.
1. Soil and Rubble	3	0
2. Trigonia-Grit, consisting of irregular oolitic limestones with but few fossils	12	0
3. Gryphite-Grit = Cephalopoda-bed of Dorset, full of fossils, as at Bradford	6	0
4. Bed of hard sandy oolite = *Dew bed* of Bradford	2	0
5. Oolitic sands with occasional beds of sandy oolite seen on the line	25	0
This bed to the bottom of the valley is nearly	100	0

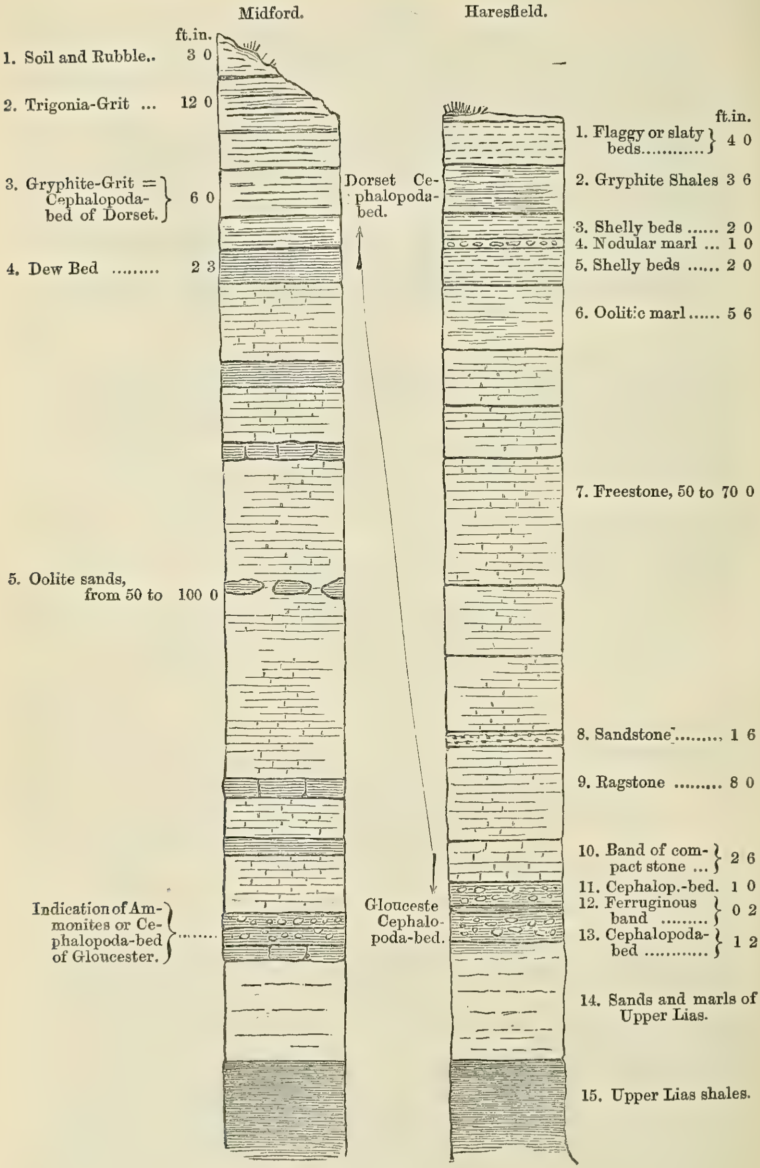
The detailed section at Haresfield Beacon :—

			ft.	in.
Inferior Oolite of Gloucestershire.	1. Flaggy Beds = Trigonia-Grit		4	0
	2. Soft Beds = Gryphite-Grit		3	6
	3. Shelly beds } 4. Nodular Marl }	Cephalopoda-beds of Cotteswolds	1	0
	5. Shelly beds		2	0
	6. Oolitic Marl		5	6
	7. Different freestone beds = the *Midford sand* 50 to		70	0
	8. Sandstone		1	6
	9. Ragstone, more or less oblique cleavage		8	0
	10. Compact bed of stone		2	6
	11. 12. 13. Two beds of soft Oolite, full of Cephalopoda, separated by a ferruginous band	Upper Lias of Dr. Wright	2	4
Upper Lias.	14. Sands and Arenaceous Marl of Upper Lias.			

We take it, then, that the sections at Crickley Hill and Haresfield Beacon, in Gloucestershire, in their shelly oolites and ragstones, are the exact equivalents of at least 120 feet of the sands which at Midford and other places in Somerset, Bradford Abbas and Sherborne in Dorset, are identical.

These sands, as we have before shown, are interrupted by occasional beds of stone both at Midford and Bradford, which stones are usually as full of comminuted fossils as the shelly oolite of Leckhampton Hill ; many of them, however, are capable of being identified, and the list to be given presently will show much the same fossils as occurring in both.

Fig. 1.—*Sections in Midford and Haresfield Quarries.*



It should, however, be noted that in the sands there are occasional seams of carbonate of lime, apparently derived from the decay of layers of Testacea which have been decomposed in the porous stratum.

The Gloucestershire sections and the Somerset and Dorset ones agree in having a Cephalopoda-bed at the base and another high up. Our grand Cephalopoda-bed in Dorset is the equivalent of the Gryphite-Grit on the top of Leckhampton Hill, and both are marked by a list of characteristic Ammonites, amongst which are the following:—

List of Ammonites common to the Upper Cephalopoda-beds of Dorset, Somerset, and Gloucester.

Ammonites Brocchii, *Sow.*	Ammonites Humphriesianus, *Sow.*
—— Sowerbii (Brownii?), *Sow.*	—— Parkinsoni, *Sow.*
—— concavus, *Sow.*	—— subradiatus, *Sow.*
—— corrugatus, *Sow.*	—— læviusculus, *Sow.*

Now these species are common to both districts; and be it recollected that as sand underlies this *upper* Cephalopoda-bed in Dorset, while sand underlies the *lower* Cephalopoda-bed in Gloucestershire, these two beds have been considered as belonging to the same horizon; it was so thought by the late Prof. Phillips, and hence he aimed at getting rid of the difficulty by naming these as follows:—

"MIDFORD SANDS.

"The last of the liassic strata, to which the inferior oolite has not quite relinquished its ancient claim, is a variable series of fine sands, deposited on the upper lias clay in such a manner as often to defy the geologist to draw a hard line between them. These sands are bluish under ground, yellowish at the surface. They are covered in many districts in the south of England by calcareous and shelly beds, which on the first view appear naturally associated with the oolitic rocks above; but they contain many fossils which are frequent in the sands and not common in the oolites. Thus we have in general terms

Inferior oolite above.

Shelly calcareous bed.
Fine-grained sands.

Upper lias clay below.

"Here, then, is a transition series of beds, which for convenience and for reasoning may be joined with either or both of the greater deposits, which, in fact, they feebly tie together"*.

Now when we consider that the sands at Midford are the equivalents of a great mass of the Inferior Oolite of Leckhampton, Horsfield, and Crickley, it will be seen that, however the name of either Oolite or Lias sands for the beds below the Gloucestershire freestones may apply, the term Midford Sands cannot apply to the equivalents of the freestone and ragstone beds of the Cotteswolds, of which these so-called Midford Sands undoubtedly *are* the equivalents.

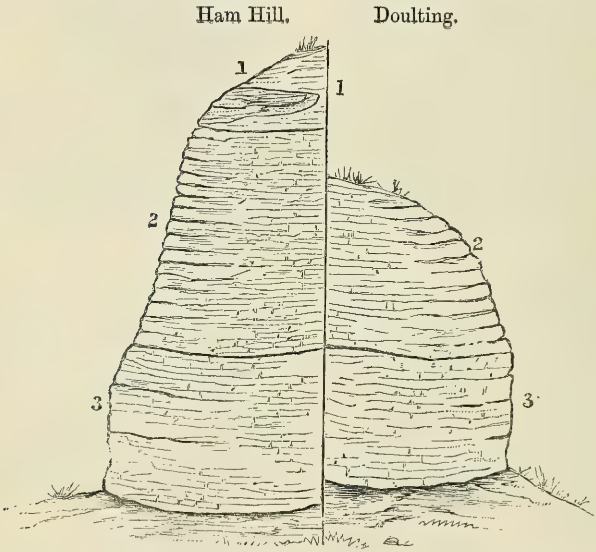
Hitherto we have described the beds below the so-called Cephalo-

* Geology of Oxford and the Valley of the Thames, p. 118.

poda-bed at Midford, Sherborne, and Bradford Abbas as sands; and it is interesting to mark how persistent they are over a wide area; but we must guard against its being supposed that it is always so. On the contrary, at Ham Hill, and so far off as Doulting, in Somerset, the equivalents of these sand beds with *occasional* beds of shelly oolite will be made up *wholly* of shelly oolite, so much so as to afford thick masses of characteristic oolitic building-stones, for which both quarries have for ages been celebrated.

In order to make this the more clear, we append the following:—

Fig. 2.—*Sections of Ham Hill and Doulting Quarries.*



Fossil-bed denuded, so that the whole of this section is below the Cephalopoda-bed.

1. Sand bed with enclosed block of shelly oolite.
2. Foxy-coloured thin-bedded Freestone.
3. Freestone cut out in thick blocks.

Doulting (= The sand beds of Sherborne, Bradford, &c.):

1. The sands denuded.
2. White thin-bedded Freestone.
3. Thick blocks of whitish Freestone.

These sections may be detailed as follows:—

Section at Mr. Trask's Quarry, Ham Hill.

	ft.	in.
1. Sands including a portion of a 'pot-lid' of shelly oolite	12	0
2. Ochre-beds=equalling in part the Leckhampton freestone bed	50	0
3. Beds of ochraceous building-stone made up of comminuted shells=shelly oolite	30	0
4. Rough grey stone=Pea Grit	10	0
5. Sands=the so-called Oolite Sands (Lias of Dr. Wright) at Cheltenham.		

It will be seen that the next quarry is by no means so deep a working as the Ham-Hill section. This latter is the highest and deepest-worked of the series.

Section at Mr. Trask's Quarry, at Doulting.

	ft.	in.
1. The upper beds denuded		
2. Thin-bedded white freestone, more or less made up of comminuted shells	10	0
3. Blocks of freestone used for best building-stone	25	0

This section shows that the Ham-Hill equivalent has been denuded from the upper part of the quarry, while the beds below the freestone are covered up; but, judging from the district, we conclude that the building-stone is underlain by the blue or grey bed, and this, again, by some sands.

At Milborne Wyck we have beneath the fossiliferous or Cephalopoda-bed beds much of the same character as those at Doulting; but here the colour is neither foxy nor wholly white, but is occasionally tinctured with green grains, probably derived from some phosphatic salt.

From these remarks it will be seen that the composition of the bed under review is so very variable that the mistakes made in its reading may be easily accounted for, as the difference between a thick rock of yellowish sand only occasionally interrupted by bands and pot-lids of shelly oolite occupying a thickness of over 100 feet. The ochraceous building-stone at Ham Hill and the Doulting beds, as also their equivalents in Gloucestershire, are of about the same thickness. The differences here noted, then, are very marked, so far as lithological structure is concerned; the thicknesses at the same time very nearly accord. It is not true, then, that "the Inferior Oolite, which near Yeovil immediately overlies the sands, is comparatively thin, in consequence of the absence of the thick-bedded limestones which impart such a thickness to this formation in Gloucestershire" *.

The so-called Midford Sands, the sands at Bradford and near Sherborne, together with the building-stones at Ham Hill, Doulting, and other places, are neither more nor less than Inferior Oolite, as they are all on the same horizon as the middle and lower beds of this rock which are so well exposed over the Cotteswolds.

Now inasmuch as the sands to which Prof. Phillips gave the name of "Midford Sands" are not the same as the sands in Gloucestershire, but belong to a higher (Oolitic) series of beds, the proposed name will in no wise solve the difficulty; and we feel convinced that had Prof. Phillips been made acquainted with the true nature of the sands of Somerset and Dorset, as now explained, he would never have proposed it.

We look upon it, then, that the Inferior Oolite is of about the same thickness in Somerset and Dorset as in Gloucestershire; there is no missing link, as some have attempted to explain; still, however, the lithology differs from that of the Cotteswolds, but not more than may be observed in different parts of the Cotteswolds themselves, or

* Quart. Journ. Geol. Soc. vol. xvi. p. 34.

than the difference of the sands at Midford compared with the admitted oolites of Ham Hill and Doulting.

If we look to the fossils of this part of our Oolite series we shall find the subject beset with many difficulties, the chief being that where the rock is hard, as at Ham Hill, it is absolutely made up of a mass of comminuted shells cemented by an oolitic matrix, so that great industry, patience, and knowledge of fossils is required to get them and to make them out. They are, however, both in texture and even in colour at Doulting, like the "shelly oolite" of Brodie, and certainly contain many of the fossils of that member of the Cotteswold series.

Another difficulty as regards the making out of the fossils arises from the fact that as this sand bed has been correlated with Lias, so many of the shells are considered as indicating Lias. It is also true, as regards the Jurassic of the west, that several Lias forms do actually occur in the true Oolitic deposits, thus mounting higher than they do in the Cotteswolds; on the other hand, what we have hitherto taken as positively indicative of high Oolitic rocks are found here in the sands,—facts which will be seen from the list we now append to this paper.

The following, then, is offered as an imperfect list of the fossils from the sand (so-called Midford) of Dorset and Somerset; it must, however, be understood that if they could be made out there are probably very many more species than we have been enabled to determine.

List of Fossils from the Sands of Dorset and their equivalents.

Pentacrinus, ossicula of, frequent.

Apiocrinus Parkinsoni, Brown and others. I have a series of ossicula from the sands, and also a body from the Dorset Ammonite-bed, Bradford Abbas.

ECHINODERMS. Plates and spines of various species occur in the sands, also in the stones at Ham and Doulting.

Serpula socialis occurs frequently on the surfaces of the blocks of oolite and on the harder beds which occur in the sand.

CRUSTACEA, claws and portions of.

Belemnites quadricanaliculatus, Quenstedt.

—— *tricanaliculatus*, Quenstedt, probably the same species. These are common in the sand bank.

—— *irregularis*,
—— *subtenuis*,
—— *compressus*. } Occur on the blocks of stone occurring in the sands, Bradford Abbas.

Nautilus intermedius,
—— *latidorsatus*,
—— *excavatus*,
—— *inornatus*. } Rarely in the blocks of stone in the sands.

Ammonites jurensis. Common to the sands and the Ammonite-bed.

—— *Moorei*,
—— *Germaini*,
—— *Ægion*. } From the sands at Coker. *A. Moorei* is common.

GASTEROPODA. So rare that we cannot be said to have made out a single species*.

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* Since the above was written we have broken up a block of stone in the sand at Bradford containing bits of at least two Ammonites and three species of Univalves.

BRACHIOPODA, very crushed and fragmentary. We fancy we have made out the following from Ham Hill:—

Terebratula hemisphærica, *Waldheimia carinata*, *Rhynchonella concinna*, —— *cynocephala*. } Very rare on the blocks of freestone.

——. Other forms occur in oolite blocks in the sand bed.

LAMELLIBRANCHIATA.

Avicula complicata. Buckm. Geol. of Cheltenham, t. 6. f. 5.
Gervillia Hartmanni. Common on the sandy slabs.
Ostræa bullata. Ditto.
—— *Marshii*. Ditto.
Hinnites velatus. Ditto.
Pecten clathratus, —— *discites*, —— *annulatus*, —— *lens*, —— *demissus*. } On the slabs intercalated in the sands everywhere.
Lima densipunctata and others. Ditto.
Pinna Hartmanni. Ditto.
—— *ampla*. The same as the Cotteswold Great-Oolite species; sands.
Astarte elegans. Ditto.
—— *pullus*. Ditto.
—— *clathratus*. Ham Hill.
—— *rigida*. Ditto.
Trigonia sculpta. Bradford Abbas.
—— *formosa*. Ditto. These forms are like those of the sands. There are perhaps two or three others of both the costated and clavellated forms in the sands.
Isocardia concentrica. Sands.
Modiola. Two or three forms.
Tancredia donaciformis. Sandy stones.

If the foregoing list be examined, fragmentary though it be, it will convince any one of the true Oolitic facies of the beds from which the fossils are derived.

We conclude, then, from the foregoing remarks that the so-called Midford Sands are true Oolitic beds, not freestone at Midford, though decidedly so at Ham Hill, Doulting, and over a great part of the Cotteswolds.

And we especially dissent from the notion that this sand bed at Midford or in Dorset can in any way be classed with the so-called Oolitic sands of some, Lias sands of others, of the Cotteswolds. They are, however, still confounded in our maps, though the sands below the freestones of the Cotteswolds are situated at least 100 feet below the sands of Dorset with which they have been confounded.

DISCUSSION.

Mr. HUDLESTON agreed with the author in regarding the Cephalopoda-bed of Dorset as quite distinct from that of the Cotteswolds. The real difficulty, he thought, would be found in the correlation of the Yeovil Sands.

57. *On* Lepidodiscus Lebouri, *a new* Species *of* Agelacrinitidæ *from the* Carboniferous Series *of* Northumberland. By W. Percy Sladen, Esq., F.G.S., F.L.S. (Read June 25, 1879.)

[Plate XXXVII.]

On this side of the Atlantic the *Agelacrinitidæ* are forms of the Echinodermata of such rarity of occurrence that each may well be spoken of as a veritable Phœnix amongst fossils! More than thirty years have elapsed since the first-discovered and hitherto solitary British species, *Agelacrinites Buchianus*, Forbes*, was found in the Bala Limestone of North Wales; and to this there can be added only two other forms, viz. *A. bohemicus*, Römer†, from the Silurian of Bohemia, and *A. rhenanus*, Römer‡, from the Devonian of the Eifel, to make up a full list of the representatives of the group in Europe. Indeed so great is the rarity of these Cystideans that the number of individual specimens obtained from the whole area may literally be counted in units on the fingers alone.

Turning, however, to the American continent, where *Agelacrinites* was originally made known, the group of species is found to be somewhat more numerous, whilst forms occur amongst them which rank as allied genera§, and the vertical distribution extends from Lower Silurian up to Lower Carboniferous strata.

The organism which furnishes the subject of the present communication was obtained at East Woodburn, in Northumberland, from a schistose limestone belonging to the Lower Carboniferous series, and is especially interesting as being the first example of a Carboniferous form of the Agelacrinitidæ occurring in Europe. We are indebted for the discovery of this remarkable Echinoderm to Prof. G. A. Lebour, of Newcastle-upon-Tyne, to whose energy and industry geologists already owe much information on the Carboniferous measures of the north of England. When originally found, the fossil was greatly obscured by adherent matrix, and further clearing seemed impracticable, owing to the extreme delicacy of the specimen. From the imperfect examination only then possible, Prof. Lebour was led to refer the form to the fossil described by Meek and Worthen as *Lepidodiscus squamosus* ||, under which name he contributed an interesting note to the Geological Society of Belgium ¶ upon its occurrence in England, and drew sundry inferences from its associations.

* Mem. Geol. Survey, vol. ii. (1848), pt. ii. p. 521.

† Recorded by Beyrich in Leonhard and Bronn's N. Jahrb. f. Min. Geol. u. Petref., 1846, p. 192.

‡ Verh. d. Naturh. Vereins f. Rheinl. u. Westph. 1851, viii. p. 357.

§ *Hemicystites*, Hall, and *Lepidodiscus*, Meek and Worthen, comprise forms originally described as *Agelacrinites*.

|| Proceed. Acad. Nat. Sci. Philad. 1868, p. 357; Geol. Surv. Illinois, vol. v. (1873) p. 513.

¶ Ann. de la Soc. Géol. de Belg. t. iii. p. 21.

Subsequently Prof. Lebour kindly entrusted his specimen to the writer for examination, when, after carefully cleaning away the obstructing film of matrix which covered a great portion of the disk, it was at once evident that the fossil was distinct from any hitherto recorded.

I have very much pleasure in associating the name of my friend with this species, of which the following description will furnish the characters:—

LEPIDODISCUS, Meek and Worthen, 1868.

LEPIDODISCUS LEBOURI, sp. nov. Plate XXXVII.

Agelacrinites (*Lepidodiscus*) *squamosus*, Lebour, Ann. de la Soc. Géol. de Belg. t. iii. p. 21 (*non* Meek and Worthen).

Body depressed, discoid or subconoid in form, marginal contour slightly oval; covered with imbricating plates. The rays, which are six in number, are elevated in relief above the plane of the disk, and are long, narrow, and strongly curved in semispiral (five sinistral and one dextral), as they radiate from the centre to the periphery, parallel with the margin of which they are prolonged for some distance. The apical portion of the disk, which is formed by the common union of the radii, consists of seven or eight irregular plates, compactly fitting to one another, which form an uninterrupted and continuous surface with the plates which belong to the radial series. The brachial plates may consist either of broad, short*, band-like plates, which span across the ray, or (more frequently?) of alternating pairs of wedge-shaped pieces, the elements of the pairs being reciprocal and presenting every degree of relative proportion. On account of this irregular development there is an absence of uniformity in the arrangement of the plates, especially in the middle portion of the ray; and this is further augmented by a tendency to division manifest in some of the plates. A careful study of the specimen leads to the conclusion that the wedge-shaped plates are consequent on a certain retardation of development, and that the result is produced somewhat after the following manner:—A ray-plate, by reason of retardment of development, has its distal margin sloped away, thus producing a wedge-formed piece, which of necessity requires a corresponding modification of the succeeding plate, in order to maintain the equilibrium of the series. Two alternating wedges are the result. The stages of diminution or retardment of development are present in every degree, the size of the companion plate varying proportionally and reciprocally. It frequently happens that two neighbouring plates have the proximal margin of the inner and the distal margin of the outer plate, on the

* It may be well to explain that the terms of length and breadth used throughout this paper are applied to the plates in respect to their proportions when in natural position on the organism, and do not necessarily correspond with those which would be employed when familiarly describing the same object in an *isolated* state. Thus, in the present case, length is measured between the proximal and distal margins, and breadth is the extent across the ray.

same side, curtailed, so that they form together a wedge-shaped pair; this requires a reciprocal modification of the following plate, or next two plates, as the case may be. The apex of the wedges, whether single plates or pairs, not unfrequently reaches nearly to the opposite side of the ray, the corresponding companion plate being in consequence reduced to a quite insignificant secondary plate or scale. Sometimes the alternation of wedge-shaped plates, or pairs of plates, is continued, in the manner above indicated, for several successive series, without a break, along the ray (see fig. 3).

The broad, band-like plates occur at intervals between the others, and in one or more of the rays a series of three or four follow in succession immediately after the irregular apical plates, and form the first of the brachial series at the inner extremity of the ray. In one of the rays, on the outer portion which surrounds the periphery of the disk, there is a large and uninterrupted series of simple plates; but whether these occur in the same portion of every ray it is impossible to say, in consequence of the damage which our specimen has suffered. Each of these broad plates has generally both the proximal and the distal margins somewhat bevelled off at either side, and the extremities more or less rounded, thereby leaving a narrow, triangular space or aperture at the extremities of the suture between any two plates and close up to the junction with the adjacent imbricating interbrachial area (see fig. 4). The lateral ends of these plates are also a little thickened; and at a short distance from the same the plate is somewhat rapidly, although only slightly, arched upwards, thus conforming to a dorsal convexity of the ray—a character which the wedge-shaped plates also exhibit in a greater or less degree.

The interbrachial areas are narrow and irregularly subpetaloid, with the inner or arm-angle well rounded; they are covered with large subrhomboidal plates, which are strongly imbricated inwards—that is to say, an outer plate overlaps the margin of its more internal neighbour. In relative proportion the length of a plate is usually equal to, or sometimes greater than, the breadth, one of the largest measuring 0·1 of an inch. The free angle is slightly rounded, and this becomes more pronounced as the plates approach the periphery, where they are also proportionally broader. The plates immediately within the marginal portion of the ray are somewhat smaller and more squamiform than the rest; whilst those on the outer side, which form the margin of the disk, become broad short scales, quite different in facies from the diamond-shaped plates which constitute the general tessellation of the interradium. It seems probable that this marginal series of scales was imbricated outwardly, that is, in the opposite direction to the inner series; but, unfortunately, very little of this portion of the fossil remains. Along the line of junction of the interradia with the raised rays are traces of a series of small scale-like plates, which imbricate or abut upon the flat ends of the plates of the brachial series; these, however, can only be detected here and there, owing to the condition in which the fossil is preserved, and their obscurity is explained by the supposition that

Lepidodiscus was to a certain extent collapsible, and that the upper ray-plates could be more or less drawn in when the animal assumed its retracted or uninflated state.

The interbrachial area enclosed between the single dextral ray and the sinistral one which stands opposed to it is subtriangular in contour and larger than any of the other areas; it contains also an orifice, situated in the angle formed by the curve of the sinistral ray, which was originally closed by narrow wedge-shaped plates, and was in all probability the periproctium, and the homologue of the anal tube of Crinoids.

The imperfect preservation of the part of the disk just mentioned prevents, unfortunately, the extremity of the odd dextral ray being followed to its final termination. This ray, after extending for some distance along the area within the curve of the sinistral ray, bends inward towards the periproctial aperture, and is lost in the confusion which occurs amongst the plates in that vicinity.

The surface of the plates is finely granular, and when magnified is seen to be densely covered with accurately rounded spherules; no order is traceable in their arrangement on the plates of the interradia; but on those of the rays the granules show a tendency to run into one another, and usually assume a linear arrangement across the plates.

Absolutely nothing can be said respecting the under surface of the present fossil, and hardly any light, beyond the record Forbes has given of the fragmentary structures preserved in *Agelacrinites Buchianus* *, has yet been thrown upon the structure of this part of the Agelacrinitidæ by any specimens hitherto described. In commenting upon an example of *Lepidodiscus cincinnatiensis*, Römer, found at Richmond, Indiana, which seemed "to have grown on one of the valves of an *Ambonychia*, and from which the shell had separated in such a manner as to take with it the underside of the *Agelacrinites*, and leave its upperside in the matrix so situated as to expose its inner surface," Mr. Meek † states that "the inner side of each arm or ray is here seen to be composed of a single series of quadrangular pieces that are not imbricating, while the disc-plates near the outer margin show, on their inner surfaces, little parallel ridges, directed inward, and apparently fitting into corresponding furrows in the lapping edges of the contiguous pieces." Of the plates mentioned above as forming the floor of the radii, there are indications in the present specimen, at the broken extremity, of more than one of the rays; but respecting their individual form in this species, or of the other structures observed by Mr. Meek, it is impossible to speak.

The dimensions of the specimen are as follows:—the greater diameter measures 0·98 of an inch, the lesser 0·8; breadth of a ray near the inner extremity about 0·07.

Remarks.—The specimen has been crushed and somewhat distorted prior to or during the process of fossilization, and its margin has also suffered considerable damage when the matrix was first roughly

* Mem. Geol. Survey, vol. ii. pt. 2, p. 522.

† Geol. Surv. Ohio, vol. i. pt. 2 (Palæont.), p. 55.

cleared away. The whole organism, as usual in most of the remains of Agelacrinitidæ yet found, is much flattened, a circumstance which renders it difficult to say what was the exact form presented by the body when in life. That its dorsal surface was more or less convex or subconoidal is beyond doubt; and it is also extremely probable that in the present type of *Lepidodiscus*, at least, the hard test was to a certain degree flexible and collapsible: hence the fair deduction follows that the animal would doubtless have astonished its captors, if there had been dredgers in those early seas, as much as *Asthenosoma* (= *Calveria*, Wy. Thomson) did by its palpitations when first hauled on board H.M.S. 'Porcupine' during the expedition in 1869. The imbricating scale-like nature of the plates would alone naturally lead to this conclusion; and the presumption is further strengthened when the manner is noted in which the spirally disposed radii are displaced and contorted under the action of the flattening to which the test has been subjected. In addition to this it should not be lost sight of that the form of the plates of the radial series likewise furnishes strong evidence in favour of such a view; for the arched margins, the bevelled ends, and the blank interspaces are all provisions calculated to afford flexibility; and although the property, it is true, might be possessed only to a very limited degree by the radii taken as a whole, it would nevertheless be sufficient, in all probability, to correspond with the movement of the disk-plates—a concord, it may be noted, without which the utility of the imbrication of the latter would seem very remote.

Some American palæontologists remark on what they have considered to be traces of pores (presumably of ambulacral function from the manner in which the statement is made), situated between the plates of the radial series; but in no instance that I am aware of have such pores been actually discovered. There is certainly nothing of the kind in the Northumberland specimen; and I would suggest, without slighting in any way the observations just alluded to, the possibility that the blank interspaces which have been described in *L. Lebouri* as situated at either end of the line of junction of the ray-plates may have been mistaken for true tentacular foramina—an error which might easily occur if the specimen had only been imperfectly cleared.

The early writers on Agelacrinitidæ regarded the mouth as opening on the central portion of the dorsal surface, at the junction of the radii, although none of the fossils then known were in a condition to prove whether an orifice existed or not. This view must now be considered erroneous, as several of the recently discovered specimens, which are more perfectly preserved, show unmistakably that no such orifice was present on the dorsal surface. The fossil now under notice is closely plated in the centre of the disk, and certainly possessed no external aperture in that region of the test.

The orifice situated in the large interbrachial area was referred to by Forbes (*loc. cit.*) as the "ovarian pyramid;" this opinion has been followed by numerous writers up to the present time, whilst others have considered it to function as mouth or mouth-anus respectively.

Dr. Lütken*, however, has pointed out some time ago the analogy of this aperture in Agelacrinitidæ with the anal tube of recent and the so-called "proboscis" of Palæozoic Crinoids; concurrently, therefore, with that view, the opening in question has been spoken of in the above description as the periproct or anal aperture.

Affinities and Differences.—Although the various species of Agelacrinitidæ present a general facies whose similarity at first sight is very striking in a group maintaining such an extended distribution both in a vertical and horizontal direction, they will nevertheless be found on analysis to exhibit numerous divergences from the type which are very difficult to understand, and of which the explanation is most hazardous, and, indeed, scarcely possible from the very scanty and isolated material which palæontologists as yet have at their disposal. In support of this remark no further instance need be cited than the occurrence of the *Agelacrinites*-form and the *Lepidodiscus*-form in the Lower Silurian, and also both in the Lower Carboniferous as well, thus leaving us unable to say which of these should be looked upon as the original type; whilst the entire absence of all intermediate forms prevents us from throwing any light upon the causes which brought about the modification or the stages that have intervened. As our knowledge of this interesting group is unfortunately so fragmentary, we are unable to do more than point out the external characters which distinguish the present form from those with which we are already familiar; and a glance at the list which is given below will show that the number of species with which we can thus draw comparison is very small.

The Carboniferous forms of Agelacrinitidæ have been known to us hitherto only from America—the only two species being *Agelacrinites kaskaskiensis*, Hall, and *Lepidodiscus squamosus*, Meek and Worthen; the former found in the Kaskaskia limestone at Kaskaskia, Illinois, and the latter coming from the Keokuk beds of Crawfordsville, Indiana.

The resemblance of *Lepidodiscus Lebouri* and *Agelacrinites kaskaskiensis* is merely superficial, for the imbricating plates and the character of the radial series furnish diagnostic features which readily separate the two species. The affinity with *Lepidodiscus squamosus* is much closer: the Northumberland specimen resembles the Indiana form in having imbricating interradial plates; but these are distinguished in *L. Lebouri* by being much more angular (rhombic) in form, and by having their length equal to or greater than the breadth, and the margins always rounded; and *L. Lebouri* further differs in having larger, and consequently less numerous, disk-plates, which are also more uniform in size than in *L. squamosus*. There is a wide difference between the two species in the structure of the radial series. In *L. squamosus* these consist of a double row of narrow plates, but little broader than long, which abut against one another in the median line; whilst in *L. Lebouri* they are either wedge-shaped pieces alternating with one another, or single band-like plates which extend across the ray. It is also

* Vidensk. Meddel. f. d. Naturh. Forening i Kjöbenhavn for 1869, p. 187.

to be noted that *L. Lebouri* is distinguished from *L. squamosus* by having six rays, which are, moreover, proportionally narrower than in the American fossil, and very slightly tapering. The two remaining species of *Lepidodiscus* (*L. cincinnatiensis*, Römer, and *L. pileus*, Hall, both from the Lower Silurian) are differentiated from our species still further than those which have been compared above. *L. Lebouri* is also very distinct from each of the European Agelacrinitidæ. The Devonian species (*A. rhenanus*, Römer), however, presents a feature which is interesting when compared with the present Cystid; the fossil, which is imperfectly preserved, is represented as possessing a single series of broad plates which span the rays, a character hitherto looked upon with doubt, and considered as abnormal amongst the group, but which now, when viewed by the side of *L. Lebouri*, will be regarded as presenting a stage in the series, although an extreme type, it is true, and difficult to associate with our present knowledge of the forms of Agelacrinitidæ.

The following list indicates the stratigraphical distribution of the group, as well as the generic subdivisions into which they have been classified :—

AGELACRINITIDÆ.

(α). Agelacrinites, Vanuxem.

(Plates of the interradia not imbricating; radii curved.)

A. Buchianus, Forbes. Lower Silurian: Bala Limestone.
A. Dicksoni, Billings. Lower Silurian: Trenton Limestone.
? *A. vorticellata*, Hall. Lower Silurian: Cincinnati group.
? *A.* [*Edrioaster*] *Bigsbyi*, Billings. Lower Silurian: Trenton Limestone.
A. hamiltonensis, Vanuxem. Devonian: Hamiliton group.
A. rhenanus, Römer. Devonian: Eifel Limestone.
A. kaskaskiensis, Hall. Lower Carboniferous: Kaskaskia Limestone.

(β). Lepidodiscus, Meek and Worthen.

(Plates of the interradia imbricating; radii curved.)

L. cincinnatiensis, Römer. Lower Silurian: Cincinnati and Trenton Limestones.
L. pileus, Hall. Lower Silurian: Cincinnati group.
L. squamosus, M. & W. Lower Carboniferous: Keokuk group.
L. Lebouri, Sladen. Lower Carboniferous: Bernician beds.

(γ). Hemicystites, Hall.

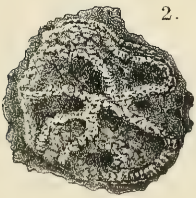
(Radii straight.)

H. [*Agelacrinites*] *bohemicus*, Römer: Lower Silurian.
H. [*Agelacrinites*] *Billingsii*, Chapman. Lower Silurian: Trenton Limestone.
H. stellatus, Hall. Lower Silurian: Cincinnati group.
? *H.* (*Cystaster*) *granulatus*, Hall. Lower Silurian: Cincinnati group.
H. parasitica, Hall. Upper Silurian: Niagara group.

Locality and Horizon.—Prof. Lebour has kindly given me details of the geological position of this Cystidean, which was found by him in an impure limestone cropping out in the river Rede, where it forms a low water-fall just north of the bridge above the village of

1.

2.



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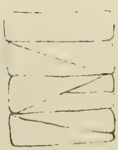

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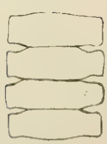


A S Foord lith

Mintern Bros. imp

LEPIDODISCUS LEBOURI, *Sladen.*

East Woodburn. The limestone occurs in thin courses, separated by bands of calcareous shale, and is remarkable for the great quantity of well-preserved Polyzoa to be found in it. It is somewhat flaggy, having a tendency to split up into flakes, and the faces are crowded with specimens of *Fenestellæ*, *Cerioporæ*, *Leda attenuata*, *Orthoceratites*, &c. The limestone is sometimes known as the "Brigg Limestone," and is associated with a thin coal which has been worked from time to time, but only in a very small way. Both limestone and coal are in the Lower Bernician, or lower part of the Carboniferous Limestone series, not very far below the Ridsdale Ironstone shale.

EXPLANATION OF PLATE XXXVII.

Fig. 1. *Lepidodiscus Lebouri*, Sladen: magnified $3\frac{1}{3}$ diameters.
2. The same: nat. size.
3. Diagrammatic representation of the wedge-shaped plates of the rays, much enlarged.
4. The simple broad plates on the marginal portion of a ray, much enlarged.

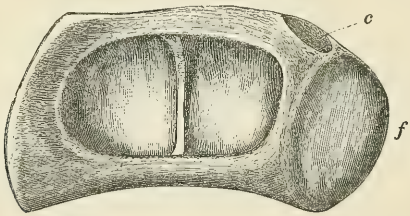
58. *Note* (*3rd*) *on* (EUCAMEROTUS, *Hulke*) ORNITHOPSIS, *H. G. Seeley*, = BOTHRIOSPONDYLUS MAGNUS, *Owen*, = CHONDROSTEOSAURUS MAGNUS, *Owen*. By J. W. HULKE, Esq., F.R.S., F.G.S. (Read May 28, 1879.)

THE following paper contains a description of an unusually perfect dorsal vertebral centrum of *Ornithopsis*, additional information respecting the cervical and anterior dorsal vertebræ, and a comparison of its præsacral vertebræ with those of several recently discovered Colorado Dinosaurs, bringing out several concordances but also such differences as prove the generic distinctness of *Ornithopsis*.

Our knowledge of the skeleton of this remarkable Wealden Dinosaur is still so incomplete that I deem myself fortunate in being able to submit to the notice of the Society an unusually well-preserved vertebral centrum, which I obtained from the sea-cliff, near Chilton, Isle of Wight, in 1875; the description of which and the remarks that follow may be regarded as a continuation of two former notes on the vertebræ of this Saurian*.

This new centrum (No. 178, Coll. H †) (fig. 1), like that with which

Fig. 1.—*Reduced side view of a Trunk-centrum of* (Eucamerotus, *Hulke*) Ornithopsis, *Seeley*.



f. Front. *c.* Canal.

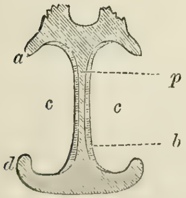
I identified my neural arch (No. 67, Coll. H) in the summer of 1870 (the Mantellian fossil, No. 28632, Brit. Mus. Catal., Wealden, S.E. England), is characteristically opisthocœlous, the posterior cup being deeply hollow, and the anterior convexity correspondingly prominent. The contour of the articular ends is oval, the longer diameter vertical, the upper end of the oval cut off. In its present state the vertical diameter of the posterior surface is about 3·5 inches, the horizontal diameter about 2·9 inches; but these measures must be regarded only as approximative, because the edge of the cup is worn, and the whole form is slightly distorted by pressure. I think that when the shape was perfect, the difference of the diameters was less

* Quart. Journ. Geol. Soc. vol. xxvi. p. 318, pl. xxii. 1870; and vol. xxviii. p. 36, 1871 (read Nov. 22, 1870).

† This no. refers to the Catalogue of my collection. I give it because I have myself often felt how advantageous it would be to be able, at a future time, to identify the actual fossil described by an author.

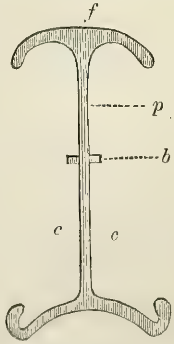
than now. The under surface of the centrum is flattened transversely (this flattening may have been increased by pressure, but it has not, I believe, been wholly caused by it), whilst longitudinally it is made very concave by the swelling of the centrum towards the articular ends. The sides of the centrum are excavated by a large chamber, which is its most striking feature. The external opening of this chamber is an oval not less than 3·5 inches long and 2·2 high. The upper border of the opening is thinner and more arched than the lower border, which is stouter and nearly straight. Inside this opening the chamber extends forward into the convexity of the front end of the centrum, reaching to within a short distance of the articular surface; it stretches backwards almost to the surface of the posterior cup; it dips downwards to a lower level than the lower border of the opening; and it rises above to the under surface of the floor of the neural canal which assists to form its roof. The depth of this large chamber, measured vertically from the chord of the lateral surface of the centrum, is about 1·4 inch; and the chambers in the opposite halves of the centrum approach one another so closely that they are separated only by a very thin partition-wall in the longitudinal median plane, which, below, rests on the lower part of the centrum, and above bears up the floor of the neural canal. On each side, near its middle, this partition-wall is strengthened by a vertical buttress-plate, which also furnishes additional support to the floor of the neural canal and the roots of the neural arch. The annexed sectional diagrams will assist in forming a clear idea of this singular structure (figs. 2, 3).

Fig. 2.—*Transverse Section of the Trunk-centrum* (fig. 1).



a. Upper lip of side opening.
d. Lower lip of ditto.
c, c. Chambers.
p. Partition.
b. Buttress.

Fig. 3.—*Horizontal longitudinal Section of the Trunk-centrum* (fig. 1).



f. Front.
c, c. Chambers.
p. Partition.
b. Buttress.

The bony tissue forming the outer surface of the centrum, as also that which lines the chambers and composes the partition-wall and buttress-plate, has a fine grain; it is less smooth and polished than is my first vertebra (No. 67, Coll. H.), shown to the Society February 9, 1870. The spongy tissue, almost restricted to the ends and lower part of the centrum, is coarse, but not nearly so large-celled as in No. 67. This textural difference may not improbably be due to the different ages of the two animals to which the vertebræ belonged. No. 67 was one of the largest, and this centrum (No. 178, Coll. H.) is by much the smallest of a score which at the present time are known to me. A gradational difference of texture capable of simple and natural explanation, and outweighed by very close correspondence of figure, does not appear to me to be a sufficient ground for regarding the smaller centrum as representing a new species, and I consider it simply as coming from a much younger individual. The absence of rib-joint from the centrum places this vertebra in that part of the vertebral column which in the crocodile is behind the 12th centrum; and the very large size of the lateral openings and of the chambers confirms this position.

The genus *Ornithopsis* was founded in 1869, by Mr. H. G. Seeley, on two vertebral centra preserved in the British Museum. Both originally formed part of the collection of the late G. A. Mantell. The first is labelled No. 28362, Wealden, S.E. England. The second, No. 2239, Mantell regarded and figured as the tympanic bone of *Iguanodon*, although, as he mentions, he had recognized in it some resemblance to a vertebra*. This determination was adopted by Prof. R. Owen, who described it as a tympanic bone in his "Reports on Brit. Foss. Rept.," 1841†, and again described and figured it as such in Pal. Soc. vol. for 1854, with the reservation that it might perhaps be the tympanic bone of *Ceteosaurus* or of *Streptospondylus*‡. The vertebral nature of this fossil, as has been mentioned by Prof. Owen in 1875, in his memoirs on *Bothriospondylus*, was first clearly perceived by Prof. H. G. Seeley§. In a paper read at the sitting of the Cambridge Philos. Society, November 22, 1869, he announced this new view of its skeletal position, sketched the more striking features common to it and to the centrum No. 28362, Brit. Mus. Catal., asserted their distinctness from all known vertebral forms, drew attention to their likeness (in respect of the extreme lightness of their construction and the side opening) to the vertebræ of Pterodactyles and birds, threw out suggestions relative to the habits and affinities which this structural resemblance seemed to indicate, and gave to the new genus represented by these fossils the generic name *Ornithopsis*‖.

A few months after this, my first note, "On a new and undescribed form of Wealden Vertebra," was read here¶. It showed the former existence in the Wealden district of a huge Saurian, far exceeding Mantell's Iguanodon in bulk, having trunk-vertebræ

* Geol. of S.E. England, pp. 305, 306, pl. ii. fig. 5, and Fossils of Brit. Mus. (8vo, London, 1851), p. 255.

† Brit. Assoc. Rept. 1841, vol. xi. p. 124.

‡ 'Monogr. Foss. Rept. of Wealden,' p. 18, pl. x. (Pal. Soc. vol. 1854).

§ Monogr. Mesozoic Rept. part ii. p. 23, pl. vii. (Pal. Soc. vol. for 1875).

‖ Annals and Mag. of Nat. Hist. 1870, vol. v. p. 279.

¶ Quart. Journ. Geol. Soc. (1870) vol. xxvi. p. 318, pl. xxii.

texturally characterized by great compactness of the cortical bone, which occurred chiefly in the form of thin sheets, and by an extremely large-celled cancellous tissue. As regards their form, the vertebræ were distinguished by having superadded to the usual zygapophyses a vertical bolt-plate produced downwards from the median junction of the postzygapophyses, and a corresponding notch with smooth articular sides for its reception between the præzygapophyses — an arrangement in principle comparable to zygosphene and zygantrum. These are shown in figures 1 and 4, pl. xxii., vol. xxvi. (1870).

Further, these vertebræ bore a double rib-joint; they had a singularly complex spinous process, and an unusually developed platform in the level of the crown of the arch from which the transverse process (diapophysis) jutted boldly upwards and outwards to a considerable distance, strutted and buttressed by thin sheets of bone, between which are large and deep recesses.

These characters collectively justified me in referring the animal represented by this fossil to the order *Dinosauria*; and the singular beauty of the groined entrance of the neural canal suggested the name *Eucamerotus*.

The close agreement of their bony tissues and plan of construction had impressed me with the idea of the identity of my neural arch and the Mantellian centrum, No. 28632, the first of the two centra on which Seeley's genus *Ornithopsis* was founded; but at the moment proof of this was wanting. Very shortly afterwards the Rev. W. Fox showed me in his collection a mutilated centrum, retaining enough of the arch and superstructures to establish beyond doubt the identity of *Eucamerotus* and *Ornithopsis*, No. 28632 being regarded as the type of this latter. The identification necessarily entailed the withdrawal of *Eucamerotus* as a generic name in favour of the prior *Ornithopsis*; and the latter acquired, in addition to its opisthocœlous, large-cancellated, side-chambered trunk-centra, the characters derived from the neural arch and processes of *Eucamerotus*.

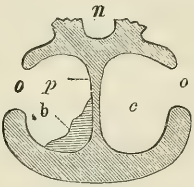
On September 28, 1870, I found, in a local collection in the Isle of Wight, a trunk-centrum of *Ornithopsis* which, although both ends had been shortened by abrasion, measured 11 inches in length, 6·5 inches across, and about 9 inches in height, affording additional evidence of the immense size of the animal. The external opening of the side-chamber was a long oval, of which the height was to the length roughly as 1 : 2.

A persevering search along the cliffs through the whole length of the Wealden exposure at the west end of the Isle of Wight, by the Rev. W. Fox, resulted in the addition of several instructive pieces to his collection. My own occasional efforts were rewarded by the vertebra exhibited to-night and a large very mutilated cervical centrum.

These new acquisitions, to which Mr. Fox, on his part, kindly permits me to refer, show that in some of the trunk-vertebræ the spinous process is expanded transversely to the direction of the axis of the vertebral column. The accompanying diagram (fig. 4) from my notebook, May 26, 1873, shows the construction as seen in a centrum, broken across its middle, in Mr. Fox's collection.

Fig. 4.—*Transverse Section of a large Trunk-centrum in the Collection of the Rev. W. Fox.*

n. Neural canal.
p. Partition.
b. Buttress.



c. Chamber.
o, o. Lateral openings to chambers.

In 1876, Prof. R. Owen described and figured, under the new name *Bothriospondylus* (*B. magnus*), the Brit. Mus. fossil No. 28632 (the first of the two vertebral centra on which, in 1869, Mr. Seeley had founded *Ornithopsis*, and with which, as just mentioned, in 1870, I had identified *Eucamerotus*). The prior name, *Ornithopsis*, was rejected by Prof. Owen, substantially, as he is careful to explain, because he deemed it misleading*. Since, however, *Ornithopsis* (*ὄρνις* and *ὄψις*) merely expresses *bird-likeness*, and in their peculiarly light construction, lateral openings, and large-cancellated tissue, the trunk-vertebræ do exhibit such a likeness, I have not felt myself warranted in abandoning the prior name for the newer *Bothriospondylus.*

The side and front view of this fine centrum (28632), in pl. viii. of Prof. R. Owen's Monograph, give a good idea of the form and the position of the lateral opening into the side chamber, and of the general character of the cancellous tissue; but the artist has very imperfectly displayed the beautiful arrangement of the large cells at the circumference of the ball where this begins to rise from the non-articular surface of the centrum. Here the cells are of very considerable and uniform size, their form is prismatic, the base of the prism is outwards, the thin edge inwards, converging towards a central point, and the long axis is approximately parallel to the long axis of the centrum. Such definite arrangement has evidently reference to the direction of strains.

The cervical vertebræ were long a puzzle to Mr. Fox and to myself. As far back as 1865 he showed me a much crushed cervical centrum, which he informed me had been determined by an eminent palæontologist to be the basioccipital bone. Others were afterwards acquired by Mr. Fox, and one by myself, most of which, like that first obtained, showed great flattening of the under surface of the centrum and great elongation. One much mutilated and distorted centrum was so long that even so keen-sighted and experienced a collector as Mr. Fox, deceived by its great length, passed it by several times in the cliff, thinking it was a log of the

* Monogr. Mesoz. Rept. part ii. p. 24, pls. viii., ix. (Pal. Soc. vol. for 1876).

fossilized wood so abundant there, and finally had it taken home under the impression that it was the long bone of a limb. A mutilated cervical centrum in my collection, which I dug out of the cliff-foot near Brixton Chine, is in its present worn state 12 inches long, and would have been originally about 2 inches longer (No. 144, Coll. H.)

Its under surface is flattened, and the side is impressed by a long narrow pit, the bottom of which is marked with an oblique ridge. I term the lateral hollow in the cervical centra a "*pit*," because it is a wide-mouthed depression, closed at its bottom, and not in communication with an internal chamber, the interior of the centrum being wholly composed of large-cancellated issue. The immense spaces of this are well shown in the instructive plate illustrating the supplement to Prof. R. Owen's Monograph on the "Fossil Reptilia of the Wealden," issued in 1876, in which an exceptionally preserved cervical centrum is described under the new name of *Chondrosteosaurus magnus**.

Up to this time no other parts of the skeleton than præsacral vertebræ had been identified. Huge limbs or pelvic bones of forms commonly referred to *Ceteosaurus* had been obtained from the same bed which had yielded Ornithopsidian vertebræ, but not in such close association with these as to warrant me in assigning them to this genus. Besides, the widely different character of the bony tissue prejudiced both Mr. Fox and myself against such identification, probably, as we now have reason to think, wrongly.

It will be remembered that in 1870 I had suggested that (*Eucamerotus*) *Ornithopsis* and *Ceteosaurus oxoniensis*, with perhaps *Streptospondylus Cuvieri*, were members of one genus (this would have been more correctly expressed "of one *family*") in the order Dinosauria, characterized by opisthocœlous trunk-vertebræ bearing a highly complex neural arch, and having a large lateral hollow in the anterior part of the centrum, opening externally under the neurapophysis†.

In July 1877 a brief notice by Prof. O. C. Marsh of some very large reptilian remains then recently acquired by the Museum of Yale College appeared to refer to a member of the above family, since a "very large cavity in each side [of the centrum in the sacral vertebræ], connected with the outer surface by an elongated foramen below the base of the neural arch," was mentioned as an important character. For the animal indicated by these fossils Prof. Marsh made the new genus *Titanosaurus*, *T. montanus*‡. Afterwards, finding *Titanosaurus* preoccupied, he replaced this name by *Atlantosaurus*, and *T. montanus* became then *A. montanus*§. Its femur, about 7 feet long, had no prominent third trochanter, but only a swelling in its place.

In the meantime Prof. Cope had, out of other reptilian remains

* Suppl. Monogr. Foss. Rept. Wealden, pl. v. fig. 2, p. 5 (Pal. Soc. vol. 1876).
† Quart. Journ. Geol. Soc. (1871) vol. xxviii. p. 36.
‡ Amer. Journ. Sc. and Arts, vol. xiv. pp. 87, 88 (July 1877).
§ *Ibid.* p. 514, Nov. 1877.

from the same district in Colorado, defined the genera *Camarasaurus* and *Amphicœlias*, the species of which, mostly of surpassing bulk, had præcaudal vertebræ laterally excavated by large internal chambers as in (*Eucamerotus*) *Ornithopsis* and *Atlantosaurus* *.

Last autumn (1878) Prof. Marsh and, later, Prof. Cope saw my fossils, and recognized their likeness to some of the new Colorado Dinosaurs. A closer comparison of *Ornithopsis* with these was desirable; and for my assistance in this task both these gentlemen forwarded me copies of all their published papers relating to them, for which, as also for much valuable information respecting them otherwise imparted to me, I here express my sincere thanks.

Of the Colorado Dinosaurs whose vertebræ present correspondences with those of *Ornithopsis* the following genera have been defined:—

Prof. O. C. Marsh.	Prof. Cope.
1. *Titanosaurus* = *Atlantosaurus*.	1. *Camarasaurus*.
2. *Morosaurus*.	2. *Amphicœlias*.
3. *Apatosaurus*.	3. *Epanterias*.
4. *Allosaurus*.	
5. *Diplodocus*.	

Professor Marsh's five genera form a natural group or suborder in Dinosauria, designated by him *Sauropoda*, distinguished by the principal characters of their feet, which are plantigrade and pentadactyle, having their carpalia and tarsalia distinct. The fore and hind limbs are nearly equal in size. The præcaudal vertebræ are opisthocœlous; their centra contain large cavities apparently pneumatic. The sacral vertebræ do not exceed four, and each supports its own transverse process †.

The first of Professor Cope's three genera, *Camarasaurus*, has been identified by him with *Atlantosaurus* of Marsh ‡; but this is disallowed by Prof. Marsh on the ground of the different construction of the sacral vertebræ, which Marsh finds in *Atlantosaurus* to have chambered centra, those of *Camarasaurus* being described by Prof. Cope as solid §.

Of *Camarasaurus*, Prof. Cope writes:—" The vertebræ of the cervical, dorsal, and lumbar region are all opisthocœlous, or reversed ball and socket. The centra of the cervicals are very elongate, but those which follow them diminish rapidly in length until, in the lumbar region, they have but a small antero-posterior diameter." " The centra of the cervicals and dorsals are hollow, and the interior chambers communicate with the cavity (outer surface ?) of the body by a large foramen on each side, which is below the base of the diapophysis. In the cervical vertebræ it is very elongate, and extends between the base of the parapophysis and diapophysis. In

* Prof. E. D. Cope, Pal. Bulletin, No. 25, August 1877 (and Proc. Amer. Phil. Soc. same date); and Pal. Bulletin, No. 27, Dec. 1877.

† Principal characters of American Jurassic Dinosaurs, by Prof. O. C. Marsh, parts 1, 2 (1878–9).

‡ American Naturalist, June 1878, p. 406.

§ Pal. Bulletin, No. 28, p. 235, July 12, 1878.

the dorsal centra there are but two chambers, which are separated by a longitudinal median septum. The neural arches are coossified with the centrum throughout the column; they are extraordinarily elevated, and their antero-posterior diameter is small. The zygapophyses are at its summit, and have extensive articulating surfaces. The anterior pair are divided by a deep median fissure, while the posterior are united and support, as a pendant from their inferior median line, a *hyposphen*, a structure more fully described under the head of *Amphicœlias*, where it is equally developed. When the vertebræ are in relation, the base of the hyposphen enters the fissure between the anterior zygapophyses, and maintains them in position. This structure is obsolete in the lumbar vertebræ. The diapophyses...... of the dorsal vertebræ are light, and concave below. They are supported by thin osseous buttresses, the most important of which are the two inferior ones. The anterior of these is much the most prominent, and bears the capitular articular face for the rib. In no case is this surface seen on the centrum; but it descends somewhat in the posterior vertebræ, but not so low as the level of the neural canal. The neural spines are rather short, and are set transversely to the axis of the animal. The superior portion is expanded transversely, and in an anterior dorsal vertebra is widely emarginate above, so as to appear double"*. With *Camarasaurus* Prof. R. Owen has recently identified (generically?) his *Chondrosteosaurus* (= *Ornithopsis*), from British Wealden beds, and on this basis has offered a reconstruction of the latter animal †. It is to me a matter of sincere regret that the material at Prof. Owen's disposal for this was limited to three centra, two very mutilated, from none of which was it possible to gain a true insight into the construction of the arch and processes. In their opisthocœlous form, large lateral foramen, great internal chambers, median partition-wall, and magnicellular cancellous tissue and double rib-articulation, the dorsal vertebræ of *Chondrosteosaurus*, as Prof. Owen points out, exhibit correspondences with those of *Camarasaurus* ‡; and this holds equally good with those of *Atlantosaurus*. Yet, with these correspondences, there are differences which cannot be quite passed over. In every dorsal vertebra of *Ornithopsis* known to me, the lateral foramen, unless distorted by pressure, is longer than high. In this, *Ornithopsis* more nearly resembles *Anphicœlias* than *Camarasaurus*. In *Camarasaurus* the opening is figured as partly in the neurapophysis; this I have never seen in *Ornithopsis*. In their great elongation, and in the long narrow shape of the lateral opening, the cervicals of *Ornithopsis* (*Chondrosteosaurus*, Owen) agree with those of *Camarasaurus* §; but in *Ornithopsis* the hollow is a wide-mouthed pit, contracting towards its bottom, and not a linear foramen leading into an inner chamber, as Prof. Cope's

* Pal. Bulletin, No. 28, pp. 233–246, from Proc. Amer. Phil. Soc., Dec. 1877.
† Annals and Mag. Nat. Hist., 1878, vol. ii. pp. 202–215, pls. x., xi.
‡ *Ibid.* pp. 201-208.
§ Owen, *ut suprà*.

description implies it does in *Camarasaurus**. In this latter, also, the upper surface of the cervical parapophysis exhibits a very characteristic excavation, which is wanting in the known cervicals of *Ornithopsis*. These, however, might be regarded as trivial differences, not entitled to generic rank.

In the neural arch and processes a similar interchange of concordances and differences is observable. In *Ornithopsis* and *Camarasaurus*, as also in *Epanterias*†, the free end of the neural spine is expanded transversely in some of the trunk-vertebræ; but its construction is less complex in *Camarasaurus*, in which, too, the deep entering angle between its postzygapophysial roots for the attachment of the interspinous ligament, so noticeable in *Ornithopsis*, is absent.

A more notable difference, to which my attention has been called by Prof. Cope‡, is the bifid divergent form of the neural spine in a dorsal vertebra of *Camarasaurus*, which, by the situation of its parapophysis, held a correspondent place in the vertebral column to that of my first vertebra (No. 144, coll. H.). Although the free extremity of the spinous process is defective, enough is preserved to show that it could not have had the remarkably forked divergent form represented in Prof. Cope's figure 2.

I agree with Prof. Cope that this is a difference certainly of generic value.

The presence of a supplemental articulation, comparable in principle to zygosphene and zygantrum, in both *Ornithopsis* and *Camarasaurus*, is another singular agreement in which *Amphicœlias* also participates, as it does in the lateral foramen and internal chambers§. In both these North-American Dinosaurs the zygosphene has the form of an inverted wedge, and its base is represented free and unattached, resembling in form and connexion the zygosphene represented by Phillips in *Megalosaurus* and in *Ceteosaurus oxoniensis*, Phillips ‖: but in the corresponding vertebra of *Ornithopsis* the zygosphene is a laterally compressed vertical plate, the posterior face of which is an oblong, from each of the lower angles of which the stout border of a thin sheet slants downwards and forwards upon the posterior margin of the corresponding neurapophysis, near the union of this with the centrum. The two sheets of opposite sides in this way form a sloping eave, which in the articulated vertebral column (when the zygosphene is received into the interpræzygapophysial notch), roofs in that part of the spinal canal, which, owing to the relative shortness of the neurapophysis, would be otherwise comparatively unprotected. This also appears to me a difference of more than trivial value.

Full and complete descriptions of the vertebræ of *Morosaurus*, *Apatosaurus*, and *Allosaurus* are still wanting: their discovery is

* Pal. Bulletin, No. 28, p. 234.

† *Epanterias*, not having chambered externally opening dorsal centra, needs no further notice here.

‡ Cope, Pal. Bulletin, No. 28; Proc. Am. Phil. Soc. pl. 1. fig. 2.

§ The centra of *Amphicœlias* being amphicœlian or platycœlian, this alone suffices to separate it from *Ornithopsis* and *Camarasaurus*.

‖ 'The Geology of Oxford,' p. 256, diagram 87.

yet so recent that sufficient time for their complete investigation has probably not elapsed; but from the clear, though extremely reduced, figures given by Prof. O. C. Marsh, I infer that in *Morosaurus* the cervical vertebral centrum is less depressed than in *Ornithopsis*. The same figures also show that its parapophysis had a conspicuous pit in its upper surface, as in *Camarasaurus*, Cope*.

The side hollow appears also less narrow in the cervical centrum of *Morosaurus*, and the ridges crossing its bottom are differently directed from what they are in *Ornithopsis*. The cervical centra are less elongated in *Apatosaurus*. In *Allosaurus* the vertebræ have zygosphene and zygantrum, but the centra have not side chambers. Only caudals of *Diplodocus* have been yet made known; they are extremely long—the combined length of four exceeded 34 inches. The chevrons are peculiar. Comparison of *Ornithopsis* with it is not yet possible.

The comparison of *Ornithopsis* with the Colorado Dinosaurs has brought out in the præsacral vertebræ such noticeable concordances that a family affinity cannot be doubted; but it has also shown the existence of such important differences that the generic distinctness of *Ornithopsis* will, I think, hardly be disputed. In the main features of agreement, a significant resemblance to *Ceteosaurus oxoniensis* is also discernible.

Before long, I hope to place before the Society evidence of other parts of the skeleton of *Ornithopsis* from British Wealden beds, which will, I believe, greatly assist in establishing its nearest affinity.

Discussion.

Prof. Seeley stated that in giving the name *Ornithopsis Hulkii* to the two vertebræ which he had studied in 1869, which were the only parts of this animal then known, he desired to call attention to the remarkable avian resemblances of the bones. The large deep pits in the vertebræ had reminded him of the similar, but relatively shallower, pits which impress the dorsal vertebræ of Gulls. He had regarded the character as "bird-like," but had neither stated nor believed that it justified an inference that the animal was able to fly; for he had regarded the type as intermediate between Dinosaurs, Pterodactyles, and Birds; and perhaps that conclusion was not so far from the truth as it might have been, considering the materials on which it was founded. He accepted generally the conclusions at which Mr. Hulke had arrived as to the nomenclature and relations of the British forms of *Ornithopsis*, but thought that subgeneric differences were to be detected in Prof. Cope's American types. With regard to the systematic position of the group, he still thought there were grounds for placing the animals in a new subordinal division, especially in the characters of the pneumatic cavities which excavate the centrums; but in face of the circum-

* Proc. Amer. Phil. Soc. vol. xvii.

stance that the Dinosaurian head is not avian, that the only birds which showed any vertebral characters in common were Penguins, that the fore limb was not avian, and that the avian characters of the hind limb were not developed in all Dinosaurs, it would be unsafe to infer that *Ornithopsis* had bird-like lungs; and he thought the pits might indicate a lung founded on the type of the Chamæleontidæ, and therefore be reptilian though bird-like in form.

Prof. Owen said, In contributing a subject for discussion I am sensible of the privilege of submitting it to the Society. To a searcher after truth no gift is so valuable as an indication of an error into which he may have fallen, or of a wrong direction which he may have taken. Such valued return I find to be so constant on the part of my fellow labourers Mr. Hulke and Prof. Seeley whenever I venture to submit a paper to the Society, however remote its subject may be from that which they criticise, that I am led to look upon the circumstance as standing more in a relation of cause and effect than of accidental coincidence, and to flatter myself that I am not only a contributor, but a cause of contribution in others. The considerations involved in Mr. Hulke's present paper are of two kinds, somewhat akin to those which animated the realistic and nominalistic disputants of old times.

There is small likelihood of the generic term *Ichthyosaurus* being superseded by that of *Proterosaurus*. Yet Home's claim of priority was invalidated by a much less amount of unfitness in the term than attaches to *Ornithopsis*. The vertebræ of a *Squalus maximus*, the limb-bones of an elephant, and both parts of the skeleton of an eagle show large unossified tracts. These, in the petrified state, are filled with matrix; but the ossified portions are as determinable as in *Chondrosteosaurus*. The physical question therefore is, whether, in the living animal, the unossified spaces were occupied by chrondrine, by marrow, or by air. On the latter hypothesis the amazement of the beholder of the huge vertebra indicating the magnitude of the flying dragon may be conceived! The inferences from the chondrosal conclusion are tamer, but, in my mind, truer. Mr. Lucas's discovery in the Wealden of Colorado of additional parts of *Chondrosteosaurus* amply demonstrated, as Prof. Cope has recognized, its generic distinction from *Bothriospondylus*. The neural arch of *Eucamerotus*, Hulke, is generically distinct from that of *Camarasaurus*, Cope; the cervical centrum of *Camarasaurus supremus*, Cope, is specifically identical with that of *Chondrosteosaurus gigas*, Owen.

Mr. Hulke pointed out that the name *Chondrosteosaurus*, quite as much as *Ornithopsis*, was founded on theoretical considerations, while *Eucamerotus* was founded on fact.

59. *On the* Ancient River-deposit *of the* Amazon. By C. Barrington Brown, Esq., F.G.S., Assoc. R.S.M. (Read June 25, 1879.)

[Plate XXXVIII.]

It is my intention to endeavour to describe in this paper the mode of occurrence, deposition, and general characters of a vast deposit of ancient alluvial matter which forms a great portion of the valley of the Amazon, and to deduce therefrom some facts regarding the deposition of detrital matters by this great river.

In ascending the Amazon, one cannot fail to be struck by the appearance of lines of cliffs at long intervals apart—first on one hand, and then upon the other—which, rendered conspicuous by their bright colouring, form a pleasing contrast to the monotonous line of low greyish-clay river-sides which elsewhere meets the eye. In fact, they on the one hand, and a great plain of recent alluvium on the other, when the river is flowing on one side or the other of its present valley, are the chief features in the physical geography of the Amazon and its tributaries.

The accompanying diagrammatic section (fig. 1) will explain the relative position of the two.

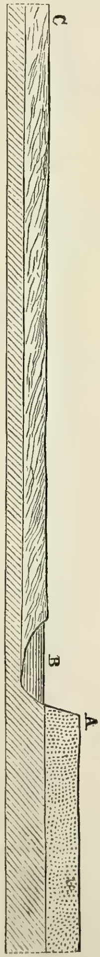


Fig. 1.—*Diagrammatic Section across the Valley of the Amazon.*

A. Cliffs. B. River Amazon. BC. Alluvial plain.

Exceptions to the above-described conditions are only seen on the Lower Amazon at Almeyrin and Montealegré (where views of some picturesque scenery are obtained, produced by sandstone mountains of doubtful Triassic age), and at Santarem, on the Tapajos river, on the Trombettas river, at Parintins, Juruty, and Faro (where there are table-lands rising, in some instances, to a height of 460 feet above the general level, which are composed of beds of friable sandstone and clay, of grey, white, and reddish colours). The age of these last-mentioned beds has not been determined, owing to the entire absence of fossil forms; and it is a question whether they belong to the upper part of the Triassic sandstone or are of a more recent date.

They evidently at one time filled a great part of the valley of the Amazon, and can now be traced from Montealegré to Manaôs, but are not found on the banks of the Upper Amazon, or Solimões, as it is usually termed.

Both the elevated plateau of the ancient river-deposit and the plain are, as a general rule, thickly clothed with trees and vegetation of the most luxuriant description. With the exception of a narrow strip, in many places along the river's edge, which is raised a foot or two above the water-level in time of floods, the whole of the alluvial plain is at certain seasons covered with a sheet of water, produced by the rising of the river's surface above the level of its banks. On these occasions, which occur periodically, the inhabitants who cultivate the rich alluvial soil in the immediate vicinity of the river's borders retire to the small towns, villages, and hazêndas built on the elevated river-deposit.

The cliffs then seen from the river are the face-sections of an elevated tract of almost level country, spreading continuously along the course of the Amazon in both northerly and southerly directions for many miles, and terminating generally where the underlying rocky stratum, by its superior elevation, has been left untouched by fluviatile action. They afford the means of determining the composition of the whole area occupied by the deposit in the vicinity of the Amazon; whilst similar sections on the borders of most of the great tributaries give equal facilities for studying it in opposite directions. Their crests vary in height from levels of 10 to 160 feet* above the river's flood-mark, whilst their bases are generally exposed when the river is at a low ebb.

From hasty examinations made in numerous places, I have, as a general rule, found the cliffs to be composed of layers of sand and clay, exhibiting every degree of false bedding, and varying greatly in structure and composition when traced in lateral directions.

The sand beds are of white, red, yellow, or variegated colours, while the clay beds are chiefly bluish or variegated. No very coarse materials ever enter into their composition. Resting upon, and sometimes passing into, them is a homogeneous deposit of reddish loam, capped by a yellow clay or a dark vegetable soil.

In order to afford a clear idea of the structure of these cliffs, I here give some sections, taken in various places, the localities of which will be seen by reference to the accompanying map (Pl. XXXVIII.). The measurements of these are approximate only, as, owing to the often inaccessible nature of the cliffs and to the short time at my disposal, exact measurements could not be taken.

Beginning with the Lower Amazon, I give a sketch section of a portion of the Barreiras (cliffs) of Montealegré (fig. 2), the vertical scale of which is exaggerated in order to show their structure more clearly.

* In my paper on the Tertiary deposits of the Amazon, in the Quarterly Journal of the Society, vol. xxxv. part 1, I said that the old river-deposit is seen in cliff-sections "ranging from 10 to 300 feet in height." Since that was written I have gone more thoroughly into the matter, and have modified my views regarding its thickness.

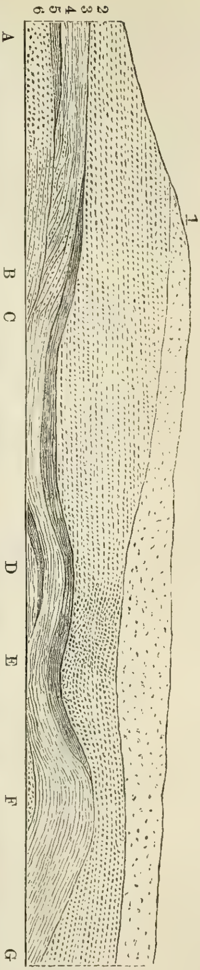
Near the centre portion of the section, bed 2 contains layers of pinkish sand, and is there exceedingly false-bedded. At section B bed 4 is seen to have changed into a false-bedded yellow sand and clay; at C to a greyish-white clay; at D to a grey clay; at E to a grey arenaceous clay, marked with curved layers of the same material; at F to red, white, and grey clay in regular layers; and at G to its original composition and colour. Bed 6 changes at B to a white arenaceous clay; at D to a white clay, striped with red layers; and at F to a white sand again.

In this portion of the cliff the base of the beds was not seen, but to the eastward it was shown by an exposure of ferruginous sandstone.

At Obidos, however, the base of the deposit is clearly exposed when the river is comparatively low, and is composed of pinkish sand. This rests upon the soft, variegated, red and white friable sandstone before referred to, which has a slight dip in a westerly direction.

Cavaraucu cliffs give a section in one place 190 feet in height; but as they are the front of land rising to heights of over 200 feet above the river, I am inclined to believe that they are, in part at least, sections of the friable-sandstone deposit. With the exception of some 10 ft. of red and yellowish clay on the top, the whole of the section was formed of grey, pink, and lilac layers of arenaceous clay, having in it patches of red coloration, as well as thin layers of pure white clay. The red clay from the top having been washed down the face of the cliff for some distance, gave it the appearance of being composed of red clay in all its upper portion.

Fig. 2.—Sketch Section of part of the Barreiras of Monte Alegré.



1. Red sand, of a loamy nature in its upper portion. 2 White sand. 3. Striped purplish sand and clay. 4. White clay. 5. Purplish clay. 6. White sand.
A, B, C, D, E, F, and G show the places at which vertical sections were taken.

The cliffs along the borders of the Solimões are not so high as those upon the Lower Amazon. The first of these, occurring at Manacaparu, is 60 feet in height. It is composed of reddish and yellow loam, resting on sand beds in one part. Both at the base and near the top iron-impregnated layers of clay, forming a honeycombed variety of ferruginous rock, occur; while in another place white clay beds are seen resting on bright red beds.

Coary cliffs are composed of red loam, red clay, and sand, and bluish, grey, and reddish clay, in descending order. Here the deposit rests upon a bluish arenaceous clay, the surface of which must have been much eroded before the deposition of the superincumbent mass. The first place where this subjacent stratum is seen is near the mouth of the Purus river; and I am inclined to the belief that it belongs to the upper part of the Tertiary deposit, sections of which are seen further up the Solimões. In this part, however, it does not contain any fossil shells, but has a few layers of leaves.

Not far above Coary are cliffs called Tanacoara, where the following section was obtained:—

ft.	
15	Red loam.
20	Pink sand beds.
1	Yellow clay.
34	Light greenish-grey clay.

At the upper end of this section the underlying, false-bedded, bluish clay makes its appearance, forming further on the full height of the river's bank, with the exception of a few feet of grey clay, into which it seems to pass. No portion of it rises above the level of high-water mark of floods, which, at the time of my visit, was 40 feet above the then level of the water.

The next Barreira—that of Camara Coary—is composed at its eastern end of 70 feet of pinkish and white arenaceous loam, upon 30 feet of red and yellow sand; while at its western end we find it made up of beds of

Red argillaceous loam.
Red and white sand.
Yellowish sand.
Red sand, resting upon the denuded surface of the blue clay before mentioned.

At Tapera Barreiras, a little further on, this latter assumes a rock-like aspect, and its bedding dips eastward at an angle of 5°.

Motun Coary cliffs differ greatly in their composition, being at their eastern end of red loam, resting upon beds of red sand; and at their western, of white sand upon white clay. Near their western end they are composed of red loam upon yellowish and reddish speckled sand, resting upon the subjacent bluish clay, which at this spot, where baked by the sun's rays, has a shale-like appearance. Its beds have lines of deposition in various directions and in irregular curves. A thickness of some 10 feet of it was seen above the water, which at the time stood at a level of 40 feet below its floodmark. It contained some portions of imbedded tree-stems, and its eroded surface was covered with a thin layer of hydrated sesquioxide of iron.

About a quarter of a mile down the river, in the same barreira, there was a great and almost circular bay in the face of the cliff, of 200 yards in diameter, the entrance to which was only about 50 yards in width. This resembled somewhat the crater of a volcano, and was an instance of the prodigious power exerted by the river in suddenly washing down great portions of its banks. Entering the bay in a boat, I had an opportunity of examining its side sections. The deposit here consisted of grey and white sand beds for almost the full height of the cliff; upon them rested white clay with red loam on top. In the centre of the bay rose a small, narrow peninsula of whitish-grey sand, forming a thin peaked ridge of about one half the height of the cliff, and joining with the base of the cliff in the middle of the back of the scoop. In this sand were pellets of blue clay, and in some parts trunks of large trees in a semicarbonized state, showing that they had been imbedded for a long period. The washing-out of this great mass of material, of 600 feet in diameter by 80 feet in height, was performed mainly by the river, the current of which made an eddy at its edge at the foot of the cliff, and thus cut rapidly into the soft sand of which the latter is composed. The force thus exerted was probably assisted by springs of water which issued through the base of the sand above the bluish clay.

Guara Barreira rises to a height of only 10 feet above flood-mark, and is composed of the following beds :—

ft.	in.	
0	5	Brown loam.
11	0	Red arenaceous clay, passing into mottled red and grey clay.
12	0	Banded red and grey clay-beds.
3	0	Yellow sand.
20	0	Light-yellow sand.

Here the river's level at the time was 6 feet above the lowest point it ever attains, and was by measurement $36\frac{1}{2}$ feet below the water-mark of the highest point it reaches in the rainy season. There is a constant fluctuation in the level of the river day by day ; for, even when subsiding gradually, it will sometimes rise a few feet, and then as suddenly fall again. This is owing to heavy rains in the Andes, or at the source of some of its large tributaries, producing a sudden accession of water to the main river.

At Fonte Bôa Barreiras, 60 feet in height of which was exposed, the following sections, taken not far apart, show a considerable difference in the composition of the beds of the deposit over a small area :—

	feet.	
I.	3	Red loam.
	37	Red sand.
	8	Yellowish sand.
	5	Red, pink, yellow, whitish, and variegated plastic clay.
	7	Yellow sand.
II.	30	Red loam. Mottled clay. Grey and red-banded plastic clay.
	30	Red speckled sand. Grey sand. Yellow sand.

A section at Jutahy Barreiras gave the following :—

ft.	
5	Yellow loam.
10	Red loam.
1	Purple clay.
14	Reddish-pink sand.
30	Yellow sand.

The latter rested upon the eroded surface of the bluish, arenaceous, laminated clay, which dipped to the west, and enclosed a thick layer of yellowish sand, containing lines of clay ironstone.

Two sections taken at Tonantins were as follows :—

	ft.	
I.	10	Red loam.
	40	Yellow sand, with layer of gravel near its base.
	5	Yellow sand, with layers of iron-clay in irregular folds.
	20	Pink and white banded clay of fine texture.
II.	10	Red sand and loan.
	35	Yellow sand.
	20	Banded red and grey clay.
	25	Blue laminated clay, having thin layers of sand between the laminæ, and containing imbedded leaves. Yellow laminated clay.

In one part white sand took the place of the yellow sand ; while in another the bluish, laminated, micaceous clay made its appearance, dipping west at a low angle. Upon its denuded surface rests the iron-oxide layer, along with yellow ochreous clay in yellow sand, with pink clay and sand above. The fine, soft, yellow ochreous clay is used by the natives as a pigment.

About one mile below St. Paulo we have as follows :—

10 feet of reddish arenaceous loam.
15 „ white sand, containing pebbles.

These rest upon bluish-grey clay beds, which I consider to be of Tertiary age.

At Caldeirão the section is a tolerably clear one, and is as follows :—

ft.	in.	
1	6	Red loam.
12	0	Grey and mottled clay.
11	0	Reddish sand.
12	0	Yellowish speckled sand.
2	0	Blue clay.
2	0	Grey sand.
2	0	Blue clay.
2	0	Grey sand.
5	0	Blue clay.
10	0	Yellowish and grey sand, stained with iron oxide.

Having now given the details of a number of the principal cliff-sections on the main river, I will proceed to describe a few of those occurring on its tributaries, so as to show the composition of the deposit in both northerly and southerly directions.

The Trombetas does not afford any good section, as the deposit does not extend far up it. At Urua-tapera Point, however, there is a cliff 90 feet high, composed of red and purplish sand beds of the river-deposit, resting upon an older formation of red shale.

On the upper part of the Rio Negro there are beds of the river-deposit which have been laid down by the Negro itself. The first set of cliffs above Caburie shows grey and mottled clay, resting upon yellowish and grey false-bedded sand. In the third set of cliffs there are but few sand beds, and the whole front is made up of clay beds.

The top portion is grey, mottled with red specks, resting on beds of grey, white, and bluish-grey clay, which are in thick beds in parts, or in thin false-bedded layers in others. In one place they contained a sort of peat, mixed with brown clay and pieces of carbonized wood.

Thomar cliffs show

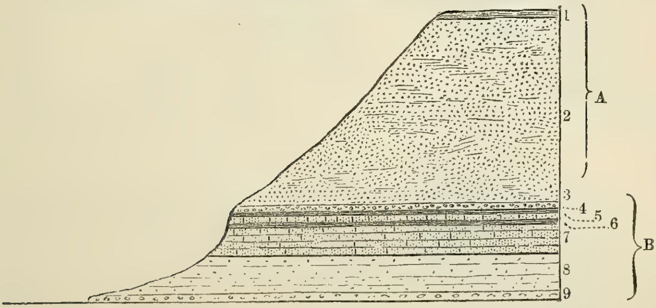
15 feet of red loam.
15 ,, yellowish false-bedded sand.

These sections are all above the flood-level, as the river was full at the time they were taken.

Turning now to the southern tributaries, we find that this deposit is not represented upon the Tapajos, the red and yellow cliffs bordering that river belonging to the sandstone formation before mentioned. The face of the high land above Aramanahy is sloping and tree-covered, and does not afford a section showing its composition; but it evidently belongs to the sandstone deposit, especially in the greater part of its lower portion. The upper part may, however, be composed of a deposit made by the Amazon when it ran at a higher level. In fact, the upper part of the tableland at Parentins, Juruty Faro, &c. may be an old river-terrace.

I here introduce a section occurring at Porto do Aleagre (fig. 3), in order to show the structure of a part of the underlying strata just spoken of, as well as a deposit which I take to be a more ancient river-terrace than the one under discussion. The terrace portion is made up entirely of reddish, yellow, and red-mottled false-bedded sand, capped by red loam, the whole having a thickness of 147 feet.

Fig. 3.—*Section at Porto do Aleagre.*



A. Old river-terrace. B. Sandstone.

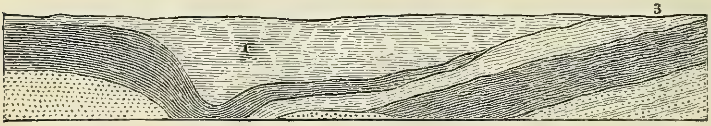
A. {
1. 3 feet red loam.
2. 144 ,, false-bedded red, yellow, and mottled sand.

B. {
3. 5 ,, coarse, waterworn gravel bed.
4. 2½ ,, grey clay.
5. 5 ,, purplish and grey irregularly bedded sandstone, cemented by white clay.
6. 2½ ,, mottled red and white clay.
7. 24 ,, friable sandstone.
8. 30 ,, angular and partially rounded grains of yellowish sand, cemented by yellow clay into a friable sandstone.
9. 4 ,, hard, whitish, pebble sandstone.

220

Upon the Madeira river the first red cliffs below the mouth of the Jamary, which at the time (owing to the comparatively high state of the river) showed only 30 feet vertically, are composed of mottled red and grey clay, with red clay on top in their upper half, and false-bedded brownish sand in their lower. The sand beds dip to the north-east; and a few yards further on the clay forms the whole thickness of the cliff, coming down to the water-level. About the middle of the cliff's front there is only 1 foot of brown sand above water, then comes a fine greyish-brown clay, irregularly interbedded with a curious light-bluish clay, which in one part contains fragments of unaltered leaves, and is 5 feet in thickness. Upon it lies a bed of grey clay 4 feet thick, and above comes 20 feet of red clay and loam. A few yards north-east of this these beds turn up quickly, and the mottled red and grey clay, commencing at the water's level, thickens out, rising at an angle of 3°. It rests upon a layer of red and grey finely laminated clay, which runs a considerable distance with a thickness of about 15 feet, and then passes horizontally into red and grey mottled clay (fig. 4). The accompanying diagram shows the arrangement of these beds.

Fig. 4.—*Rough Section of Abeila Cliff below Jamary.*



1. Red clay.
2. Mottled and grey clay.
3. Greyish-brown clay.
4. Mottled clay.
5. Brown sand.
6. Red sand and grey clay.

Near Baetas, on the west bank of the same river, is the following section:—

ft.	
5	Fine red argillaceous sand.
4	Grey clay.
20	Grey, white, and yellow sand.
½	Coarse sand.
¼	Hard iron-cemented clay.
10	Fine bluish-grey clay.

Upon the Purus river there are many fine cliff-sections; but as it would take up too much space to record them all, I will merely describe two rather striking ones, viz. that at Maniwa, some 800 miles up, and one at Berury, near the mouth. In the diagram of the former (fig. 5), at a number of vertical sections through different spots, marked A, B, C, D, &c., we find the beds arranged as follows:—

At Section A we have:—1. Mottled red and yellow clay; 2. Red sand; 3. Yellow sand; 4. Pink, red, and grey clay, alternating with grey sand.

At Section B we see that bed No. 1 has become red arenaceous clay; at D a mottled clay; and at G a red loam.

At Section B, bed No. 2 becomes red and pink false-bedded sand; at D, red false-bedded sand; at F to H, red sand. At Section C, deposit No. 4 becomes a pink and grey clay in thin beds, alternating with grey and yellow sand; at D it loses its pinkish colour and becomes grey; at F is grey clay and sand; at G is false-bedded pink clay and sand, passing immediately into thick-bedded, greenish-grey sand and clay, to the end of the cliff. This last set may possibly belong to an older deposit. The dark-coloured portions at C, E, and F, in the upper part of No. 4, are layers of bluish clay, containing leaves and pieces of carbonized wood at C, and with thin layers of oxide of iron at their base at E and F. No. 3 is a bed of yellow sand containing thin layers of oxide of iron.

Of this section 51 feet vertically are hidden when the river is at its highest stage.

The layers of iron oxide above mentioned have been deposited by water charged with that substance, obtained from the red ochreous surface-loam, which has percolated through the sand beds, and has been precipitated in a thin sand layer between the blue clay and the clay of No. 3 beneath.

At Hytanahan, a place further up the river, and at many other places where similar yellow sand beds are seen, layers of this iron-rock occur. They are composed of fine-grained, ferruginous sandstone, more or less compact, arranged around a nucleus of almost pure oxide of iron, which in some places assumes the form of botryoidal masses, and in others of curved laminæ, which frequently send layers down into the sand beneath as offshoots, at right angles to the parent mass, forming quite a network of fantastically arranged planes. They vary in width from ½ inch or less to

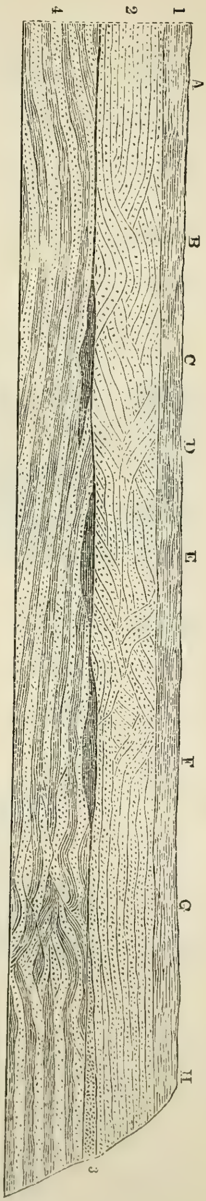
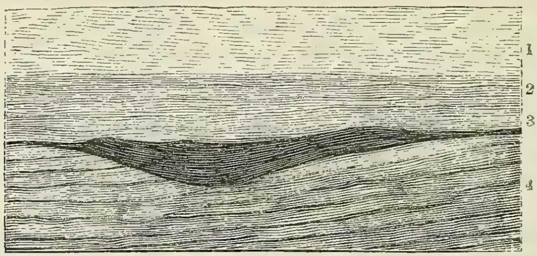


Fig. 5.—Section at Maniwa, on the Purus River.

5 feet. When an ordinary thick layer is left on the river's edge—as is often the case, from the resistance it offers to the wearing action of the water and the protection it affords the clay on which it rests, —a dome-like pile of broken rock is left, having a formidable appearance, but which in reality is a very friable heap. One very curious form of this ironstone is seen in a clay-bed at Hytanahan, where it is in small, detached, smooth, hemispherical nodules, greatly resembling in form the iron slag from the bottom of a crucible.

At Berury cliff, when the river stood at a level of 41 feet below the highest point it reaches in the rainy season, the following section (fig. 6) was observed :—

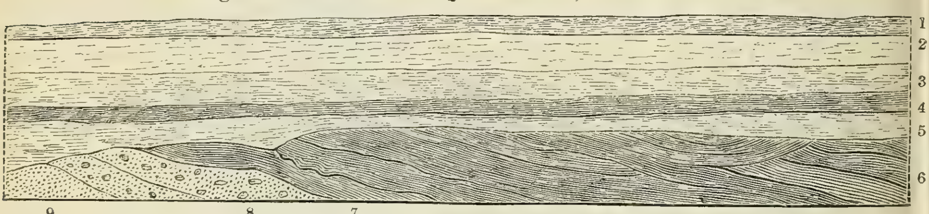
Fig. 6.—*Section in the Berury Cliff, Purus River.*



1. Mottled clay. 2. Banded red and grey clay.
3. Bluish clay, with layers of leaves.
4. Bluish arenaceous laminated clay, probably of Tertiary age.

The sections on the Jurua river are very similar to those on the Purus ; and I therefore give only one section (fig. 7), which was taken at Gavião Barreiras.

Fig. 7.—*Section at Gavivo Barreiras, Jurua River.*



River-deposit:
1. Red loam.
2. Grey clay.
3. Reddish clay.
4. Yellow clay.
5. Grey clay.

Older deposit, probably Tertiary:
6. False-bedded blue clay, containing imbedded leaves.
7. Grey laminated clay.
8. Clay conglomerate, of masses of yellow sand and pink clay, coated with crust of iron oxide, imbedded in yellow sand.
9. Red sand.

I will now conclude the description of the various sections of the old river-deposit by recording one which occurs on the Javary at Santa Rosa :—10 feet red loam ; 30 feet white sand.

This rests upon 20 feet of Tertiary clays of the Eocene formation.

From a careful study of these recorded sections, I think it is only possible to arrive at the conclusion that they have been deposited by river-action. The absence of imbedded fossil shells, the great and persistent instances of false-bedding, and the non-continuity of the beds favour greatly the supposition that the materials of this deposit were produced by the wearing action of the Amazon and its tributaries, and by them deposited in their valley, as they eroded its surface, on the way to the ocean.

Examining with attention the action of this great river on the line of country through which it flows, we find that as it moves onward in any one portion of its course it cuts away the materials composing its banks on the convex side of its bends; while at the same time it deposits near its opposite shore, in the concave curves, false-bedded irregular layers of clay and sand derived from materials so cut away from places higher up its course; that, owing to its curving course, the deepest portion, with its greatest volume, exercising the most powerful eroding action exerted by any part of its width is on one side, while at a distance of a few miles higher up or lower down it is on the opposite side. Thus slowly, but surely, is it widening out its present valley by encroaching on its banks in opposite directions. Upon the side opposite to where the current is the cutting-action is absent, and the water has but slight movement, allowing materials in suspension to be deposited steadily there upon its bottom, and gradually filling up its bed, forming a sloping foreshore, which is seen when the waters are low. Thus layers of mud and sand spread themselves out over the river's bottom, being thick near that side, and thinning off towards mid-river as they come within the influence of the rapidly flowing current, and add to the growth of the level alluvial tract now being laid down by the river. Of course there are exceptions to this rule where the river flows in a perfectly straight course in the general direction, and has one or more deep-bed channels; but this does not affect the above-described general conduct of river-action; for as the curved portions of the river advance they efface and destroy the straight portions, and force the whole to assist in the general work of destruction and remodelling. The alluvial tract is below the level of the river's surface in times of flood, so that it is then covered with a sheet of currentless water laden with sediment, which, settling down as layers of loamy matter, year after year, forms at last a thick covering of homogeneous structure.

Thus two great works are now being performed by the Amazon at the same time, viz. the cutting away of portions of the deposit which it formerly laid down, and which is the subject of this paper, and redepositing the materials so obtained in a thick layer of recent alluvium at a much lower level. From a study of the present deposition of the recent alluvium, we learn how the older deposit was formed over the portion of the Amazon which I had an opportunity of examining. In order to describe this we must suppose there was a time when the Amazon commenced flowing over the lowest level portions of a great plain, which rose gradually above the sea to the west of the vicinity of the great Tertiary estuarine strata on the Javary river, and extended eastward until it reached considerably beyond its present limits; for it is probable that the Amazon (a shorter river then by 2000 miles) was one of the rivers which flowed from the Andes into the estuary in which the Tertiary beds were formed. The rocks of the plain were chiefly of comparatively soft materials, such as sandstane, shale, and limestone; although in some parts of its borders they were of granite, gneiss, and quartz-porphyry. On these substances the river began to exert its wearing action, and to move gradually sideways in a southerly direction in one part, and in a northerly in another, over the plain, cutting slowly deeper and deeper as it thus moved, and depositing the materials in its currentless portion (see diagram, fig. 8).

By the time it had crossed its valley at any given part (see fig. 9) it was at a much lower level than at the side it was deflected from, and then, the direction of its curves becoming altered, it travelled back to the vicinity of its starting-point at the extreme limit of its valley on that side (see fig. 10). There, from having cut deeper and deeper as it went, it has a cliff composed of materials of its own deposition as a limit; while on the other side it left a cliff, D (see fig. 10), of the rocky strata of the plain; and stretching from that latter cliff to the river's edge is a great alluvial plain, partially submerged when the river is at its highest stage. By supposing that the river once more recrossed its plain as in fig. 11, I think we have the conditions that are now in force on the Amazon in the vicinity of Monte Alegré and its barreiras. For if the upper portion of the higher tableland is composed of an old deposit of the river, it was formed under the conditions shown in fig. 8, and is represented in fig. 11, at B, as the first laid down alluvium; while the old river-deposit is represented by G in the same diagram, and was formed under the conditions shown in fig. 10. The recent alluvium at present bordering the Amazon is given at I in fig. 11.

In some places on the Amazon (at Obidos, for instance), where the river in its ordinary state comes only to about the level of the base of its old-deposit cliff, we must infer that in crossing and recrossing its valley it cut gradually downwards a distance equal to about twice its depth. There we find that the thickness of the old deposit corresponds in measurement with the depth of the river, as it naturally should. Here, then, we have a proof that the thickness of materials deposited by a river is not greater than the depth of the river; and likewise that the strata beneath the bottom of its bed are not composed of alluvial matters, as we are led to believe by viewing some sections in geological works. By a study of river-action, as shown in diagrams 8 to 10, we see that it is impossible for a river, in its non-tidal portion, to have deposited materials at a lower level than the deepest part of its bed. This can only take place near its mouth, where it is forming a delta, or in the case of a gradual rise of country near its mouth arresting its flow and converting it into a lake. In both

Figs. 8–11.—*Diagrams illustrating the Action of the River Amazon upon its Valley.*

Fig. 8.

Fig. 9.

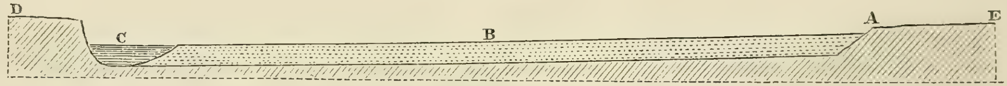


Fig. 10.

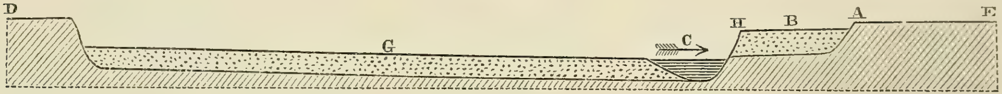
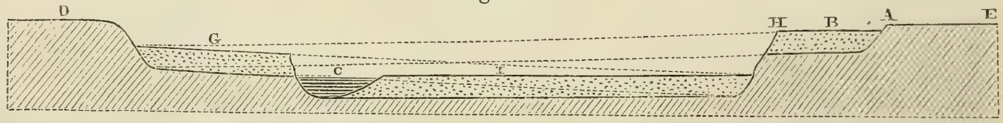


Fig. 11.



A. Starting-point of river in transverse section.
B. Alluvial matter deposited by river.
C. River cutting its way into strata in direction represented by arrow.
D, E. Country recently risen above the ocean.
G. Redeposited alluvium.
H. Cliff of old deposit.
I. Recent alluvium.

these cases sections of the deposit would show their origin—the delta-beds by their containing brackish-water shells, and the lake-beds by their even and regular deposition. None of the beds of the deposit now under consideration have been formed thus.

Where there are no old deposits left on either side of a valley we know that the river, by cutting close up to the underlying rocks on either hand, has taken away on its return that which it laid down previously; and then we find it bordered only by recent alluvium. This will be seen where a river flows swiftly along a narrow mountain valley, but not where it winds along a sloping plain.

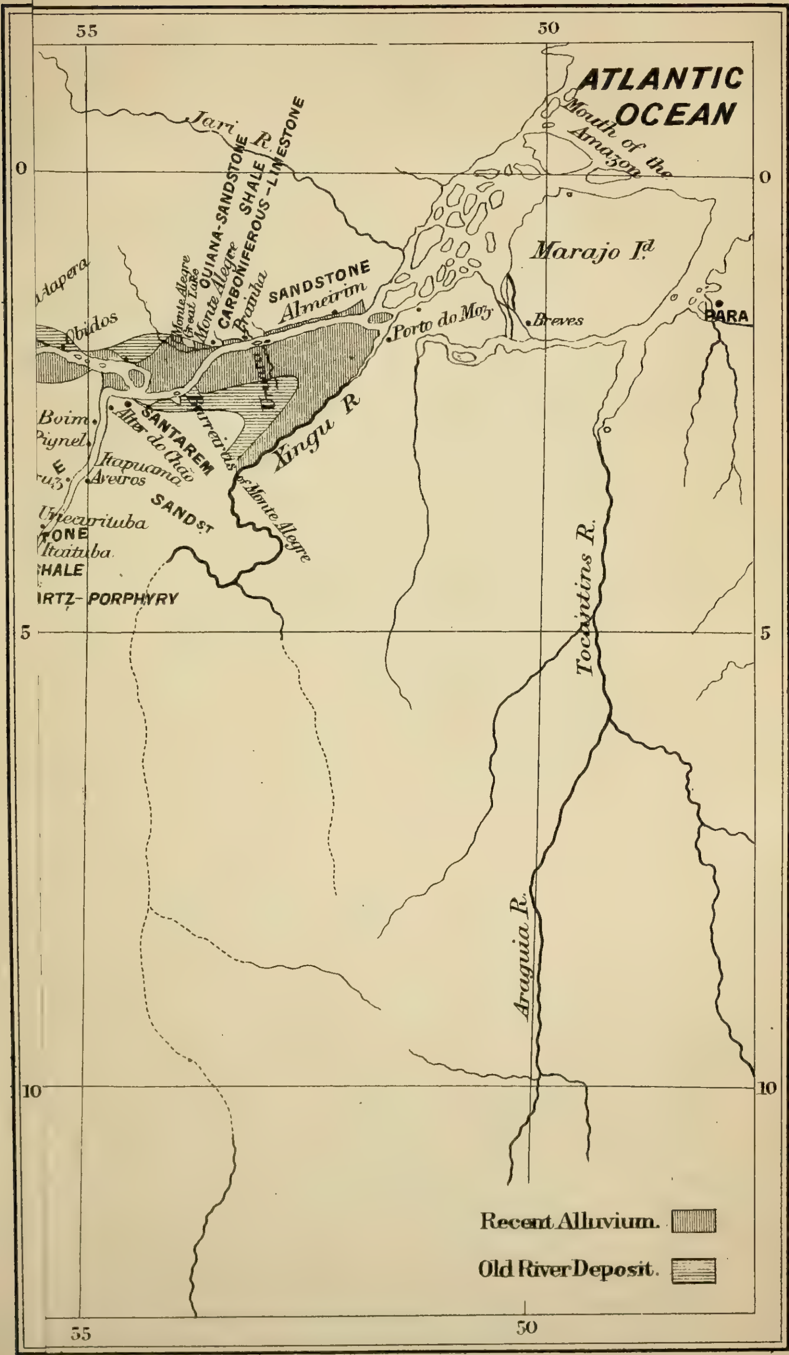
In some instances, where the river suddenly abandons its old course by cutting a new one across a neck of land between two curves, it leaves the old channel as a lake to be filled up very slowly with fine materials. Thus irregularities in the surface of its older deposit were produced, causing it in places to vary very much in altitude and thickness. Good examples of these old river-courses are to be seen in its present alluvial plain at Monte-Alegré great lake, at Jamunda-mouth, Sapukia, and other places.

On the Purus and Jurua, where there are numbers of these river-lakes, there are instances of the rivers having cut through narrow necks, leaving large loop-shaped patches of still water. The existence of these loops explains a difficulty which it would otherwise be hard to account for. I refer to the river passing from one side of its valley to the other, and leaving a portion of an older formation untouched at a higher level than its plain. We have a case of this sort in a patch of Tertiary clays at St. Paulo, the river having at one time flowed on the south side of it, while now it is on the north. To account for this, we must look upon such a tract as the centre portion of a loop, which the river partially flooded in the seasons of high river.

The recent alluvium on the Purus river is a grey clay upon grey sand; but in places where the river has cut through one of its old silted-up curves, left originally as a sort of lake, it is a grey loam, containing great quantities of unaltered leaves and tree-stems in thick beds. The alluvium of the Solimões is also a grey clay, upon which is a brownish loam; and the material being now added to its surface in flood-time is a greenish-brown arenaceous loam. Upon the old deposit this latter is represented by the red loam so frequently mentioned in the foregoing sections, which must have been thrown down upon the sand and clay beds in still water during times of flood. It is very persistent in its occurrence over the whole valley, and appears on the surface of the old deposit at various levels, from having settled down in some places in shallows, and in others in deep water, corresponding to the present alluvial lakes.

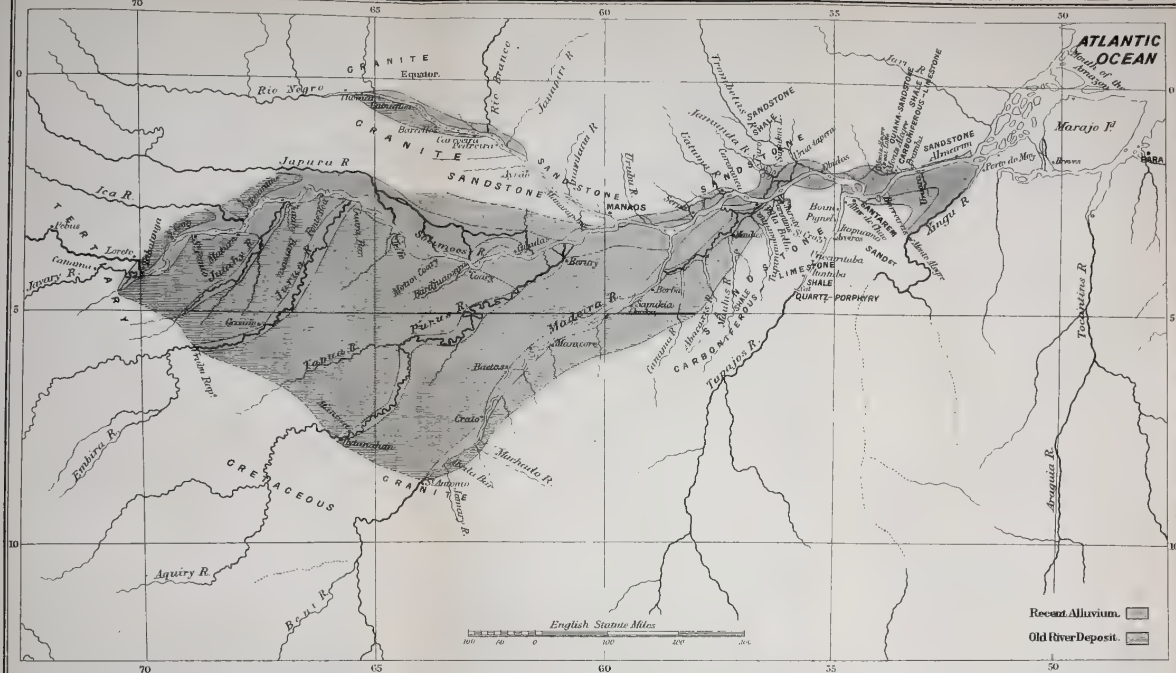
The surface of the great valley-deposit has of course been modified to some extent by atmospheric agencies, and is much cut up by small streams, which have formed gullies and ravines through it.

Upon the accompanying map (Pl. XXXVIII.) I have traced out the approximate boundaries of the old deposit and the recent allu-



Dangerfield. Lith. 22. Bedford St. Covent Garden.

the Amazon, east of Tabatinga.



Dangerfield Lith. 22 Bedford St. Covent Garden

Map of a portion of South America, showing the position and extent of the Old River Deposit on the Amazon, east of Tabatinga.

vium, so that some idea may be obtained of the great area occupied by the former. The outcrop, as it were, of the underlying strata is marked where its composition is known.

In conclusion, I have to express a hope that by this memoir I have brought into notice the general action of a great river, and have given a correct though slight record of its work in the economy of Nature.

60. *The* Glaciation *of the* Shetland Isles.

By B. N. Peach, Esq., F.G.S., of the Geological Survey of Scotland, and John Horne, Esq., F.G.S., of the Geological Survey of Scotland. (Read March 26, 1879.)

[Plate XXXIX.]

Contents.

I. Introduction.

One of the most interesting problems connected with glacial geology is the explanation of the glaciation of those groups of islands which lie at some distance from the north-east corner of the mainland of Scotland. It is now almost universally admitted, by those who have carefully weighed the evidence, that during the maximum cold of the glacial period, Scotland, Ireland, and the greater part of England were buried underneath an ice-sheet, which moved off the high grounds towards the sea-level. This has been clearly proved by the careful mapping of the ice-markings indicating the trend of the old glaciers, as well as by a minute examination of the stones in the Boulder-clay which accumulated underneath the ice, and was rolled along with the onward motion of the mass. So far most geologists are agreed; but when the glaciation of the Orkney and Shetland Isles has been discussed, it has given rise to considerable difference of opinion. Doubtless this want of uniformity has been largely due to the imperfect evidence hitherto obtained from the isles regarding the direction of glaciation and the nature of the various superficial accumulations. There has been no systematic examination of Shetland, or even of Orkney, with a view to determine these questions; and hence the absence of reliable observations has given scope for some latitude of opinion, and has likewise retarded the final settlement of the question.

The group of islands to which this paper especially refers may be said to form a broken rampart running nearly north and south for a distance of about 70 miles. The isles are about 200 miles distant from the Norwegian coast-line at Bergen, and about 86 miles from the north-east corner of Scotland. Though they are thus completely isolated from both countries, it will be shown that their physical history is to some extent associated with that of Scotland and Norway.

The earliest references to the dispersion of boulders in these isles were made by Dr. Hibbert, who inferred that "the great diluvial wave which swept over the low elevations of the whole of Scotland and England had in the latitude of Shetland a north-easterly origin, or, in other words, that it had a south-westerly direction" *.

More recently certain observations on the glacial phenomena of Shetland were made by Mr. C. W. Peach, who visited Lerwick, the outskerries of Whalsey, and the island of Unst; and at each of these localities he noted the ice-worn aspect of the rocks, the striæ, and the existence of Boulder-clay †.

To our colleague, Dr. Croll, belongs the merit of having first suggested the probability of the North Sea being filled with ice, enveloping alike the Orkney and Shetland groups of islands. This suggestion was first thrown out in a paper on "Glacial Submergence," which appeared in the 'Reader' of the 14th Oct. 1865. In a subsequent paper "On the Origin of the Caithness Boulder-clay" ‡, he pointed out that the Scandinavian and Scotch ice-sheets probably united on the floor of the North Sea, and thence moved northwards and northwestwards towards the Atlantic. He showed that in all probability the enormous *mer de glace* which pressed out on all sides from Scandinavia, produced, in virtue of its greater size, a slight deflection of the Scotch ice, and caused it to override portions of the mainland. He indicated that in all likelihood both the Orkney and Shetland Isles were overtopped by the combined ice-sheets in their onward march towards the Atlantic.

In the autumn of 1876, one of us visited Shetland with the view of determining the question whether the glaciation of that group of islands had any connexion with that of Scotland and Norway. From the traverses then made, it was evident that these isles had been glaciated by Scandinavian ice, though in certain areas it seemed as if a more recent local glaciation had well nigh effaced all traces of the original movement §.

The rich variety of rocks in Shetland renders it a comparatively easy matter to determine the direction of the ice-movement; but in order to insure accuracy it seemed desirable to map out approximately the areas of the respective rock-formations. During our leave of absence from official work in the summer of 1878, we therefore returned to the isles for the purpose of accomplishing this end with as much minuteness as time would permit. We were induced

* Edinb. Journ. of Science, vol. iv. pp. 85–91.

† Brit. Assoc. Report, 1864, p. 59. It should be remembered that Mr. C. W. Peach gives the magnetic readings in his paper; and hence, in order to obtain the true direction of the ice-markings, due allowance must be made for the magnetic deviation.

‡ Geol. Mag. vol. xvii. pp. 209 and 271. The fullest exposition of Dr. Croll's views is given in 'Climate and Time,' chap. xxvii.

§ Nature, vol. xv. p. 139.

to work out the succession of the representatives of the Old Red Sandstone as developed on the Mainland, as well as the relations of the associated contemporaneous and intrusive igneous rocks, on account of the important evidence which they furnish regarding the ice-movement. While pursuing this object, we were fortunate enough to discover in the Walls district a rich series of plant-remains in rocks which have been hitherto considered as forming part of the metamorphic series. The general character and physical relations of these altered rocks will be briefly described in a subsequent page (p. 785).

II. General Distribution of the Rock-formations.

As the distribution of the rock-formations has an important bearing on the question of the glaciation, it will be desirable to give a brief outline of the nature and respective limits of the various formations, so far as these have been already determined. The stratified rocks belong to two periods:—(*a*) the Old Red Sandstone; (*b*) the great series of metamorphic crystalline rocks on which the representatives of the Old Red Sandstone rest unconformably. To what precise part of the crystalline rocks of the Highlands the metamorphic series of the Mainland and the north isles belongs, we do not at present presume to say*.

There are also associated with the metamorphic series some intrusive igneous rocks, and certain masses which may be viewed as products of extreme metamorphism. These may probably be relegated to the time when the metamorphism of the ancient stratified rocks took place. At least some of the igneous rocks now referred to must be older than the basement breccias of the Old Red Sandstone, inasmuch as the latter in certain localities are composed of angular fragments of the former.

But, further, there are abundant proofs of volcanic activity during the Old-Red-Sandstone period, as is evident from the great development of contemporaneous and intrusive igneous rocks on the Mainland. Similar phenomena are met with in the isles of Papa Stour, Bressay, Noss, the Holm of Melby, and Meikle Rooe; but the magnificent sections on the western shores of Northmavine justify the conclusion that the proofs of volcanic activity on the Mainland surpass in grandeur and extent those of the other Shetland islands.

The Metamorphic Series.

On the Mainland these may be grouped in two divisions, which are clearly marked off from each other by distinct lithological characters.

(*a*) Dark blue, green, and grey schists and clay-slates, with bands of quartzite and limestones.

* For detailed descriptions of the lithological varieties of the metamorphic series, see Hibbert's admirable volume on 'The Shetland Isles,' published 1822; also a series of valuable papers by Professor Heddle on "The Mineralogy of Shetland," Mineralog. Mag. vol. ii. pp. 12, 106, & 155.

(*b*) Coarse-grained micaceous and hornblendic gneiss, with associated limestones, bands of quartzite, talcose and micaceous schists.

These subdivisions are peculiarly serviceable to the glacialist, as they help him to determine the different movements of the ice during successive phases of the ice age. The representatives of the former series extend from Fitful Head northwards by the Bonxie and Cliff Hills to Laxfirth Voe; while the members of the gneissose series lie to the north-west of the area just described. They occur in the districts of Tingwall, Weesdale, Nesting, Lunnasting, Delting, and along the eastern seaboard of Northmavine. The strike of these metamorphic rocks is generally N. 10°–20° E.; and though opposing dips are frequently met with, indicating repetitions of the strata, they usually dip to the north of west at high angles. Hence we have a gradually ascending series from the schists and clay-slates of the Cliff Hills to the coarse micaceous gneiss west of the vale of Tingwall, and the massive limestones of Whiteness and Weesdale.

To the persistent trend of the metamorphic rocks must be ascribed the remarkable ridge-shaped contour of the ground in the centre of the Mainland. The coincidence between the trend of the strata and that of the parallel ridges seems to indicate a direct relationship between the two, the denuding agents being guided in their operations by the relative hardness and softness of the materials exposed to their influence. Hence it follows that we have a series of intervening hollows running parallel with the ridges, which usually terminate seawards in long narrow voes or sea-lochs. The erosion of these hollows has doubtless, in some instances, been due to the partial removal of the bands of limestone by the chemical action of carbonated waters, inasmuch as the outcrop of the limestones coincides with the course of a longitudinal hollow.

The coarse-grained gneiss of Whalsey and the Outskerries, with the associated limestones, is merely the prolongation of the Mainland series; and the same remark is applicable to the gneiss occurring in Yell.

The structure of Unst and Fetlar is somewhat different, inasmuch as these isles contain well-marked zones of serpentine and gabbro, the distribution of which has an important bearing on the question of the dispersal of the stones in the Boulder-clay. In the island of Unst, the Vallafield ridge which flanks the western seaboard, whose highest elevation is about 697 feet, is mainly occupied by coarse-grained gneiss, dipping to the south of east at comparatively high angles. On the eastern slopes of the ridge the gneiss is succeeded by grey mica-schists and green chloritic schists, and these are overlain in turn by black graphitic schists. These dark schists seem to form a reliable horizon with reference to the masses of serpentine and gabbro, as they usually crop out along the margin of the areas occupied by these masses and generally dip underneath them. Though these schistose rocks form but a narrow band from Belmont Bay northwards to Baliasta, they occupy a much broader area to the north of the latter point, constituting, in fact, the group of hills round Saxavord. They reappear again in the south-east corner of the island, where they cover a strip of ground about a mile in breadth between Skuda Sound and the ruins of Muness Castle.

The masses of serpentine and gabbro in Unst lie in a trough formed by these schists. They may be said to form two parallel zones crossing the island from south-west to north-east, the serpentine lying to the west of the gabbro. The serpentine area is the larger of the two, though somewhat irregular in outline; at the northern limit between Baliasta Kirk and Swena Ness, the mass is nearly two miles in breadth, but as it is traced southwards it diminishes to half a mile in breadth. Another patch of gabbro is to be met with on the promontory east of the ruin of Muness Castle.

It seemed to us that the serpentine has resulted from the metamorphism of the gabbro. Here and there in the gabbro area, as, for instance, on the west side of Uya Sound, lenticular patches of serpentine occur, as if the transmutation had partly begun and had been interrupted. The gradual transition from the one rock to the other is well seen in the promontory on the south side of Balta Sound. Professor Heddle, who advocates this view, states that the gradual passage can be seen in hand specimens on Swena Ness.

The structure of the northern portion of Fetlar is comparatively simple. The central hollow coincides with a low anticlinal axis of black graphitic schists and chloritic schists similar to those in Unst, and apparently occupying the same horizon with reference to the gabbro and serpentine. These rocks throw off on both sides of the arch beds of gabbro and serpentine, forming the elevated ground round the Vord Hill on the east and the hills near Urie on the west. At Urie the serpentine which overlies the gabbro is immediately succeeded to the west by coarse-grained gneiss, the perfectly conformable junction between the two being distinctly visible on the shore west of the promontory of Urie. The broad mass of serpentine which stretches from the Vord Hill eastwards to Gruting Bay is thrown into a synclinal trough, which is nowhere deep enough to bring in the overlying gneiss to the west of Urie. To the east of Gruting Bay occur the micaceous and chloritic schists as well as the graphitic schists, which contain in minor folds small patches of serpentine.

Intrusive Igneous Rocks in the Metamorphic Series.

Under this heading we shall only indicate those intrusive rocks and those products of extreme metamorphism which are probably older than the Old-Red-Sandstone period. We have already referred to the areas of gabbro and serpentine in Unst and Fetlar; but in addition to these there are certain masses on the Mainland deserving special notice.

Of these by far the largest is the mass of diorite occurring in the districts of Delting and Northmavine on the Mainland. It is upwards of ten miles in length, and in places it exceeds two miles in breadth; but it ought to be borne in mind that the whole of the area now described is not occupied by the diorite, nor is the boundary line so uniform as we have represented. A minute examination of this tract convinced us that the groundwork of the area, so to speak, is formed of metamorphic schists, which are traversed in all directions by large and small veins of this rock. Both the diorite and the schists are intersected by innumerable veins of quartz-felsite which were injected at a more recent date, the whole series of rocks forming a complicated network.

Again, in Dunrossness, between Quendale Bay and Loch Spiggie, there is a mass of intrusive rock termed by Hibbert epidotic syenite, which is traceable northwards through the islands of Oxna, Hildasay, the Sandistura rocks, the Channes, and part of Papa west of Scalloway, to the Mainland in Bixetter Voe and onwards to Aith Voe. This rock varies considerably in character throughout its course; in some places it is a quartz-felsite, while in the neighbourhood of Bixetter and Aith Voes it is a true porphyritic granite, with large crystals of orthoclase. There can be no doubt that it is an intrusive mass, because it crosses obliquely the strike of the metamorphic rocks on Fitful Head and the Wart of Skewsburgh; and it is equally clear that the eruption was prior to the Old-Red-Sandstone period, as the basement breccias of that formation rest unconformably on this rock, and are largely made up of angular fragments of the subjacent mass.

A similar mass of porphyritic granite occurs in Unst on the bluff headland of Lambaness and on the rocky promontory north of Skaw Bay, which likewise bears important testimony regarding the direction of the ice-movement. In addition to these masses there are minor veins of granite, gabbro, and serpentine, some of which are indicated on the map. There is one fact bearing on the age of the veins of serpentine on the Mainland which is worthy of note; and that is, the occurrence of fragments of this rock in the basement breccias of the Old Red Sandstone in Dunrossness. This circumstance plainly indicates that the formation of the serpentine veins in that neighbourhood preceded the formation of the breccias.

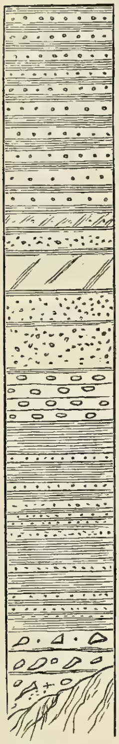
The Old Red Sandstone.

A glance at the map will show the various areas occupied by the members of this formation in Shetland. Beginning with the irregular areas on the east side of the Mainland, the succession may be most readily grasped by means of the following section (fig. 1, p. 784)*.

Owing to a series of faults which form the boundary-line between the metamorphic rocks and the Old Red Sandstone, over a great part of the districts of Lerwick, Quarff, Conningsburgh, and Dunrossness, it so happens that different zones in this vertical section are brought into conjunction with the schistose rocks. The true base of the series, however, is exposed in the neighbourhood of

* For previous references to the Old Red Sandstone of Shetland, see Hibbert's 'Shetland Isles,' 1822; Memoirs of Wernerian Soc. vol. i. p. 162; Quart. Journ. Geol. Soc. vol. ix. pp. 49, 50, also vol. xv. p. 413; "The Old Red Sandstone of Western Europe," by Prof. Geikie, Trans. Roy. Soc. Edin. vol. xxxviii. p. 414; 'The Old Red Sandstone of Shetland,' by Dr. Gibson, Edinburgh, 1877.

Fig. 1.—*Vertical Section of Old Red Sandstone strata on east side of Shetland.*



East Quarff, on the hills to the north of the bay and to the south towards Fladabister; while still another locality is met with near Loch Spiggie in Dunrossness. In each of these localities the breccia varies in character according to the nature of the underlying rock.

In the bay west of Brenista Ness, the overlying series of the Brenista Flags is thrown against the breccias and underlying schists by a fault which is traceable inland in a N.N.W. direction. This series consists of well-bedded red flags, which persistently dip to the east till Gulberwick Bay is reached. The fault just referred to, when traced inland, always throws the flags down against the basement-breccia, and hence the actual superposition is not satisfactorily seen in the neighbourhood of Brenista. Between East Quarff and Fladabister, however, the one group may be seen resting conformably on the other; and, in addition to this, we find that the basal breccia, which forms vertical cliffs on the coast-line about 200 feet high, thins out inland till there is only about 3 feet of breccia between the underlying schists and the overlying Brenista Flags. In some instances the breccia disappears altogether, and the Brenista Flags rest directly on the schists, a fact which points to the gradual submergence of the area.

Returning to the shore-section north of East Quarff, there is a gradually ascending series from the Brenista Flags to certain coarse conglomerates seen in a small stream at the head of the bay of Gulberwick, which are totally different from the basal breccias already described. Not only are the enclosed pebbles well rounded, but to a large extent the stones are composed of different materials. These beds are traceable up the slope of the Gulberwick hollow, to the road between Lerwick and Scalloway, where they form crags on the hill face, and where they may be seen in small quarries by the roadside. They may be followed also across the hills northwards to Rovey Head, about two miles north of Lerwick, where they are brought into conjunction with the schists by a fault which is well seen on the shore. From Rovey Head southwards to the ridge overlooking the head of Fitch Dale, this fault forms the boundary-line between the conglomerates and the metamorphic rocks. At this point it dies out, and the boundary-line southwards towards Fladabister is formed by the basement breccia already described.

At Rovey Head the conglomerates are thrown into synclinal and anticlinal folds; but eventually they dip to the south-east, and are succeeded immediately by grey sandstones, with blue and grey flags passing upwards into the series of the Lerwick Sandstones. The dominating members of this series are coarse grits, frequently conglomeratic, with partings of fine red shales.

In Bressay, however, these arenaceous and conglomeratic strata are overlain by a more flaggy series, which is more or less persistent till Noss Head is reached. We were struck with the resemblance which some of these grey flaggy bands bear to the calcareous flags of Orkney and Caithness containing the fish-remains; but a careful search failed to bring any to light. Numerous plant-remains have long ago been detected, not only in these strata but also in some of the other groups on the eastern shore of the Mainland.

In the peninsular tract of country which lies to the west of the Weesdale district there is a great series of rocks which, with the exception of a small tract at Melby, have been hitherto considered as forming part of the metamorphic series. The small strip of Old-Red-Sandstone rocks at Melby, measuring about a mile and a half in length, has been referred to by previous observers. They are separated by a fault from the red quartzites and shales of Sandness Hill; and on approaching the fault it is observable that the beds are much shattered on account of this dislocation. They consist of reddish sandstones with dark blue flags and shales, dipping to the east of south and south-east, from Sandness to near Melby.

The great series of rocks which occupies almost the whole of the remainder of this peninsular tract, and which by their fossil contents we have proved to be of Old-Red-Sandstone age, has a somewhat different lithological character. Over a great part of this area the beds consist of grey and blue altered sandstones, with green and pale shales. The altered sandstones are usually traversed in every direction by joints, which are coated with peroxide of iron; and in places the beds have a marked schistose character. Sometimes the sandstones are converted into genuine quartzites, and the shales interbedded with them are distinctly cleaved. The strata lie in a trough the axis of which runs approximately from Fontabrough Voe eastwards by the village of Walls to the head of Bixetter Voe. On the north side of the syncline we have a gradually ascending series exposed on the coast-line from the cliffs of Sandness Hill southwards towards Fontabrough Voe, the average strike of the beds being E. 20° N.

We discovered the plant-remains on the hills north of Walls, and subsequently in quarries by the roadside east of the village, and on the hills between Gruting and Bixetter Voes. They have been examined by Mr. C. W. Peach, who has kindly furnished the notes on the specimens embodied in the Appendix. He is of opinion that the plants are identical with those found in the Old-Red formation of

Caithness and Orkney; and the strata in which they are imbedded, altered though they be, must be relegated to that period.

This conclusion is still further strengthened by the occurrence in these rocks of interbedded porphyrites and tuffs in a highly altered form, which we detected on the headlands between Aith Ness and Clouster, and on the western shore south of Dales Voe, resembling in many respects the contemporaneous volcanic rocks to be described presently. Further, we are inclined to believe that the series of altered thick-bedded sandstones and shales which occupy the greater portion of this peninsular tract are on the same horizon with the Lerwick Sandstones on the eastern side of the Mainland.

It is not improbable that the alteration of the strata in this wide area may be due to the existence of a mass of granite underneath these rocks. We shall have occasion to refer to the mass of granite in the heart of these beds in Sandsting, and to similar intrusive masses of Old-Red-Sandstone age to the north. The extent of ground occupied by these acidic rocks indicates the great volcanic activity which prevailed during that period; and though these are now isolated at the surface, it is highly probable that they may be connected underneath.

These altered fossiliferous strata are brought into conjunction with the gneissose rocks to the east and north by two great faults which we have traced on the ground, the one running north and south, and the other approximately east and west. Usually the altered strata are terribly shattered and baked close to the lines of dislocation, and are likewise injected with numerous veins of very fine-grained felsite.

Contemporaneous Igneous Rocks.

In the western district of Northmavine, between Stennis and Ockren Head, at the mouth of Roeness Voe, there is an important development of ancient lavas and ashes, associated at certain localities with ashy sandstones and red flags belonging to this period. The tract of ground occupied by these rocks measures about six miles in length, and varies in breadth from one to two miles. The structure of this narrow tract is comparatively simple, as the strata form a flat syncline, in the centre of which lies coarse ash, and underneath a series of slaggy porphyrites with occasional beds of red ashy sandstones and flags.

On the south bank of Roeness Voe, rather more than a mile from Ockren Head, in a steep grassy geo, the slaggy porphyrites are brought into conjunction with the pink quartz-felsite by a fault. In Braewick Bay, west of Hillswick, the interbedded and intrusive igneous rocks are not found in such close proximity, the junction being concealed by the sandy beach; but there can be little doubt that the same fault runs out to sea in this bay.

Crossing the coarse volcanic breccia, which forms the centre of the syncline, to Ockren Head, at the mouth of Roeness Voe, the successive lava-flows are admirably shown, piled on each other in regular succession. This headland, as well as the adjacent stack, exhibit at least four different lava-flows, capped by coarse ash. The lavas thicken and thin out rapidly, and likewise exhibit the usual slaggy structure at the top and bottom of the flow. Some of these beds are also highly involved, and show clearly the way in which the partially solidified crust has been caught up and rolled over and over in the advancing current of still molten lava.

We have already alluded to the porphyrites and tuffs which occur in the altered rocks north of Walls. We also detected a bed of lava in the Holm of Melby, and a thin bed of tuff associated with the grey flags on the east side of Bressay, opposite the north end of the island of Noss. The contemporaneous volcanic rocks found in Papa Stour have been previously described by Professor Geikie.

Intrusive Igneous Rocks.

In the north and western portions of the Mainland there is a splendid development of highly siliceous intrusive rocks, which occupy the most elevated ground in the island. They extend from a point on the north end of the Mainland opposite the island of Uya, southwards to Roeness Voe, culminating in the dome-shaped mass of Roeness Hill. Thence they cross the peninsular tract to the Heads of Grocken, west of Hillswick, reappearing in the slender columns of the Drongs. The western portion of Meikle Rooe is formed of the same material, and likewise the north-eastern headlands of Vementry, while the small area of quartz-porphyry at Melby must also be included in the same great intrusive series. In addition to the areas now referred to, there are other lenticular masses varying in size down to veins a few feet across, occurring at intervals from Mavis Grind, northwards to Roeness Voe and Ollaberry. These traverse the Northmavine diorite and metamorphic rocks alike, increasing in number and extent as they approach the Roeness mass.

These rocks vary considerably in character; but they all agree in possessing a large proportion of silica, while the felspar is usually orthoclase. As a rule, they are coarsely crystalline, the two prevalent ingredients, quartz and orthoclase felspar, being distinctly crystallized, which causes the rock to assume a marked granitoid texture. There can be little doubt that these coarsely crystalline rocks must have originally consolidated under great pressure, though the materials under which they lay buried have been wholly removed by denudation. Further, the marked columnar structure which meets the eye along both banks of Roeness Voe, and from the Heads of Grocken to Braewick Bay, as well as along the western shores of Meikle Rooe, suggest the idea of a great intrusive sheet, forced in like a wedge between the metamorphic series and the members of the Old Red Sandstone long since worn away. A similar intrusive sheet occurs in Papa Stour, as described by Professor Geikie, where the same columnar structure is apparent, and where a fragment of the once superincumbent strata is still to be seen at the Horn of Papa. Fortunately the intrusive nature of this latter sheet is placed beyond doubt, inasmuch as the pink porphyry is seen cutting across the underlying sandstones from a lower to a higher horizon.

As the result of careful mapping of the boundaries of the Northmavine mass, we are of opinion that the Roeness-hill plateau is a great intrusive sheet which forced its way upwards and laterally between the metamorphic strata on the one hand, and the members of the Old Red Sandstone on the other, at the time when the Mainland lay buried under the sedimentary deposits which accumulated during that period. It is not at all improbable that this immense mass may have been connected with the surface by pipes which traversed the superincumbent strata, and may have discharged volcanic materials at the surface.

Its relations to the metamorphic series are admirably defined. Along the eastern seaboard of Northmavine it forms a mural escarpment about 200 feet high, part of which is known by the name of the Biurgs. Innumerable veins of quartz-felsite branch off from the main mass and intersect the metamorphic series. Further, it sometimes happens that portions of the adjacent rocks are enclosed in the quartz-felsite, as, for instance, near Colifirth Voe, where a fragment of serpentine is caught up in the mass. Again, on the north bank of Roeness Voe, the sheet spreads over the edges of the diorite and metamorphic rocks without producing any deflection of the strike of the metamorphic series, as shown in the accompanying section (fig. 2).

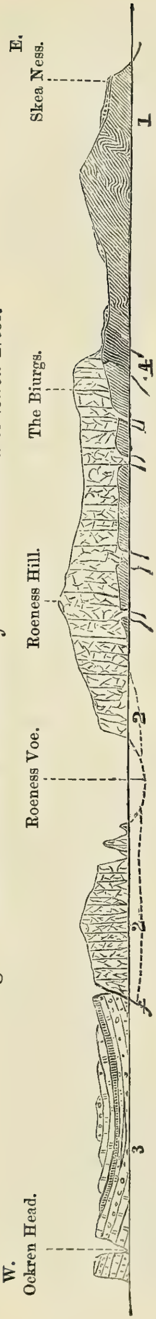


Fig. 2.—*Section across Northmavine from Ockren Head to Skea Ness.*

1. Metamorphic rocks.
2. Pink granite and quartz-felsite.
3. Bedded porphyrites and ashes.
4. Serpentine.

To the west of Hillswick, on the picturesque Heads of Grocken, the highly siliceous quartz-felsite is thrown against the metamorphic series by a fault, which is well seen on the cliffs. This fault passes out to sea between the little islets of Waterhouse Holm and the Drongs, and reappears in Meikle Rooe, separating the quartz-felsite from the diorite of that island. In all likelihood this dislocation is the northward prolongation of the great north-and-south fault already described, which brings the metamorphosed Old-Red-Sandstone rocks into conjunction with the gneissose rocks of Weesdale.

Our conclusion regarding the Roeness plateau is strengthened by a consideration of the relations of the granite mass of Sandsting to the altered Old-Red strata of that district. This siliceous intrusive rock has several lithological varieties; but away from the margin of the area, as, for instance, on the hills above Gruting and round Skelda Voe, it is an ordinary granite consisting of pink orthoclase, quartz, and mica.

On the shores of Gruting Voe, at the foot of Culswick Hill, the junction of the granite with the Old-Red quartzites and shales is well seen, from an examination of which it is evident that the granite is intruded along the lines of bedding of these strata. The junction-line has nearly the same inclination as that of the quartzites, which dip to the north at an angle of about 20°. The two rocks are not strictly conformable, however; for the granite here and there cuts across the bedding, indicating in an unmistakable manner the intrusive nature of the igneous rock. The junction is a sharp and well-defined line, as small hand-specimens can easily be got, 2 inches across, including the granite and the quartzite, the two being firmly welded together. Near the junction of the two rocks the quartzites are pervaded by numerous dykes of pink felstone proceeding from the main mass.

The mass of granite in the north of Delting and on the western shores of Sulem Voe was probably erupted during the same period of volcanic activity; but the evidence is not so convincing as that referring to the areas already described.

But in addition to the grand series of intrusive rocks we have just indicated, there is evidence to prove that even these quartz-felsites and granites were invaded by a still later series of dykes, of a basic character. Hibbert detected the existence of these dykes on Roeness Hill; and during our traverses in the district of Northmavine, Delting, and Meikle Rooe we came across many similar masses, varying in breadth from 2 feet to several yards. Along the cliffs of Roeness Voe, and in the island of Meikle Rooe, these dykes are strikingly exhibited, forming great wall-like masses, running generally in a north-and-south direction. Sometimes they project above the acidic rocks, while, again, they weather more rapidly, forming great clefts in the face of the cliff. They are fine-grained, and consist of a dark-green diabase porphyrite. They traverse the metamorphic rocks, as well as the porphyrites and tuffs, west of Braewick; and there can be little doubt, therefore, that they form the last indications of volcanic activity during the Old-Red-Sandstone period in Shetland.

Close by the entrance to the Noss Sound, on the Bressay shore, we detected a series of necks arranged in a linear manner, which seem to have come to the surface along a line of fissure. Similar necks occur on Noss, on the opposite side of the Sound. It is highly probable that these volcanic orifices served merely as vents for the discharge of steam, with occasional showers of triturated materials derived mainly from the sides of the vents. The adjacent bed of tuff, associated with the grey flags, as well as the nature of the agglomerate which now fills these necks, seems to support this view.

III. Glaciation.

From Sumburgh Head northwards to Hermaness in Unst, we find everywhere the clearest evidence that Shetland must have been at one time smothered in ice. The ice-worn islets along the shore-line, the polished and striated surfaces on the low grounds, the abraded and fluted appearance of the highest hills on the Mainland, alike point to the action of a thick mass of ice, which must have enveloped the isles. It is quite true that over considerable areas much of the evidence is obscured by a thick covering of peat; but wherever the peaty covering has been worn away, there are convincing proofs of that intense abrasion which we are accustomed to meet with in highly glaciated regions.

Before describing the proofs of glaciation in the different islands, it may be well to state, as the result of our observations, that most of the *roches moutonnées* and striations indicate the movement of an ice-sheet across the islands from the North Sea to the Atlantic; but, in addition to this, there is satisfactory evidence for maintaining that, as the climatic conditions gradually ameliorated, the primary ice-movement gave place to that of local glaciers, which moved off the high grounds in the ordinary way, depositing their terminal and lateral moraines as they shrank back into the hills.

Along the eastern seaboard of Unst the direction of the ice-markings varies from W. to W. 20° S. From Norwick to Haroldswick numerous striæ occur on the cliff-heads running W. to W. 20° S., some of which were found on the top of a cliff 500 feet high; while in the southern parts of the island the average trend is W. 30° S. In Fetlar the general direction of the striæ along the northern coast, from Gruting Bay to the promontory of Urie, is W. 30° S., though they vary from W. to W. 30° S. Two exceptions to the foregoing examples were found on the west side of the island—one on a glaciated surface of serpentine west of the promontory at Urie, running north and south, and the other on gneiss at the north-west corner of the island, pointing N. 10° W. These instances, however, have no connexion with the main set indicating the general glaciation of the island.

Again, on the north-east coast of Yell the striæ point W. 25° S., harmonizing with the direction of those found on the south side of the island of Unst; but on the western seaboard from Sandwick to the Noup of the Graveland the trend varies from W. 30°–39° N. In spite of this variation we are convinced, from evidence obtained in the Mainland, that these instances belong equally to the period of primary glaciation. It would seem that the ice-sheet abutted on the eastern seaboard of Shetland with a S.S.W. and S.W. trend, and after reaching the crest of the Mainland it swung round to the N.N.W. and N.W.

Along the north-west coast of Whalsey, between Skaw Taing and Symbister, the average direction of twenty-one instances is S. 28° W., varying, however, from S.W. to S. 15° W., the variation being due in many cases to inequalities of the ground; while on the south-eastern shore the trend varies from S. 15° W. to S. 23° W. Now it is apparent, on a moment's consideration, that the direction of the striæ would have been widely different had the island radiated its own ice, and had the glaciation been purely local. Both on the north-west and south-east shores the striæ are either parallel with the long axis of the island or cut obliquely across it; and hence, in order to produce these striæ, there must have been, during the primary glaciation, a mass of ice moving in that particular direction.

In addition to this, there is evidence to prove that this island possessed local glaciers at a later period; for to the north of Challisetter ice-markings occur, trending N. and N. 10° E. Close by these later striations, numerous small moraines are seen on the gentle slope which flanks the central ridge in the northern portion of the island.

There is, perhaps, no district in Shetland where the intense abrasion typical of glaciated regions is so patent as in the out-skerries of Whalsey. When sailing from the latter island to the Skerries, we were struck with the ice-worn aspect of the numerous little domes of rock projecting above the water. Housay, Brury, and Gruna may be described as large *roches moutonnées* which have been ground down, bared, and striated in a wonderful manner. From the top of the little hill south of the schoolhouse, one sees all round a succession of bare hummocks and domes of rock, destitute of any drift-covering, and with little vegetation, revealing unmistakably the great pressure to which the islands have been subjected. In Gruna the striæ vary from S. 10° W. to W. 42° S.; in Brury, on the top of the highest hill, S. 35° W.; and in Housay, S.S.W. to S.W.

A glance at the map will show that the instances now adduced coincide in direction with those occurring in Whalsey, and, with the exception of a little more southing, they agree with those in Unst, Fetlar, and on the east coast of Yell. In the case of the Skerries this south-westerly trend has a marked significance, inasmuch as no one can possibly dispute that the glaciating agent must have been quite independent of the islets. It is equally clear that the markings are not due to the action of any local sheet radiating from the Mainland of Shetland. Apart altogether from the fact that the position of the *roches moutonnées*, as well as a minute examination of the striated surfaces, convinced us that the ice crossed the Skerries from the north-east towards the south-west, there are other reasons why these markings cannot be attributed to any such local cause. When we come to discuss the evidence supplied by the Mainland in regard to the extent of the later glaciation, we shall see that there is satisfactory ground for maintaining that the later glaciers did not spread far beyond what is now the coast-line of that island. Moreover, the direction of the later glacier movement on the east side of the Mainland is at variance with the trend of the striæ occurring in the Skerries. For these various reasons, therefore, we are justified in inferring that the glaciation of these outlying islets is due to the action of an ice-sheet originating far beyond the sphere of Shetland.

On the eastern seaboard of Northmavine, in the Mainland, between Ollaberry and North Rooe, the general trend of the ice-markings is in a south-westerly direction. On the north shore of North Rooe Bay two sets of striæ were observed—one pointing S. 40° W., belonging to the primary glaciation; the other S. 30° E., produced by later glaciers moving down the bay. Near Fethaland Point two sets of striæ were observed, which clearly prove the general movement of the ice during the primary glaciation, and at the same time a separate movement of the lower portions of the mass caused by an undertow. On the headland north of the fishing-station the striæ run N.W. and N. 20° W.; while on the south side of the bay, about a mile from the fishing-station, the markings on the cliff-heads point N. 6° W., N. 10° E., N. 20° W., indicating a varying movement in a northerly direction. On ascending the polished slope which overlooks the foregoing examples, the direction is S. 10°–35° W. This divergence is readily accounted for by supposing that the lower current moved in a north and north-west direction, while on the slopes of the ridge the upper current moved towards the south-west in harmony with the general movement along the eastern seaboard of the Mainland.

Again, in the upper part of Roeness Voe, the striæ point W. and W. 10° N.; but on descending the sea-loch they swing round to the north-west, the instances near the mouth of the voe trending N. 20°–28° W. The same northing of the striæ is splendidly seen on the area occupied by the interbedded volcanic rocks between Braewick Bay and Hamna Voe, the direction varying from N. 20° W. to N.W.

Along the highroad from Ollaberry to Mavis Grind, numerous instances were observed which likewise indicate a passage of ice from the North Sea towards the Atlantic. On reaching Sulem Voe from the north, the eye at once fixes on a large *roche moutonnée* of diorite, which rises to a height of 200 feet above the sea-loch, and the surface of which is finely polished and striated, the markings pointing W. 5° S. And so, also, the narrow neck of land at Mavis Grind is similarly grooved; indeed, over the whole of the district round Hagrister and Islesburgh and north of Magnusetter Voe, the ice-worn aspect of the hills is very apparent, the smooth slopes looking to the east, while the rough slopes face the west, indicating the direction from which the ice came.

On the eastern shores of the districts of Nesting, Lunnasting, and Delting there is no lack of evidence regarding the glaciation, as striæ are plentiful, and in certain areas there is but a scanty covering of peat and herbage. It is difficult to convey an adequate impression of the singularly bare and mamillated appearance of the tract of ground which forms the peninsular headlands of Lunnasting. Bare dome-shaped hills, dotted all over with lochs, occur in the tract between Dourye and Vidlon Voes; and the same features are apparent on the rocky promontory north of the latter sea-loch. Indeed, so perfect and so abundant are the *roches moutonnées* that it may be correctly described as by far the finest district on the Mainland for studying the effects of the primary glaciation.

The average trend of the ice-markings in the districts now referred to is W. 35° S., though they vary from W. to S.W. The position of the *roches moutonnées* leaves no room for doubt as to the direction of the ice-movement. In Swining Voe, which lies to the west of Vidlon Voe, there is a gentle Boulder-clay slope on the east bank, and a steep rock-face on the west bank, rising to a height of from 400 to 500 feet. Notwithstanding this steep slope, the whole rock-face is splendidly glaciated; and, strange to say, the striæ do not run parallel with the coast-line but obliquely across it, the direction being nearly south-west. In one remarkable instance, about halfway down the voe, on a glaciated surface, which slopes downwards into the sea-loch at an angle of 65°, striæ were observed which could be traced from the water-level up the rock-face at an angle of 25° with the surface-plane of the sea-loch. We shall point out presently how the dispersal of the stones in the Boulder-clay completely substantiates this south-westerly movement of the ice.

The tract of country which stretches from Weesdale westwards to Melby and Walls presents the same glaciated aspect, though in many places the *roches moutonnées* have been much broken up by atmospheric waste. Nevertheless the rounded outline of the hills testifies to the moulding of the whole tract by ice, while the striæ have a marked north-westerly trend, quite in keeping with the northing already referred to on the western shores of Northmavine. Not only so, but the highest ground in the centre of the Mainland is likewise ground down and striated. The ridge which extends from Weesdale hill (842 feet) to Scallafield (916 feet) reveals the finer lines as well as the flutings of the ice-chisel wherever the peat is worn away, the direction varying from W. 28°–40° N. Near the gap in the ridge overlooking the head of Weesdale Voe, the polished surfaces and striations are as fresh as if the ice had but recently passed away. Further, the same north-westerly trend is met with on the banks of Olna Voe, east of Meikle Rooe, and in the numerous sea-lochs opposite the isles of Papa Little and Vementry.

In the districts of Lerwick and Quarff, on the eastern seaboard, there is conclusive evidence of the existence of two systems of ice-markings, the one set belonging to the general glaciation trending in a south-westerly direction, and the other set belonging to a later period, indicating a movement in a south-easterly direction, produced by local glaciers. Indeed, so severe must have been the later glaciation in the neighbourhood of Lerwick, that most of the instances belonging to the primary system were well-nigh effaced by it. Both the abundance and the freshness of the striæ belonging to the later system plainly indicate the power of the local glaciers in this neighbourhood; but we shall see presently that at no time were they large enough to override the island of Bressay. Several interesting examples of cross-hatches were observed near the fort at Lerwick, also north of the docks, and again near the village of Sound, the older markings running S.W. and the newer ones S. 40° E. to E. 40° S.

In the long tongue of land stretching southwards from Quarff to Sumburgh Head, the striæ belong mainly to the later glaciation, the direction varying from E. 29° S. to S. 34° E.; about half a mile from Boddom, however, by the roadside, some examples occur in which the trend is W. 3°–9° N., produced by ice moving in a westerly direction.

From the evidence we obtained in Bressay, it is clear that the south-westerly system is the one which is most prominently marked in that island; indeed, so abundant are the ice-markings belonging to the early glaciation, that some parts probably escaped the movements of the later glaciers altogether. This much is certain, that the local glaciers of the Mainland were only able to override the north-western portions of Bressay. Along the eastern coast, from Heogan to the lighthouse, as well as by the roadside from Cullensbro to Gardie, the trend varies from W. 20° S. to S. 30° W. But on the slopes east of the Wart the later system points S. 20° E. to E. 16° S.

In the island of Meikle Rooe, which lies to the west of the Mainland, the average trend is N. 30° W.; in Papa Stour it varies from N. to N. 28° W.; while in Foula, the most isolated of the Shetland group, situated about 18 miles to the S.S.W. of the village of Walls, well-marked striations were observed, running N.W. and W. 30° N.

Altogether we recorded upwards of three hundred and twenty instances of striations in the Shetland Isles, the great majority of which belong to the primary glaciation.

IV. Boulder-Clay.

The Boulder-clay and morainic deposits confirm in a remarkable manner the conclusions already established regarding the double system of glaciation in Shetland. The rich variety of rocks, not only in the Mainland, but also in Unst and Fetlar, enables us to test the truth of these conclusions by noting carefully the distribution of the included stones and the sources whence they were derived. If it be true, as has just been stated, that the ice moved from the North Sea to the Atlantic during the primary glaciation, it naturally follows that the Boulder-clay or *moraine profonde* occurring to the west of the serpentine areas in Unst and Fetlar should contain a certain percentage of stones derived from those areas. The very same reasoning is also applicable to the Mainland; and in order to show how completely the dispersal of the stones in the Boulder-clay substantiates this conclusion, we shall briefly describe a series of traverses we made in Unst, Fetlar, and the Mainland, where the rocks vary in lithological character, indicating the variations in the Boulder-clay and the distribution of the included stones.

Round Balta Sound, in Unst, this deposit is sparingly distributed, only occasional sections being visible on the north and south sides of the bay, the included blocks being almost wholly derived from the gabbro and serpentine areas. Due west of the Sound, in the hollow along which flows the Baliasta burn, there is a considerable covering of Boulder-clay, the included stones being mainly composed of serpentine and dark graphitic schist, though the underlying rock consists of green chloritic schist and gneiss. Ascending the Vallafield ridge, the slope is found to be covered with heather and peat, and well-nigh destitute of drift. Where this covering has been removed, numerous bleached fragments of serpentine are to be found; while near the top of the ridge, where the slope is more gentle, occasional patches of Boulder-clay are met with in which well-striated fragments of serpentine, gabbro, and black schist occur. No Boulder-clay is to be seen on the watershed, which reaches a height of over 600 feet at this point; still, where the peat is worn away, a few bleached fragments of serpentine are observable.

Along the western coast, from Woodwick to Wick Bay, a narrow ledge or terrace intervenes between the rock-slope and the coast-line, which is covered with Boulder-clay more or less continuously. Excellent sections of it are exposed at the heads of the numerous geos. At Collaster it consists of a tough fawn-coloured clay, full of striated stones of all sizes up to blocks 2 to 3 feet long. The following percentages were taken from the banks of the voe at this locality:—

	North side of bay.	South side of bay.
Gneiss and schist (underlying rock)....	53 per cent.	60 per cent.
Serpentine (from east side of watershed)	32 ,,	22 ,,
Gabbro ,, ,, ,,	11 ,,	9 ,,
Black schist ,, ,, ,,	1 ,,	3 ,,
Vein-quartz	2 ,,	3 ,,
Granite (from Lambaness)	1 ,,	2 ,,
Vein-granite	..	1 ,,
	100	100

In all the sections south of Collaster, towards Wick Bay, fragments of serpentine and gabbro are invariably present in this deposit. Moreover, it is important to note that the relative distribution of the gabbro and serpentine stones in the Boulder-clay between these localities is in direct proportion to the respective areas occupied by these rocks on the east side of the watershed. The following are the proportions in the Boulder-clay sections at three localities:—

	Serpentine.	Gabbro.
North side of Collaster Voe	32 per cent.	11 per cent.
Houlon Ness	21 ,,	22 ,,
Wick Bay	22 ,,	26 ,,

This relative distribution of the stones is not a mere accident; for a glance at the map will show that to the E. and E.N.E. of Collaster the serpentine occupies a much greater breadth of ground than the gabbro, while to the east of Wick Bay the conditions are reversed. Such a direct relationship is inexplicable on the hypothesis that the primary glaciation of the island was due to floating ice.

If we traverse the southern shore from Muness Castle to Belmont, similar evidence is obtained from the Boulder-clay regarding the ice-carry. Again, in the north part of the island, in the lee of Saxavord hill, this deposit occurs on the east bank of Burra fiord, about 300 feet above the sea-level, where it reaches 50 feet in depth. The material is mainly derived from the talc-schist and quartzose bands which constitute the hill; but a considerable proportion of the stones likewise consist of the peculiar granite of Lambaness. Now it must be borne in mind that, ere these granite-fragments could have reached this position along the path-line indicated by the striæ, they must have been transported in the *moraine profonde* across the shoulder of Saxavord hill, where it attains a height of 800 feet; whereas none of the Lambaness granite occurs *in situ* at a greater height than 150 feet.

On the west coast of Fetlar, blocks of gabbro and serpentine, derived from the centre of the island, occur in the Boulder-clay north and south of Burgh Hall; while striated fragments of the same rocks, from Unst, are found in this deposit on the north-east coast of Yell. We likewise observed smoothed fragments of gabbro from Fetlar in this deposit on the east coast, between Mid Yell and Basta Voe.

A traverse across the district of Northmavine, in the Mainland, from Ollaberry on the east coast, by Hillswick, Braewick, Tanwick, to the Grind of the Navir, furnishes admirable opportunities for examining the distribution of the stones in the Boulder-clay. A glance at the map will show the variety of rock-formations which occur along this line; and the marked lithological characters of the rocks fortunately prevent any possibility of mistaking them. It is particularly observable that the till partakes of the physical character of the rock-formation on which it rests, though there is also a percentage of foreign stones derived from localities which lay in the path of the ice-sheet. The distribution of the stones in the Boulder-clay along this line of section places beyond all doubt that the ice-sheet, as it impinged on the Mainland, moved in a W.S.W. direction, and as it left the Mainland it veered round towards the N.W. and N.N.W.

The sections in the neighbourhood of Ollaberry, and along the road to the Pondswater loch, show that the Boulder-clay is made up of the underlying gneissose and schistose rocks. The deposit consists of a stiff stony clay, containing fragments of schists, gneiss, and quartz rock. None of the fragments of the diorite, nor any of the lavas and ashes along the western shores, occur in the Boulder-clay. But when the diorite area is reached, the schists and gneiss to the east are represented in small patches of the deposit lying in hollows between the *roches moutonnées*. Beyond the diorite-area again, in the lee of the ridge of the metamorphic rocks of Hillswick, one of the finest Boulder-clay sections to be found in the Mainland occurs. This section, which is upwards of 100 feet in depth, rests on grey micaceous schists, with bands of quartz-rock, which are much broken up immediately underneath the Boulder-clay. These rocks are intersected by dykes of pink quartz-felsite, which are well seen on the beach at the base of the cliff. The deposit is very tough and clayey, and quite homogeneous from the top to the bottom of the section; it is likewise quite unstratified, the stones being scattered through the clayey matrix in an irregular manner. The lower part of the section is mainly made up of the underlying rocks; but about halfway up the section, a percentage of stones was taken which yielded the following results:—

Diorite (*in situ* to the east of section) ..	71	per cent.
Felsite and hornblendic porphyry	17	,,
Vein granite	6	,,
Vein orthoclase felspar...............	4	,,
Syenite	1	,,
Serpentine........................	1	,,
	100	

It may seem strange that none of the underlying schists are represented in the above percentage; but it so happened that the stones we selected high up in the section averaged about 4 inches across. In another percentage of stones measuring about 2 inches across, the underlying schists number about 15 per cent. The prominent ingredient in this section is the diorite, which occurs to the east of Hillswick; but it ought to be remembered that not a single fragment of the lavas and ashes to the west are to be found in this deposit.

About two miles to the west of the foregoing locality, in the north-east corner of Braewick Bay, a section of Boulder-clay, about 12 feet high, is exposed resting on the intrusive quartz-felsite, containing diorite, schist, and felsite stones; while still further west, within the limits of the contemporaneous volcanic rocks, sections of Boulder-clay occur in the bays of Tanwick and Stennis, the included stones being dull purplish porphyrite, blocks of tuff, quartz-felsite, schist, and diorite. Further, along the storm-swept cliffs of the Grind of the Navir, a thin deposit is traceable containing the same ingredients as at the localities last mentioned. The diorite stones, however, are comparatively rare at the Grind of the Navir; in fact they gradually diminish in number in proportion to the distance from their parent source; and the very same remark applies to the other ingredients.

We traversed the south bank of Rocness Voe from the head of the sea-loch to Ockren Head, where similar phenomena were observed, viz. the invasion of the quartz-felsite area by the diorite stones, and the invasion of the area occupied by the porphyrites by the diorite and quartz-felsite stones. Indeed the evidence obtained along these lines of section completely refutes the theory that these north-westerly striæ could have been produced by ice coming from the North Atlantic.

Another traverse, from Vidlon Voe westwards by Swining Voe and across the high grounds to North Brae, indicates in an unmistakable manner the direction of the ice-movement during the primary glaciation. In passing out of the Vidlon valley, across the watershed into Swining Voe, the eye readily fixes on a rocky ridge or, rather, a series of semi-detached *roches moutonnées*, which present their bare slopes to Vidlon Voe, in the lee of which lie well-marked "drums" of Boulder-clay, whose long axes coincide in direction with the trend of the striæ. This deposit covers the whole of the gentle peat-covered slope which forms the eastern boundary of Swining Voe; and it contains numerous fragments of a band of nodular gneiss, which crosses Lunnasting in a north-and-south direction about midway between Lunna and Lunna Ness.

But, further, the Boulder-clay in both the valleys draining into Swining Voe consists of a tough tenacious clay, full of striated stones, derived mainly from the underlying schists, quartzites, and dark hornblendic rocks; and associated with these are fragments of the coarse gneiss of the promontory of Lunna and the nodular band already referred to.

Now it is interesting to note that both in the Vidlon and Swining Voes, which lay across the path of the ice-sheet, the Boulder-clay is found to have the greatest development on the eastern shores; while the western slopes, which were exposed to the full sweep of the abrading agent, are finely *moutonnées* and striated, and well-nigh destitute of drift. But if we take the adjoining Colafirth and Dales Voes, which coincide very nearly with the direction of the ice-markings of the primary glaciation, we find well-marked Boulder-clay slopes on both sides of the sea-loch, indicating that the deposit was distributed more or less equally along the bottom and sides of the valley.

These features remind one very much of the familiar terraces of Boulder-clay in the high-lying valleys in the south of Scotland; while the deposit itself is in all respects identical with the ordinary Scotch till. Indeed, whether we consider the resemblance in the mode of occurrence, or the character of the deposits in Scotland and the Shetland Isles, we cannot resist the conclusion that both have a similar origin.

But even in the Dales and Colafirth Voes it would seem that the deposit steals further up the slopes, and attains a greater thickness on the north than on the south banks—a phenomenon which may be accounted for by the supposition that the ice, as it moved up the sea-lochs, had a greater erosive effect on the one seabank than the other. This supposition is confirmed by a glance at the striæ-map, which shows that the markings are not quite coincident with the banks of the voes, but cross the southern shores at a gentle angle.

After crossing the Leas of Deal and descending the valley between the Duddon and Gallows hills towards Busta Voe, the boundary-line of the diorite is again crossed, when fragments of this rock are found abundantly both in the moraines and the underlying Boulder-clay. Not a single block of this rock, however, is to be met with on the surface or in the drifts to the east of the boundary-line.

In the district which stretches from Weesdale westwards to Walls, and thence to Melby, the Boulder-clay sections furnish corroborative evidence of the north-westerly movement of the ice in that region. In the vales of Tingwall and Weesdale there is no trace of the altered Old-Red-Sandstone rocks which occupy the peninsular tract of country to the west. But as soon as the line of the great fault is crossed, which bounds these strata between Aith Ness and Selic Voe, abundant fragments of the gneissose rocks of Weesdale and adjoining tracts, as well as blocks of the porphyritic granite, are found in the Boulder-clay resting on the altered Old-Red rocks.

Again, in the sections round the coast-line in the neighbourhood of Melby, the fragments in the subglacial deposit entirely consist of the underlying sandstones and the red quartzites and shales of Sandness Hill, along with some pink quartz-felsites; but none of the purplish porphyrites which occur in Papa Stour are represented in these sections. Had the movement been *from* the north-west, then assuredly some fragments of the porphyrites would have been met with round Melby. Instead of this being the case, however, the Boulder-clay of Papa Stour contains numerous fragments of the altered Old-Red-Sandstone rocks from the Mainland.

Another traverse across the island, from Gulberwick to West Quarff, reveals phenomena no less remarkable. On the slopes of the hills above Gulberwick, fragments of the red flags of Brenista and grits are met with; and they also occur in some patches of Boulder-clay near the head of the burn draining into the bay at East Quarff. On the west side of the watershed the Sandybanks burn is reached, which flows into Cliff Sound about a mile and a half to the north of West Quarff. In this hollow there is a deep covering of Boulder-clay, attaining a thickness near the farmhouse of 20 feet. Following this burn to its source, the deposit is found to consist of tough tenacious clay, with well-scratched stones, many of which consist of grit, red sandy flags, and shales of Old-Red-Sandstone age, associated with grey schists derived from the underlying rock. But further along the western seaboard, between the mouths of Sandybanks burn and West Quarff, similar phenomena are observable. Where this stream enters the sea, large blocks of the Lerwick sandstones and well-rounded conglomerates, measuring 2 feet across, were met with both in the Boulder-clay and on the surface. A hundred yards to the south of this locality fragments of the Brenista flags appeared, and became more numerous as we followed the coast-line southwards. Not far from West Quarff blocks of the basement breccia were met with, associated with fragments of the Brenista Flags and Rovey-Head conglomerates, in the thin coating of Boulder-clay on the slope and on the shore.

We have already indicated the relative areas occupied by these subdivisions of the Old-Red-Sandstone rocks between Rovey Head and East Quarff, for the special purpose of showing the analogous distribution of the stones in the Boulder-clay on the western seaboard.

On referring to the map it will be seen that the members of the

Old-Red-Sandstone occupy the strip of low ground from Levenwick southwards by Loch Spiggie to Quendale bay. Now from Channerwick southwards along the hill-tops to the Wart of Skewsburgh (854 feet), smoothed blocks of the red flags, varying from 2 inches to a foot across, are to be found in those places where the peat has been worn away. These blocks are readily detected on the top of Skewsburgh hill, in spite of their being bleached by the peat.

Further, if we cross from Channerwick to the west coast, and traverse the coast-line from Maywick to Loch Spiggie, numerous blocks derived from these areas are likewise met with. In the hollow which runs south from Maywick to Bigton, striated blocks from the red flags are strewn on the eastern slope overlooking the valley, the largest of which have been used as building-material by the villagers of Maywick. Again, on the hill-slope about a mile east from Bigton, blocks of flaggy sandstone are very numerous; and they likewise occur very abundantly in the Boulder-clay on the top of this hill. On both sides of Bigton Bay, the sections of Boulder-clay contain numerous fragments of red flags, though the majority of the stones are made up of the underlying schists. Close to the point where the sand-bar joins the island of St. Ninians to the Mainland, a similar admixture of stones, derived from the red flags on the east side of the island, is to be seen in the Boulder-clay underneath the blown sand. And so, too, southwards towards Loch Spiggie, wherever patches of Boulder-clay have escaped denudation, the same phenomena are observable.

Again, on the slope of Fitful Head, at a height of 800 feet by aneroid measurement, there are small patches of this deposit, in which we observed smoothed stones of syenite and coarse grits *in situ* to the east; while on the hill-top (929 feet) blocks of syenite were noted, which must have been carried up the slope. These facts unquestionably point to the same westerly flow of the ice; but at the base of the slope, along the margin of the syenite area, there is an excellent section of morainic stony clay, in which blocks of schist, syenite, and Old-Red grits are commingled. This deposit is evidently the product of a later glaciation, when the Fitful Head shed its own glacier, and when the detritus which had accumulated on the slope during the primary glaciation was rolled downwards to the low ground at the foot of the hill.

From the evidence now adduced it cannot be doubted that, during the primary glaciation, the great *mer de glace* crossed the Mainland from the North Sea to the Atlantic. We might have multiplied the evidence considerably by referring to the Boulder-clay distributed over the other islands; but we have confined our observations to those lines of section where there is the greatest variety of rock-formations, in order to show both the strength and harmony of the evidence. Ere leaving this division of the subject, we ought to state that, though we carefully searched the numerous sections of Boulder-clay in the different islands, we found no traces of shells in the deposit.

There are certain phenomena still to be discussed, which indicate the gradual retreat of the great ice-sheet when this northern archipelago was no longer influenced by the ice-sheets of adjoining countries, but nourished a series of local glaciers which deposited their moraines as they shrank back into the hills.

V. Morainic Deposits belonging to the Later Glaciation.

On referring to the striæ-map, it will be seen that numerous instances occur along the east coast of the Mainland, from Lerwick to Dunrossness, running in a S.S.E., S.E., and E.S.E. direction, the trend being affected by certain local influences. Now, along this tract there is an irregular covering of a loose morainic deposit, passing into an ordinary Boulder-clay, resting on the areas of the Old Red Sandstone, and containing fragments of the schists from the Cliff Hills, along with the stones derived from the underlying formation. These sections are exposed on the shore between Lerwick and Rovey Head, in the Clickamin bay, Wick Sound, Gulberwick Bay, and in the Old-Red-Sandstone areas from Sandlodge to Boddom. After a careful examination of these sections, we felt convinced that the small fragments of blue and grey schists occurring in the Boulder-clay and morainic matter have been derived from the hills which extend from the Wart of Skewsburgh northwards by Scalloway to Dales Voe. It has been already shown that these schists and clay-slates form the highest ground between Dunrossness and Dales Voe north of Lerwick; and the occurrence of fragments of these rocks in the drift along the eastern seaboard points merely to a local radiation of the ice, after the great *mer de glace* that overflowed Shetland had melted back and was no longer confluent with the small glaciers that lingered on during the later glaciation.

That this is the explanation of the foregoing phenomena seems still more likely when we examine the eastern sea-board of Northmavine between Colifirth Voe and Fethaland Point. At certain localities, in the narrow strip occupied by the metamorphic rocks, we found similar deposits mainly made up of the débris of the underlying rocks, but likewise containing stones derived from the Roeness plateau. These sections occur on the north bank of Colifirth Voe in the North-Rooe bay; and again round the Fethaland fishing-station and in the Sand Voe. Now from Colifirth Ness northwards to Calsta extends a well-marked ridge parallel with the Biurg range, against which the local glaciers abutted, which were shed from the Roeness plateau. A similar ridge runs from North-Rooe Bay to Fethaland, culminating in the Lanchestock hill (416 feet). These ridges deflected the later glaciers, and caused them to move southwards into Colifirth Voe, and northwards into North-Rooe Bay and Sand Voe. Here and there, however, where the ice must have been heaped up, it streamed across the lower portions of the ridge flanking the sea. From the configuration of the ground it is apparent that the Roeness plateau must have shed its largest glacier in the direction of North Rooe. Hence it follows that only at certain localities reached by the local glaciers are fragments of the quartz-porphyry to the west associated with the schists in the drifts. The same remarks are applicable to the erratics of pink granite and quartz-felsite scattered over the surface between Fethaland and Colifirth Voe.

These accumulations were in all probability extruded at the snouts of the local glaciers when the great *mer de glace* had melted away from the immediate vicinity of Shetland. This is rendered all the more likely from the number of striated stones in the deposit, and its tolerably coherent nature, differing somewhat from the loose débris of the ordinary surface-moraines. But, in addition to these later deposits, there is abundant evidence to show that when the hill-tops had emerged from the icy covering which so long held sway during the primary glaciation, the severe frosts which prevailed caused an accumulation of blocks and rubbish on the surface of the attenuated glaciers. In course of time, as the glaciers melted back, loose heaps of rubbish were laid down, sometimes as isolated mounds, but frequently in concentric lines indicating pauses in the retreat.

As might be expected from the size of the valleys and the limited elevation of the hills, the moraines are not large; but they are nevertheless very abundant; indeed there are few of the important valleys draining a mass of high ground which do not contain well-marked groups. They consist of loose débris with angular and subangular stones; and in some cases the deposit is merely an assemblage of small stones without any matrix. Numerous examples occur, however, where the heaps show distinct traces of stratification and the stones are somewhat waterworn.

In a small valley about two miles in length, draining the east side of the Bonxie hills and flowing into the bay below Conningsburgh, a fine series of moraine heaps occurs, displaying the usual concentric arrangement. They vary in length from 5 to 10 feet; and numerous *blocs perchés* of the Bonxie-hill schists rest on the mounds.

In the district of Delting, moraines are to be found in the main valleys and round the heads of the larger sea-lochs, as for instance the Dales, Colifirth and Swining Voes on the east coast, and near Voe, North Brae, and Voxter on the west coast. And so also on the banks of Vidlon and Dourye Voes in Lunnasting, similar deposits are seen resting on the Boulder-clay. We frequently observed that the moraines became more numerous where two or more valleys converge at the head of a sea-loch, which is just what might be expected when the tributary glaciers must have coalesced at this point. At the head of Swining Voe two streams join the sea; and at the point where the valleys converge a well-marked series of concentric mounds is met with. The dividing ridge is strewn all over with innumerable moraines, doubtless the lateral moraines of both glaciers; and in the various burn-sections the morainic drift is found to rest on the Boulder-clay. The evidence derived from the disposition of these mounds shows clearly that at the time they were deposited the glaciers did not fill the valleys to any great extent, neither did the trunk glacier extend very far down the voe.

The scarcity of striæ produced by the later glaciers in the district of Delting, when compared with their great abundance on the eastern seaboard, near Lerwick, is deserving of note; but their absence is doubtless due to the fact that the glaciers slipped forward over a terrace of Boulder-clay which effectually buried the underlying rocks.

Abundant moraine heaps with enclosed tarns and innumerable *blocs perchés* were also observed between Colifirth and Sand Voes, and in the valleys draining into Roeness Voe, and likewise in the districts of Weesdale and Sandness.

The islands of Unst, Yell, Whalsey, and Bressay nourished a similar series of local glaciers, as is evident from the moraines now strewn on their slopes. In the morainic deposit found on the north-western shore of Bressay, near Heogan, while the great majority of the stones consist of grits and liver-coloured quartz rocks belonging to the Old Red Sandstone, there is also a considerable number composed of grey schists, which we identified as belonging to the hills round the head of Dales Voe in the Mainland. This deposit resembles in every respect the sections occurring in the opposite side of the Sound near Grimmester, and again in the bays between Lerwick and Brenista. It is clear therefore that this deposit points to the advance of the local glaciers of the Mainland; they must have been powerful enough to cross the northern portion of the Sound, and to override the north-western part of Bressay. We searched carefully for traces of this more recent deposit in other parts of Bressay, but failed to discover them. The evidence in proof of the existence of local glaciers in the neighbourhood of the Wart at the south end of the island seems to indicate that their further advance would be checked on this account. We may well believe, therefore, that as the local glaciers of the Mainland streamed into the Sound, they were met by the small sheets of ice shed from the Wart, and thence moved southwards along the path of least resistance.

VI. Erratics.

From an examination of the numerous boulders scattered over the Mainland and the other islands, it is evident that their dispersion belongs to two distinct periods of glaciation. We saw none which cannot be satisfactorily accounted for by the double system of glaciation already established, without invoking the aid of coast-ice or icebergs.

Along the slopes of the Vallafield ridge in Unst we observed numerous blocks of serpentine, some of them measuring 5 feet across, which were dispersed during the primary glaciation. In the Mainland they occur in dozens on the rocky plateau of Roeness, on the diorite area north of Mavis Grind, and on the rocky headlands of Lunnasting.

In the valleys draining the eastern slopes of the Roeness plateau, and in the low hills between Colifirth Voe and Fethaland, blocks of pink quartz-felsite are strewn, sometimes on the moraine heaps, on *roches moutonnées*, or on the drift-slopes, all of which were distributed by the later glaciers.

Again, boulders of the Northmavine diorite are scattered over the low ground between Hillswick and the Grind of the Navir, while blocks of metamorphic rocks were carried by the great *mer de glace* and the later glaciers from the Leas of Deal and the surrounding heights onto the diorite area of Busta Voe. The peculiar band of nodular gneiss on the promontory of Lunna has supplied boulders which can be followed westwards towards the head of Swining Voe, and the ridge overlooking Dourye Voe, in harmony with the primary ice-movement.

West of Weesdale, blocks of the porphyritic granite in Bixetter Voe, as well as boulders of gneissose rocks from the Weesdale hills, are strewn over the area occupied by the altered Old-Red-Sandstone rocks; while boulders of the Sandness-hill quartzites have been borne seawards to Melby.

Perhaps the most interesting series of erratics occurs on the ridge of high ground which extends from Scalloway to the Wart of Skewsburgh, where small blocks of the Brenista Flags and the Lerwick Sandstones, varying from a few inches to a foot across, are exposed in places where the peat has been worn away. These have been carried from lower to higher levels; indeed they have been carried to the tops of the highest hills along this tract. We have already incidentally referred to this remarkable fact, and to the occurrence of similar blocks in the Boulder-clay on the west coast, and as erratics on the slopes of the hills. Those which are found on the western sea-board are much larger than those on the hill-tops, as they sometimes measure 3 feet across; many of them still show ice-markings. We believe that their occurrence in the drifts on the west coast and as erratics on the hill-tops is due to the same cause, viz. to the westerly movement of the great *mer de glace*, which was powerful enough to override the watershed.

VII. Freshwater Lochs and Voes.

The freshwater lochs abound chiefly in the Mainland; and in certain districts they occur in great numbers. They are due either to the irregular deposition of the Boulder-clay or moraine-matter, to hollows in the peat, or to rock-basins which have been eroded by the ice. Indeed they are so abundant in some of the rocky districts as to recall portions of the north-west of Sutherlandshire. At present we are only concerned with those which occupy rock-bound hollows, and which are the result of glacial erosion.

These occur most abundantly on the rocky plateau of Roeness, in the diorite-area of Northmavine, on the rocky headlands north and south of Vidlon Voe, and in the district of Walls. In each of these localities the sheets of water, with certain exceptions, fill eroded hollows in the rocks; and, from the manner in which their rocky margins are grooved and polished, from the freshness of the *roches moutonnées* which encircle them, there can be little doubt they have been eroded by the ice during the general glaciation. From one of the hills north of Magnusetter Voe, in Northmavine, we counted about twenty small lochs in the heart of the diorite-area.

On the promontory of Lunnasting they likewise occur in great numbers, varying in size from basin-shaped hollows to lochs more than a mile in length. Their long axes coincide with the strike of the underlying gneiss; but, owing to the scooping-agent having crossed the lines of stratification nearly at right angles, their outlines are very irregular. Similar strike-basins are to be found on the promontory between Vidlon and Dourye Voes; and from the manner in which they are hemmed in by *roches moutonnées* on every side, it is impossible to resist the conclusion that they are due to ice-action. The lochs now referred to must have originated during the primary glaciation, because there is no evidence that the later glaciers ever overflowed the headlands of Lunnasting.

The voes or sea-lochs are among the most interesting features of the Shetland Isles; and the question of their origin is not free from difficulty. Flowing, as they do, for miles into the heart of the country, it sometimes happens that only a narrow isthmus is left to prevent the waters of opposite shores from uniting. Yell is nearly bisected by the Whalefirth and Reafirth Voes; and a submergence of a few feet would separate Northmavine from the Mainland, and allow the waters of Sulem Voe to flow westward into St. Magnus Bay. Sometimes the voes are flanked by gentle slopes of Boulder-clay, as we have frequently indicated; at other times they are bounded by steep walls of rocks, as in the well-known Roeness Voe. Many of the most characteristic sea-lochs lie along the line of strike of the metamorphic rocks, of which the Weesdale, Stromness, Whiteness, Dales and Laxfirth Voes may be cited as the best examples; but there are others which have no connexion with the lines of stratification. As a rule, they are found to merge into narrow valleys draining the high grounds, the width of the voes being in direct proportion to the size of the valleys. This relationship would seem to indicate that these narrow fiords are submerged land-valleys which existed long before glacial times. In the course of our traverses in Shetland, we heard frequent testimony pointing to the conclusion that the ridge-shaped contour which is so prevalent in the Mainland, Yell and Unst, likewise extends along the sea-bottom; and it is highly probable that it is due to the same cause in both cases. If this be true, then these fjord-valleys may have been carved out by the ordinary agents of denudation when the floor of the sea which now surrounds Shetland formed dry land. Both in Scotland and along the east coast of England the evidence derived from buried river-channels would lead us to believe that these countries stood at a higher level in preglacial times than they do now; and we may well believe that Shetland shared in the same continental conditions. The absence of shells in the Boulder-clay seems to strengthen this conclusion.

At any rate the agents of denudation would be guided in their operation in a large measure by the strike of the metamorphic rocks; and if there was a wide area of land round what now constitutes the Shetland archipelago, they would accomplish greater results, as the size of the rivers would be in proportion to the area of drainage. We have seen also that some of the voes and inland valleys coincide with the outcrops of bands of limestone, the erosion of which would be aided by chemical agencies.

There can be no doubt, however, that the sea-lochs in Shetland were deepened by ice-action during the primary glaciation; indeed numerous instances have been cited in this paper where the great *mer de glace* took advantage of the existing hollows in crossing the island, This produced, in certain instances, fjord-basins, of which we shall adduce two examples. The soundings given in the Admiralty chart show that Sulem Voe, which is one of the largest of the sea-lochs in the Mainland, measuring upwards of seven miles in length, varies from 10 to 15 fathoms in depth between Foula Ness and the mouth of Voxter Voe. Beyond the latter point, however, to the head of the voe, the depth suddenly increases to 21 and 25 fathoms. This increase of 60 feet in depth at the head of the sea-loch is doubtless due to the intense abrasion caused by the ice as it impinged on the rocky isthmus of Mavis Grind. We have already pointed out how distinctly the east face of this narrow isthmus has been polished and striated; and this fjord-basin helps us to realize still better the erosive power of this agent. Still another instance occurs in Roeness Voe; for at the bend north of Urie Firth the depth varies from 102 to 138 feet, while about two miles further down the loch shallows to 42 feet.

There is one peculiar feature connected with these voes which may be dismissed in a few words. It frequently happens that spits of gravel are thrown up by tidal action near the head of the sea-loch. These banks are seen in all stages of formation in Shetland, sometimes extending a third, a half, or nearly the whole of the way across the loch. Ultimately the voe is crossed by a continuous bank of gravel which isolates the upper part; and this isolated portion is converted into a sheet of brackish water.

VIII. Conclusion.

1. *Summary of the Evidence regarding the Primary Glaciation.*—We must now, very briefly, recapitulate the evidence regarding the primary glaciation of Shetland, in order to show the conclusions which may be justly drawn from the facts, and also to determine the relation which the glacial phenomena of these isles bear to the glaciation of Norway and Scotland.

It has been shown that in the islands of Unst, Fetlar, Whalsey, the Outskerries, Bressay, and along the eastern sea-board of the Mainland and Yell, there is one uniform system of ice-markings trending W.S.W., S.W., and in some cases S.S.W.; while in the western districts of the two latter islands, as well as in Meikle Rooe, Papa Stour, and Foula, the striæ swing round to the N.W. and N.N.W. From a careful examination of the striated surfaces and the *Stossseite* of the *roches moutonnées*, it is evident that the agent which produced them must have crossed the islands from the North Sea to the Atlantic. Fortunately this conclusion is placed beyond all doubt by the distribution of the Boulder-clay, as well as by the dispersal of the stones in this deposit. On the western sea-board of Unst the Boulder-clay contains fragments of serpentine, gabbro, and graphitic schists, all of which occur *in situ* on the east side of the Vallafield range. Moreover the relative distribution of the serpentine and gabbro stones in this deposit on the western shore is in direct proportion to the relative areas occupied by these rocks to the east of the watershed. It follows, therefore, that the agent which glaciated Unst must have crossed the watershed, carrying the bottom-moraine up the slope, and depositing it in the lee of the range. In Fetlar, blocks of gabbro and serpentine are likewise found in the Boulder-clay on the west coast; while along the east coast of Yell, blocks of gabbro occur in this deposit which have been brought from Unst and Fetlar, testifying alike to the same westerly movement.

The evidence derived from an examination of the Boulder-clay sections on the Mainland is equally conclusive; for it matters not whether we cross the northern, central, or southern portions of the island, we are compelled to admit that the ice-flow during the primary glaciation must have been towards the Atlantic. In the central part of Northmavine it has been clearly proved that the Boulder-clay partakes of the physical character of the rock-formation on which it rests, while a certain percentage of the stones is derived from localities which lay in the path of the glaciating agent. Abundant evidence has been adduced to show that the quartz-felsite area between Tanwick and Roeness Voe has been invaded by the diorite stones, while the area occupied by the bedded porphyrites has been invaded by the quartz-felsite and diorite stones. Moreover it is particularly observable that the blocks derived from the successive areas occupied by these rocks, which are present in the Boulder-clay, diminish in number in proportion to the distance from their parent source.

Again, in the long tongue of land which stretches from Scalloway southwards to Fitful Head, blocks of the Old-Red-Sandstone rocks occurring on the eastern sea-board are found, not only on the tops of the highest hills, but also in the Boulder-clay on the western shore. Moreover the distribution of the fragments of the Lerwick Sandstone, Brenista Flags, and basement-breccia in the Boulder-clay north of West Quarff is in perfect harmony with the relative areas occupied by these subdivisions of the Old Red Sandstone south of Lerwick. The same relationship holds true in the district between Maywick and Fitful Head. It is clear, therefore, that the glaciating agent must have overflowed the watershed, as we found to be the case in Unst.

2. *Insufficiency of Icebergs or Coast-ice to account for the Phenomena.*—Perhaps some may attribute the numerous striated surfaces, as well as the Boulder-clay, to the action of icebergs or coast-ice on a sinking area; but a little consideration will show that either of these causes is quite inadequate to explain the phenomena. We have shown that over the whole of Shetland the glaciating agent must have conformed to the inequalities of the surface, descending into

the smallest hollows and overflowing the projecting knobs of rocks, indicating in an unmistakable manner that the agent must have pressed steadily and firmly over the whole area. Nay, more, the islands have been grooved and striated in one determinate direction, while rocky slopes have been likewise abraded; and from the manner in which the striæ run obliquely up the hill-face, it is evident that the agent must have ascended the slopes, and ultimately overflowed the high grounds. Now it is hardly necessary to point out that neither coast-ice nor icebergs are capable of producing such results as these. It is impossible to conceive that icebergs or coast-ice could press steadily on a wide archipelago like Shetland, so as to plane down the inequalities on the surface; far less could they produce this uniform system of striation. We may well ask, by what means could floating ice or coast-ice ascend a rock-slope several hundred feet high, leaving at the same time indelible impressions of the upward movement? Such an occurrence would be a physical impossibility.

Again, the phenomena of the Boulder-clay are quite at variance with the floating-ice theory; for if this deposit be due to the droppings of icebergs or coast-ice, then assuredly it would have been more or less stratified; whereas, from one end of Shetland to the other, the Boulder-clay, with but few exceptions, is quite amorphous. If it be really a marine deposit, how could it possibly partake of the characters of the rock-formation on which it rests, and how could the relative ingredients diminish in number in proportion to the distance from their parent source?

Further, the occurrence of blocks in the Boulder-clay on the western sea-board of Unst and the Mainland, which must have crossed the watershed to reach their present position, is still less explicable by this hypothesis. For if the high grounds of Unst or the Mainland were submerged so as to allow a free passage for icebergs in their westward career, where are the areas of gabbro, serpentine, or Old Red Sandstone which could have supplied the materials found in the Boulder-clay? Even if we suppose that ice rafts drifted off the eastern sea-board laden with such materials, we must suddenly invoke a special subsidence of several hundred feet at least, both in Unst and in the Dunrossness area, to enable them to cross the watershed. But this improbable supposition still leaves unexplained the relationship which exists between the relative distribution of the stones in the Boulder-clay on the west coast, and the relative areas occupied by the rock masses. For these reasons, therefore, and others which it is not necessary to specify, it is impossible to reconcile the glacial phenomena of Shetland with the theory of icebergs or coast-ice.

3. *Shetland glaciated by Scandinavian Ice.*—Similar phenomena to those now referred to have been observed and described again and again in Scotland and other highly glaciated regions, where they have been almost universally ascribed to the action of land-ice. It is not necessary for us to show how the uniform system of striation, or the rounded outlines, or the close relation between the Boulder-clay and the rocks on which it rests, are satisfactorily ex-

plained by the passage of land-ice over Shetland. It is sufficient for our present purpose if we show that, during the general glaciation of Scotland, Boulder-clay was transported across important hill-ranges by the ice which radiated from the Grampians. On the south of the Sidlaw range, as well as on the south side of the Ochils, the Boulder-clay contains fragments of schist, gneiss, and granite, which must have been transported from the Highlands. Further, on the top of Allermuir hill small patches of Boulder-clay were observed by Dr. Croll containing striated stones derived from the Highlands to the north-west. It is evident, therefore, that the Scotch ice-sheet was powerful enough to override such important ranges as the Sidlaws, the Ochils, and portions of the Pentlands, and must likewise have rolled forward the bottom moraine, depositing it in the lee of the hills. And if such was the case in Scotland, then why may not the same thing have happened in Shetland? Indeed, had Shetland formed a part of the western sea-board of Scotland, there would have been no hesitation in ascribing the striated surfaces and the Boulder-clay to the action of land-ice.

The land-ice which glaciated Scotland could only have come from Scandinavia, as the striated surfaces clearly point in that direction. And we must now briefly consider what grounds there are for believing that the Scandinavian *mer de glace* was powerful enough to invade the North Sea. The researches of Erdmann, Hörbye, Esmark, Helland, Törnebohm and Linnarsson have revealed to us the extent of the ancient glaciation of Norway and Sweden. They clearly show that Scandinavia was not glaciated by Polar ice moving southwards from the Arctic regions; for the ice-markings generally radiate from the great tablelands as they do in Scotland. It must have been buried underneath an ice-sheet which moved off the land in all directions. It has been generally supposed that this *mer de glace* must have broken up in the form of bergs when it reached the shallow North Sea; but fortunately we are now supplied with data which enable us to prove that this could not have been the case. If we take the estimate given by Helland for the minimum thickness of the ice in Sogne Fjord during the period of extreme cold, it follows that, instead of the ice breaking up in the form of bergs, it must have invaded the North Sea and moved in a westerly direction towards the Shetland Isles. He gives 6000 feet as the estimate at this point; and when we remember that the average depth of the German Ocean is about 240 feet, we can readily understand how such a mass of ice could never have floated between Norway and Shetland, much less between Norway and Scotland.

When this *mer de glace* impinged on the Shetland frontier, it would necessarily be deflected to some extent by the opposing high ground. Hence, as we move southwards from Unst, where the average trend of the ice-markings is W. 10°–20° S. towards Bressay and Lerwick, the deflection increases to S.W. and in some cases to S.S.W. But as soon as the ice reached the crest of the Mainland, it would naturally follow the path of least resistance, veering round to the N.W. and N.N.W. It is highly probable that this northing may be due in part to the resistance offered by the Scotch ice-sheet, which must have coalesced with the Scandinavian *mer de de glace* in the North Sea. That this union must have taken place is evident from the proofs of the deflection of the glaciers along the eastern sea-board of Scotland and England; and it would even now appear that the great Chalky Boulder-clay of East Anglia is a product of land-ice which moved inland in a north-east and south-west direction. These phenomena point to the existence of some constantly opposing force which was capable of overcoming the seaward motion of the Scotch and English glaciers. In other words, the two ice-sheets must have united on the floor of the North Sea, one great outlet for this ice-field being towards the north-west by the Pentland Firth and the Orkney Islands. When the Orkney Islands are examined in detail they will doubtless yield conclusive evidence in support of this north-west movement.

After the *mer de glace* had ceased to be confluent with the local glaciers of Shetland, the latter lingered on for a time, filling all the main valleys and flowing off the land in all directions. The deposits met with on the eastern coast of the Mainland between Lerwick and Boddom, and again between Colifirth Voe and Fethaland Point, must be attributed to this local movement; while the numerous moraine heaps sprinkled over the valleys indicate the immense quantity of débris which must have been borne downwards on the surface of the small glaciers.

4. *Absence of Gravel Kames and Raised Beaches in Shetland.*—Throughout the isles we searched in vain for those ridges of gravel which form such a notable feature in Scotland. Here and there the moraine mounds and the moraine débris, which is spread irregularly over the slopes of the hills, show signs of rude stratification, while the stones are more or less waterworn; but no one would readily mistake them for true kames. Moreover there is a remarkable absence of raised beaches indicating changes in the relative level of sea and land. Though we examined the islands with considerable minuteness, we never found a trace of those familiar terraces which are so characteristic of parts of the Scotch coast-line. This is all the more remarkable, as the voes or sea-lochs are admirably adapted both for the formation and preservation of sea-beaches. We cannot help believing that, if such deposits had been formed, we must assuredly have met with some indications of them; and for this reason it seems just to infer that they never existed in Shetland. The remarks made by Professor Geikie in an article in 'Nature'* clearly show that their absence has an important bearing on the question of their origin. For if they be due, as Dr. Croll suggests, to the rise of the sea-level, owing to an accumulation of ice round the North Pole during the glacial period, then we should naturally expect to find them in localities which are so well adapted for their formation; but since this is not the case, we may infer that they indicate pauses in the gradual elevation of the land which must have been general over the whole of Scotland in postglacial times. It would seem, however, that Shetland did not participate in these general movements of upheaval.

* 'Nature,' vol. xvi. p. 414.


SHETLAND
Foula 19¾ miles due West from Skeldaness
Foula.
The Sneug
1369
Ham.
Rovey Head
Dales Voe
Whiteness Voe
Scalloway
HILDASAY
PAPA
OXNA
Culswick
Westwick
Selwick
Skeldaness
Noss Head
NOSS
Bard of Bressay.
BRESSAY SOUND
Prebisterness
Gulberwick
W. Quarff
E. Quarff
Fladobister
BURRA
SOUND
CONNINGSBURGH
Sand Lodge
Aith Voe
MOUSA
Noness
Levenwick
SANDWICK
Troswick
Lambhoga
DUNROSSNESS
Gretness Voe
Quendale Bay
Fitful Head
Sumburgh Head
COLSAY
Sᵀ NINIAN Iᴰ
Iᴰ OF HAVERA
CLIFF SOUND
English Miles 69 to a Degree.
Longitude 1° West of Greenwich
Mintern Bros. Chromo lith

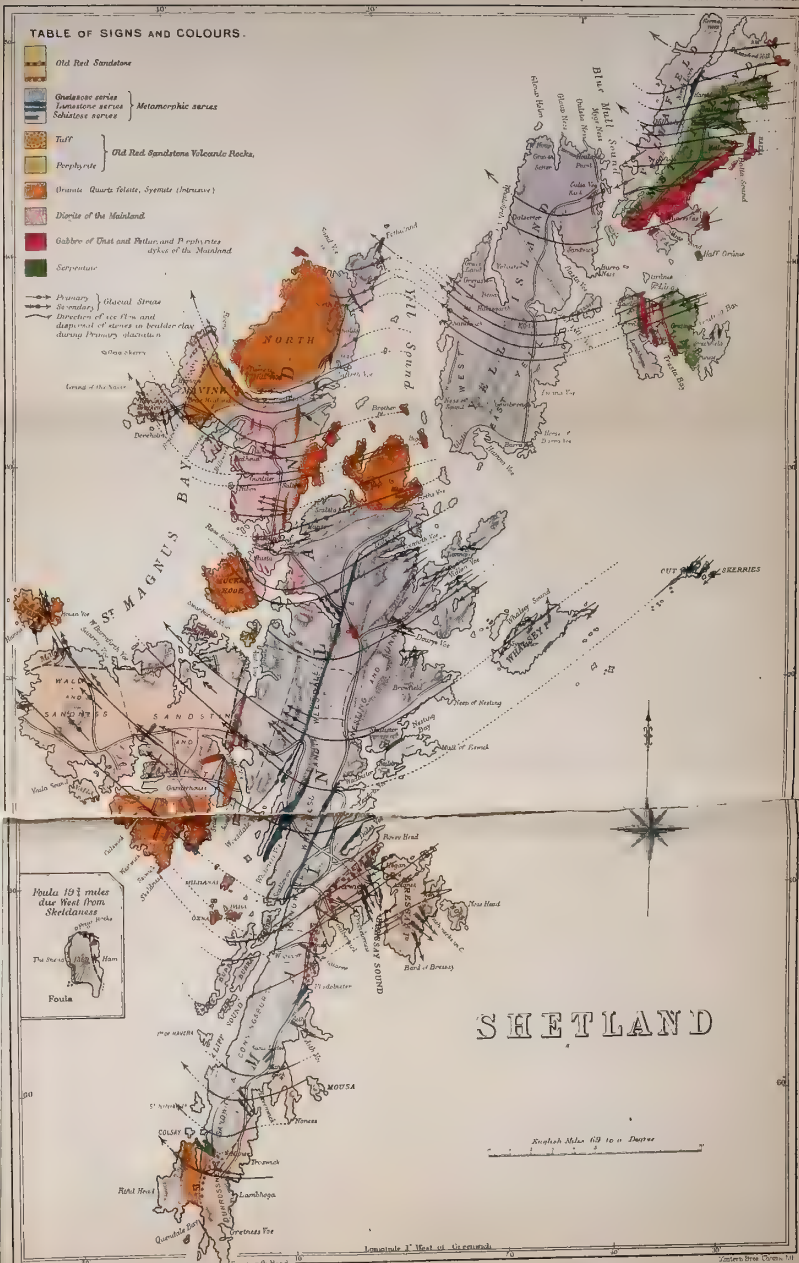


TABLE OF SIGNS AND COLOURS.
Old Red Sandstone
Gneissose series
Limestone series
Schistose series
Metamorphic series
Tuff
Porphyrite
Old Red Sandstone Volcanic Rocks.
Diorite of the Mainland
Gabbro of Unst and Fetlar, and Porphyrites dykes of the Mainland
Serpentine
Primary
Secondary
Glacial Striae
Blue Mull Sound
Yell Sound
ST MAGNUS BAY
NORTH
WEST
EAST
SANDSTONE
MUCKLE ROE
Brother Is.
Balta Sound
Trasta Bay
CUT SKERRIES
Whalsey Sound
WHALSEY
Neep of Nesting
Nesting Bay
Mull of Eswick
Rovey Head
Noss Head
Bard of Bressay
BRESSAY SOUND
MOUSA
Nóness
Troswick
Lambhoga
Fitful Head
Quendale Bay
Gretness Voe
Sumburgh Head
COLSAY
Vaila Sound
Foula 19¾ miles due West from Skeldaness
Foula
Ham
SHETLAND
English Miles 69 to a Degree
Longitude 1° West of Greenwich
Mintern Bros Chromo. lit.

Appendix.

A List of Fossil Plants, collected in Shetland, by Messrs. B. N. Peach and John Horne, of the Geological Survey, in 1878.
By C. W. Peach, Esq.

No.		
1 & 1*a*.	*Calamites cannæformis*, from Bressay	Small specimens. In the Sandstone quarries of Bressay and those on the opposite side of the Sound, very large ones are far from rare, known by the name of "Corduroy" by the quarriers.
2.	*Lepidodendron nothum*, Unger, from Walls district	Unfortunately these are obscure; they, however, show sufficiently well for identification, and that they are what Salter called *L. nothum* of Unger? They may belong to *Lepidodendron*. I rather think they are nearer to *Lycopodites Milleri*, also figured by Salter. They have not *stigmarian* roots, but masses of *long flat rootlets* (the *Fucoids* of Miller and others). I got in Caithness some of these, with splendid masses of *rootlets* attached.
3.	,, ,, ,, ...	
4.	,, ,, ,, ...	
5.	,, ,, ,, ...	
6.	,, ,, ,, ...	
7.	,, ,, ,, ...	
8.	,, ,, ,, ...	
9.	,, ,, ,, ...	
10.	,, ,, ,, ...	
11.	,, ,, ,, ...	
12.	,, ,, ,, ...	
12*oo*.	On the opposite side of 12, is a nice example of *Psilophyton princeps* of Dawson, showing leaflets.	
13.	*Psilophyton* (from Noss).	
14.	*Psilophyton princeps*, Dawson (from Walls)	This is the most abundant plant of the Old Red Sandstone of Shetland, Orkney, Caithness, &c. &c., and of Canada, America, and Turkey &c., in the Devonian of the latter countries.
15.	,, ,, ,, ...	
16.	,, ,, ,, ...	
17.	,, ,, ,, ...	

Discussion.

Dr. Hicks, having studied the adjoining rocks of the mainland of Scotland, differed from the authors as to the age of the metamorphic series, and thought they must be Pre-Cambrian, and belonging to two if not three Pre-Cambrian series.

Prof. Bonney asked as to the evidence of the passage of gabbro into serpentine.

Mr. Horne replied that they did not attempt in the paper to fix the age of the metamorphic rocks referred to by Mr. Hicks, and insisted on their views as to the intrusive character of the quartz-felsites of Shetland.

In reply to Prof. Bonney, he stated that he and his fellow author had not minutely studied the supposed passage of one rock into the other, but that Dr. Heddle, who had so studied them, had arrived at the same conclusion as themselves.

61. *On the* South-Scarle Section *. By E. Wilson, Esq., F.G.S.

(Read June 25, 1879.)

At South Scarle, a point about halfway between Newark and Lincoln, an unsuccessful boring for coal some short time ago disclosed a most interesting, but, so far as its lower portion was concerned, somewhat puzzling geological section. The object of this communication is to identify, if possible, the lower rocks passed through in these borings.

The following generalized section is quoted from a paper "On a deep Boring for Coal at Scarle, Lincolnshire," by Prof. E. Hull, F.R.S., F.G.S. (see Proc. Inst. Civil Engineers, vol. xlix. part iii.) :—

South-Scarle Section (after Hull).

		ft.	in.
	Alluvial or Drift strata	10	0
	Lower Lias Clay and Limestone	65	0
	Rhætic beds	66	0
	New Red Marl (Keuper)	573	0
	Lower Keuper Sandstone	244	0
	New Red Sandstone (Bunter)	542	0
	Upper Permian Marls	118	6
	Upper Magnesian Limestone	40	6
	Middle Permian Marls	141	0
	Lower Magnesian Limestone	56	0
	Lower Permian Sandstone	16	0
Carboniferous strata.	Greyish earthy limestones and calcareous shales with small bivalves	118	0
	Greenish coarse grit and breccia	1	0
	Red marls or clays, in which the boring was discontinued	10	0

Down to 26 feet in the Lower Magnesian Limestone the above classification of the Scarle cores appears to be approximately correct. Below that depth, however (1827 feet), there came up from 50 to 60 feet of a very hard dark grey to black rock, generally oolitic, though apparently unfossiliferous, the analysis of which showed it to be an argillaceous dolomite. This was succeeded by 16 feet of sandy (?) sediment too loose for cores; then came 118 feet of grey earthy limestones or calcareous shales, with a foot or so of greenish grit or breccia at the base. Last of all (at 2020 feet), compact red or purplish-red clays with nodules of hæmatite were penetrated to a depth of 10 feet. On seeing the first specimens of the "grey earthy limestones," Professors Ramsay and Hull both came to the conclusion, founded on lithological grounds, that these rocks were to be referred to the Lower Yoredale series. The succession below, however, of fine greenish grit, or breccia, and chocolate-coloured clays proved very puzzling; and the fact of such strata not being known

* This is an extract from the author's paper "On the Physical Geography of the North-east of England in Permian and Triassic Times."

among the Yoredale rocks led Prof. Hull to conclude instead that the grey earthy limestones, breccia, and red marls, one and all, belonged to the uppermost beds of the Coal Measures. That is how the matter stands up to the present time. Now, beyond all doubt, the grey earthy *limestones* belong, *not* to the Carboniferous, but to the Permian formation, constituting, in fact, with the overlying dark oolitic dolomites and loose sands (?) the Marl Slates; for they are identical with the Marl Slates of West Notts in lamination, colour, and mineral composition, they yield similar obscure plant-remains, and a doubtful shell, "either *Anthracosia* (?) or *Axinus*," the *latter* of which occurs in the Notts Marl Slates; like these, too, they occasionally become oolitic; and, finally, they are underlain by a coarse greenish grit or breccia, clearly the selfsame bed as that which, as described by me on a former occasion, constitutes the base at once of the Marl Slates and of the Permian formation (see my paper "On the Permians of the North-east of England," Q. J. G. S. vol. xxxii. p. 533). (*Note.* The total absence of ironstone in all this thickness of grey shales is strongly against their being Coal Measures.) Not only, then, are the Marl Slates represented at Scarle, but they there attain their greatest known thickness in this country.

The "Red Marls" remain to be accounted for. Prof. Hull says (*loc. cit.*) these shales closely resemble portions of the Upper Coal Measures of the North Staffordshire and Manchester coal-fields. The question whether productive Coal Measures exist at all, and at a workable depth, beneath West Lincolnshire, is a matter not only of considerable theoretical interest, but of enormous commercial importance; and any thing bearing on it should therefore be handled with the utmost caution. The red marls from the bottom of the Scarle boring certainly do manifest a very close textural agreement with certain Upper Coal Measures, *e. g.* those of North Staffordshire. On theoretical considerations the occurrence of Upper Coal Measures at Scarle is by no means improbable. So far, then, as the red marls are concerned, I coincide with the later and more hopeful opinion of Prof. Hull; and I venture to think that such opinion will be considerably strengthened now that the overlying grey rocks are eliminated from the Carboniferous strata and placed with the Permians.

In conclusion I append what I believe to be the correct reading of the lower portion of the Scarle Section:—

			ft.	in.	ft.	in.
		Down to Lower Magnesian Limestone			1801	0
		Lower Magnesian Limestone			26	0
Permian (continued).	Marl Slates:	dark oolitic dolomites	58	0	193	0
	,,	lost cores	16	0		
	,,	thin-bedded grey argillaceous dolomites, sandstones, and shale	118	0		
	,,	basement breccia	1	0		
Carboniferous.	Upper Coal Measures.	Deep-red indurated Marls with nodules of hæmatite, penetrated to...			10	0
		Total depth			2030	0

GENERAL INDEX

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[The fossils referred to are described; and those of which the names are printed in italics are also figured.]

END OF VOL. XXXV.

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