THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

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

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

Vol. XXXIII.

1. *The* Cephalopoda-beds *of* Gloucester, Dorset, *and* Somerset.

By J. Buckman, Esq., F.G.S., F.L.S., late Prof. of Geology and Rural Economy, R. A. Coll. (Read June 21, 1876.)

Every student of the geology of the Cotteswolds has recognized a band at the base of the Inferior Oolite under the name of the "Cephalopoda-bed," so named from the important list of Ammonites, *Nautili*, and Belemnites which it has been found to contain.

To quote from Mr. Hull's 'Memoir on the Geology of the Country around Cheltenham,' "This bed had been long known to geologists as 'the ammonite bed;' but the ammonites were supposed characteristic of the Inferior Oolite, and its true importance was overlooked. Dr. Wright, however, found that the species were identical with specimens from the Upper Lias of Whitby, in Yorkshire. About the same time the work of M. D'Orbigny made its appearance, wherein nearly all the cephalopoda from the ammonite bed are figured and described as '*Toarcien*,' or Upper Lias forms, while even in our own district several of the species . . . . . were known to be characteristic of the Upper Lias Shale" (p. 26).

Mr. Hull refers to a paper by Dr. Wright in the 'Proceedings of the Geological Society,' vol. xii., in support of the view that the Cotteswold Cephalopoda-bed belongs to the Upper Lias and not to the Inferior Oolite, and, further, that the learned Doctor had traced it to the Dorsetshire coast; and, indeed, in this very paper we find the following remarks upon sections at Half-Way House and Bradford Abbas, which we quote, as showing that Dr. Wright had at this time identified the Dorset Cephalopoda-bed with the one in Gloucestershire.

"Between Yeovil and Sherborne" *the* "Cephalopoda-bed is well developed and extensively exposed; and at the Halfway House its relations to the Sands below, and the Limestone of the Inferior Oolite above, may be satisfactorily made out. Here it contains a great many large *Ammonites*, *Nautili*, and *Belemnites*,—as

Ammonites dorsetensis, *Wright*.
—— jurensis, *Zieten*.
Nautilus inornatus, *D'Orb*.
Belemnites breviformis, *Voltz*.
—— compressus, *Voltz*.

"*Section* VI.—*At Bradford Abbas, near Yeovil, Dorsetshire.*

"*Inferior Oolite.*

	ft.	in.
"A. Coarse, hard, brown ragstone, slightly oolitic, very irregularly bedded, and containing few fossils: about	2	0
B and C. Absent.		

"*Cephalopoda-bed.*

"D. A coarse, brown, oolitic ragstone, composed in part of hard, calcareous, sandy layers, grey and brown, and having softer marly sandy seams running through the rock; it breaks with an uncertain fracture, and sometimes has a flinty hardness: the ragstones are speckled with dark brown flattened oolitic grains of hydrate of iron, and contain many fossils: about	2	6"*

It was then clearly Dr. Wright's view (in which he was, indeed, both preceded and followed by other geologists) that the Dorset Cephalopoda-bed was identical with that of Gloucestershire; and indeed we have seen fossils from the Bradford bed just described labelled as from Upper Lias.

Mr. Strickland, in 1850, considered the ironshot oolite of Dundry the equivalent of the Cephalopoda-bed of the Haresfield Hill. He says, "A few miles to the south the Pisolite disappears and is replaced near Painswick and at Haresfield Hill by strata containing ferruginous oolitic grains in a brown paste. This is the precise equivalent of the well-known oolite of Dundry, near Bristol, which may be recognized as far off as Bridport, on the Dorset coast"†.

Now this view was quoted by Dr. Wright in a paper published in the 'Quarterly Journal' for 1860, only to be dissented from; for he says of the above, "a comparison, however, of the species of *Ammonites* and other shells collected in these different localities shows that, besides a similarity in lithological structure, there is nothing in common between the strata"‡; and he accounts for the appearances by supposing that the *Ammonites-Murchisonæ* zone, by thinning out, has brought the zone of *Ammonites Humphresianus* into close relation with the sands of the Upper Lias‡.

* Quart. Journ. Geol. Soc. vol. xii. (1856) p. 309. † *Ibid.* vol. vi. p. 250.
‡ *ibid.* vol. xvi. p. 18.

As, however, the shells of the 2 feet 6 inches bed, described as the Cephalopoda-bed at Bradford and other places in Dorset, are identical with those at Dundry, and at both Bradford and Dundry it contains with others

Ammonites Parkinsoni, *Sow.* (A. dorsetensis, *Wr.*),
—— Humphresianus, *Sow.*
Ammonites Murchisonæ, *Sow.*
—— jurensis, *Ziet.*

we conclude that the Cephalopoda-beds at Bradford and Dundry are on the same horizon, and, further, that neither the one nor the other has the slightest connexion with the Cephalopoda-bed of Gloucestershire ; and if this be so, the fact that the four Ammonites just quoted have been made representatives of four distinct zones, will be a difficult problem to solve for those who implicitly believe in zones.

One of the more recent papers, "On the Correlation of the several subdivisions of the Inferior Oolite in the middle and south of England," is by Dr. Holl, who concludes that the true position of our Dorset and Somerset beds is higher in the series than is stated by the geologists just quoted, and "that they are, in fact, the southern extensions of the Upper and Lower Ragstones of Mr. Hull, the uppermost of which is not represented in the typical section at Leckhampton, having risen above the level of the country, and cropped out before reaching the brow of the hills"*.

We agree with this view, except that we consider the Dorset Cephalopoda-bed the equivalent of the *Gryphite Grit* at Leckhampton, and that the roughly bedded stone above is the representative of the *Trigonia Grit* of Cold Comfort. The constant presence of the same typical Ammonites on the top of Leckhampton hill and in the Bradford Abbas quarries seems to prove this assertion, such as

Ammonites Sowerbyi, *Miller.*
—— Brocchii, *Sow.*, *M.C.*
—— Humphresianus, *Sow.*, *M.C.*
—— Parkinsoni, *Sow.*, *M.C.*
Ammonites concavus, *Sow.*, *M.C.*
—— subradiatus, *Sow.*, *M.C.*
—— Murchisonæ, *Sow.*, *M.C.*

and others.

From this, then, it follows that, while the Gloucestershire Cephalopoda-bed is at the base of the Inferior Oolite or top of the Upper Lias, the Dorset Cephalopoda-bed is near the top of the former ; and yet they have not only been confounded the one with the other, but this position has been supported by the *similarity*, not identity, of the Cephalopods, which, indeed, have been held to point to Lias rather than to Oolite.

Dr. Holl's view of the case seems to be, that while we have thus the Upper Ragstones, the lower members of the Inferior Oolite are deemed to be absent ; for he says :—

"On the southern side of the Mendips the Inferior Oolite nowhere

* Quart. Journ. Geol. Soc. vol. xix. (1863) p. 307.

exceeds 28 or 30 feet in thickness, of which from 8 to 10 feet belong to the lower subdivision. The upper subdivision immediately underlies the Fuller's Earth; and its light colour, lithological structure, and general poverty in organic remains readily distinguish it from the hard, brown, more or less massive or rubbly limestone beneath, which is everywhere very fossiliferous"*.

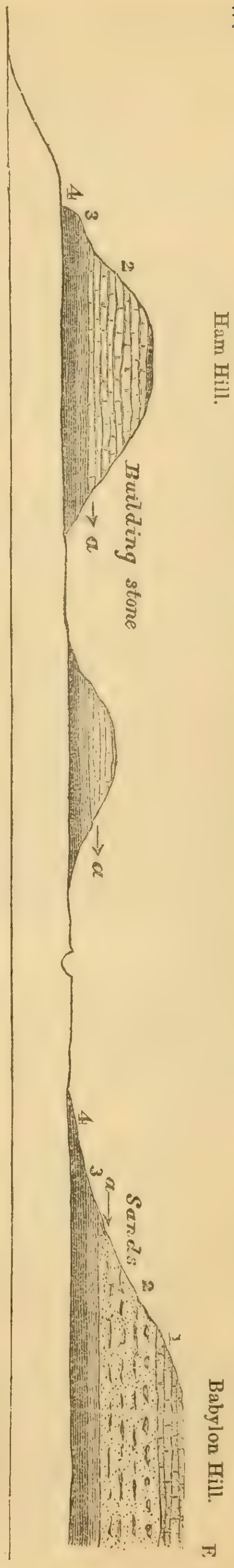
Now we take it that, although the learned Dr. Holl is right as regards the position of the Dorset Cephalopoda-bed, he is not so in supposing that the lower members of the Inferior Oolite all thin out in Dorset—our view being that quite 100 feet of the sands, with its occasional bands of shelly oolite, as these occur at Bradford Abbas, really represent the lower oolitic mass of Leckhampton and Crickley, in Gloucestershire; and, in fact, our Dorset sands represent the lower freestones of Gloucestershire.

The connexion between the sands of one place (Babylon Hill) and the building-stones on the same horizon at Ham Hill is shown in the accompanying section (fig. 1).

At Ham Hill the equivalent of the sand-bed at Babylon Hill is a reddish brown freestone, apparently made up of comminuted shells. At Babylon Hill the brown sandy beds present occasional courses of comminuted shelly oolites.

The two sections here placed in juxtaposition (fig. 2) are remarkable for their dissimilarity at first sight; but if the brown sands were a little more indurated (and the presence of a few more shells or a little more lime might well

Fig. 1.—*Section from Ham Hill to Babylon Hill.*

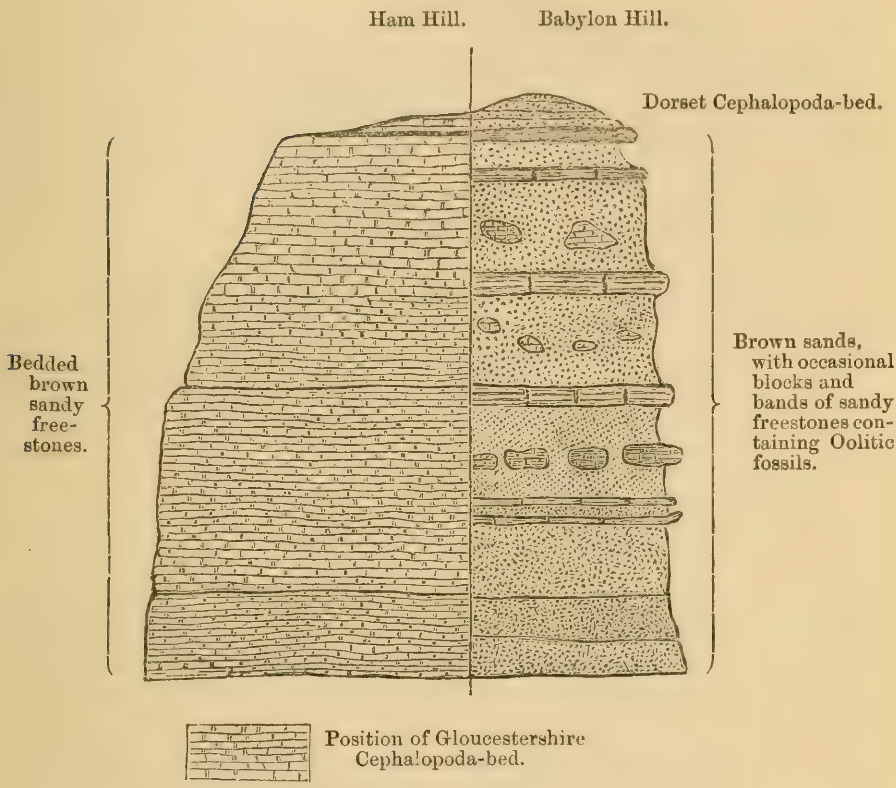


1. Cephalopoda-bed of Dorset.
2. Sands and bands of Oolitic rock at Bradford, building-stones at Ham Hill. *a*. Position of Cephalopoda-bed of Gloucestershire.
3. Upper Lias. 4. Lias Marls.

* Quart. Journ. Geol. Soc. vol. xix.

bring that about), there would not be much difference between the Ham-Hill section and several other sections near Sherborne.

Fig. 2.—*Comparative Sections of Beds at Ham Hill and Babylon Hill.*



Ham Hill has always been a puzzle to the geologist; but if we place it on the same horizon as the so-called "Lias Sands" at Bradford, the difficulty is at once cleared up.

Mr. Moore, in his paper "On the Middle and Upper Lias of the South-west of England," speaking of Ham Hill says:—

"The workable freestone at this spot is 58 feet thick, and almost entirely composed of comminuted shells, united by an irony cement, and is a remarkable deposit; for though attaining so considerable a thickness, it does not appear to be represented in any other locality. It has been largely worked for centuries, and yields a very excellent stone, of a light-brown colour, due to the presence of carbonate of iron, an analysis of the deposit proving it to contain 14 per cent of metallic iron" *.

The best Gloucestershire equivalent of this bed is to be seen in the straight wall of rock at Crickley Hill, which latter section we consider the equivalent of the freestone-beds at Ham Hill, and the

* Proceedings of the Somersetshire Archæological and Natural-History Society, vol. xiii. 1865-66.

sands with shelly oolite interpolated in slabs at Bradford Abbas, Babylon Hill, and the adjacent district.

The following list of fossils from the freestone at Ham Hill and the shelly oolites of Dorset can nearly all be matched in the lower beds of the Inferior Oolite of Gloucestershire.

Belemnites compressus, *Blainv.*
—— tricanaliculatus, *Ziet.*
—— subtenuis, *Simps.*
—— abbreviatus, *Mill.*
Nautilus latidorsatus, *D'Orb.*
—— inornatus, *D'Orb.*
Ammonites jurensis, *Ziet.*
—— Moorei, *Lycett.*
—— opalinus, *Rein.*
—— Edouardianus, *D'Orb.*
—— Murchisonæ, *Sow.*
——, other species.
Ostrea bullata, ?
—— Buckmanni, *Lyc.* (?) (Gryphæa).
—— subloba, *Desh.*
—— Marshii, *Sow.*, = flabelloides, *Lam.*
Lima densipunctata, *Röm.* t. 14. f. 3.
—— grandis, *Röm.* t. 13. f. 10.
—— rigida, *Sow.*
Pecten lens, *Sow.*
—— annulatus, *Sow.*
—— discites, *Goldf.*
——, other species.
Gervillia Hartmanni, *Goldf.*
Pinna Hartmanni, *Ziet.*
Avicula complicata, *Buckm.*
Astarte elegans, *Sow.*
—— pullus, *Röm.*
—— obliqua, *Desh.*
——, other species.
Trigonia, costated species.
——, clavellated species.
Lucina bellona, *D'Orb.*
Ceromya (Isocardia) concentrica, *Sow.*
Tancredia donaciformis, *Lyc.*
Spines of Cidarides.
Ossicula of Apiocrinus.
Serpulæ, &c. &c.

Now this list of fossils is sufficient to mark the oolitic nature of these thick beds below the Cephalopoda-bed of Dorset; and if this new reading of the matter be correct, our sands are not the equivalents of the Gloucester sands, or rather the Cotteswold sands, but the representatives of the lower beds of the Inferior Oolite, which at Ham Hill is a good freestone, from containing so much lime, while at Bradford it is hard, in bands consisting of a shelly oolite, with thick beds of sand between, not sufficiently indurated to be used as stone.

If this be so, then it is clear that the name of "Upper Lias Sands" cannot be retained for *these* sand-beds.

The most recently published notion upon the sands is from the pen of Professor Phillips, in which he proposes to name them the "Midford Sands"*, as they were studied by Smith at the village of Midford, and decided by him to be "sands of the Inferior Oolite." If, however, the sands of the west be really of Inferior-Oolite date, they ought not to be correlated with the sands of the Cotteswolds, as these are in a considerably lower position.

Leaving then this question for further consideration presently, we will now more particularly describe the Cephalopoda-bed of Dorset; and in doing this, it will perhaps be well to first give a section of the oolitic rocks in the middle station at Bradford Abbas, premising that the Ammonite-bed is the most constant in the district.

* 'Geology of Oxford,' p. 109.

Section of Bradford-Abbas (East-Hill) Quarry.

	ft.	in.	
1. Soil	0	4	Trigonia Grit of Buckman, Geol. of Cheltenham.
2. White oolite with irregular cleavage	6	0	
3. Band of marl, with *Astarte* and *Lima*, *Belemnites*, &c.	0	3	Cephalopoda - bed = Gryphite Grit of Buckman. (beds 3–9)
4. Hard ironshot rock, with *Ammonites*, *Belemnites*, &c.	1	0	
5. Band of brownish stone, marly at top, full of Univalves and *Ammonites*	0	6	
6. Ironshot oolite, a mass of Cephalopods	1	0	
7. Marl with *Astarte trigonalis*	0	3	
8. Bed with *A. aalensis*	0	9	
9. Blue-centred oolite, with *Isocardia concentrica*	1	2	

10. Reddish sands, commencing the lower freestone system of the Cotteswolds.

How far the term Cephalopoda-bed for the fossiliferous portion of this section may be justified will at once be seen from the following list of the family of fossils after which it has been named, the whole of which have been found at Bradford Abbas, or the equivalent bed near Sherborne.

List of Cephalopoda from the Dorset equivalent of the "Gryphite Grit."

Belemnites compressus, *Blainv.*
—— ellipticus, *Miller.*
—— giganteus, *Phill.*
—— abbreviatus, *Sow.*
—— canaliculatus, *Schl.*
—— Blainvillii, *Voltz.*
—— terminalis, *Phill.*
—— anomalus, *Phill.*
—— sulcatus, *Mill.*
Ammonites Truelli, *D' Orb.*
—— subradiatus, *Sow.*
—— læviusculus, *Sow.*
—— Murchisonæ, *Sow.*
—— Sowerbyi, *Miller.*
—— cadomensis, *D' Orb.*
—— Parkinsoni, *Sow.*, including A. niortensis, *D' Orb.*, and A. dorsetensis, *Wright.*
Ammonites Garantianus, *D' Orb.*
—— polymorphus, *D' Orb.*
—— Martinsii, *D' Orb.*
—— ooliticus, *D' Orb.*
—— Eudesianus, *D' Orb.*
—— zigzag, *D' Orb.*
—— Tessonianus, *D' Orb.*
—— Edouardianus, *D' Orb.*
—— discus, *Sow.*
—— Blagdeni, *Sow.*
—— Humphresianus, *Sow.*
—— Braikenridgii, *Sow.*
—— linguiferus, *D' Orb.*
—— Brongniartii, *Sow.*
—— Kaumontii, *D' Orb.*
—— Sauzei, *D' Orb.*
—— Gervillii, *Sow.*
—— dimorphus, *D' Orb.*

and others, with some undescribed forms.

Ancyloceras annulatum, *D' Orb.*
—— bispinatum, *D' Orb.*
Ancyloceras subannulatum, *D' Orb.*

(From D'Orbigny's Lias list.)

Nautilus latidorsatus, *D' Orb.*
—— striatus, *Sow.*
—— semistriatus, *D' Orb.*
—— inornatus, *D' Orb.*
—— truncatus, *Sow.*
—— excavatus, *Sow.*
—— lineatus, *Sow.*
—— sinuatus, *Sow.*
—— clausus, *Sow.*
Ammonites candidus, *D' Orb.*, aalensis, *Ziet.*
—— cornucopia, *Young.*
—— jurensis, *Ziet.*
—— Germainii, *D' Orb.*
—— insignis, *Schubler.*
—— variabilis, *D' Orb.*
—— concavus, *Sow.*
—— torulosus, *D' Orb.*

and others.

Here then we have designedly tabulated about sixty species of Cephalopoda from D'Orbigny's 'Paléontologie Française, Terrains Jurassiques,' as this author has referred fully one quarter of the species to the Lias. It is an extraordinary list (even though not yet fully made out) for about two feet of rock.

If we inquire how it is that so many of the species have been allocated to the Lias, we shall find that *some* few of them have undoubtedly ascended upwards from the lower stratum; but most of them have been called Liassic upon the assumption that our Bradford Cephalopoda-bed and our sands were the equivalents of those beds in Gloucestershire, and both supposed of Lias age. This we know, not only from references by D'Orbigny himself, but also from having seen fossils from my own quarry of the age of the Gryphite Grit labelled as from "the Upper Lias."

From all this it appears evident that while some English geologists have confounded two beds fully 100 feet apart, and made their lists of fossils harmonize with this view, both some foreign and home savans (taking, be it observed, these two beds to be one) have, in the same way, made them to harmonize with the Upper Lias of the Continent.

Now I have not had the pleasure of a personal examination of foreign oolites, but I can plainly see that they have been interrogated to support theories no less than have those at home; and I can well believe that if they at all harmonize with our Dorset strata, foreigners, like ourselves, may have confounded two beds widely apart.

That they do so harmonize we are strongly inclined to believe from D'Orbigny's drawings of Cephalopoda, as in Dorset we have not only a large number of species referred for the first time to our home rocks, but they are for the most part in a fine state of preservation—so much so, that the terminations of the Ammonites have in many cases been clearly made out.

It may be further remarked upon this list of Cephalopods, that although the bed in which they occur has been made out over a wide district, and in all cases it preserves its peculiar character, yet it differs at various points as to the prevalence of species.

Thus at Bradford Abbas the *Ammonites subradiatus* prevails. At Babylon Hill the *A. Murchisonæ* is more common, while midway the *A. Sowerbii* takes the lead. At Halfway House the *A. Parkinsoni* is the characteristic fossil for a part of the quarry, and the *A. subradiatus* for another part. Further to the east, at Sherborne, the *A. Humphresianus* assumes importance; whilst at Clatcombe, a mile from there, the *A. Braikenridgii* is not only a common but a most perfect fossil.

Now if it be assumed that this Cephalopoda-bed at these different points occupies a different horizon, of course we can recognize them as different zones, and name them after their prevailing Ammonites; but it is not so; and it is a remarkable fact that from 2 to 3 feet of the oolite rock in a limited area should present not only so great a crowd of individuals but such a variation in species.

We have hitherto confined our attention to the Cephalopods; but the Gasteropods tell the same tale. In the Bradford-Abbas quarry alone have been found as many as fifty species of univalves, many of which belong to the Cotteswolds*. There is, however, a large array of new forms in the genera *Pleurotomaria*, *Chemnitzia*, *Turbo*, *Trochus*, *Natica* and *Solarium*; and others abound.

These, like the Ammonites, are in a wonderful state of preservation.

The Brachiopoda are not so numerous as in the Cotteswold district; still the forms met with in the Cephalopoda-bed point also to the high position it occupies in the Inferior Oolite; such are

Terebratula Phillipsii, *Mor. & Dav.*
—— perovalis, *Sow.*, and var. ampla, *Buckm.*
—— Buckmanni, *Dav.*
Terebratula sphæroidalis, *Sow.*
Rhynchonella spinosa, *Schl.*
—— media, *Sow.*
and others †.

And others abound.

The Conchifera afford a list for our limited area as large as is to be met with in the whole of the Cotteswolds, numbering over 150 species. Amongst them the following genera—*Trigonia*, *Lima*, *Pecten*, *Cucullæa*, *Modiola*, *Perna*, *Cardium*, *Astarte*, and others, present a most interesting assemblage of forms.

Neither the *Echinodermata* nor the *Zoophyta* present the same number of species as the Cotteswolds; but in places a few species occur abundantly.

Taken then as a whole, we may conclude that the Dorset Cephalopoda-bed is one of the richest deposits in the country, although as yet we cannot pretend to have exhausted or to have made out all its treasures; but it would seem that within this thin stratum are stored up most of the important forms which make up the mass of the Cotteswold fauna.

It would appear, indeed, that out of about 250 species of shells tabulated by myself in the second edition of Murchison's 'Geology of Cheltenham,' fully 200 belong to the Cephalopoda-bed of Dorset; whilst in this latter county are found many specimens of which the Cotteswolds cannot boast, most of which, so far as the Cephalopoda and Gasteropoda are concerned, are figured in D'Orbigny's 'Terrains Jurassiques.'

* These have since been increased to nearly 100 species.

† Since the above was written the Brachiopoda from the district have been sent to Mr. Davidson, and he has made out nearly 30 species.

2. *On the* Relation *of the* Upper Carboniferous Strata *of* Shropshire *and* Denbighshire *to Beds usually described as* Permian. By D. C. Davies, Esq., F.G.S. (Read June 21, 1876.)

[Plate I.]

The strata I am about to describe occur in the north-west corner of Shropshire and in the adjacent south-east corner of Denbighshire. They are cut through by the rivers Ceiriog and Dee; and a good section of a portion of them may be seen along the banks of the Dee, from the mouth of the Ceiriog downwards towards Erbistock.

I directed attention to these beds in the year 1873 *. Since that time I have been engaged constantly in colliery operations in the district and strata then referred to; and I propose in this communication to narrate the results of my observations during the interval, and also to inquire into the relative position of these strata with others which are usually described as Permian.

The order of the beds and their relation to the underlying Coal-measures will be understood by a reference to the horizontal section which accompanies this paper (Pl. I. B). This section extends from the Brynkinallt Colliery, near Chirk, on the west, past the new sinkings of the Ifton-Rhyn Collieries on the east. The line of the section was carefully surveyed by Mr. F. B. Henderson, F.G.S.; and the geological details are supplied by the section of the Brynkinallt Colliery on the west, the Hafod-y-bwch pit-section on the north, the recent sinkings and borings at Ifton on the east, taken together with the outcrops of the strata which are visible along the line of the section.

Section no. 11, of the Diagram of Sections (Pl. I.), gives in a condensed form the details of the strata to be described from the *Spirorbis*-limestone upwards.

Prior to the year 1873 this limestone had not been recognized in the North-Shropshire and North-Wales coal-field. Early in that year I was taken to see some supposed ironstone beds in the Pentre-Isaf ravine, near Wynnstay. I was struck with the calcareous nature of these supposed ironstones; and upon a close examination I observed the little spiral shell, *Spirorbis carbonarius*, together with another minute shell which Mr. Etheridge, to whom I submitted a specimen of the limestone, regards as *Cythere scotoburdigalensis*. Both Mr. Etheridge and Mr. Daniel Jones, F.G.S., who has paid much attention to the *Spirorbis*-limestone in South Shropshire and the Forest of Wyre, confirmed me in the conclusion I came to, that the supposed ironstone beds were none other than the *Spirorbis*-limestone itself. I may on a future occasion describe these limestones and their associated strata more minutely; at present I would simply add that in February of this year the same limestones were passed through in the No. 3 pit, at Ifton-Rhyn Collieries on

* "On Coal-seams in the Permian at Ifton, Shropshire," Proceedings of the Geologists' Association, vol. iii. no. 3.

the Shropshire side of the river Dee, and three miles S.E. of Pentre Isaf, where they were first seen. Their position is shown on both the horizontal and vertical sections.

Starting with the *Spirorbis*-limestone as our base-line, we have, in ascending order, first a series of red and blue rocks, shales, green and brown sandstone, and grit rocks, with ten thin coal-seams and their underlying clays. The total thickness of this series, from the *Spirorbis*-limestone to the topmost coal-seam, is 220 feet. I may here remark that, with some variations, the same strata have been proved in various sinkings and borings in the neighbourhood.

Above this group of strata we have next about 300 feet of green and greenish-grey rocks with brown and grey sand and gritstones, with pebbly conglomerated and brecciated beds, usually of a greenish colour. These are interstratified with red marls and clays. The green rocks present a great variety of texture; some are fine-grained sandstones, others rougher grits passing through fine and course breccias into conglomerates. In the Ifton section the fragments and pebbles do not exceed three inches in length by one inch and a half in breadth. It is, however, probable that if we could follow these deposits westward to what would be their shore-line, we should find the pebbles and angular fragments increased to boulders and blocks of a larger size. These beds are also exposed along the banks of the rivers Ceiriog and Dee; and there we find that the breccias and conglomerates are not continuous over a large area, but form oval, wedge-shaped, and irregular masses in the midst of the finer sandstones and marls.

They thus present the appearance of deposits made in a shallow sea subject to currents, eddies, and storms. The pebbles and fragments consist chiefly of Lower or Cambro-Silurian rocks with their imbedded quartz, felspar, greenstone, and porphyry, together with fragments of Wenlock Shale and Carboniferous Limestone. The whole series indicates a source in the hilly region about Glyn-ceiriog and Llanarmon, which lies from ten to twenty miles west of their present position. Associated with these breccias and conglomerates are drifted plant-remains.

It will be seen by a reference to the horizontal section that this series of beds thins out before it reaches the shafts of the Brynkinallt Colliery on the west; nor is it present, except in an attenuated form, in the Hafod-y-bwch shafts of the Ruabon Colliery, five miles to the north.

This series of strata is overlain by another of nearly equal thickness consisting of red, white, purple and variegated marls. These marls are interstratified in the lower part of the series with red and brown sandstones. In the middle portion there are numerous thin bands of grey calcareous rock. In the upper marls are numerous calcareous clayey concretions charged with crystals of sulphide of iron.

There are two thin layers of carbonaceous matter in this series—one near the base, in which I have detected traces of *Calamites*, and one near the middle of the series, which forms a true coal-seam a quarter of an inch thick, with an underclay. This ring of coaly matter thickens northward, so that at Hafod-y-bwch, it forms an impure coal five inches thick.

Above this group we reach a thin deposit of blue shale. This is succeeded by a fire-clay four feet thick; and this, in its turn, is surmounted by a coal-seam sixteen inches thick, of fair quality. This coal has a hard grey shale roof, which is a perfect storehouse of plant-remains: a brief attempt was recently made to work the coal; and in doing so a fine calamite stem, twenty feet long and from twelve to eighteen inches in diameter, was exposed in the roof shale. *Pecopteris* (*Bucklandi* ?) abounds; so also do *Stigmariæ* and *Lepidodendra* of various species. There are also *Asterophyllites, Neuropteris* (*cordata*), *Araucaria*, *Sternbergia* and other plant-remains. In driving a road through this shale some distance above the coal, there was found an erect trunk of *Calamites* or *Calamodendron gigas*, which measures eighteen inches across the base, and about six feet in length of which was excavated and is preserved. This specimen retains portions of the outer bark in a carbonized state. These fossiliferous shales are covered by a hard grey rock locally known as the "half-yard rock," above which we reach about five yards of fire-clay, of which I wish especially to remark that it contains numerous rounded balls of limestone, which are imbedded throughout it.

This thick clay is surmounted by a group of coals, of which the following is a section.

	ft.	in.	
Top.—Coal	2	6	
Dirt	0	7	
Coal	0	6	
Fireclay	0	10	
Coal	1	3	
Fireclay	0	6	
Coal	0	6	
	6	8	or Coal 4 ft. 9 in.

A noticeable feature in this coal, which is worked and is now known as the "Morlas Main," is the occurrence (rather too often) of "*brasses*," which are exclusively the pyritized stems of *Calamodendron commune*: many of these are very instructive specimens, which show the original structure of the wood as well as of the inner and outer bark.

For a reason which will be obvious presently, I wish to call especial attention to the almost unique mineral composition of these pyritized stems. Mr. D. Hesketh Richards, of Oswestry, gives the following analysis of them:—

Iron	30·506
Sulphur	34·864
Carbonate of lime	25·500
Other constituents not determined, but consisting for the most part of coal and insoluble matter...	9·130
	100·000

The clays interstratified with these coals are full of the rootlets of *Stigmaria ficoides*; and the overlying shale, which is four or five yards thick, is charged with *Sigillariæ*, *Calamites*, and *Lepidodendra*, of several species, *Pecopteris* (*Bucklandi* ?), *Neuropteris cordata*, *Asterophyllites*, *Araucarites*, *Dadoxylon*, *Sternbergia*, and other plant-remains, the grouping being similar to that of the lower seam just described.

Above this shale we reach a rock which is known in the district as the Coedyrallt rock, a good section of which may be obtained in the Coedyrallt wood on the right bank of the Dee, a little below the junction of the Ceiriog with that river. It is also worked in quarries along its outcrop on the right bank of the valley of the Morlas. North of the Dee it is quarried in Wynnstay Park, as well as near a farm-house one mile to the N.E. of Ruabon.

It consists of buff, yellow, and greenish grey sandstones, in which obscure traces of organic remains are found. These sandstones enclose large irregular masses of limestone, which are not drifted fragments, but which form integral parts of the rock.

The limestone is usually grey in colour and of a coarse crystalline texture. Some idea of the quantity of calcareous matter contained in this rock may be formed from the fact that below Escob Mill, on the right bank of the brook Morlas, a deposit of calcareous tufa of considerable extent and thickness has been formed by water percolating through it.

The rock also contains in its upper portion a bed six feet thick, of calcareous nodules and concretions set in a clayey matrix. Above the Coedyrallt rock, which varies in thickness from 40 to 80 feet, is a bed of red marl; shales follow until, at a height 210 feet above the Morlas-main coal, we reach a double coal-seam with a parting of fine fire-clay, as follows:—

	ft.	in.
Coal...................	1	6
Fire-clay...............	10	0
Coal....................	1	6

This coal has been worked a little in the "New Flannog Pit." It is succeeded by 45 feet of blue and dark grey shales, which are capped by a rock which, in the New Flannog pit, was about 6 feet thick.

This rock cannot, I think, be far from the base of the dark red sandstones, group 4 of Section 11; but the exact distance is not at present ascertained.

Good sections of these upper sandstones may be seen along the left bank of the Dee from near the new bridge recently erected on the Penyllan estate to Erbistock ferry. Fragmentary sections are also seen in the brooks about Pant Mill. Near their base these beds are of a marly nature; but they become massive sandstones as we ascend. Towards their middle portion there are occasional irregular beds of small pebbles. There is much false-bedding among the sandstones, which also vary in colour from brown to grey; they also contain white gypsiferous bands.

The thickness of this series of sandstones is very great; it has been estimated by Mr. Hull* at 1500 feet; and possibly it reaches that thickness; but it is difficult to define the uppermost limit of the group, as it appears to graduate into the overlying Bunter, as may be seen by following the ravine Shellbrook upwards towards the S.E.

These sandstones have recently been bored through near the village of Whittington, two miles N.E. of Oswestry, and six miles south of the Dee-side section. The boring, after leaving the drift, passed through bright red soft sandstone belonging to the "New Red," and entered these dark sandstones, which proved to be 620 feet thick. They there consist of coarse- and fine-grained dark red and brown sandstones, occasionally streaked with white; and near their base there is a bed of white rock 2 feet thick. With the exception of a thin bed containing a few fragments of darker rock, there are no conglomerates or brecciated beds; at this point these upper sandstones rest immediately upon the lower portion of the red marls of group 3, the Ifton Coal-measures and the upper portion of the red marls being absent. At Croeswylan, two miles south of this boring, these upper sandstones have thinned out to about 70 feet in thickness, and they rest upon the red marls. At Llynclys, two miles to the south of Croeswylan, they rest immediately upon the Carboniferous Limestone and Millstone Grit. At Alberbury, seven miles S.E. of Llynclys, they cover the calcareous conglomerate for which that place is celebrated.

I have been careful to trace these upper sandstones in their progress southwards, because of their bearing upon the inferences to be drawn presently as to their true stratigraphical position.

In the year 1859 I described† the coal-seams at the top of group 3, section 11, as ordinary Coal-measures, and I argued from them for an extension of the Coal-measures eastward; for I should here observe that in the maps of the Geological Survey the boundary between the Coal-measures and the Permian crosses the horizontal section at point A (Pl. I. B). In 1869 Mr. Hull‡, in speaking of the red marls, group 3, as seen at Newbridge and at Hafod-y-bwch Colliery, describes them as Upper Coal-measures, and he begins the Permian at the base of the dark sandstone of the Dee, group 4, section 11.

Subsequently to the publication of my paper† in 1859 I observed from time to time the unconformability of groups 2 and 3 to the underlying Coal-measures—an unconformability amounting sometimes to between 700 and 800 feet; I noticed also the identity of the red marls of group 3 with those mapped as Permian at Plassau, N.E. of Ruabon, and elsewhere. On reading the description by the late Sir R. I. Murchison and Prof. Harkness§ of the Permian strata of the N.W. of England, I was struck with the similarity of the plant-remains of the shales in group 3 of their section No. 3, to those found at Ifton, section 11 in the same group, as well as with the re-

* Triassic and Permian Rocks of the Midland Counties, p. 22.

† "On the Eastern Boundary of the North Wales Coal-field," Proceedings of the Geologists' Association, vol. i. p. 14.

‡ The Triassic and Permian rocks of the Midland Counties, p. 22.

§ Quart. Journ. Geol. Soc. vol. xx. p. 144.

semblance of certain rock structures in the associated beds. So in 1873 I was led to describe the Ifton Coal-measures as coal-seams in the Permian*.

Since the publication of that paper I have been constantly engaged in boring, sinking, and other mining operations in the district under consideration, and I have thus had great facilities for the minute study of the peculiarities of its strata. More recently, in an attempt I have been making to correlate the Coal-measures of North Wales with those of other coal-fields, I have been led to compare the Ifton section with all the known sections of Permian and Upper Coal-measure strata which I could procure. The result is that the conviction at which I have inevitably arrived is this:—Call them by what names we will—Magnesian Limestone, Permian, Dyas, Permo-Carboniferous or Upper Coal-measures, the strata described by modern writers as Upper and Lower, and by the older writers as Middle and Lower Permian are identical with the groups 2 and 3 of the Ifton section No. 11.

As this is a question of general interest, I will ask you to accompany me somewhat closely through the process by which I have arrived at this conclusion.

In the diagram of vertical sections (Pl. I. A) I have collected a number of accredited Permian sections from the typical Permian country, from the earlier English home of the strata, from Saxony, Bohemia, North America, and from various counties in Great Britain; I have placed the Ifton section in the midst of them, together with one or two others from North and South Staffordshire which may heretofore have been considered doubtful. In most of the sections the true thickness, as given by the respective authors, is given; but in one or two cases no thickness has been assigned. I have divided the sections into groups of "Upper Coal-measures," Lower, Middle and Upper Permian, and "Bunter Sandstone;" I have taken as my base-line the *Spirorbis*-limestone. In dividing the sections horizontally I have taken as the extent of each group the greatest known thickness of that group; and I have placed the strata of the other sections, as nearly as I could from the descriptions given, in their corresponding place in the respective groups.

It will be observed how very fragmentary in many sections are the representatives of each group. The gaps between these fragmentary portions in each division serve to show either, first, the attenuated condition of the strata at that point, or, secondly, the amount of denudation that has taken place, and, thirdly, the amount of real unconformability there is between the various strata of each section as compared with the typical section of the group.

With these preliminary observations I will now ask you to consider with me each section separately.

Section 1 is that of the typical Permian district as described by the late Sir R. I. Murchison †. Sir Roderick states that the strata

* "On Coal-seams in the Permian at Ifton, Shropshire," Proceedings of the Geologists' Association, vol. iii.

† 'Russia in Europe,' p. 146; also 'Siluria,' 1854, p. 296–97.

of group 2, which are sometimes gypsiferous, become in other places coarse grits interlaminated with sandstones and yellow, white, and greenish marls, which contain plants and small seams of impure coal. Group 3 is variously described. In places it is made up of limestones and marls, in others of red grits and conglomerates, and, again, of red sands with copper ores; occasionally there is much sulphur and asphalte. Group 4 consists of sandstones and conglomerates.

Section 2 is one given by Mr. Binney* of the strata at Canobie. Mr. Binney describes the upper Coal-measures, group 1, as the highest in the kingdom. He considers the Permian to begin with the lowest breccia in group 2. These breccias are made up of Carboniferous gritstones and limestones. They are interstratified with red shales containing rootlets of *Stigmaria ficoides*, and also with a bed of limestone together with brown sandstones. Group 3 consists of red shaly clays with bands of gritstone and thin veins of gypsum. These are surmounted by a brown sandstone (group 4), which Mr. Binney considers to be the equivalent of the sandstone of Shawk and St. Bees on the south, and of Glenzier and Cove on the north.

Section 3 is the one I have already referred to as described by the late Sir R. I. Murchison and Prof. Harkness †. They describe the base of group 2, as consisting chiefly of fragments of Carboniferous Limestone; this is succeeded by red sandstone, followed by breccias which are sometimes rotten, and which are capped by rocks containing quartz-crystals passing into fine-grained breccia containing fragments of slate rocks. They give the thickness of this group as 2000 ft.; but this estimate should, I think, be taken with some reserve. The base of group 3 is interesting as being composed of shales from which the authors collected the following plant-remains:—

Sphenopteris Naumanni.
—— dichotoma.
——, sp.
Alethopteris Gœppertii.
Ullmannia selaginoides.
—— Bronni.
Odontopteris, sp.
Cardiocarpon triangularis.
Portions of coniferous wood.

The impure limestones of this group, the authors take to be the equivalent of that of Barrowmouth, and together with that, the equivalent also of the more largely developed magnesian limestones of the north-eastern counties.

The sandstone of group 4, they describe as being identical in mineral character with sandstones on the same horizon in East Cumberland and Westmoreland.

Section 4 was originally described by the late Prof. Sedgwick ‡,

* "Triassic Strata of Cumberland and Dumfries," Memoirs of the Philosophical Society of Manchester, vol. ii. 3rd series, p. 315 *et seq.*

† "The Permian Rocks of the North-west of England," Quart. Journ. Geol. Soc. vol. xx. p. 144.

‡ Geol. Soc. Trans. new series, vol. iv. p. 398.

and afterwards by Mr. Binney *. It is an interesting section, combining, as it does, the features of the strata on both the western and eastern sides of the North of England. Prof. Sedgwick says the Magnesian Limestone of group 3, is the exact equivalent of the Magnesian Limestone of Nottingham, Yorkshire, and Durham. The same is true, he states, of the red marls and gypsums, while the red sandstone of St. Bees Head, group 4, is unquestionably the exact equivalent of the Upper Red Sandstone of those counties. The lower part of the section, group 2, is more fully described by Sir R. I. Murchison and Prof. Harkness in the paper already referred to.

Section 5 takes us over to the eastern coast of England. It is taken from the pit-section of the Monkwearmouth Colliery. It will be observed that the same order prevails in group 3 as on the western coast, except that here the limestone has thickened considerably. Group 2 is represented by about 45 feet of red and grey sandstones. Group 4 is not represented at all. This district is more fully described in section 17.

Section 6 brings us southward down the eastern side of England, to the country around Leeds. It is given by Messrs Aveline, Green, Ward, Dakyns and Russell †. The upper limestone is described as grey, hard, and full of fossils. It contains little or no magnesia.

The lower limestone is yellow in colour; it decomposes readily near the surface. It sometimes contains a hard flinty rock locally known as "calliard;" and, in places, its lowest beds are pebbly. Its common fossils are *Schizodus* of three species. The interstratified and overlying marls are red and variegated. They alternate with beds of soft sandstone, which, in places, contain deposits of gypsum. The authors describe these beds as slightly unconformable to each other; but they hardly mean to imply, I should think, that they represent the three great divisions of the Permian strata.

A more complete view of the Permian strata of South Yorkshire is the following, given by Mr. J. W. Kirkby ‡.

Group 3 of Sections.

	ft.
Brotherton Limestone and lower red marl and gypsum of Brotherton, Knottingley, Womersley, Wadworth, Tickhill, &c.	120
Small-grained dolomite of the Vale of Went, Lound Hill, Cusworth, Levit, Hagg, Roche Abbey, Warmsworth, &c. ...	200
Lower Limestone of Pontefract, Wentbridge, Conisborough, &c.	120

Group 2 of Sections.

	ft.
Lower red, yellow, and variegated sandstone of Pontefract, Hickleton, Cadeby, &c.	100

This section brings us nearer, geographically, to Section 7, which shows the strata overlying the Nottinghamshire coal-field. Group 2 is taken from the pit-section of the Shire-Oaks Colliery; the red and grey sandstones at its base are taken by local engineers to be

* Mem. Phil. Soc. of Manchester, vol. ii. 3rd series, p. 373.

† The Geology of the Carboniferous Rocks north and east of Leeds, 1870.

‡ "On the Permian Rocks of South Yorkshire," Quart. Journ. Geol. Soc. vol. xvii. p. 287.

the equivalent of the Rotherham Red Rock. From its place below the Magnesian Limestone, as well as from its general resemblance to the rocks of group 2, it should, I think, be placed low down in the Permian strata. As in some of the other sections, this group here contains a thin bed of coal. Group 3 is taken from the sinking at Annesley as described by Mr. Headley *. He states that, though not sunk through at Annesley, the lowest stratum of this group is a bed of conglomerate. A quantity of lignite, in the shape of branches of trees, was found in one of the thin limestones. Group 4 consists of red sandstones, which are divided by thin and not continuous beds of red marl.

Section 8 brings us again to the western side of the Pennine chain. I am indebted for it to the kindness of Mr. J. Ward, F.G.S., of Longton. In group 1 we have, as in the Canobie section, a considerable series of Coal-measures above the *Spirorbis*-limestone, with the difference that, whereas in the Canobie section we have only plant-remains distributed among the shales, here the vegetation has been dense enough to form thin coal-seams. It will be observed that, with these coal-seams, and its other strata, this part of the section corresponds with the same group in the sections of Ardwick, Patricroft, Ifton, and Alberbury; and the whole of these, together with the Canobie section, correspond with the same group in the Nova-Scotia section, no. 20. Groups 2 and 3, are described so minutely that they explain themselves. I may say, however, with reference to the bands of hard grey rock in the red marls of group 3, that probably, had they been examined at the time they were sunk through, they would have been found to be more or less calcareous. They may be taken to represent the limestone bands of the sections on either side.

Section 9 is one well known; it was referred to by Sir R. I. Murchison †, by whom the limestones were correlated with the calcareous breccia in the same group at Alberbury, section 12. It has since been carefully worked by Mr. Binney, as the leader of the Manchester geologists, as well as by others. Groups 2 and 3 are taken from the sections of Mr. Dickenson ‡, F.G.S., H. M. Inspector of Mines, and supplemented by the sections of the Geological Survey. The limestones in group 3 are held by Mr. Binney to be the equivalent of the Magnesian Limestone of the north-eastern counties, with which both they and those of the Patricroft section are connected by a series of sections in the north-western counties. Many of these, which were originally worked out by Mr. Binney, are quoted by Mr. Hull §. For the sake of comparison, and in order to show their connexion with each other, as well as the variations which take place in the same groups over a large area, I subjoin the following examples:—

* "The Sinking of Annersley Colliery," British-Association Report, 1866, Nottingham meeting, p. 238.

† Silurian System, p. 145.

‡ Trans. Manchester Geol. Society, vol. iv. p. 155 *et seq.*

§ The Geology of the Country around Wigan. The Geology of the Country around Bolton.

Sections of Permian or Upper Carboniferous Strata in the North-west of England.

	1. Bispham.	2. Sutton.	3. Edge Green.	4. Aye Bridge.	5. West Leigh.
5. Bunter.		Soft, bright sandstone (base of Trias).	Red sandstone with pebbles, 95 feet.		
4. Red, brown, and grey sandstones, &c.					
3. Red and variegated marls, limestones, &c.	Red and purple shales with thin layers of limestone, 30 feet thick. "The representative of the Magnesian Limestone of the east of England." "May have formed a part of the Magnesian Limestones of Stank, Barrowmouth, and other places in the north." E. Binney.	Purple and mottled marls with thin limestones, 30 feet. "Mr. Binney found Permian fossils in the limestones."	Red sandstones and marls, 70 feet.	ft. Red metal .... 42 Grits and metals ...... 20 Red sandstone, and metal .... 25 Hard siliceous rock ... 10 "The sandstones are soft, reddish, and greenish, and sometimes conglomeratic at the base."	Red marls, 39 feet.
2. Sandstones, green and grey rocks, breccias, &c.	Brown, and red sandstone, 100 feet, with spar veins. "The representative of the Lower Permian Sandstone of the central counties." E. Hull.	Conglomerate, red sandstones, soft, fine-grained and streaked, 90 feet. Fossils found — *Schizodus Bakewellii* and *Turbo*.	Hard burr rock, red and variegated sandstone, 109 feet.	ft. Red sandstone .... 43 Red sandstones and shales 41	Conglomerate-like gravel, 1 foot, supposed by Mr. Binney to be the conglomerate which immediately underlies the red marls. Black sand, 13 feet. Red Sandstone, 31 feet. Calamites, *Sigillariæ*, and fossil wood lay in the débris of this sandstone.
1. Upper Coal-measures.					
	E. Binney and E. Hull, 'Geology of the Country around Wigan,' p. 27.	Hull & Binney, 'Geology of the Country around Prescot,' p. 14; 'Geol. C. ar. Wigan,' p. 28.	E. Hull.	E. Hull, 'Geology of the Country around Bolton,' p. 18.	E. Hull, *ibid.* pp. 19, 20.

Sections (continued).

	6. Peel Hall.	7. Snedley Print-works.	8. Collyhurst.	9. Dawson's Croft, Salford.	10. Albert Bridge, Salford.
5. Bunter.		Soft red sandstones with rounded pebbles of quartz, 139 feet.		Red and streaked sandstone, 180 feet.	Red sandstone, 470 feet.
4. Red, brown, and grey sandstones, &c.					
3. Red and variegated marls, limestones, &c.	Red marls with 52 beds of limestone, 131 feet.	ft. in. Tough red marl ... 8 0 Hard, red, sandy clay. .... 0 6 Red clay, gritty sandstone and soft grey rock 6 0 Red clay and beds of limestone ... 44 0 Red clay .... 4 0 Hard white rock ... 2 0 Red clay with bands of limestone ... 63 0		Red marls with 4 thin beds of limestone, 210 feet.	Red marls with limestones, 120 feet. Red sandstones and clays in alternate beds.
2. Sandstones, green and grey rocks, breccias, &c.	Red sandstones, 150 feet.	ft. in. White rock .... 0 6 Red sandstone with beds of raddle ... 11 6 Bluish-white rather soft stone 0 6	Sandstones &c., 250 feet, have expanded from 11 ft. 6 in. at Snedley, 2½ miles off.	Soft bright red sandstone, not passed through.	Hard sandstone, not passed through.
1. Upper Coal-measures.	Clay and shale containing coal-plants.				
	E. Hull, 'Geology of the Country around Bolton,' pp. 19, 20.	Mr. Binney's section, *per* E. Hull, *ibid.*	E. Hull, *ibid.*	E. Hull, *ibid.*	E. Hull, *ibid.*

Section 10 is one of Mr. Binney's, given by Mr. Hull*. I insert it because of its resemblance on a restricted scale to that of Ardwick on the one side and that of Ifton on the other. It is separated from the last by a distance of about forty miles; and the country between consists of a trough filled up with Triassic beds which hold the great salt-deposits of Cheshire.

Section 11 is that of Ifton, which I have already described, and to which I shall have occasion to refer again.

Section 12 is one which, in its middle portion, group 3, is well known and often quoted. It was, I think, first described by Prof. Sedgwick †, in the year 1832, though alluded to by Messrs Conybeare and Phillips in 1822; and it has subsequently been noticed by Sir R. I. Murchison, Prof. Ramsay, Mr. E. W. Binney, Mr. Hull, and others. Prof. Sedgwick described it, in descending order, as follows:—

Group 4. "Red and variegated sandstone descending into the great plain of Shropshire, and of unknown thickness."

Group 3. "A very fine magnesian conglomerate, in mineral structure like the Bristol and Devonshire conglomerates."

Group 2. "Coarse reddish sandstones, in character intermediate between a coarse coal-grit and a true red or variegated sandstone." Between this last and the upper coal-measures may now be added various green rocks, breccias, and conglomerates."

Group 1. "Coal-measures."

Sir R. I. Murchison places the conglomerate group 3, on the same horizon as the Ardwick limestone bands and the Magnesian Limestone beds of the north-east counties. Mr. Hull, however, is inclined to place it, along with the conglomerates of Shiffnal, South Staffordshire, and Enville, in the lower part of the Permian series. In deciding a point of this kind, the position the strata occupy is of more importance than their mechanical structure and the derivation‡ of the materials of which they are composed. Seeing, then, that

* Geology of the Country around Boltôn le Moors, p. 17.

† Geol. Transactions, ser. 2, vol. iv. p. 398 *et seq.*

‡ A few words concerning the derivation of the limestone fragments and boulders of this conglomerate may not be out of place here. They *are* derived fragments, and not concretions formed with the rock like those of Coedyrallt. Mr. Hull, in the work quoted below[1], assigns some of them, as does also Prof. Ramsay, to the Mountain Limestone, and others to the thin band of *Spirorbis*-limestone which, at some depth, lies between them and the coal. In considering this explanation several difficulties meet us:—1. While in colour the fragments have a general resemblance to the lower cream- and buff-coloured beds of the Mountain Limestone, they are of a paler cast, and often have a greenish tinge. 2. There is an entire absence of the gritty, reddish, and greyish beds of the middle portion, and also of the bluish-grey beds of the upper series of the Mountain Limestone of North Wales. 3. Hitherto I have failed to detect in them any Mountain-Limestone fossils.

Then the *Spirorbis*-limestone, at the most, consists of only thin bands, and it would take the denudation of a large area to supply the materials for this conglomerate. It is also closely associated with coal-strata; and if it supplied the

[1] Triassic and Permian Rocks of the Midland Counties, p. 21.

the conglomerate immediately underlies the great mass of sandstones of group 4, and that it is underlain in its turn by the sandstones and breccias of group 2, I incline to the opinion of the older geologist, and place it, with him and Prof. Sedgwick, in the middle group of Permian strata.

Section 13 is regarded by Mr. Hull* as a typical section. With that of Alberbury, it has, in group 2, sandstones and marls, in group 3 a somewhat similar conglomerate, with a base of trappoid breccia, which perhaps belongs more properly to the top of group 2; these are overlain by the usual mass of red and purple sandstones.

The district lying between this point and the Bristol Channel has been well described by Prof. Ramsay†, who places the Abberley conglomerates on the same horizon as that of Alberbury. There is a remarkable resemblance in the mineral composition of the breccias described by him and those of group 2 in the Ifton section, composed, as both are, of felstone, porphyry, greenstone porphyry, amygdaloid slate rocks, altered sandstones, and quartz.

It was from the occurrence of large scratched boulders in this conglomerate that Prof. Ramsay inferred the prevalence of glacial conditions in the climate of that period.

Section 14 is from the pit-sinking of Coppice-Hall colliery, near Walsall: I had hoped to be able to give the section of the new sinking at Sandwell Park instead; but all the attempts I have made to obtain any information of it or of the promised book descriptive of it have been ineffectual. Both the Walsall and Tunstall sections are situated, though far apart, on the eastern side of the New-Red-Sandstone plain of Shropshire and part of Staffordshire; and they are interesting from the similarity of the strata in group 2 to those of the Ifton section in the same division, pointing (as this similarity does) to a continuity underground through the intervening area.

Section 15 is one described by Mr. Howell ‡ of the strata overlying the Warwickshire coal-field. In group 1, Mr. Howell states that the *Spirorbis*-limestone occupies a position about 50 feet below

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limestones, we should naturally expect to find fragments of the coal also, which we do not. There is also, as far as I am acquainted with them, an absence in the limestone fragments of the characteristic fossils of the *Spirorbis*-limestone. From what source or sources, then, were they derived? I offer the following suggestion towards a solution of the question. By a reference to group 3 of the vertical sections, it will be seen that a large quantity of calcareous matter was deposited during the accumulation of the red marls, in the shape of concretions and interstratified beds. If we imagine any considerable area of these, which were older than the conglomerate itself, exposed to denuding agencies, it is easy to conceive how in a rough shallow sea the denuded limestone boulders would be rolled up along the shore-line and become cemented together by such portions of the denuded red sands and marls as did not float back into still water. May not the conglomerate therefore be made up of denuded Permian limestones redeposited with, and cemented together by, Permian marls?

* Triassic and Permian Rocks of the Midland Counties, p. 13.

† Quart. Journ. Geol. Soc. vol. xi. pp. 191–199.

‡ The Geology of the Warwickshire Coal-field, p. 26.

the Permian strata; this limestone is traceable over a large portion of that coal-field. From Mr. Howell's description, I imagine that the sandstones and breccias of group 2 are not much represented in the district, and that the calcareous conglomerates interstratified between purple sandstones and red marls belong mostly to group 3 of my sections. The sandstones and marls of group 4 were proved in a boring near the town of Warwick; but detailed sections of this group are much needed.

Section 16 represents the magnesian conglomerate of Somersetshire. I have felt considerable hesitation in including this section among Permian strata, because of the degree of uncertainty which seems to prevail as to its true stratigraphical position. Mr. Etheridge, in his able memoir on the subject*, reasoning chiefly from fossil evidence, places it towards the base of the Keuper sandstone. In the sections of the Geological Survey, its true position is left somewhat an open question. Local geologists also appear undecided on the matter. Prof. Sedgwick, in 1832, spoke of its resemblance to the Alberbury conglomerate, and placed it on the same horizon as that deposit †.

In 1854 Sir R. I. Murchison‡ described this conglomerate as having "usually been placed on the same parallel as the Magnesian Limestone of the north of England; and the analogy of the succession in Shropshire, where the Lower Red Sandstone is interpolated between the coal-fields beneath and the magnesian conglomerate, favours the view." Prof. Phillips§ described these lower beds as "red or claret-coloured sandstones and marls, chiefly the former." Probably this diversity of opinion is owing in part to the fact alluded to by Prof. Ramsay as shown by Sir Henry De la Beche, that the conglomerates of the district are of *various* ages; so that the different authors may be speaking of conglomerates of ages widely apart. Personally I only know the conglomerates of the country between Wells and Shepton Mallet; and on reviewing the whole question, I am inclined, from the great similarity in colour and composition, as well as from the apparently greater similarity of the underlying sandstones and marls to those of Permian than to those of Triassic age, to regard the conglomerates generally as belonging to the former period rather than the latter. The inferences drawn in this paper, however, are not affected by this question; and the section need not be taken into account by those who differ from my opinion of the age of these conglomerates.

Section 17 is the original typical English section, as given by Prof. Sedgwick in 1832. And really, when I look at the completeness of that section, exhibiting, as it does, all the groups in almost every known variety of strata, and read the lucid and comprehensive memoir in which they are described, I wonder that English geologists were

* "The Geological Position of the Dolomitic Conglomerate of the Bristol area," Quart. Journn. Geol. Soc. May 1870.

† "On the Magnesian Limestone," Geol. Trans. vol. iii. 2nd series, p. 64 *et seq.*

‡ Siluria, p. 302.

§ Memoirs of the Geological Survey, vol. i. p. 256.

ever content to adopt, years afterwards, a foreign name for a group of strata whose typical completeness lay in their own country. Group 2 is represented as presenting a great variety of mineral structure, which is shown by the comparison of a number of sections. It contains a bed of carbonaceous shale, which, in places, becomes an impure coal. This group, the Professor considers the equivalent of the Roth-todtliegende of Germany. Group 3 is described as being represented on the west coast of England by the thin limestones and shales of the same division, and with them as being the equivalent of the Zechstein of the continent of Europe. Group 4 is described as the equivalent of the St. Bees sandstone on the west (Sections 3 and 4). Prof. Sedgwick places it in its true position below the New Red Sandstone, though possibly he regards it as having more in common with the strata above than with those below. He may not have been far wrong in this supposition, inasmuch as the more complete the sections are that we obtain of groups 4 and 5 the less does the supposed break and unconformity become.

Section 18 is a pit-section at Zwickau, Saxony. It is given in an interesting account of the coal-fields of that country which recently appeared in the 'Colliery Guardian'*. Group 2 has, it will be seen, all the characteristics of the same group in the other sections. It may be regarded as typical; for we are told that in many other parts of Germany the coal-formation is immediately overlain by a predominating coarse grey conglomerate. Group 3 has the usual limestones; and group 4 consists, as in the other sections, of sandstones.

Section 19 is a very complete one: it was described by Sir R. I. Murchison† as occurring near Semil, in Bohemia. It presents the usual features of groups 2, 3, and 4, with a preponderance, as in the Ifton section, of carbonaceous matter and clays over limestones in group 3.

Section 20 was recently described by Dr. Dawson‡, of Montreal; and it is perhaps one of the most complete sections hitherto given of the strata under notice.

The section starts, in group 1, with the *Spirorbis*-limestone, which Dr. Dawson considers the equivalent of that of the English coal-fields. The strata by which this is overlain contain the usual coal-plants with Entomostracan and fish-remains. The uppermost shales abound in *Cythere* and fish-scales. Group 2 consists of thick grey and reddish sandstones with shales of the same colour, together with thin coals, clays, and nodular limestones: they contain Calamites trunks of *Dadoxylon materiarum*, *Lepidodendron*, *Pecopteris* and *Neuropteris*. Group 3 is made up of red and grey shales, grey, red and brown sandstones, and a thin coal-seam five inches thick, with

* "The Coal-fields of Saxony" as translated by Messrs Hill and Fairley, 'Colliery Guardian,' April 23, 1875.

† "On the Permian Rocks of North-eastern Bohemia," Quart. Journ. Geol. Soc. vol. xix. p. 301.

‡ "On the Upper Coal-measures of Eastern Nova Scotia," Quart. Journ. Geol. Soc. vol. xxx. p. 212.

Stigmarian rootlets in the underclay. Along the strike of the strata there is, at Carribou Island, a thicker coal-seam. Some of the shales contain concretions of limestone which sometimes form a nearly continuous bed; and analyses show that some of the limestones are highly magnesian. These are overlain by a great mass of red and grey sandstones, chiefly red (group 4), which, in their turn, are covered without apparent unconformability by Triassic strata. Dr. Dawson thinks that the strata of the section bear such strong points of resemblance to parts of the European Permian, both in their mineral character and organic remains, that they may be fairly termed Permo-Carboniferous.

The Permian strata are sometimes divided into upper, middle, and lower groups, and somtimes into upper and lower only. In my grouping I have, as will be seen, adopted the tripartite division of the strata. This threefold division is, I think, more true to nature. For while each of the groups 2, 3, and 4 does, in some of the sections, bear resemblances to certain portions of the other groups in other sections, yet, taking the sections altogether and looking at them comprehensively, each group has one or more characteristic features by which it may be distinguished from the others.

Thus the lowest division, group 2, is characterized by the prevalence of conglomerates and breccias, by the preponderance of grey over red sandstones, by the large proportion of the fragments of Cambrian and Silurian rocks in its breccias, by the greenish colour of many of those breccias, as well as by the plant-remains which have been found in most of the sections, and which (in sections 7, 8, 17, 19, 20, as well as in Russian sections corresponding to section 1) have been numerous enough to form thin coals. By these features this group may be distinguished from the sandstones and marls of group 4.

Group 3 is well marked by the presence of calcareous matter, which, usually mixed with magnesia, is more or less interstratified with white, red, and variegated marls, the calcareous matter being most abundant in the north-eastern counties of England. In none of the sections of any thickness are red sandstones and trappean-like breccias present in any force. This group is also characterized, in sections of any thickness, by the presence of shales with plant-remains.

Group 4 is distinguished by the prevailing dull red colour of its sandstones and marls, together with the massiveness of the former and the thinness of the latter, by the infrequency of its breccias and their dissimilarity to the prevailing character of those of group 2, and also by the great dearth of carbonaceous matter and the rarity of plant-remains, although, occasionally, solitary specimens of the latter are found which show a relationship, more or less remote, existing between this and the groups below.

If now we fix our attention on the Ifton section, 11, and compare it with recognized Permian sections on either side of it, we shall see how strikingly in each group it resembles them and possesses their characteristic features.

We see how in group 1 it has a series of upper coal-measures interstratified with red shales to the thickness of 220 feet, resting upon the *Spirorbis*-limestone, and how in this respect it compares with the sections of Canobie, Ardwick, Patricroft, Alberbury, Warwickshire, Staffordshire, and Nova Scotia.

The section commences therefore at more than the average height above the *Spirorbis*-limestone at which Permian strata are usually made to begin in English sections.

In group 2, or the lowest usual division of Permian strata, we see how it contains in its breccias, its green, grey, red, and brown sandstones, as well as in its drifted plant-remains, all the varied phases of the group over the wide range embraced by the sections.

In group 3 (middle Permian) this resemblance is also very great. There are the ever present red, white, yellow, and variegated marls; then in the calcareous bands interstratified with those marls, in the rolled and nodular limestones under the Morlas main-coal, in the 25 per cent of carbonate of lime contained in the pyrites of that coal-seam, in the limestone masses of the Coedyrallt rock, as well as in the bedded calcareous concretions of that rock, we have, I think, unmistakably the equivalent of the more massive limestones of the north-east, the "brockrams" of the north-west, the thin limestones of Lancashire, and the calcareous conglomerate of the West Midlands, as well as of the representatives of these in Russia, Saxony, Bohemia, and Nova Scotia.

I now approach that development of coal-measures in the upper part of group 3 of the Ifton section (No. 11) which, to some minds, will form a strong objection to the acceptance of these beds as equivalents of Permian strata. But why? We see how these beds are paralleled by the dark fossiliferous shales of Eden, by the dark shales of Bohemia, and by shales and coal in Nova Scotia. A comparison of the list of fossil plants found at Ifton with that given by Murchison and Harkness, and by Mr. Dawson, in the papers already referred to, and of all these with lists from the continent of Europe, will show a family likeness running through the whole, and will further show how in all those widely distant localities the same new forms appeared in the midst of the survivors of the older Carboniferous flora.

The uppermost sandstones, group 4, by their colour, massiveness, homogeneity, and mineral composition, correspond to the uppermost sandstones of the same group wherever these are developed; while they do not correspond to, or contain within them the representatives of the groups below them. Besides, as I have pointed out, they may be traced at intervals until they are seen lying above the calcareous conglomerate at Alberbury. Their place, therefore, at the summit, and not at the base, of the Permian strata is clearly proved.

The conclusion is therefore to me inevitable, that, in their stratigraphical position, their mechanical arrangement, their fossil remains, and in their mineral composition, the strata of groups 2 and 3 of the Ifton section (No. 11) are the equivalents of the middle and lower divisions of the strata usually described as Permian in this and other countries.

If this be so, it will be seen that while the strata we have been considering, in their conglomerates, breccias, sandstones, limestones, and marls, indicate the widespread prevalence of marine conditions throughout an immense period of time, yet, in the strata charged with plant-remains and in the better-defined coal-seams, we have evidences that during the whole of that period there were, as, indeed, we ought to expect there would be, land surfaces on which the survivors of the coal-measures proper lingered amid the growth of new forms of life. The carbonaceous and fossiliferous shales are the memorials of estuaries and lagoons into which were drifted the fragments of the fauna and flora of the land; the coal-seams are the relics of land-surfaces themselves, especially of those favoured spots where a dense and luxuriant vegetation could flourish.

It would be easy by numerous quotations to show the difficulty which all geologists who have made these strata their study find in drawing the exact line where the Coal-measures end and the Permian strata begin. By some that line is marked by the absence of *Stigmaria ficoides*; but gradually that fossil is found higher up in the series. Then it is the distance above the *Spirorbis*-limestone*. Often, as in Germany, it is marked by the first conglomerate, and in Scotland, Lancashire, Staffordshire, and Shropshire by the green rock and breccias. The truth is, as it appears to me, that there is no well-marked boundary-line; the change is gradual, and it is locally different. That change is marked generally by a decadence of the density and luxuriance of the coal-measure flora, by the greater paucity of land-surface, and by the wide spread and long continuance of marine conditions.

Taking the whole of the sections together, it will be seen that, looked at comprehensively, there is no real general break in the sequence of the strata or in the continuity of life, but that there are only local and great unconformabilities of strata, marked by equally great local gaps in the succession of life.

It is also interesting to note how very similar in many respects were the birth and growth of the great Carboniferous flora to its decadence and final exit. In the midst of the marine conditions of the deposition of the Carboniferous Limestone in Scotland, in the midst of similar conditions during the formation of the Yoredale Rocks and Millstone Grit of Yorkshire, there were here and there land-surfaces on which grew the harbingers of that flora which was destined to attain to such magnitude and extent in the Coal-measures proper. So also, in the midst of the marine conditions under which were formed the marls, limestones, and breccias of the strata we call Permian, there were, as we have seen, land-surfaces on which that flora still lingered, changed somewhat in character by the appearance of new forms in its midst. A stray plant found here and there tells us how the survivors lingered on during the deposition of the upper sandstones, group 4. Mr. Binney † tells us that a *Sternbergia* has been

* Would not this limestone form a good base-line for all these Upper Carboniferous strata?

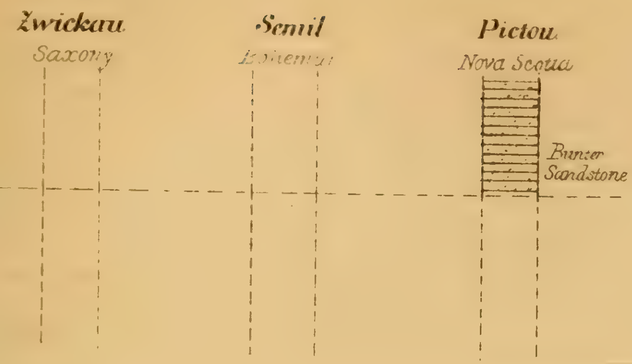
† Triassic Strata of Cumberland and Dumfries, p. 355.

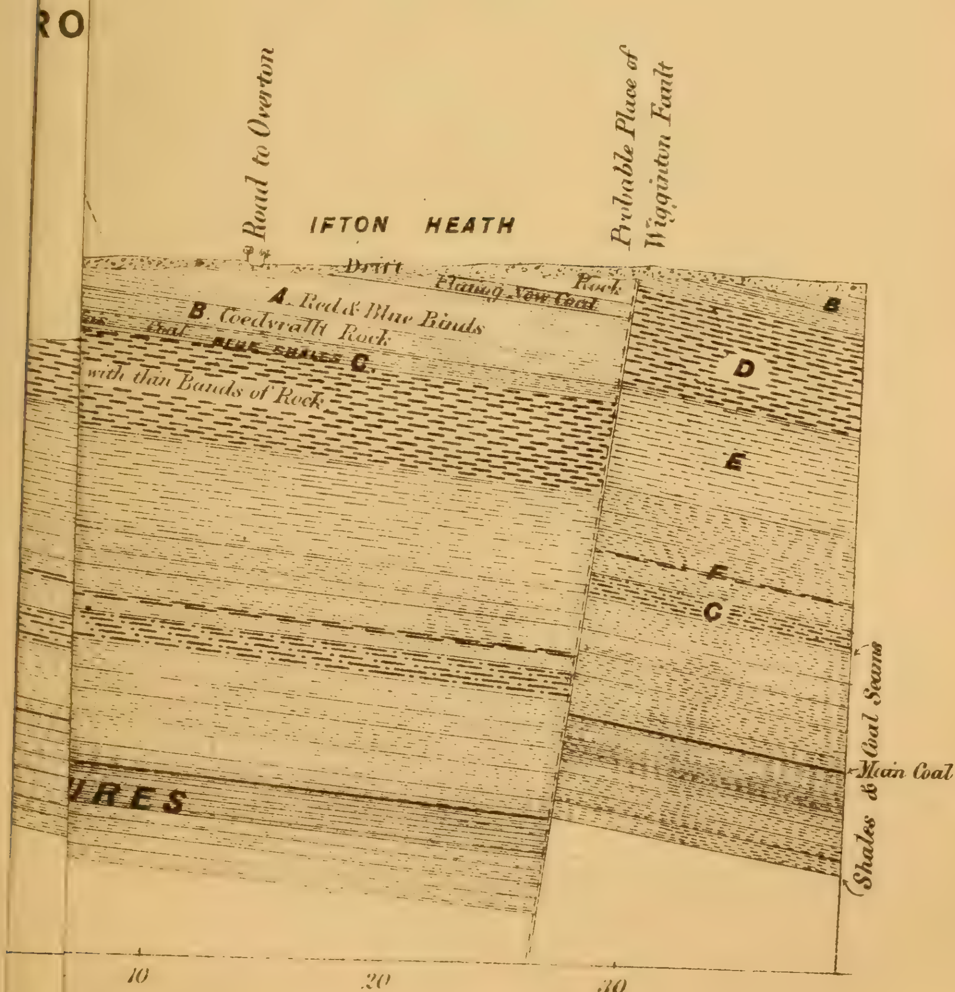
found in Triassic strata near Runcorn, and several Calamites in the water-stones of Lymm, near Warrington. Gradually, therefore, I doubt not, the land-surfaces of the period of the dark red sandstone, as well as of the overlying Triassic beds, will be discovered, and the connexion be traced between the plants of the great Carboniferous era and those of succeeding ages.

EXPLANATION OF PLATE I.

A. Diagram sections showing the correlation of Upper Carboniferous or Permian strata. Scale 1 in. to 200 yards.

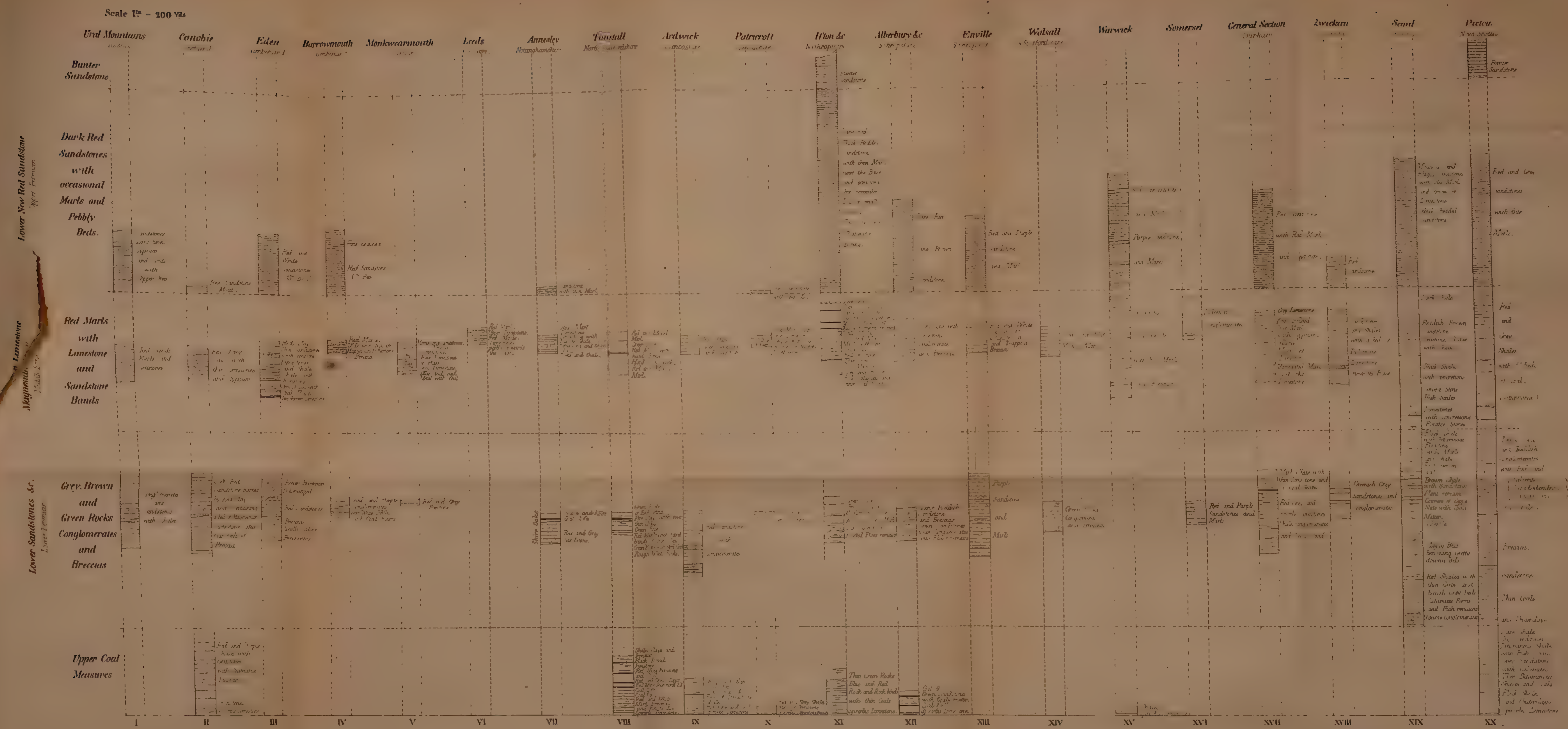
B. Section of strata from Chirk, Denbighshire, to Ifton Heath, Shropshire. Scale 1 in. to 250 yards.



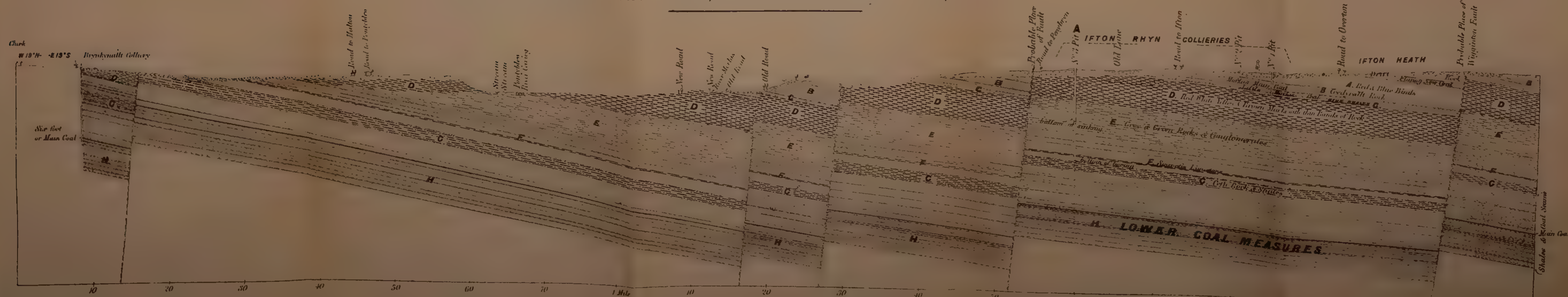


Dangerfield. Lith. 22. Bedford St Covent Garden

A. CORRELATION OF UPPER CARBONIFEROUS OR PERMIAN STRATA.



B. SECTION OF STRATA FROM CHIRK, DENBIGHSHIRE TO IFTON HEATH, SHROPSHIRE.



Vertical Scale 1 inch to 250 yards.

3. *On the* Chesil Beach, Dorsetshire, *and* Cahore Shingle Beach, *County* Wexford. By G. Henry Kinahan, Esq., M.R.I.A., &c. &c. Communicated by Prof. Ramsay, F.R.S., V.P.G.S. (Read June 21, 1876.)

[Plate II.]

Preliminary Remarks.

Sea-beaches are common around our coast lines; but none seem to have attracted so much attention as the Chesil Beach on the north-east margin of Lyme Bay, Dorsetshire. This is probably due to the circumstance of the beach being situated on a much resorted-to coast, its great length, and the peculiar assortment of the fragments composing the accumulation, these being arranged as if they had been passed through a series of sieves of gradually decreasing coarseness. This last particular has even attracted the attention of the fishermen, who say they can tell, on the darkest night, at what part of this beach they have landed, by the size of the pebbles at the place.

The latest published paper on the Chesil Beach is that of Prof. Prestwich, read before the Institution of Civil Engineers, February 2nd, 1875; and from the discussion at the reading of it it is evident that opinions still differ much on the subject. This has emboldened the writer of this paper to come forward, more especially as no previous writer seems to have taken into consideration the special effects that the "flow" of the tide, which is most accelerated at the nodal or hinge-line in the English Channel, must have on the east shore of Lyme Bay—also because he has specially studied Cahore shingle beach, co. Wexford, which in many points is analogous to the Chesil Beach.

Tides in the English Channel and Irish Sea.

At Portland Bill on the English Channel, and at Cahore Point on the Irish Sea, the tidal currents are considerable, and must work more or less actively; but to understand them, it is necessary to give an epitome of what is known about the tides in these seas. The tidal waves and currents in the seas surrounding Great Britain and Ireland were but imperfectly known until after the investigations carried on by the late Admiral Beechey and Lieut. F. W. L. Thomas, R.N. The result of their researches in regard to the English Channel and Irish Sea is given in the manual of Tides and Tidal Currents by the Rev. S. Haughton, F.T.C. Dublin; and to it we are indebted for much of the following*.

The tides *rise* and *fall* twice in a little more than twenty-four hours†; but the risings and fallings are not always of equal extent,

* Galbraith and Haughton's Scientific Series.

† This and other statements below in reference to the tides will be found fully explained and proved in Haughton's book.

whether on the coast or in the open sea, they being greatest at the Full and Change of the moon. On examining the cotidal map of the seas round Great Britain and Ireland, it will be seen that the tidal wave coming in from the south-west is divided when it reaches Ireland, one part (A) going round the northern, and the other part (B) going round the southern end of Ireland. The northern branch (A) is again divided, a part (A′) going northward, then round the northern extremity of Scotland, and afterwards southward along the eastern coast of Scotland and England, while the other portion (A″) goes southward into the Irish Sea. The southern portion (B) of the wave coming in from the south-west, when it has passed the S.W. of Ireland, splits—a portion (B′) running northward up the Irish Sea, while the other part (B″) goes east into the English Channel. The first of these (B′) meets the offshoot (A″) from the northern part of the wave in the Irish Sea in a line joining St. John's Point, co. Down, Ireland, with the Calf of Man, and Maughold Head with the centre of Morecambe Bay, England, the range of tide on the Irish coast being 15 feet and in Morecambe Bay 31 feet, which are the greatest ranges in the Irish Sea, on the Irish and English coasts respectively. The second branch (B″) meets the offshoot (A′) from the northern wave of the preceding tide after it has gone north-about round Scotland; thus when they meet, A′ is twelve hours older than B″,—the place of meeting being a line which extends from the North Foreland to the east of Calais, the water rising 24 feet at Beachy Head, England, and 34 feet at Cayeux, on the French coast. These meetings of the north and south tidal waves are known as the *end* or *head of the tides.*

It will of course be carefully borne in mind that the motion of a tidal *wave* is quite distinct from that of the *water* composing the wave. Nowhere in the Irish Sea does the current caused by the tide move faster than five knots per hour; yet the high water nowhere appears to move more slowly than twenty knots per hour; and in the open waters of the Indian Ocean and South Atlantic this is still more striking, as in those seas the high water seems to travel as fast as the moon, or nearly 1000 knots an hour.

The "flow" and "ebb" are regulated by the "rise" and "fall" of the tide—the "flow" commencing after the *slack* of low water, and ending with the *slack* of high water, and the "ebb" commencing after the *slack* of high water, and ending with the *slack* of low water. At the "head of the tide" there is the greatest rise*, while the lowest rise of the tide is at the "nodal" or "hinge-

* We now refer to the tides in sea-channels open at each end. In some of the confined bays and estuaries, the rise is higher, due to counter and converging tides. Thus, in the Bristol Channel there are three "flow" tides entering it at the same time—one going N.E. from Land's-End, another eastward from St. David's Head, and a central one due to the "offing tide." These, meeting near the head of the bay, raise the water on an average 47 feet at spring tides, but, when aided by a south-westerly wind, raise it at Chepstow between 50 and 60 feet.

lines." The "nodal" or "hinge-lines" of the tide possess the following properties:—

First. The least rise and fall of the tide takes place along these lines.

Second. The quantity of water which passes during the flow and ebb of the tidal stream through a section drawn along these nodal lines is greater than the quantity of water passing through any other section of the seas; and consequently, *cæteris paribus*, the tidal stream is greater along these lines than in any other section of the channel.

As the tidal currents flow and ebb to and from the "head of the tide," there must be two nodal lines, one on each side of the "head of the tide;" and such we find in the North Sea and English Channel and in the Irish Sea. In the North Sea it is situated near Yarmouth, on the Norfolk coast, and in the English Channel at Swanage Bay, Dorsetshire; while of those in the Irish Sea, the northern one occurs between Ballycastle aud the Mull of Cantyre, and the southern one between Courtown and Aberystwith. With the nodal lines and their accompanying currents at Swanage Bay and Courtown we are most interested, as they respectively affect the Chesil and Cahore beaches.

In the Irish Sea the "head of the tide" is a line across the greatest breadth of the sea, while the "head of the tide" between the North Sea and the English Channel is a line across the Straits of Dover, the narrowest section of the sea. This dissimilarity gives rise to some remarkable differences as to the meeting of the tides in the two cases. In the Irish Sea, west of the Isle of Man there is a tract apparently tideless, and the line of the "head of the tide" is constant (Full and Change); but in the Straits of Dover the line of meeting and of separation oscillates during each tide between Beachy Head and the North Foreland (60 miles) in the following manner:—"When the water on the shore at Dover begins to *fall*, a separation of the Channel stream takes place at Beachy Head; as the fall continues, this line of separation creeps to the eastward; at two hours after Dover high water it has reached Hastings; at three hours, Rye; and thus it travels on until at low water, by the shore, it has arrived nearly at the line joining the North Foreland with Dunkirk. At this time the Channel stream on both sides is slack, but for the 60 miles from the Foreland to Beachy Head is still running to the westward. When the water begins again to make on shore, the Channel streams commence to run towards the strait from both sides, and the line of separation again occurs at Beachy Head, and begins to travel again slowly to the eastward"*.

The nodal lines are also lines of "tide and half-tide;" for when it is low water at the "head of the tide" in the Irish Sea, the stream commences to flow both in the north and south channels—that is, three hours before high water at the nodal lines; so that the "offing tide" begins to flow at half-flood on shore; and in

* Beechey, Phil. Trans. 1851.

like manner the offing tide on the nodal lines begins to ebb at half-ebb on shore—which is the relation between the offing tide and the onshore tide, known to sailors as "tide and half-tide"*.

Driftage of Sea-beaches.

Now as to the driftage of sea-beaches. In Prof. Prestwich's paper on the Chesil Beach, and the discussion that followed thereon, certain points were raised. Of these the *first* and principal one seemed to be that wind-waves have greater driftage power than the tidal current. On this point it would appear, from the report, that Prof. Prestwich and nine of his critics believe in the greater driftage-power of wind-waves, one of the latter in wind-waves and tidal currents combined, while only two believed in the superior power of the tidal current over wind-waves †. As to the *second*, the author of the paper goes so far as to state that the currents of the flow and ebb tides neutralize each other's effects. The *third* point brought forward was that a current carried the smallest fragments furthest.

First point.—From what has been stated it is evident that the following is at variance with the opinions of many eminent men. In another place ‡ I have attempted to show that on the Irish coast the current due to the flow of the tide has greater drifting powers than wind-waves, the driftage due to the latter, if contrary to that of the incoming tide, being eventually carried back again, and that the maximum driftage results from a combination of the tidal current and of waves caused by a wind blowing in a similar or nearly similar direction to the flow of the tide.

Wind-waves make a great appearance ; but if we look for the results, they seem to be very like the noisy fussy worker, who is "all show but little work ;" while the tidal current may be compared to the quiet steady man who has most to show at the end of his day's work. Wind-waves can throw up beaches ; but it would seem that, unaided, they cannot cause them to travel. In the delta of the Rhone (Ansted "On the Lagoons and Marshes of the Shores of the Mediterranean," Proc. Inst. C. E. vol. xxviii., read February 16, 1869) the wind-waves throw up beach after beach. So also on the north coast of Wales, where we find series of "storm-beaches" consisting of beach after beach, each outside the preceding

* In the English Channel and the Irish Sea, the *surface tidal currents* are known from the investigations carried on by the officers of the Royal Navy ; there are, however, *under tidal currents* that have never been investigated. They are known to exist ; but their laws and relations one to another are perfectly unknown. On the subject of an inquiry like the present,they must exercise a vast influence ; but unfortunately we cannot refer to them.

† Of the ten advocates for the wind-waves, all seem to have studied principally on the south coast of England, where, as the prevalent wind-waves and the "flow" of the tide are in the same direction, one force may easily be mistaken for the other ; while of three who believe in the tidal current, two have studied the wave on the south, and the other on the west coast of England. One of the other commentators, who has studied on the east coast of England, does not give any definite opinion.

‡ "Tidal Currents *versus* Wind-waves," Proc. Roy. Irish Academy, ser. 2, vol. ii. p. 443, and Geol. Mag. dec. ii. vol. iii. p. 83.

one. Such beaches, however, do not travel, but gradually add to the surface of the land.

The following facts may also be appealed to in favour of the greater power of tidal currents:—a ship at anchor always rides with the tide, except in excessive wind; and then it is the wind, not the wind-wave, that veers round the ship. Fishermen's nets that break loose during a storm always float with the tidal current; so also do wrecks, timber, and the like: these being below or only a little above the surface of the water, cannot be driven by the wind; but if the wind-waves are more effective than the tidal currents, they ought to go with the former, not with the latter*. We also find that off-shore banks and shoals always lie with the course of the flow-tide currents, irrespective of the direction of the most prevailing or most effective winds†.

It will be found that if the effective winds come in a contrary direction to the flow tide, all permanent sand and gravel banks, diverting the "invers" or mouths of rivers and streams, are due to the currents of the flow tide. Continued winds in a contrary direction may often temporarily pile up a bank; but as soon as they cease, the bank is rapidly carried away and disappears‡. Many interesting facts may be learned from the study of wrecks on sea-beaches. If a ship is cast broadside on, and the wind and tidal currents are in the same direction, the beach inside the wreck is scooped out. If, however, the current and wind-waves are contrary, a bank is cast up behind the wreck, the greater accumulation of the sand being to

* Instructive experiments may be made with bottles so filled that they will float at, but not above, the surface of the water, also with corks. These will go with the flow of tide (though not with its ebb) across a whole gale of wind.

† In some places on the east coast of Ireland both the flow and ebb tide, as marked on the Admiralty charts, run obliquely across the off-shore banks. In such places, however, they are only surface currents, as there are undercurrents along the banks. It may be stated that the latter currents are caused by the banks; but if so, what originally formed the banks? As the banks are parallel to the flow-tide current in the channel of the Irish Sea, does it not appear probable that these undercurrents may be the edge of the mid-channel current?

The most prevailing and most effective winds are not necessarily the same. In the south of Ireland the most prevailing wind is from the S.W.; this wind sweeps across the lowlying S.E. portion, and on the S.E. coast is an off-shore wind that has little effect, the most effective winds coming from the S.E. and N.E.

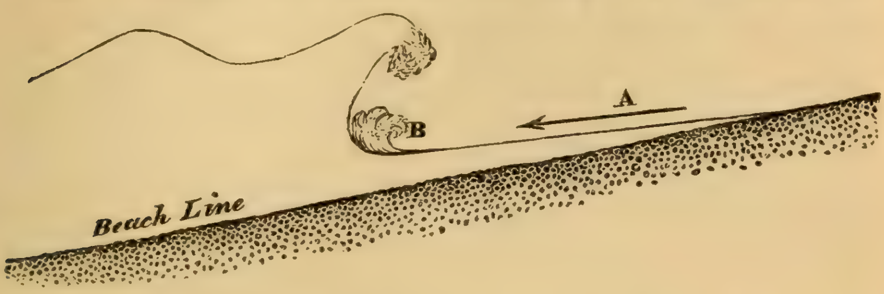
‡ In the East Bay (Portland) there are two drifts, one northward from Portland towards Weymouth, and the other westward from Lulworth towards Weymouth. It has been suggested that these driftages are due to the bay being open to the full force of the wind from the S.E. If, however, we examine the tidal currents, we find that an offset incoming stream runs from Portland northward while the offing tide forms an on-shore tide in the eastern portion of the bay, which flows from east to west. The set of the offing tide on shore here must be very considerable on account of the long loop each hour's tide makes up the channel (see any cotidal map), the VII.-o'clock wave (Full and Change of moon) touching the shores at Portland Bill and Cape la Hogue at the same time that the end of the loop is further up than Portsmouth; while the loop of the VIII.-o'clock wave is still further out of proportion.

windward or leeward respectively, if the tidal current or wind-waves have the greater power. In the latter case, if the cargo "breaks loose" it will be carried, if not very heavy, by the wind-waves; heavy cargoes, such as coal, if the gale be continued, will be more or less carried to leeward, but eventually will go with the tidal current; a cargo of green timber or "pit wood," as it floats just at the surface, is usually stranded to windward, having been carried by the tide against the wind-waves. While examining into the relative driftage powers of wind-waves and tidal currents, there is one kind of the latter nearly always ignored; that is, the current due to the on-shore set of the offing tide. A wreck may be off the coast and the wreckage drifting, say northwards, across a gale from the east or north-east; it will be carried in that direction for half tide (three hours); but after the offing tide sets in, it will be carried to the shore. This on-shore driftage is usually supposed to be due to the wind; and fishermen explain it thus:—"The wind has no force till half the tide is gone."

Second Point.—"Flow and ebb of the tide are equal and opposite, and therefore counteract one another's effects." Let us examine into certain effects of the ebb and flow of the tide which can be distinguished. On a calm day, when there is not a ripple on the water nor a perceptible ground-swell, if the tide is ebbing it imperceptibly drops away from the shore, leaving every thing undisturbed. If, however, it is flowing, the strand under similar circumstances gets saturated with water before the waves go over it, which causes each particle to be more or less buoyant; so that even in low neap tides, where the current is least, fragments of considerable size will be moved, although only an inch or two. During spring tide, the incoming tidal current is greatest; therefore it might be supposed that the outgoing current also would be greatest at this state of the tide; yet under such circumstances we find the water drop away from the shore without disturbing those portions of the beach that are never uncovered except during "spring tides." This of course only refers to ordinary coast-lines; as in "narrows," and round certain points there are ebb-tide currents which effect considerable local driftage. Furthermore, in estuaries and bays the mud and sand banks always indicate, from their shapes and positions, that they are more due to the flow than the ebb of the tide. This is to be seen even in estuaries into which large rivers flow, and in which the ebb tide is there augmented. It may also be pointed out that the margin of the flow tide, no matter how calm the water may be, is always more or less "dirty" (with fragments of seaweed and such like); but this dirt is left behind when the tide ebbs. The flow tide when it comes to a stranded object pushes it before it; but a slight resistance will prevent a similar object from being dragged out by the ebb.

When the flow tide is helped by the wind its effects are considerably increased; but wind-waves do not proportionally augment the ebb tide. This can be seen during a moderate gale of wind, when waves are breaking on a beach. If the tide is flowing, the back wash (A, fig. 1) of each wave will carry a quantity of sand and the like with it, which at the junction (B) with the incoming wave

Fig. 1.—*Diagram of a Wind-wave breaking on a shelving beach.*



will be met, tossed about, and carried back again; but if the tide is ebbing, scarcely any particles will be carried by the back wash, and the junction (B) with the incoming wave will scarcely have even a particle of sand in it. In the first case, a bucketful taken at the junction would be sand and water, while in the second it would be nearly pure water.

Third Point.—"Currents carry the smallest fragments furthest." Tidal currents are different from other currents. They break on the shore in successive waves, whether these be augmented by wind-waves or not, drive the fragments obliquely up the beach, the larger ones to remain or only to be brought back a little way, while the smaller ones are caught in the "back wash," and carried back again till they meet the succeeding incoming wave. Thus the larger fragments have a tendency to be driven higher, and further up, and along a beach than the smaller ones. Also, if the progress of a beach is stopped by a groyne, whether natural or artificial, the larger pebbles accumulate behind it, and form a shingle beach.

Chesil and Cahore beaches are remarkable on account of their being very similarly circumstanced in several particulars; this will be evident from the following table of comparison. All the statements in regard to the Cahore beach are given from personal examination; but for those relating to the Chesil beach we have to rely on the notes and publications of other observers. Some of the points of comparison are partly speculative, but agreeable with the known results of certain natural laws.

A Comparison of the Conditions at the Chesil Beach, Dorsetshire, and at the Cahore Shingle Beach, co. Wexford.

Chesil Beach.	Cahore Shingle Beach.
1. The beach is situated on the north side of the English Channel, where there is a smaller "rise" of the tide than on the south side (coast of France).	1. The beach is situated on the west side of the Irish Sea, where there is a smaller "rise" of the tide than on the east side (coast of England).

2. It lies on the N.E. shore of Lyme Bay (the large bay between Start Point and Portland Bill).

3. This beach is a barrier dividing the lagoon called The Fleet from the open sea (Lyme Bay). The Fleet has its embouchure into the sea on the east of Portland Island. This high tract must have been an island when the sea was a little higher than at present.

4. The pebbles in the beach graduate regularly from sand at the western end to shingle at the eastern end.

5. Towards the eastern termination the beach increases considerably both in bulk and height.

6. The beach ends at Chesilton, some distance north of Portland Bill.

7. Many of the pebbles in the beach are similar to those found on the west shore and in the country west of Lyme Bay, but especially in the "raised beach" that occurs in places at Start Bay and elsewhere.

8. Possibly most of the pebbles found in Chesil beach have travelled from the westward across the deep water in Lyme Bay. According to the records of different observers some pebbles travel eastward, along the north shore to Pinney Bay, immediately west of Lyme Regis; but, according to the Admiralty Chart, there could not be a continual tidal driftage round the shore of Lyme Bay from the Start to Chesilton, as

2. It lies on the N.W. shore of Wexford Bay (the shallow bay between Greenore and Cahore Points).

3. This beach fringes a long irregular accumulation of Æolian drift (blown sand), this latter dividing a reclamation, or intake, formerly a lagoon, from the sea in Wexford Bay. The ancient lagoon had its embouchure into the sea on the south of Cahore highland, which hill was an island when the sea was a little higher than at present.

4. The beach in its southern part is a mixture of sand, gravel, and shingle; while near its north end it is a clear shingle.

5. Towards the north the beach slightly increases in bulk, also nearly due west of the north end of Rusk Bank.

6. The beach terminates 400 yards S.S.E. of Cahore Point.

7. Many of the pebbles in the beach are fragments of the rocks *only* found in the country south of Wexford Bay, but especially between Greenore and Carnsore Points.

8. Many of the pebbles found in the Cahore shingle beach must have travelled across the bay from Greenore*, as there is not a continuous travelling of the beach round the shore of the bay. From Greenore some fragments of the Greenore rocks travel, first westward and then northward, round the shore of the south or Ballygeary Bay; these, however, with others that have come across the deep water, collect as shingle on

* I am informed by T. Winder, Esq., M.Inst.C.E., that during last summer, while making a submarine survey for the extension of Ballygeary Pier, he found a stream of pebbles travelling northward across the bay from Greenore.

there are "countertides" in different places, the principal one being off Beer Head, where the tide revolves, the "flow" tide at the same time running both to the N.E. and to the W., while there is a "drain" to the S.S.W. From the soundings on the Admiralty Charts very little can be learned concerning the travelling of fragments in deep water: one fragment on every square foot of the bottom of the bay would pass unnoticed, while one fragment on every square yard would be more than sufficient to supply the materials to keep up the Chesil beach.

9. Portland Bill, the headland that bounds Lyme Bay on the east, is the headland, down stream (in regard to the "flow" tide), nearest to Swanage, the English end of the *nodal* or *hinge-line* of the tide in the English Channel.

10. At Portland Bill it is high water (at full and change of moon) at 7 o'clock.

11. At Swanage is the least "rise" of tide and the greatest current in the English Channel. The range is 5 feet.

12. The current in the English Channel from its Atlantic entrance (a line from the Scilly Islands to Ushant Isle)* increases

the beach to the S.W. and on the back (south) of the Dogger bank (the shoal off the mouth of the lagoon called Wexford Harbour). From the Dogger bank this shingle drifts N.E. into deep water, from which some pebbles are cast up on the Blackwater bank, along which they seem to travel, some to be driven in shore on the Cahore beach, while many of them go northward past Cahore Point, where they are found on the different beaches.

North of the Dogger bank, between it and the Cahore beach, the rock-fragments that fall from the drift-cliffs (which in places are composed of very stony material) are sucked seawards by the back wash, and few or none travel along the beach: neither are there any pieces of the Greenore rocks to be found hereabouts.

9. Cahore Point, which bounds Wexford Bay on the north, is the headland, down stream (in regard to the "flow" tide), nearest to Courtown—the Irish end of the *nodal* or *hinge-line* of the tide in the Irish Sea.

10. At Cahore Point it is high water (at full and change of moon) at 7 o'clock.

11. At Courtown is the least "rise" of tide and the greatest current in the south portion of the Irish Sea. The range is 2 feet.

12. The current in the Irish Sea from its Atlantic entrance (a line from Cape Clear to the Scilly Islands)* increases till it

* In both cases the currents do not increase in regular progression from the entrance, on account of the tide in places running more swiftly round headlands, also on account of the complications of tides due to the respective offset bays—that of the Gulf of St. Malo off the English Channel, and that of the Bristol Channel off the Irish Sea.

till it reaches the nodal line off Swanage, a distance of 150 miles.

13. The current in the Channel between Portland Bill and Cape la Hogue is about 3·5 knots an hour*.

14. In Lyme Bay there is a small bank (Skerries bank) at the S.E. of Start Bay.

15. As there are no off-shore banks across the mouth of Lyme Bay, also as the narrow between Portland Bill and Cape la Hogue tends to augment the force of the current, already progressively increasing, after it has passed Start Point and is approaching the Swanage nodal line, the landward movement of the water into Lyme Bay from the main up-channel current ought to increase progressively in power from Start Point to Portland Bill.

16. As the tidal wave going eastward up the English Channel proceeds much faster at the centre than on its margins (see any cotidal map), there is necessarily an "offing tide" setting into the different bays. This ought to tend to generate "on-shore" or "countertides" at the eastern sides of the different bays. If such a countertide existed to the east of Lyme Bay, it would cause a driftage northward from the Bill of Portland toward Chesilton. It would also account for the Chesil beach ending at Chesilton.

17. The fifteen-, twenty-, and twenty-five-fathom lines on the

reaches the nodal line off Courtown, a distance of 150 miles.

13. The current in the Channel between Cahore Point and Braichypwll is 2·5 knots an hour.

14. In Wexford Bay there are many off-shore banks, principally in a line between Greenore and Cahore Points.

15. On account of the off-shore banks in Wexford Bay the landward movement from the main up-channel current cannot increase progressively in strength. There are also "cross tides" generated by the efflux from the Wexford-Harbour lagoon that modify considerably the effects of the landward movement from the main current.

16. At Cahore Point there is a "countertide" running on shore towards the S.S.W. for the last three hours of the "flow." This tide is due to the on-shore set of the "offing tide" generated by the tidal wave running much quicker up the centre of the Irish Sea than at its margins. This countertide has stopped the shingle beach from extending onto Cahore Point.

17. The soundings on the Admiralty Charts would suggest

* Between the line joining Start Point and the Casquets (islands a little west of Cape la Hogue) and the line joining Beachy Head and Cape Ailly (near Dieppe) the flow of spring tides is as follows:—west part 2·3 knots, central part 3·6 knots, east part 3 knots, off Cape Barfleur 5·4 knots, and over Hurd's Deep 2·16 knots per hour.

Admiralty Chart would seem to suggest that there is a current hugging the west shore of Lyme Bay from Start Point to Berry Head, and running from this part of the bay direct onto the Chesil beach.

that there are currents on either side of the long banks running direct from Greenore to Cahore.

From a consideration of this comparison, it will be evident that there is a striking agreement in the circumstances of the beaches at Chesil and Cahore. The most distinctive differences are:—1. The great length of the Chesil beach. 2. The regular gradation in the size of the pebbles forming this beach. 3. The great height to which the beach is piled up near its eastern termination. These peculiarities may be explained by the circumstances under which it was formed and is kept up. Chesil beach is open to the incoming tidal current and to winds which are not only the prevailing, but also the most effective winds, and which, at the same time, come in a direction similar to that of the incoming tidal current, and thereby considerably augment it. The Cahore beach is protected from the landward currents from the incoming tidal stream by the off-shore banks in Wexford Bay. The prevailing winds (S.W. winds) have no effect; the more effective winds in regard to the driftage, come from the S.E.; but the more prevailing winds that effect the driftage on the coast are from the N.E.; and these considerably change and modify the tidal driftage. Take, for instance, their effects on the mouth of Wexford Harbour. The tidal driftage tends to extend the Dogger bank towards the N.E. Continued winds from the north-east, however, will stop this driftage, and force the sand into the N.E. channel, and thus raise the "bar," so that at times it is scarcely passable*. These winds, while they last, have considerable effect on the Cahore beach, pushing it towards the S.S.W., and modifying the arrangement of the fragments so that the pebbles in it are arranged more like those in the Chesil beach after continued winds from the S.E., than at any other time. The off-shore banks in Wexford Bay are probably due, in part, to the frail nature of the shore-cliffs†; it is likely, however, that they may be due in part to the circumstance of the wind-waves rarely conspiring with the tidal current, which consequently seldom acts to the most advantage. The efflux out of Wexford Harbour also has a considerable effect on the banks; the Lucifer bank, since the intaking of a considerable portion of the tidal muds of the lagoon, is gradually being carried away, as is apparent on a comparison of the chart of 1847 with that of 1873. These banks,

* Wexford Bay during this winter, 1875–76, has been so silted up that the regular traders from the port can scarcely get in or out.

† Land-wind driftage must also considerably augment them, as during the continued winds from the north-eastward clouds of sand are carried for miles southward, along the coast-line into Wexford Bay; part to be lodged by the water on the banks, and part to be carried again northward by the tidal stream.

as also the stream out of Wexford Harbour, which is ebbing for some hours after the tide is flowing in the Bay, must more or less prevent the offshoots from the up-channel current increasing progressively in strength. Consequently the results on the Cahore beach are not so regular or so marked as on the Chesil beach; but notwithstanding all these adverse circumstances, the tendency on the Cahore beach is for the largest fragments to be carried furthest and thrown up highest.

Another point to be considered is the great size of Lyme Bay compared with that of Wexford Bay. Lyme Bay, as just mentioned, is open, and the Chesil beach exposed to the full force not only of the tidal current but also of the most prevailing and effective winds. The current also is progressively increasing in velocity as it goes eastward*, and therefore carries large fragments with it, to be driven on shore and accumulated in a high and massive beach when the current has its maximum power during excessive winds†. As the currents branching in shore from the main up-channel stream are continually increasing in velocity from west to east, each carries different-sized fragments, which, when stranded, cause the shore-accumulation to have its peculiar arrangement.

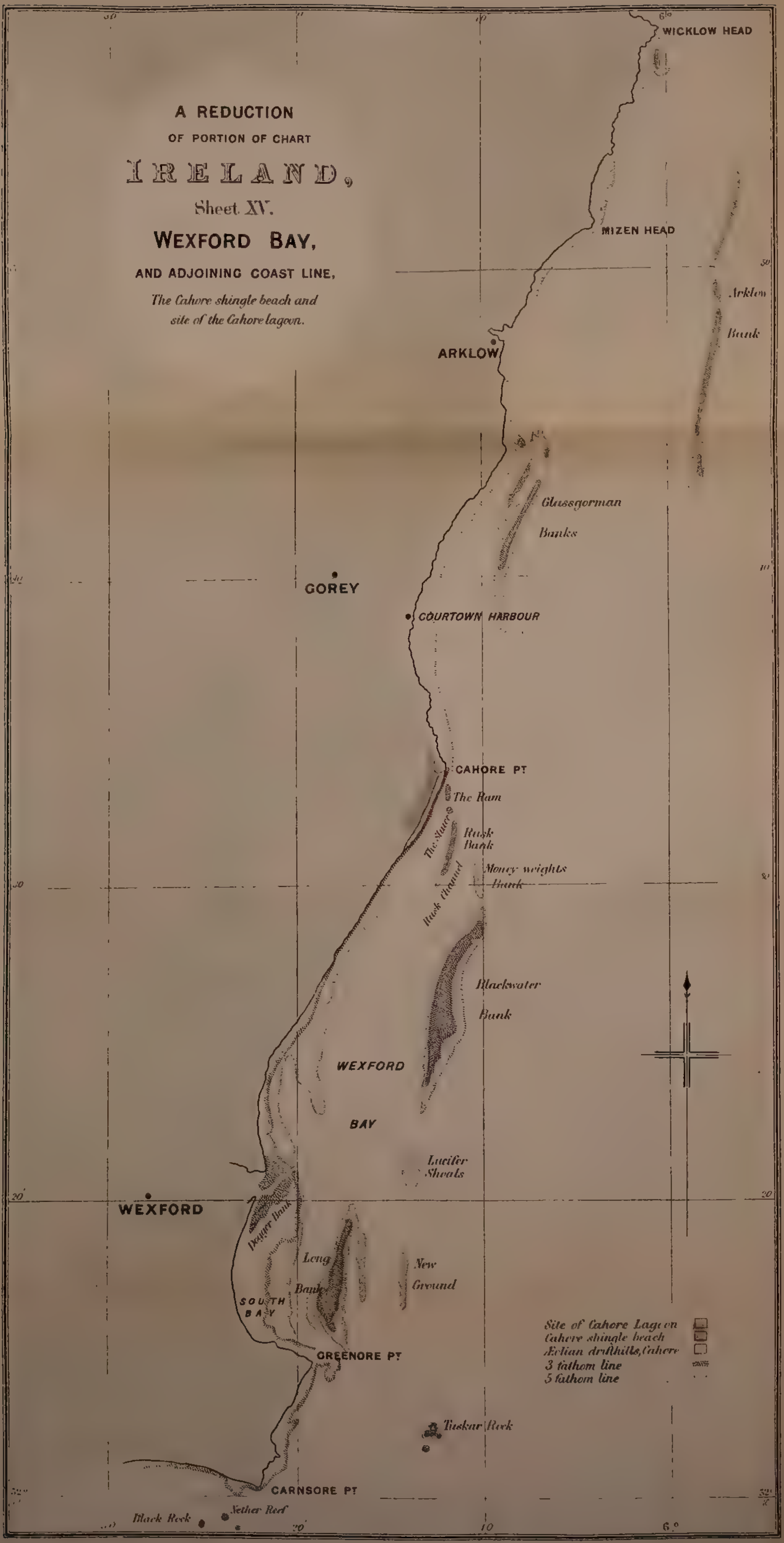
The site of the Cahore lagoon, prior to its being a lagoon, and when the sea was at least 30 feet lower than at present, was a peat-bog, the land then stretching considerably to seaward, as the bog is found off shore at the four-fathom line. Since then there have been different oscillations in the level of the sea, during one of which a gravel and shingle beach, which eventually grew into an Æolian drift bank, was formed, joining Cahore with the land to the south, and enclosing to the west of it a lagoon. As on this portion of the coast the more prevailing on-shore winds are from the north-eastward, they often, while they last, pile up large quantities of sand in Pollduff, the small bay on the north of Cahore. These accumulations, however, are carried away in an incredibly short time if the tidal current going northward is augmented by one or two heavy gales from the south-east. On account of this periodical filling-up of Pollduff, the drainage of the Cahore lagoon was at first accomplished by a canal cut through the middle of the Æolian-drift ridge. This canal, however, was always filling up by the tidal and wind driftages, and eventually, about twenty years ago, was abandoned; now, and for some years past, all traces of it are obliterated. At present the tract is drained by works that open into Pollduff.

Conclusion.

From the facts now stated, it seems reasonable to conclude that the Chesil and Cahore beaches are due to nearly the same natural causes,

* See note, p. 38.

† On the west coast of the Aran Islands, Galway Bay, the storm-waves when aided by the tidal current have great power, and hurl up and toss about huge blocks, forming a rampart, called by Prof. King, D.Sc., "the Block Beach." This beach in one place on the Middle Island caps a cliff 170 feet in perpendicular height; but usually the cliffs on which it occurs are much lower.


A REDUCTION
OF PORTION OF CHART
IRELAND,
Sheet XV.
WEXFORD BAY,
AND ADJOINING COAST LINE.
The Cahore shingle beach and site of the Cahore lagoon.
WICKLOW HEAD
MIZEN HEAD
Arklow Bank
ARKLOW
Glassgorman Banks
GOREY
COURTOWN HARBOUR
CAHORE PT
The Ram
The Stars
Rusk Bank
Money weights Bank
Rusk Channel
Blackwater Bank
WEXFORD
BAY
Lucifer Shoals
WEXFORD
Dogger Bank
Long Bank
New Ground
SOUTH BAY
GREENORE PT
Tuskar Rock
CARNSORE PT
Black Rock
Nether Reef
Site of Cahore Lagoon
Cahore shingle beach
Æolian drifthills, Cahore
3 fathom line
5 fathom line
6°
10
20
30
40
50
52°

but that at Chesil the driftage is due to the flow-tide current augmented by waves caused by the prevailing winds, while at Cahore the driftage is solely due to the flow-tide currents, its effect being modified by adverse wind-waves; and that the sorting of the pebbles on Chesil beach is probably principally caused by the progressive increase in the velocity of the tidal current as it approaches the nodal or hinge-line of the tide in the English Channel.

EXPLANATION OF PLATE II.

Reduction of portion of chart, Ireland, sheet XV., Wexford Bay and adjoining coast-line, the Cahore shingle beach, and site of the Cahore lagoon.

4. *On the* Echinodermata *of the* Australian Cainozoic (Tertiary) Deposits.

By P. Martin Duncan, M.B. Lond., F.R.S., Pres. Geol. Soc., Professor of Geology in King's College, London.

(Read May 10, 1876.)

[Plates III. & IV.]

Contents.

I. *Introduction.*

When the Cainozoic or so-called Tertiary deposits of Australia were found to be fossiliferous in some parts, great interest was excited respecting the possibility of the Echini being able to afford satisfactory evidence regarding the geological age of the strata in relation to the European types. It was hoped that the fossils of this great group would present some of the anomalies which characterize almost every class of organism found in the great distributional province; and it was thought to be probable that relics of very ancient forms would be discovered. But the number of species of Echini which were found in the marine deposits beneath the older basalt was small; and at the commencement of their study the amount of knowledge of the living Echinodermal fauna of the coasts and neighbouring seas was not great; consequently disappointment ensued. Year by year more specimens of the fossil Echini have been discovered, and careful collecting has produced many with their ornamentation wonderfully preserved; and, contemporaneously, the labours of Gray, Agassiz, and others, increased our knowledge of the recent Australian fauna.

Of necessity, therefore, the literature of the fossil Echini of Australia is scanty; and those palæontologists who have contributed to it have only paid attention to the relation of the forms to those of other geological ages, and neglected to consider the affinities with the existing fauna.

The principal contribution to the Echini of the Australian Tertiaries is that of Laube, "Ueber einige fossile Echiniden von den Murray cliffs in Süd-Australien," in the 'Sitzungsberichte der mathematisch-naturwissenschaftlichen Classe der kaiserlichen Akademie der Wissenschaften zu Wien,' 1869, p. 183. He described several species new to science, and established two new genera. The species noticed were *Psammechinus Woodsi*, *Catopygus elegans*, *Echinolampas ovulum*, *Micraster brevistella*, *Eupatagus Wrighti*, *E. murrayensis* and *Hemipatagus Forbesi*; and the new genera were *Paradoxechinus*, species *P. novus*, and *Monostychia*, species *M. australis.*

Before Laube wrote, the Rev. Julian Woods * had noticed the *Hemipatagus* as a *Spatangus*; and I had described it, calling it *Hemipatagus Forbesi* †, Woods and Duncan. Two or three other Echinida were also noticed by Mr. Woods and myself.

In August 1875 ‡ Mr. R. Etheridge, jun., F.G.S., described a species of *Hemipatagus* from the Tertiaries of Victoria, and gave a history of the work done by his predecessors, and also a most interesting essay, to which was added a list of species.

Whilst these years were elapsing, progress was made in the Geological Survey of South Australia and Victoria; and Daintree, Etheridge, Aplin, Ulrich, Wilkinson §, and others under Selwyn, and, independently of all, Mr. Woods, described and mapped the Tertiary deposits. The general relations of the Mount-Gambier, Glenelg, Murray, Hamilton, Muddy-Creek, Cape-Otway, and Port-Phillip's-Bay (Mordialloc) Tertiaries were thus determined, and their fossils were collected.

In 1864 and 1865 ‖ I described several species of Madreporaria from the Tertiaries; and in 1870, after having had the details of the Cape-Otway section sent to me, and a very large collection of corals also, by Mr. Selwyn, I communicated an essay to this Society on the Madreporaria of the Australian Tertiary deposits ¶. The geology of the Tertiaries was given in that paper, and their local and general correlation also. The recent Australian fauna of Echinoderms had been gradually described; and collections had been made contemporaneously with the geological researches, so that the great difficulties in the path of the student of the Echini were removed **; moreover the position of the fossil specimens was decided, and they can now be compared with the recent types.

For several years I have been receiving a few specimens of Echinida from different Australian Tertiary deposits; and lately a large number have been examined by me from the collection of the Geological Society, the British Museum, and from that of H. M. Jenkins, Esq., F.G.S., most of the fossils of the last named having been collected with great care. The number of species is not great; but it is sufficient to stamp the fauna with a very peculiar facies, and to indicate that the particular characteristic of the existing fauna was not present in the past, that the facies is older than that of most deposits of similar age, and that a part of it is decidedly modern in appearance, there being but slight differences between the ancient and a part of the existing fauna.

As the details of the sections whence the fossils now described came, and which have yielded most of those determined by Woods,

* Geological Observations in South Australia. 1862.

† Ann. and Mag. of Nat. Hist. (1864), ser. 3, vol. xiv. p. 165.

‡ Quart. Journ. Geol. Soc. vol. xxxi. p. 444.

§ Reports of Geological Survey of Victoria.

‖ Ann. and Mag. of Nat. Hist. ser. 3, vols. xiv. and xvi.

¶ Quart. Journ. Geol. Soc. vol. xxvi. p. 284.

** Gray, 'Cat. Echini Brit. Mus.;' A. Agassiz, 'Revision of the Echini,' 1872–1874.

Laube, and Etheridge, were described in the essay on the fossil Madreporaria, it is not necessary to refer to them again.

Nor do I refer to the New-Zealand strata which have yielded Echini, as they will probably form the subject of a future communication. I have, however, noticed all the species of Echini hitherto described; and I have carefully compared all the fossil species not only with their geological, but also with their recent representatives and allies.

In doing this it has been necessary to absorb some genera, and to consider some species as varieties; and this proceeding has been forced upon me principally by the insight I have obtained into the variability of the recent Echini. Alexander Agassiz has placed me under great obligations by the gift of his magnificent works on the revision of the Echini; and I have been able to determine some difficult points by the study of Lovén's 'Etudes sur les Echinoïdées,' and especially those relating to the *Hemipatagi* now included in the genus *Lovenia*.

II. *List of Species of the Australian Cainozoic Deposits.*

1. *Leiocidaris australiæ*, sp. nov. Cape Otway.
2. *Psammechinus Woodsi*, Laube. Murray Cliffs.
3. *Paradoxechinus novus*, Laube. Murray Cliffs.
4. *Temnechinus lineatus*, sp. nov. Mordialloc.
5. *Echinanthus testudinarius*, Gray. Lindenow, Mitchell River.
6. *Echinarachnius parma*, Gray. Cape Otway, Cardies River.
7. *Arachnoides Loveni*, sp. nov. Mordialloc.
8. ,, *elongatus*, sp. nov. Mount Gambier.
9. ,, *australis*, Laube, sp. Murray Cliffs.
   (Syn. *Monostychia australis*, Laube.)
10. *Echinolampas ovulum*, Laube. Murray Cliffs.
11. *Rhynchopygus dysasteroides*, sp. nov. Cape Otway.
12. *Echinobrissus australiæ*, sp. nov. Cape Otway.
13. *Pygorhynchus Vassali*, Wright. East of Glenelg River.
14. *Catopygus elegans*, Laube. Murray Cliffs.
15. *Holaster australis*, sp. nov. Cape Otway.
16. *Maretia anomala*, sp. nov. Mouth of Sherbrook River.
17. *Eupatagus rotundus*, sp. nov. Murray Tertiaries.
18. ,, *Laubei*, sp. nov. Mouth of Sherbrook River.
19. ,, *murrayensis*, Laube. Murray Cliffs.
20. ,, *Wrighti*, Laube. Murray Cliffs.
21. *Lovenia Forbesi*, Woods and Duncan, sp. Mount Gambier, Mordialloc, &c.
   (Syn. *Hemipatagus Forbesi*, Woods and Duncan.)
   ,, ,, var. *minor*, nov. Mordialloc.
   Lovenia Forbesi, var. *Woodsi*, Etheridge. Mordialloc.
   (Syn. *Hemipatagus Woodsi*.)
22. *Schizaster ventricosus*, Gray. Adelaide.
23. *Micraster brevistella*, Laube. Banks of the Murray.
24. *Megalaster compressa*. Banks of the Murray.

Many spines of Echini have been found in the Cape-Otway and Schnapper-Point deposits; they appear to have belonged to species of the genus *Goniocidaris*, and possibly of *Phyllacanthus* and *Stephanocidaris*.

Note.—I have not included those forms which, although "*named*" by Professor McCoy, have not been described or figured by him, as it is not permitted by the common consent of palæontologists.

III. *Description of the new Species.*

DESMOSTICHA.

Family CIDARIDÆ.

Subfamily GONIOCIDARIDÆ, Häckel.

Genus LEIOCIDARIS, Desor.

LEIOCIDARIS AUSTRALIÆ, sp. nov. Plate III. figs. 1 & 2.

The test is greatly and suddenly depressed towards the actinosome. The ambulacra are slightly wavy, narrow, and have four vertical rows of small miliary tubercles, the inner rows having the smallest tubercles; and the poriferous zones are sunken, the pores being conjugate, and each pair separated from its neighbours by a distinct ridge.

The interambulacral tubercles are few in number, and most are very large; the perforate mamelon is small in relation to the plain, large, conical and well-developed boss. The scrobicule is deeply sunken, elliptical, and is overhung by the scrobicular circle which slopes down to the suture, being ornamented by radiating rows of two or three very small tubercles. The median interambulacral space is sunken, and the vertical sutures of the plates are distinctly marked by a lower space, which is in a zigzag from above downwards. The upper large tubercles have a smaller scrobicular area than those in the middle of the test; and the tubercles diminish rapidly in size towards the actinosome.

Locality.—Cape Otway, No. 5 Section.

The generic diagnosis of *Dorocidaris*, to which genus the species has very great affinities, is given in A. Agassiz's 'Revision of the Echini,' pt. i. p. 254, and concludes with the determination, "Poriferous zone narrow, undulating, with disconnected pores." The pores in the species now under consideration are certainly conjugate; and in this they resemble Desor's genus *Leiocidaris*. Evidently these two genera are doubtful subgenera of *Cidaris*; but there are reasons for adopting them provisionally.

The resemblance of the portion of the test preserved in the soft sandstone to a corresponding part of the very variable *Dorocidaris papillata* of the Atlantic, Florida sea, and the Mediterranean is very remarkable; but the fossil form evidently comes under the genus *Leiocidaris*, Desor.

Family ECHINIDÆ.

Subfamily Temnopleuridæ, *Desor.*

Temnechinus lineatus, sp. nov. Plate III. figs. 3–5.

The test is small, depressed, rather pentagonal in outline, and the ambitus is rounded. The actinal surface is slightly rounded from the ambitus to the mouth, but on the whole is flat. The interambulacra are twice the width of the ambulacra at the ambitus, and about one third broader at the actinosome. The pores are in a vertical row and slightly oblique, and their zones are sunken. The interambulacra have two rows of primary tubercles, which are small and imperforate. Each row is separated externally by a crowd of closely placed secondaries from the poriferous zone, and by a much wider space from the other row. This space is marked by ridges which radiate from the top and base of the primaries, and which have secondary tubercles upon them and between them. The ridges run parallel courses between the distant primaries, and are narrow, but support from four to six secondaries. There are short ridges between the primary tubercles in each vertical series, which also carry one or more secondaries. Transverse and elongated spaces exist on one side of the primary tubercles at the ambitus and elsewhere where this ornamentation is not seen. The primaries of the ambulacra are in two vertical rows, each being close to its poriferous zone. Their ornamentation by ridges and secondaries is the same as that of the interambulacra ; but the ridges which pass off towards the poriferous zone, cross it and separate the pores in vertical series. All this ornamentation is exsert and the plain surface of the test may be seen between the ridges. Around the base of the boss of the large tubercles the ridges often close in and produce a crenulated appearance.

Height of test $\frac{3}{10}$ inch, breadth $\frac{5}{10}$ inch.

Locality.—Mordialloc, No. 1.

In classifying this species in the genus *Temnechinus*, I have been led by A. Agassiz, in his admirable criticism on this group of the Temnopleuridæ (*op. cit.* p. 286). He mentions that D'Archiac and Haime have figured from the Nummulitic formation of India a number of species which are usually referred either to *Temnopleurus* or to *Opechinus,* but which belong to this same genus *Temnechinus.* Probably *Paradoxechinus novus*, Laube, is one of these, and has had its ornamentation irregularly distributed.

Suborder CLYPEASTRIDÆ.

Family EUCLYPEASTRIDÆ.

Echinanthus testudinarius, Gray.

A large Echinoderm from the Mitchell-River Tertiaries, in Eastern Victoria, so closely resembles the modern form from Brisbane, Japan, the Sandwich Islands, and California, which has been termed by some authors *Echinanthus testudinarius*, and by others *Clypeaster testudinarius*, that there can be no hesitation in identifying this fossil with that species. Except in some slight points in which there is great individual variation in the recent forms, the fossil agrees with those which Gray called *Echinanthus testudinarius* and *E. australiæ*, the latter of which has been absorbed by the former *.

The species is interesting from its close resemblance to a *Clypeaster*; but it has no pores close to the sutures of the plates within the ambulacra on the actinal surface.

Locality.—Lindenow, Mitchell River, Eastern Victoria.

Family SCUTELLIDÆ.

ARACHNOIDES LOVENI, sp. nov. Plate III. figs. 6 & 7.

The test is roundish, subpentagonal, flat, rising slightly towards the apical disk, and slightly concave on the actinal surface. It has the same longitudinal and transverse diameter. The apical disk is slightly in front of the centre.

The ambitus is sharp, and is incised at the end of each ambulacral groove; and there is a rounded excision at the periproct, which is just under the margin. The ambulacra are grooved longitudinally, and swell up on either side; and they occupy about an equal space with the interambulacra, where they are comparable. The poriferous zones reach about halfway to the ambitus, and are broad and turn in slightly. The ornamentation in the ambulacral spaces is oblique and banded, but it is without any order on the interambulacra.

On the actinal surface this oblique ornamentation is seen on either side of the ambulacral groove; and this groove enlarges near the peristome, which is subcircular. Traces of sphæridia on one side of the groove are observed.

Length of large specimen $2\frac{2}{10}$ inch; breadth $2\frac{1}{10}$ inch.

Locality.—Mordialloc, Section 2. No. 1 and No. 3, and from soft yellowish white limestone at the mouth of Curdies River, about 30 miles east of Warumbool, which is in the upper part of a series underlain unconformably by Miocene calcareous clays.

This species, eminently Arachnoidean, has, however, more defined excisions on the ambulacra at the ambitus than either of the living forms, *A. placenta*, Linn., and *A. zelandiæ*, Gray—the one from the whole eastern coast of Australia, and the other from New Zealand. The situation of the periproct is variable in the genus *Arachnoides*, and is not invariably supramarginal. It may be marginal and slightly sub- or inframarginal; and this last appears to be characteristic of the fossil forms. The resemblance between the ornamentation, the sphæridia, the actinal grooves, and the petals of the ancient and modern forms is very remarkable.

* Gray, Proc. Zool. Soc. Lond. 1851, p. 35; A. Agassiz, Rev. Echin. pt. iii. p. 514.

Arachnoides australis, Laube, sp. *

Syn. *Monostychia australis*, Laube; *Clypeaster folium*, Dunc. nec Agass.; *Clypeaster*, sp., Woods.

Laube, in his interesting paper on the fossil Echinoderms of the Murray Cliffs in South Australia (*op. cit.* p. 188), criticises Woods, who termed a flat pentagonal fossil *Clypeaster*. This form was seen by myself; and from its imperfect condition I was led to believe that it was really a species common to Malta and some other European Miocene localities. Mr. Etheridge, after examining the specimen, concluded that Laube was correct in his criticism; for he determined that the form was not a *Clypeaster*, but a species of a new genus, *Monostychia*, Laube.

After carefully examining all the specimens I have been able to obtain of this *Clypeaster* of Woods, and after carefully investigating the value of the genus *Monostychia* in relation to *Laganum* and *Arachnoides* in the Scutellidae, I have now come to the conclusion that they are not Clypeastroids, and that the proposed genus is too closely allied to *Arachnoides* to be separated from it. Laube distinguishes *Arachnoides* from his genus because the first has five, and the latter only four genital pores; but this is an error; and he makes the position of the periproct of generic importance in spite of all the other great resemblances, this being an insufficient generic differentiation.

I have therefore placed the *Clypeaster* of Woods and myself, the *Monostychia australis* of Laube, in the genus *Arachnoides*.

Arachnoides elongatus, sp. nov. Plate III. fig. 8.

This common fossil species belongs to the group which Laube would place amongst his *Monostychiæ*, but which, I think, fairly comes within the genus *Arachnoides*. The test is longer than broad, and is pentagonal, incised at the ambitus at the posterior ambulacra and periproct, and faintly so at the ambitus of the other ambulacra. The apical system is central. The test slopes very gradually upwards from the ambitus for a little distance, and then suddenly forms a sharp curve, whose sides are marked by the ambulacra and interambulacral spaces. The generative system and the madreporiform body are at the apex of a blunt surface. Each ambulacrum is divided by a longitudinal groove, that of the anterior odd one being the least developed; and the ambulacral areas are rounded and rise above the interradial spaces. The ambulacra are wide; and the poriferous zones form a curve on either side and externally, but their inner edge is straight. The madreporiform body is large; the genital pores are large, and four in number; the edge of the ambitus is rather blunt; and the actinal surface is nearly flat, except near the peristome, where it suddenly sinks.

The periproct is just under the margin.

* This species is described in Laube's essay on the Fossil Echinida from the Murray Cliffs in the Sitzungsberichte der kaiserlichen Akademie der Wissenschaften, 1869, p. 190.

Length $1\frac{4}{10}$ inch, breadth $1\frac{2}{10}$ inch, height $\frac{3}{10}$ inch.
Locality.—Mount-Gambier Limestone.

The smaller specimens are flatter; in one the periproct is marginal, and in another supramarginal; their ambitus is blunter than that of the large specimens.

PETALOSTICHA.

Family NUCLEOLIDÆ.

RHYNCHOPYGUS DYSASTEROIDES, sp. nov. Plate III. figs. 9 & 10.

The outline of the ambitus from the actinal surface is ovoid, being rounded and broad anteriorly and narrower and slightly pointed posteriorly. This outline is less evident from the abactinal surface on account of the keel which passes from the vertex posteriorly, and of the slight roundness of the test on either side of it near the ambitus. The test is thick in substance, and in general shape is rather depressed, but convex above and concave below. It is arched from the front to behind the apical system, which is slightly eccentric to the front, but is slightly flattened anteriorly, and to a certain extent laterally above the ambitus. The arched shape is not so decided posteriorly, where, near the vertex, the keel starts obliquely backwards and downwards to overhang, at about one fourth of the height, the small transverse periproct, which has a flat and shallow groove. The greatest width is just behind the antero-lateral ambulacra; and the mouth and apical system nearly correspond, the first being slightly more anterior than the other.

The apical system is elongate; and the anterior and posterior pairs of generative pores are wide apart, the ocular plates of the antero-lateral ambulacra coming well in between them (Pl. III. fig. 10). Hence the posterior; lateral ambulacra are more distant than is usual in the Cassidulidæ. The anterior generative pores are large, closer together than the posterior; and the madreporiform body is small, convex, and reaches just in front of the right ocular foramen. The posterior pairs of generative pores are wider apart and slightly smaller than the anterior, and are posterior (by the length of their own distance apart) to the ocular foramina of the antero-lateral ambulacra. The rectangular space between the anterior and posterior generative pores is slightly depressed, the madreporic body forming however an elevation in it. This space is covered with miliaries and a few small tubercles.

The ambulacra are long and narrow, being, with the exception of the anterior, which is slightly in a groove, flush with the test. The poriferous zones are lower, and are continued to the ambitus, the distance between the pairs of pores gradually increasing near the edge.

The poriferous zones are narrow, and not so wide as the interporiferous; and the pores of the inner rows are round and smaller than the oval and more or less elongate kinds of the outer rows. They are conjugate. The pores of the odd anterior ambulacrum are less developed than the others; and those of the inner or posterior zones of the lateral posterior ambulacra are few in number towards the ambitus, to which, however, they extend. The ocular pores are well developed, and a miliary granulation covers the test between all the pores and the interporiferous areas, a few scattered tertiary tubercles being there also. The tuberculation is small, and tubercles of the third order are the largest on the upper surface. They increase in number towards the ambitus, and are surrounded by a sunken scrobicule surrounded by miliaries. The keel is distinct, slightly angular, and reaches backwards so as nearly to overhang the ambitus.

The concave actinal surface has a large sunken mouth, a plain band reaching from it posteriorly, and a distinct tuberculation at the edge of the test.

Length of specimen $1\frac{9}{10}$ inch, breadth $1\frac{8}{10}$, height $\frac{6}{10}$.

Locality.—No. 5 Upper Coralline Beds, Castle Cove, near Cape Otway.

The resemblance of this species to *Rhynchopygus pacificus*, Ag. (Rev. Ech. Part i. p. 153 and Part iii. p. 554), is very decided in some points; but it differs from it and from the species from the Caribbean Sea by having an elongated apical system, and in the separated apical ends of the lateral and posterior pairs of ambulacra. This Dysasterian peculiarity resembles that of *Hyboclypus*, which may be said to be a *Galerites* with an elongated apical system, thus uniting this last genus to *Ananchytes*. The Australian Lower Cainozoic *Rhynchopygus* is unlike all the other species of the genus in this special peculiarity. The genus is represented in the Gault, in the uppermost Cretaceous rocks, and in the Tertiary tuff of Guadeloupe; and the recent forms are from the Caribbean and the Pacific coast of America. Were it not for the strong generic resemblance of the new species, the nature of the curious and suggestive apical system might determine the formation of a new genus; but it is perhaps most advisable to retain the form where it is placed, so as to make it a passage species from one great group to another.

Genus Echinobrissus, Breyn, 1732.

Nucleolites, Lamk. (part.).

Echinobrissus australiæ, sp. nov. Plate III. fig. 11.

The test is depressed and stout, and the outline of the ambitus is elliptical. Seen from above the posterior end is slightly produced, and the anterior is rounded. The vertex is central, and the apical system is anterior to it. The petals are lanceolate and narrow; the anterior extend rather more than halfway down the test; the posterior are about the same length; and all are open. The poriferous zones are of uniform breadth; and the interporiferous space is nearly of the breadth of one of the zones: it is very slightly raised so as to prevent the ambulacra being flush with the test. The pores are subequal; those of the inner row are round, whilst those of the outer are oval in outline; some are faintly conjugate, and others not so: the extension of the outer rows of pores beyond the petals and towards the ambitus is scanty. The anal furrow reaches nearly to the vertex; and the opening is triangular in outline, the upper angle being slightly rounded, whilst the base is below the level of the ambitus, with which it does not interfere. The ambitus is rounded, and the actinal surface is concave from side to side, and from before backwards, the slope being towards the actinosome, which is small, eccentric in front, transverse and elliptical in outline, the posterior lip being rather straight and on a level with the anterior. The floscelles are small. The tuberculation is small everywhere, and smallest in the anal groove.

Height of specimen $\frac{4}{10}$ inch, length $\frac{12}{10}$ inch, breadth $\frac{9}{10}$ inch.

Locality.—No. 5, Upper Coralline Beds, Cape Otway.

Pygorhynchus Vassali, Wright.

A very perfect small specimen was found east of the Glenelg river, in a matrix of white limestone crowded with Polyzoa. It resembles in its shape and details that figured by Dr. Wright, F.G.S., &c. in Quart. Journ. Geol. Soc. vol. xx. pl. xxii. fig. 6; and he considers the Maltese form there delineated to belong to the genus *Pygorhynchus*. In the Australian and also in the Maltese specimen the periproct is longitudinal, and there is no floscelle; so that both are sufficiently anomalous members of the genus. Some remarks on the species and its allies are made further on.

Locality.—East of the Glenelg river.

Catopygus elegans, Laube, *op. cit.* fig. 7, and p. 190.

This species has a pentagonal peristome, a well-developed floscelle, and a kind of plastron. It is concave inferiorly, and this is rather anomalous.

Locality.—The Banks of the Murray.

Family SPATANGIDÆ.

Holaster australiæ, sp. nov. Plate III. figs. 12 & 13.

The test is ovoid in outline when seen from above, and is slightly grooved in front, and pointed and truncated posteriorly. It is rounded at the ambitus and over the apical part; but owing to there being a keel between the actinosome and the posterior end, the greatest height is behind the apical system. The test is thick, and only marked above by one depression, for the anterior odd ambulacrum. The apical system (Pl. III. fig. 13) is long and central, the antero-lateral ambulacra being widely separate, flush with the test, long and open, and widely separated from the posterior ambulacra. The generative pores are four in number, and the posterior pair are separated from the anterior by the ocular plates of the antero-lateral ambulacra; on the other hand the ocular plates of the posterior ambulacra are posterior to those pierced by the posterior generative pores. The anterior ambulacrum is in a shallow groove, and its small pores, rather crowded above, become more distant and larger towards the ambitus; they are oblique in direction, round, and nearly equal, in pairs, being separated by a very delicate septum.

The pores of the antero-lateral ambulacra are small, equal, round, and wider apart and larger towards the ambitus, where the zones are wide apart. The posterior pair of ambulacra are rather close together, and the pores resemble those of the others. The periproct is small and situated in the truncated posterior part. The actinosome is at the anterior third; it is sunken, transverse, and the posterior lip passes into a prominent keel-like plastron. The ornamentation is very simple: there are no large or even secondary tubercles; but small tertiaries and miliaries exist, generally scattered.

Length $1\frac{1}{2}$ inch, greatest breadth a line or two less; height in front $\frac{7}{10}$ and behind $\frac{9}{10}$ inch.

Locality.—No. 5, Upper Coralline Beds, Castle Cove, Cape Otway.

Maretia anomala, sp. nov. Plate IV. figs. 1–4.

The test is thin, depressed, and the outline from above is irregularly oval and rounded anteriorly. There is a slight indentation at the ambitus, made by the shallow anterior groove; and the shape is rather angular posteriorly in the anal region, and broadest midway. The sides of the test are sharply rounded, slightly angular. The abactinal surface is highest posteriorly on account of the anal keel, which, being produced backwards, is also sloped and depressed anteriorly between the posterior petals. The apical system is small, and the four large genital openings are close to each other (Pl. IV. fig. 1), the madreporiform body passing backwards; it is in advance of the centre and anterior to the depression already noticed. The anterior and shortest petaloid ambulacra are lanceolate, and are almost transverse. The poriferous zones slope up to raised, broad interporiferous zones; and the external rows of pores are the largest, and usually more oval than round. The posterior rows are better-developed than the anterior, which are imperfect near the apical system. About 21 rows of pores exist, all of which are conjugate.

The posterior ambulacra are long, broad, flush, and wider posteriorly than anteriorly; they are nearly parallel with each other, and bound the keel on either side. The external poriferous zones are curved; the internal are much less so; and the interporiferous zones are much broader than those of the antero-lateral petals, and there are traces of two or three large secondary tubercles within their area. The odd anterior ambulacrum is nearly flush with the test, except at the ambitus, where there is a slight depression; its pores are numerous near the apical system, and are very small; elsewhere they are very rare. This ambulacrum is bounded externally by plates rather raised above the general level; they are tuberculate with large crenulate and perforate miliaries, and they separate it from the plates with the large tubercles of the anterior interambulacra. The anterior interambulacra have several horizontal rows of large and of secondary tubercles mixed and increasing in number towards the ambitus. The larger tubercles have a swollen scrobicule, a crenulated boss, and a small perforated mamelon, and the upper extremity of the boss has its crenulation projecting upwards and outwards like a frill (Pl. IV. figs. 3 & 4). The spaces between the tubercles are more or less crowded with larger miliaries; and these are again surrounded here and there by smaller. In the lateral interambulacra there are also several rows of the same kind of tubercles as in the anterior; the rows contain more tubercles, but do not approach the ambitus or the apical system more than do those of the anterior spaces. In the interambulacral spaces, between the large tubercles and the apical system are crowds of large and small miliaries.

The ambitus is sharply curved from above downwards, and is rendered irregular in its outline by the slight projection of portions of it from which the tuberculation of the actinal surface radiates inwards. On this surface (Pl. IV. fig. 2) the posterior ambulacra are bare and broad, and coalesce, forming a broad bare actinal shield, a few miliaries only existing. As a whole the actinal surface is flat, the mouth being very slightly sunken, and that only anteriorly; but between the ambulacra just noticed is a projecting plastron covered with secondary tubercles at the sides, and with miliaries on the top of its keel. The actinosome is large, elliptical, broader than long, and the sides are rounded and project slightly backwards. The posterior lip projects slightly, and has large miliary tubercles on it. The anterior phyllodes are well developed, and extend nearly to the edge of the test; and the posterior are recognizable by one or two large slit-shaped pores. The tubercles of the actinal surface radiate in lines from points in the lateral and anterior interambulacra at the ambitus, and the tubercles increase in size as they approach the actinosome with its comparatively bare surrounding plates. A very ill-developed, extremely narrow fasciole (visible under a magnifying power of 10 diam.) is seen on part of the test below the tubercular area. The frill-like crenulation is present on the actinal surface.

Length $2\frac{3}{4}$ inches, breadth $2\frac{1}{2}$ inches; height at posterior part $\frac{8}{10}$ inch, at apical system $\frac{6}{10}$ inch.

Locality.—Mouth of the Sherbrook river, with *Eupatagus Laubei*.

The resemblance of this form to *Maretia planulata*, Gray, is perfect, with the exception of the partial and extremely small fasciole.

EUPATAGUS ROTUNDUS, sp. nov. Plate III. figs. 14–17.

The test is thin, and the outline of the ambitus is nearly circular, there being a slight flatness posteriorly where the anus is situate on a truncation which slants slightly from above downwards and inwards. The vertex is nearly central, and thence there is a slight slope to the apical system; the slope continues anteriorly, and then dips down suddenly to the ambitus. Behind the vertex a keel passes backwards horizontally beyond the line of the posterior ambulacral petals, and the slope increases to the margin of the periproct. The rest of the posterior part is obliquely truncate, the surface of the truncation being slightly concave from side to side.

The periproct is large and high up. The height of the vertex is about $\frac{2}{3}$ of the length of the test. On either side of the vertex the test slopes down in a bold curve to the ambitus. The apical system is eccentric and in advance of the vertex, and is slightly depressed (Pl. III. fig. 15). There are four large genital openings: the two anterior are closer together than the two posterior, which are separated by the madreporiform body, which extends beyond the posterior; they are large, and each is more or less perfectly surrounded by a circle of miliary tubercles. The ocular pores are large, and form the angles of a pentagon which incloses the generative tract. There is no groove for the odd anterior ambulacrum, which spreads out towards the ambitus, being bounded laterally by a faint ridge on either side, and crossed by the peripetalous fasciole at about $\frac{1}{3}$ of the whole distance from the ambitus to the apical system. There are a few pores crowded near the apex of the ambulacrum, and a few widely apart between it and the fasciole.

The anterior pair of petals are widely divergent, lanceolate, slightly pointed externally; and their poriferous zones are sunken and broad, the hinder ones being the broadest. The pores are rudimentary in the upper part of the front zones; and elsewhere they are largest in the hinder zones. The pores are nearly round, the external row being more or less ovoid; they are conjugate, and the ridges intervening between the pairs are raised and ornamented with miliaries. There are from 24 to 26 pairs of pores in the posterior poriferous zones of these ambulacra. The interporiferous space is slightly broader than the posterior poriferous zone, is convex, and ornamented with large miliaries. The posterior pair of petals, rather close to each other, are slightly shorter than the anterior; they are broader, however, and less pointed at the end. The poriferous zones of these posterior ambulacra are sunken, and are nearly equal in breadth; there are the same number of pores as in the anterior; and the other details are much the same in both. The interporiferous zone is broader than in the anterior pair of ambulacra, and is convex and rather above the ordinary level of the test.

The peripetalous fasciole (Pl. III. fig. 15) passes round the extremities of the lateral and of the posterior petals, and across the odd anterior ambulacrum; it passes behind the posterior petals in an irregular course, but on the whole it is elliptical in its outline in the posterior half, and rather angular and wavy in the anterior. It is situated nearer to the apical system than to the ambitus, except anteriorly, where it is nearest to the ambitus. The tuberculation of the abactinal surface below the fasciole is uniform, and the tubercles are smaller near the fasciole and larger towards the ambitus; everywhere they are crowded, and in many places there are vacant spots like crescent fascioles. The small secondary tubercles in this part are perforate and crenulate, and the scrobicule is often imperfect and oblique, whilst there may not be a perfect miliary scrobicular circle. Above the fasciole and in the posterior interambulacral space the tuberculation is small, and like that of the interporiferous zones, there being neither large secondary nor primary tubercles. In the anterior and in the antero-lateral interambulacra there are large primary and secondary tubercles irregularly arranged and sparsely distributed, but occupying the whole of the spaces. The primaries have a perforated mamelon, crenulated boss, and a flat scrobicule. The edge of the ambitus is rather sharply rounded. The actinal surface slopes upwards in front anterior to the mouth, and is more or less convex posteriorly, on account of the sharp keel of the posterior extremity of the interambulacral actinal plastron. The mouth is slightly sunken anteriorly; and the posterior lip is rounded and projects downwards slightly, being, unlike the rest of the circumference of the opening, very tuberculate (Pl. III. fig. 16). The actinal anterior and lateral ambulacra form short and almost smooth avenues; and the posterior ambulacra form wide, almost smooth bands extending from the subanal fasciole on either side of the keel to the sides of the mouth and behind the posterior lip. The anal system is large, and almost circular in outline, and is situated in the obliquely truncated posterior extremity, of which it occupies nearly one half (Pl. III. fig. 17). The subanal fasciole is closed, heart-shaped, and reaches to the point of the keel of the plastron. The poriferous areas of the anterior odd and paired ambulacra on the actinal surface show a few slit-like pores surrounded by a scrobicule-like rim, which occupy the position of large tubercles. There are also corresponding pores in the posterior ambulacral zones close to the mouth. The tuberculation of the anterior interambulacra on the actinal surface is larger near the mouth, and so is that of the lateral interambulacra; but the tubercles diminish in size and increase in number towards certain points on the ambitus; within the posterior actinal interambulacral space the tubercles radiate from the point of the keel, and the largest are the remotest from it. The mouth is large, broader than long, curved in front, and encroached upon behind by the projecting posterior lip.

Length $2\frac{8}{10}$ inches, breadth $2\frac{7}{10}$, height of vertex $1\frac{5}{10}$ inch.

Locality.—Tertiaries of the Murray river.

Eupatagus Laubei, sp. nov. Plate III. fig. 18.

The test is thin, depressed, elliptical in outline, but narrow and somewhat pointed posteriorly. There is slight truncation of the posterior interambulacrum. The antero-lateral and posterior petals are nearly equal in length and breadth, and are lanceolate, the anterior pair diverging more than the others. The poriferous zones of both ambulacra are equal in breadth, are slightly sunken; and the anterior poriferous zone of the antero-lateral petals is the smallest. The pores are conjugate, those of the antero-lateral zones being the largest; and in both ambulacra those of the inner row are rounder and smaller than those of the outer, there being 13 or 14 rows in each petal. The interporiferous zone is slightly convex, and has miliaries and third-sized tubercles; and miliaries crowd the elevations between the successive pairs of pores. The anterior odd ambulacrum is nearly flush, bounded by tubercles larger than those within its area, and contains a few pores. The apical system is very small, and nearly central; there are four generative pores, the posterior pair being the widest apart, and the madreporiform body passing between them. The peripetalous fasciole is narrow, and incloses a cordiform space. Tuberculation small everywhere; but there are larger tubercles grouped within than without the fasciole, and they become smaller towards the sharply rounded ambitus. The actinosome is well in front, the anterior part being sunken; the phyllodes are distinct; the plastron is nearly smooth; and the tuberculation of the actinal surface, which is throughout small, becomes larger remotely from the ambitus.

Height $\frac{6}{10}$ inch, length $1\frac{6}{10}$ inch, breadth $1\frac{4}{10}$ inch.

Locality.—Section 1 mile west of the mouth of the Sherbrook river, lower part of cliff.

The small tubercles, the depressed shape, the equal size of the petals, the very thin fasciole, and the far forward mouth distinguish this species, which I have dedicated to the excellent palæontologist Prof. Laube.

The next group of Australian Echini is very characteristic of the Tertiary marine deposits of the southern provinces. Members of it have been found in the corresponding formation of New Zealand, in the later Tertiaries of Java, and in the Eocene, Miocene, and Pliocene strata of Europe.

Genus LOVENIA, Desor, 1847.

Syn. *Hemipatagus*, Desor, 1858.

Desor originated the genus *Hemipatagus* amongst the fossil Echini in 1858, to include some species of the old genus *Spatangus*, which had the following characters *:—

"Little Urchins with large tubercles on the interambulacral areas, like true *Spatangi*, but with this difference, that none are found in the odd or posterior interambulacrum. The plastron is smooth, as if rubbed; the petals are long and spread out; there are four genital pores, and there are no fascioles."

This diagnosis separated the group from *Spatangus*, which has a subanal fasciole, and tubercles in all the interambulacral areas—and distinguished it from *Eupatagus*, which has its posterior interambulacrum without tubercles, and a subanal as well as a peripetalous fasciole. The distinctness of the group was evident enough, although the generic value given to it was a matter of doubt.

Gray † had in 1855 described a fine recent Echinus under the new generic title of *Maretia*, and his diagnosis brought it into close relation to *Hemipatagus*, Desor. It has the generic characters and, in addition, an indistinct subanal fasciole; but the test is flattened.

In 1873 A. Agassiz noticed the close resemblance of the *Hemipatagi* and *Maretia*, and, considering the subanal fasciole of no moment, determined their identity.

* 'Synopsis des Echinides,' p. 416.
† Cat. Rec. Echini, Brit. Mus.

Laube stated *(op. cit.)* that there is a spectacle-shaped fasciole in *Hemipatagus*; and then R. Etheridge, jun., in 1875, writes, "Below the anal orifice is a spectacle-shaped fasciole carrying on each side a circlet of primary perforated tubercles." They thus brought the genus into actual identity with *Maretia*, which, however, was not known then to be represented in any fossiliferous deposits, and which was supposed to be a recent form.

Recent investigations upon some wonderfully perfect specimens have enabled me to add to Laube's discovery the existence of an internal fasciole; and it is therefore necessary to take the group away from *Spatangus* and *Maretia*, according to the ordinary rules of classification (although much may be said to the contrary in a classification founded on heredity), and to place it in the neighbourhood of *Breynia* and *Echinocardium*, under the head of *Lovenia*, Desor.

Lovenia has the following characters :—

Test thin, elongate, arched, flattened, truncated posteriorly. Large tubercles upon the upper or abactinal surface, but not on the posterior interambulacrum; and they are situate in deep and large scrobicules. The ambulacral petals, in somewhat triangular and adjoining zones, form two crescents on each side of the apex. There are four generative pores; and the anal system is more or less sunken in the posterior truncation. The anterior groove is slight. The actinal surface has large and other tubercles in deep scrobicules, forming a close pavement laterally; the posterior end of this surface is ornamented with regularly placed small tubercles; and the floscelles are distinct but small. There is an internal fasciole and a subanal spectacle-shaped fasciole.

The species hitherto described are *Lovenia cordiformis*, Lütk., from Guayaquil and the Gulf of California, *Lovenia elongata*, Gray, Red Sea, Australia, and Philippines (*Lovenia hystrix* is probably the same as this), and *Lovenia subcarinata*, Gray, from China, Japan, and the Sandwich Islands.

A comparison of the details of some beautifully preserved specimens of Echini from the Section at Mordialloc, on the east shore of Port-Phillip Bay, which would have been classified as *Hemipatagi*, with the diagnostic characters of *Lovenia*, proves the generic identity. In most specimens which have hitherto been collected, described, and figured, the surface has been exposed to attrition and weathering, and more or less of the fine miliary ornamentation which covers the whole abactinal surface has been removed. In many specimens there is not a trace of it left, and the divisions between the plates have become evident. This fine ornamentation reaches to the ambitus, where it becomes coarser, and gradually enlarges on the actinal surface until the large primaries are reached; but around the anal opening the ornamentation becomes finer, and the miliaries are smaller and wider apart. The internal fasciole is composed of tubercles of about one sixth the size of the finest miliaries; and those of the subanal fasciole are quite as small.

Considering that the abortion of the anterior poriferous zone of the antero-lateral ambulacra has been so often figured in *Hemipatagus*, it is remarkable that a more strict search after an internal fasciole, which could alone produce that peculiarity, has not been previously successful. The best Mordialloc specimens indicated it perfectly; and many old and worn specimens give indications of its presence now that one knows where to look for it. The subanal linear fasciole is situated just where the posterior and truncated (actinal) part of the test touches the surface on which the test rests; hence it is readily worn off, after the spines have been removed, by the ordinary attrition to which fossils are subject.

Some confusion has arisen in the nomenclature and in the specific distinction of the Australian *Hemipatagi* (now *Loveniæ*) already known, owing to my communication to the Ann. and Mag. Nat. Hist., ser. 3, vol. xiv. Sept. 1864, having been overlooked by Laube, whose admirable essay on the Fossil Echinida of the Murray cliffs was read before the Vienna Academy in 1869. He redescribed the same species which I had called *Hemipatagus Forbesi*, Woods and Duncan. In 1875 Mr. R. Etheridge, jun., described in the Quart. Journ. Geol. Soc. vol. xxxi. No. 123, p. 445, a species which he has called *H. Woodsi*, and in order to define it from *H. Forbesi* had the latter figured in outline giving a side view. This figure does not correspond with mine in Ann. and Mag. Nat. Hist. ser. 3, vol. xiv. plate vi. fig. 3; nor does it with Laube's. Again, my figure and Laube's are not exactly alike; for a certain amount of variation must be conceded to all the species of this genus; and the figure in the 'Sitzungsberichte' has a more truncated and less depressed anterior front test than mine. Mr. Etheridge's figure is shorter and more truncated still, and approximates to his new species *H. Woodsi*, so as in fact to restrict the specific diagnosis to the greater or less number of large tubercles with sunken scrobicules in the two lateral interambulacral spaces on either side.

Laube evidently had better specimens than those from which I described *H. Forbesi.* It appears, after an examination of a numerous series (35 to 40) of *Hemipatagi* from the Australian Tertiaries, that there are groups embraced under the species *H. Woodsi* and *H. Forbesi*, Etheridge; but they are connected by intermediate forms. There are *H. Woodsi*, with flat and with truncate ends, with oval or transversely elongated periprocts, with numerous tubercles in the lateral interambulacra or with few. The larger *H. Forbesi* resemble the *H. Woodsi* in shape, and have variable numbers of tubercles; and the number even differs on the opposite sides of the same individual.

The depth of the anterior furrow, the distinctness of the subanal fasciole, and the width of the ornamentation included by the internal fasciole vary in specimens possessing perfect resemblances in other structures. The number of pairs of pores in the ambulacra is, in the majority of the specimens, as follows (taking 15 as good types):—

Specimens.	Pairs of Pores in Ambulacra. Antero-lateral.	Postero-lateral.
Small specimens with 4 large tubercles in the lateral interambulacral space,		
1	13	10
2	?	13
3	11	9
With 5 tubercles,		
1	10	10
2	11	11
1	12	9
2	12	10
With 7 tubercles,		
1	11	11
2	?	10
Large specimens with 8 tubercles,		
1	11	11
2	11	10
3	12	14
With 6 tubercles,		
1	10	12
2	11	10
With 13 tubercles,		
1	14	16

LOVENIA FORBESI, Woods and Duncan. Plate IV. figs. 5–8.

Syn. *Hemipatagus Forbesi*, Woods and Duncan.

Not as figured in Etheridge, Quart. Journ. Geol. Soc. vol. xxxi. pl. xxi. fig. 8, but in Ann. and Mag. Nat. Hist. ser. 3, vol. xiv. pl. vi. fig. 3 *e, f*.

Syn. *Hemipatagus Woodsi*, Etheridge, (a variety) var. *Woodsi*.
Syn. *Hemipatagus Forbesi*, Laube.

From the Miocene tertiaries of the Murray cliffs. Mount Gambier Polyzoan limestone, east side of Port-Phillip Bay, near Mordialloc (see Etheridge, Quart. Journ. Geol. Soc. vol. xxxi. p. 447 for the section). It is a very common and variable species.

LOVENIA FORBESI, var. MINOR.

After much consideration, and having had the opportunity of examining numerous specimens, I place a small *Lovenia*, which is exceedingly variable in length, height, position of apical system, and number of tubercles in the species *L. Forbesi*, making it a good variety, var. *minor* nobis.

Some of the specimens are exquisite in their ornamentation, and afford the following new points of structure, which necessitate the aborption of *Hemipatagus* in *Lovenia* :—

The internal fasciole now observed for the first time in *Hemipatagus* forms an acute angle posteriorly, and just behind the madreporiform body, and then passes across the line of the posterior lateral ambulacra, turning forwards in the interambulacral space and being visible thence to about midway between the apical system and the ambitus in front (Pl. IV. fig. 8). The fasciole then crosses the ridges on either side of the odd ambulacrum and completes the circuit. The band of small granules constituting the fasciole is narrow, but very distinct; but the anterior transverse portion is not very marked. The cavity for the odd ambulacrum is moderately deep, and has on either side towards the apical system a ridge which is ornamented with numerous small tubercles encircled by miliaries. The abortion of the anterior poriferous zones of the antero-lateral ambulacra is evidently in relation to the presence of the internal fasciole. Our knowledge of the subanal spectacle-shaped fasciole (Pl. IV. fig. 6), first noticed by Laube, and subsequently by Mr. Etheridge, may be thus added to:—It commences in a mass of miliaries on the subanal plates, and then passes outwards and curves downwards. The union is made with that of the other side by a narrow transverse line of granules, which, as a fasciole, passes across the intervening space. The curved upper part of the fasciole on either side is, in some specimens, prolonged inwards so as to incompletely include a space which is ornamented with small tubercles, the scrobicules of which are separated by ridges. These tubercles have the mamelon very distinct; and in their neighbourhood are smaller ones in more or less definite rows, and some in a part of a circle bounding the fasciole internally.

The outer curve of this fasciole (on either side) is within the range of the posterior lateral ambulacrum, the plates of which, as they are continued to the ambitus, pass down beneath the ornamentation of the outer part of the fasciole and the outer part of the included space. It results that there are five or six pores in these plates which appear within the fasciole (Plate IV. fig. 6), in a semicircle just on its inner edge. They are distinct in worn specimens, and can usually be distinguished in others close to the tubercles. The periproct may be round, ovoid, or elongated transversely; and the subanal space may be high or low in the same variety of the species; but in all, the ornamentation of the subanal space is very distinct, and consists of miliaries and a few very small tubercles.

The peristome has the posterior lip edged with a ridge of plain ornament; and behind this are rows of small miliaries succeeded by larger ones whose numbers become less and less. The posterior lip is bent downwards; and the anterior and lateral parts of the peristome pass upwards into the funnel-shaped cavity, which is semilunar transversely.

The floscelle is tolerably well developed; and the pores are distinct and belong to all the ambulacra, the anterior odd ambulacrum being nearly destitute of them; but it presents two pores on either side and the relics of the sphæridial space. A very beautiful ornamentation is seen around the floscelle, in front especially; and it includes that of the larger first polygonal peristomial plate (interradial). This is slightly convex and has pretty miliaries on it. Distinct but small tubercles with flat scrobicules are in and around the floscelle; and the pores represent an absent boss which is replaced by the slit.

The ornamentation of the plastron (actinal) is very beautiful (Pl. IV. fig. 7). There is a triangular space in front of the transverse part of the subanal fasciole which has a slight median and central projection covered with small tubercles; and all around it the tubercles radiate, becoming large and having definite scrobicular circles and flat scrobicules until the edge of the space is reached. This ornamentation is restricted to parts of the second posterior interradial peristomial plates, and partly to the third on either side, they being crossed by the fasciole. The first plate is faintly marked with transverse ridges and distant miliaries.

The ambulacral plates on either side of these plates are narrow; and their ornamentation is composed of distant miliaries.

Finally, the shagreen appearance of the whole test, caused by the minute granular tuberculation, is remarkable.

The localities whence *Lovenia Forbesi* and the varieties *Woodsi* and *minor* have been obtained are numerous. Thus the Murray cliffs have yielded the first two forms, Mount Gambier and the Hamilton Tertiaries and the Mordialloc sections No. 1, 2, 3, and 4 the same, the last yielding also the var. *minor*.

Genus Schizaster, Agassiz.

A large specimen, partly in the form of a cast, but with the details very well preserved, came from the "Adelaide district." It belongs to this genus; and from its resemblance to *Schizaster ventricosus* I am disposed to give it that specific name.

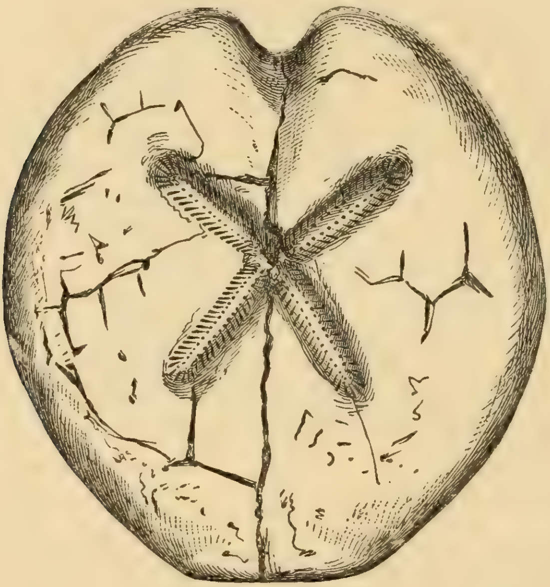
Schizaster ventricosus, Gray, Cat. of Echinida, p. 60.

Dr. Gray obtained his specimen from Australia; but the species is more common to the north and east, in Siam, the Philippines, and the Fijis.

Genus Megalaster, gen. nov.

The test is elliptical in outline, deeply incurved anteriorly and slightly truncate posteriorly. It is long, broad, but depressed; very flat inferiorly, and sloping sharply from the ambitus upwards. The apical system is in advance of the centre, and the test slopes on all sides from it; it is small in relation to the dimensions of the test, and there appear to be four small generative pores. The ambulacra are closed, petaloid, deep, and small for the size of the test. The anterior ambulacrum is aborted, and the anterior groove is broad and very deep at the ambitus. The other ambulacral petals, which are closed externally, are very deep and slightly flexuous, and the anterior pair diverge more than the posterior. The periproct is large, elliptical, transverse, and situated above the margin in a small truncation. The mouth is large, transverse, and placed close to the notch of the anterior ambulacrum. The posterior lip is sharp and slightly projecting. The tuberculation is very small. Fascioles are not apparent.

Fig. 1.—*Megalaster compressus,* abactinal surface, one half the natural size.



Megalaster compressus, sp. nov. (woodcut, fig. 1).

The test is comparatively flat; and there is a marked depression behind the abactinal area and between the posterior pair of ambulacra. The antero-lateral ambulacra are slightly longer than the posterior, and in both sets the pores are very small near the apical system. The poriferous zones have the external pores elongate, and very few pores exist beyond the petals. The ocular pores are nearly as large as the generative.

Length of test $4\frac{3}{4}$ inches, breadth $4\frac{1}{2}$ inches, height 2 inches.

Locality.—Banks of the Murray.

IV. *The Genera of Echinodermata of the Australian Tertiary and Recent Faunas.*

Suborders and Families.	Tertiary Genera.	Recent Genera.
DESMOSTICHA.		
Cidaridæ	*Leiocidaris.*	*Phyllacanthus.* *Goniocidaris.* *Stephanocidaris.*
Diadematidæ		*Centrostephanus.* *Echinometra.* *Strongylocentrotus.* *Sphærechinus.*

Suborders and Families.	Tertiary Genera.	Recent Genera.
ECHINIDÆ	*Psammechinus.* *Paradoxechinus.* *Temnechinus.*	*Microcyphus.* *Salmacis.* *Amblypneustes.* *Holopneustes.* *Echinus.* *Euechinus.*
CLYPEASTRIDÆ. EUCLYPEASTRIDAE	*Echinanthus.*	*Fibularia.* *Echinanthus.* *Laganum.* *Peronella.*
SCUTELLIDÆ	*Echinarachnius.* *Arachnoides.*	*Arachnoides.*
PETALOSTICHA. NUCLEOLIDÆ	*Echinolampas.* *Rhynchopygus.* *Echinobrissus.* *Pygorhynchus.* *Catopygus.*	*Echinobrissus*
SPATANGIDÆ	*Holaster.* *Maretia.* *Eupatagus.* *Lovenia.* *Micraster.* *Megalaster.* *Schizaster.*	*Eupatagus.* *Lovenia.* *Echinocardium.* *Breynia.* *Metalia.* *Schizaster.* *Linthia.*

V. *Lists of Specific Alliances.*

List of Species common to the Cainozoic (Tertiary) and Recent Australian Faunas.

Echinanthus testudinarius, Gray.
Echinarachnius parma, Gray.
Schizaster ventricosus, Gray.

Alliances of the Cainozoic Australian Echinodermal fauna to the Recent fauna of Australia and neighbouring seas.

	Allied to
Arachnoides Loveni .... " *australiæ* ..	*Arachnoides placenta.* Australia and New Zealand.
Echinobrissus australiæ.	*Echinobrissus recens.* New Zealand.
Echinolampas ovulum ..	*Echinolampas oviformis.* Red Sea, Moluccas.
Maretia anomala	*Maretia planulata.* East-Indian Islands.
Eupatagus Laubei	*Eupatagus Valenciennesi.* Australia.
Lovenia Forbesi	*Lovenia elongata.* Australia.
Leiocidaris australiæ ..	*Dorocidaris papillata.* Worldwide.
Psammechinus Woodsi.	*Echinus magellanicus.* South America and New Zealand.

Species of the Australian Cainozoic fauna with decided affinities to European and Asiatic Cretaceous species.

	Allied to
Leiocidaris australiæ	*Cidaris Forchhammeri.*
Rhynchopygus dysasteroides	Several forms from the Gault.
Echinobrissus australiæ ..	Cretaceous Nucleolites.
Catopygus elegans	*Catopygus* of South-Indian Cretaceous.'
Holaster australiæ	Holasters of South India and Caucasus.
Micraster brevistella	Cretaceous Micrasters.
Megalaster compressus	Cretaceous Cardiasters of South India.

Species of the Australian Cainozoic fauna with affinities to the Nummulitic faunas of Europe and India.

Temnechinus lineatus.
Pygorhynchus Vassali (and in Miocene of Malta).
Eupatagus rotundus.
Lovenia Forbesi.

VI. *Remarks on the Species.*

LEIOCIDARIS AUSTRALIÆ, sp. nov.

This form has conjugate pores in the poriferous zone, and therefore is separable from its fellow and equally doubtful subgenus *Dorocidaris* of the genus *Cidaris*. These two divisions of *Cidaris*, however, are very useful. It is interesting to find the form in the Australian Tertiaries, especially when the necessity of recognizing the genus *Phyllacanthus* as almost a synonym of *Leiocidaris* brings the Australian species *P. annulifer, P. dubius, P. imperialis*, and *P. verticillatus* into relation with it. The alliance is strongest with *Phyllacanthus dubius*, Brandt. This group of genera or subgenera has no species in the recent fauna to the south of Australia, or in the New-Zealand seas, and it belongs rather to the area of the warmer littoral tracts to the north, north-east, and west. The resemblance of the fossil form to the Cidaridæ of Malta, especially to *C. Adamsi*, Wright, is rather remote; but, taken in connexion with the resemblances of many of the other fossil Echini of the Australian area to the Maltese, it is significant of a singular homotaxis. This species is not without some resemblance to *Cidaris Forchhammeri*, Desor, from the Upper Chalk (Danien) of France.

PSAMMECHINUS WOODSI, Laube.

This species has been noticed by Mr. Etheridge, who has given a figure of its abactinal area in his "Australian Tertiary Echinoderms" (Quart. Journ. Geol. Soc. vol. xxxi. pl. xxi. fig. 10), and has thus added to Laube's descriptions and figures (*op. cit.* p. 185 and figs. 1, 1*a*, 1*b*). Laube notices its resemblance to *Psammechinus monilis*, Defr. (Falunian), and that Forbes considers this last to be a living Mediterranean form. The species is very like *Echinus macrotuberculatus*, Blainv., of the Mediterranean and Cape-Verd Islands; and A. Agassiz (*op. cit.* p. 492) notices the resemblance of this to the recent *Echinus magellanicus* of New Zealand and South America. Moreover the affinity of *P. Woodsi* to *Echinus angulosus*, Agassiz (*op. cit.* p. 489), is very close. This last is an *Echinus* not to be distinguished from *Psammechinus*, and is found in the seas of the Cape of Good Hope, Mauritius, Red Sea, Philippines, and New Zealand.

The distinction of *Echinus* proper and *Psammechinus* is not even properly subgeneric (see A. Agassiz, *op. cit.* p. 490); and this has been felt by nearly every student of the Echinodermata, from Forbes to the present time, whenever the recent and fossil *Echini* have formed part of the same course of study. The affinities of this *Psammechinus* with small tubercles are with its congeners *Echinus angulosus* and *E. magellanicus*.

PARADOXECHINUS NOVUS, Laube.

This I believe to be a badly grown *Temnechinus* allied to *T. lineatus*, nobis, from the Australian Tertiaries.

TEMNECHINUS LINEATUS, nobis.

This genus, so familiar to British palæontologists, as being found represented by species in our Tertiaries, has lasted to Recent times, and one species occurs in the Australian Cainozoic deposits. *Temnechinus maculatus*, formerly *Goniocidaris maculatus*, A. Agassiz, is found at from 30 to 100 fathoms in the American seas, and is not without its affinities with the Australian fossil. These are generic only; but the changes which occur in the ornamentation of this living species during its growth are sufficient to explain the impossibility of making accurate and arbitrary diagnoses. A. Agassiz notices the presence of *Temnechinus* in the Nummulitic of Scinde, under the guise of *Temnopleurus* or *Opechinus*. The affinities of this Australian form are therefore remotely with the Nummulitic forms to the north, and with the recent species in the Atlantic and the Crag forms.

ECHINARACHNIUS PARMA, Gray.

This ubiquitous species belongs to the recent faunas of both sides of the North-American area, and is found to the north of China and in the Australian seas. This vast horizontal range is in keeping with the fact of its being found in these Australian Cainozoic deposits; so that the form has no inconsiderable age.

The other recent species are from California, Kamtschatka, and Japan. There is a fossil *Echinarachnius* which was collected by Mr. C. Darwin in the Tertiary deposits of Port St. Julien, Patagonia. It was described by Desor, and named by him *E. juliensis*. The periproct, in this instance, he states, is inframarginal and not marginal; and the shape is discoid and flat like that of *E. parma*. The position of the anus depends on the stage of growth, and is not a specific distinction; and therefore it is as well to absorb Desor's species. Nevertheless the fact of the discovery in Patagonia is exceedingly interesting.

ECHINANTHUS TESTUDINARIUS, Gray.

This species is also found in the recent fauna of the Red Sea, Borneo, Australia, Sandwich Islands, Japan, and California. The fossil specimen is large and very Clypeastroid in appearance. It is impossible to ascertain the fossil alliances, as the genus which is so well defined in the Recent fauna admits of half a dozen well-marked genera in the fossil faunas.

ARACHNOIDES LOVENI, nobis.

This Cainozoic species is distinct from the recent forms *A. placenta* and *A. zelandiæ* described by Gray; for it has deeper incisions at the ambitus in the ambulacral areas, and there is some variation regarding the position of the periproct. This is not always supramarginal, but may be marginal and even inframarginal, all the other attributes of the species being present. The other species I have described, *Arachnoides elongatus*, links on the form described by Laube as a *Monostychia*, which I believe to be a true species of this genus *Arachnoides*.

ECHINOLAMPAS OVULUM, Laube.

This species is distinct from the modern *Echinolampas oviformis*, Gray, which is found in the Red Sea and Molucca seas. The genus has other recent species in the Florida sea and off the west coast of Africa. The fossil forms are principally Nummulitic in age; but some are found in the other Tertiaries. The Hala range yields several species; and thus *Echinolampas* was very much in its proper area when it was living in the old Australian seas. Like most other forms with a great vertical range, it has a large horizontal one.

RHYNCHOPYGUS DYSASTEROIDES, nobis.

This species has some very remarkable secondary peculiarities which resemble in their curious nature the many Australian oddities of structure of forms of genera of worldwide distribution. The form has all the generic peculiarities of *Rhynchopygus*; but its generative pairs of pores are widely apart. It has an elongated apical system; and this Dysasterian peculiarity recalls the genera *Hyboclypus* and *Holectypus*. The genus has a wide range in time, for it is represented in strata belonging to the Gault; and in space, for the recent forms are found in the Atlantic and Pacific seas of America.

ECHINOBRISSUS AUSTRALIÆ, nobis.

This species is known at once by the elliptical outline of the ambitus, the faintly projecting ambulacra, and the small size of the tuberculation. It differs from *Echinobrissus recens*, Edw. (called usually *Nucleolites recens*), a recent species from Madagascar and New Zealand; for this has longer petals, round pores, flush ambulacra, a longitudinally elliptical anal furrow with a posterior edge nearly on a level with the edge of the test, and a large tuberculation. It is distinguished from *Echinobrisssus* (*Nucleolites*) *epigonus*, Mart., of the seas washing the East-India Islands, in which the actinosome is elongated longitudinally. Both of these recent forms, however, are closely allied to the Australian fossil species. There is a fossil species of this genus called *Nucleolites papillosus*, Zitt., from the Tertiary beds of the Waikato river in New Zealand; but it is distinct from the Australian species (Zittel, Foss. Moll. und Echinod. aus Neuseeland, p. 62).

The old genus *Nucleolites* contained many forms which rendered its being broken up into others necessary; but the writings of Wright, Desor, and A. Agassiz show how unsatisfactory the present and the past classifications have been. The genus was formerly considered to belong to the Secondary ages of the world's history;

but the recent species mentioned above are good forms, and are linked on to those of the Cretaceous rocks and Oolites by the Australian and New-Zealand species. It is this species, taken with the *Holaster* and *Micraster* of the fauna and the Dysasteroid arrangement in *Rhynchopygus*, that gives the Cretaceous facies to part of the Echinodermal fauna of the Australian Cainozoic strata.

PYGORHYNCHUS VASSALI, Wright.

This species is figured by Dr. Wright in his essay on the Maltese Echinoderms (Quart. Journ. Geol. Soc. vol. xx. pl. xxii. fig. 6); and the Australian form cannot be distinguished from it. The periproct is longitudinal in the specimens from both localities; and there is no floscelle. The genus is essentially Tertiary; but Forbes described one which is probably a *Cassidulus* from the Indian Cretaceous beds. Its species are numerous, and have been found in the Eocene of France and Biarritz, in the Miocene of Corsica and Malta, in the Eocene of Georgia, and in the Miocene of Jamaica. It is not represented in the Recent faunas.

CATOPYGUS ELEGANS, Laube (*op. cit.* p. 190).

This species has a concave actinal surface and a kind of plastron on the same surface posteriorly. These are unusual; and the shape is like that of *Pygorhynchus*. The figure given by Laube resembles a *Catopygus*. This genus, so Cretaceous in Europe, thus appears to have lived in the Australian seas during the Miocene age and to have become extinct, unless it merged into *Pygorhynchus*, its near ally in structure. Its nearest ally in point of resemblance and locality is *Catopygus sulcatellus*, Stoliczka (Cret. Echin. of Southern India, p. 26).

HOLASTER AUSTRALIÆ, nobis.

This most interesting form has of course the Dysasterian genital arrangement; and the pairs of pores are rather remote. The anterior furrow is very slightly marked at the ambitus, and is lost inferiorly. The test is rather pointed posteriorly. Hence the species is, as it were, between *Holaster caudatus* and *H. indicus*—the former from the Lower Cretaceous of the Caucasus, and the latter from the Upper or Middle Cretaceous of Southern India. The genus has not previously been found in Tertiary deposits.

MARETIA ANOMALA, nobis, is a very fine form of this Spatangoid genus, and is in every respect but one like *Maretia planulata*, Gray, of the China seas, West-Indian Islands, and Mauritius; it has, in addition to the usual shape and ornamental characters, an extremely delicate and threadlike fasciole just above the ambitus. It is apparently not continuous, and is a lateral one. So small is it that I doubt the propriety of placing the form so closely resembling *Maretia* in all other peculiarities in another genus. The genus is essentialy a Recent one, and is closely allied to the Tertiary Spatangoids.

EUPATAGUS ROTUNDUS, nobis.

The genus *Eupatagus* has four well-marked distinct species in the Australian deposits; and there is a Recent form, *Eupatagus Valenciennesi*, Agassiz, in the Australian seas. Two of the species are described in this communication; and the others are to be found in Laube's essay (*op. cit.* p. 195). *Eupatagus rotundus*, mihi, is an exceedingly beautiful species and is a large form. *E. Laubei* is smaller, and with its small tubercles, petals of equal size, and the forward peristome is distinguished from all others. The genus is well represented in the Eocene, especially in the French and Indian Nummulitic. It occurs in the European Mid Tertiaries also.

Lovenia Forbesi, syn. *Hemipatagus Forbesi*, Woods and Duncan.

The beautiful fossils from Mordialloc (which have all their ornamentation perfect) prove that *Hemipatagus* is really a form of *Lovenia*. There is an internal fasciole and a subanal one also. The descriptions in the part of this paper which refers to the species are so full that it is not necessary to recapitulate here. The genus *Lovenia* (*Hemipatagus* included) is of some antiquity, as species have been found in the Nummulitic of North Africa, the Crimea, and Sinai, in the Miocene of Corsica, and of the Bavarian Alps. It is found in the Pliocene of Java and in the Cainozoic deposits of New Zealand. It is, as *Lovenia*, a Recent genus of great beauty; and there are three species—one from the gulf of California, one from China, Japan, and the Sandwich Islands, and a third from the Red Sea, the Philippines, and the Australian coast.

A great *Schizaster* is found in the Adelaide Tertiaries, and it is undistinguishable from *Schizaster ventricosus* of the Australian fauna.

The *Micraster* noticed by Laube and Etheridge is not unlike some European forms, and has a most Cretaceous appearance; but in a specimen in the British Museum there are faint indications of a lateral fasciole.

The new genus *Megalaster* is represented by one species; it recalls the Cardiasters, but there are generic differences in the relative size of the pores of the poriferous zones, and in the absence of fascioles in the new form. Nevertheless the position of the mouth and the general shape recall the Cardiasters described by Stoliczka in his monograph on the Echinodermata of the Cretaceous deposits of Southern India. The size of the species is great, and perhaps is only surpassed by *Plagionotus* at the present day. It is probably an extinct form, and was a remnant of the Cretaceous fauna which died out in the Miocene.

VII. *Conclusions.*

It will have been noticed from the description of the species, and from the summary just given of their peculiarities and alliances, that the Australian Cainozoic Echini are remarkable as a fauna. A portion of the assemblage looks very recent; another appears as if it had been selected from distant recent faunas; and a third has an evident affinity to that of the present Australian seas. Then the presence of such genera as *Temnechinus*, *Echinolampas*, *Pygo-*

rhynchus, and *Eupatagus* gives a Nummulitic-of-Europe-and-India facies to the fauna, whilst the Cretaceous aspect is presented by *Catopygus, Holaster, Micraster*, and the *Rhynchopygus* with the Ananchytic-looking apex.

It is evident that this Cainozoic fauna contains the elements of two previous ones, and that it foreshadowed a part of the recent Australian, whilst some of its species, with some modifications, resemble those of the neighbouring seas. The general facies of the whole is older than is warranted by the geological position.

Nearly all the genera are peculiar from their great vertical or horizontal range, the exceptions being in the cases of *Arachnoides* and *Maretia*. Two of the three species which are common to the Cainozoic and Recent faunas have a wide distribution in the Pacific, and one also in the Atlantic. Four of the species which resemble recent Australian forms to a certain extent are very characteristic. They are *Leiocidaris australiæ*, *Arachnoides Loveni, Eupatagus Laubei*, and *Lovenia* (*Hemipatagus*) *Forbesi*. They give the so-called Miocene facies, which, however, is sufficiently indefinite. This appearance is added to by the other species belonging to genera still existing in the neighbouring seas, the scattering of forms having been from South Australia to the east and especially to the north.

Of 25 genera belonging to the recent Australian fauna only 7 are represented in the Australian Cainozoic deposits—namely, *Arachnoides*, *Echinobrissus, Eupatagus*, *Lovenia, Schizaster, Echinanthus*, and *Echinarachnius*. The most truly Australioid genera, and those which give the facies to the recent fauna, are not found in the deposits; for no species have been discovered of *Strongylocentrotus*, *Microcyphus, Salmacis, Amblypneustes*, and *Holopneustes*. These Echinoidea were not then on the area; and their place was occupied by numerous Spatangoids, most of which foreshadowed those of the Recent fauna; and these, from their range, are not very characteristic of it.

The spines which were found, but not associated with their tests, resemble those of some recent Australian genera, such as *Phyllacanthus*, *Goniocidaris*, *Stephanocidaris* and *Brissus*: the nature of the spines of *Leiocidaris australiæ* from the Cainozoic is unknown. It is not safe to argue from such resemblances concerning specific or even generic relationships; but nevertheless the presence of the spines should be an incentive to the further search for Cidaridæ.

It is interesting to find the fossil Echini affording the same evidences as the fossil corals respecting the affinities of the Cainozoic and recent Australian faunas. Of the 31 species of corals not one has yet been found in the recent coral fauna; and out of 20 recent Australian coral genera, only three very worldwide ones are represented in the Cainozoic deposits.

It was remarked in the essay on the fossil corals that they appeared to have a facies of the fauna of the seas to the north of extratropical Australia; and this holds good for the Echini. The inference that there was then a warmer climate in the southern districts and seas close by was deduced from the examination of the shells by Mr. Jenkins ("Austr. Tert. Corals," Quart. Journ. Geol. Soc. 1870, p. 318); and the vegetation of the lignites which are at the base of the Cainozoic series is stated by Müller and Etheridge to indicate a more tropical climate than the present. The proof of the former extension of the coral isotherm to the south of the area of these Cainozoic deposits has been afforded by the presence of reef-building fossil corals in the corresponding deposits of Tasmania; and thus the existence of former warmer climates and warmer sea-tracts receives confirmatory evidence *.

The geology of these Australian deposits was sufficiently described from the elaborate surveys of the Victorian geologists in the essay on the fossil Madreporaria; and it is therefore not necessary to reintroduce the subject. But it is advisable to remember that very considerable physical changes have occurred since the deposition of the strata containing the Madreporarian and Echinodermal faunas, although some of the fossils are so very recent-looking. A vast outflow of basalt covered these Lower Cainozoics; and an upheaval took place of the coast-line of some hundreds of feet. Then the upper or gold-drifts collected on the basalt or on the strata where uncovered, they being the results of subaerial denudation. A second basaltic outflow covered these; and the final elevation of the coast-line followed, the marine Cainozoics being found up to 600 feet. Since then the rivers have cut valleys through these deposits, and the alluvium has collected in which and in contemporaneous caves the remarkable fossil Marsupial fauna has been preserved—a relic of the remote past foreshadowing the present fauna. Since then the climate has changed, and the coral isotherm is now many degrees to the north; and probably since the lifetime of the Echini which form the subject of this essay, the worldwide elevations and subsidences which terminated the Miocene have occurred.

EXPLANATION OF THE PLATES.

Plate III.

Fig. 1. *Cidaris* (*Leiocidaris*) *australiæ*, sp. n., fragment, showing half an ambulacrum, natural size.
2. Part of the same, enlarged, showing an interambulacral plate, and half the corresponding part of the ambulacrum.
3. *Temnechinus lineatus*, sp. n., side view, natural size.
4. The same, abactinal surface, wanting the apical system, natural size.
5. Portion of the same, enlarged.
6. *Arachnoides Loveni*, sp. n., abactinal surface, natural size.
7. The same, an ambulacrum, three times natural size.
8. *Arachnoides elongatus*, sp. n., side view of test, natural size.
9. *Rhynchopygus dysasteroides*, sp. n., side view of test, natural size.
10. The same, apical system, enlarged.
11. *Echinobrissus australiæ*, sp. n., abactinal surface, natural size.
12. *Holaster australiæ*, sp. n., side view of test, natural size.

* P. M. Duncan, Quart. Journ. Geol. Soc. vol. xxxii. p. 345.

13. The same, apical system, enlarged.
14. *Eupatagus rotundus*, sp. n., side view of test, natural size.
15. The same, apical system and fasciole, natural size.
16. The same, actinal surface, showing peristome and floscelle, natural size. *a*, a tubercle, enlarged.
17. The same, periproct and subanal fasciole, natural size.
18. *Eupatagus Laubei*, sp. n., apical system and fascioles, twice natural size.

PLATE IV.

Fig. 1. *Maretia anomala*, sp. n., abactinal surface, natural size.
2. The same, actinal surface.
3. Boss of a tubercle of the same, from above, enlarged.
4. The same, side view.
5. *Lovenia Forbesi*, Woods and Duncan, from above, natural size.
6. The same, periproct and subanal fasciole, twice natural size.
7. Plastron of the same, three times natural size.
8. Abactinal surface of the same, about four times natural size.

DISCUSSION.

Mr. EVANS was glad to find that this subject, concerning which he had lately expressed his own views, had been taken up by the author; but he thought it possible that Dr. Duncan would, on further consideration, be inclined to modify somewhat the theory promulgated in this paper in favour of some other view. In order to account for the occurrence of reef-building corals of Miocene age in latitudes now too cold for them, the author had reverted to the old idea of the vertical position of the poles. If the interior of the earth is fluid, a sliding crust, such as the speaker had formerly suggested, is possible, though it would be difficult to prove the existence of a fluid interior, and still more difficult, did that exist, to prove that the crust would slide on it. But even supposing the earth to be a nearly solid body, elevations and depressions enough must take place on the surface to alter the relative positions of the poles with regard to the surface of the earth. Because there were proofs of warmer climate having existed in Miocene times in Greenland, near the one pole, and in New Zealand near the other, there was no need to suppose that belts of warmer temperature had extended nearer the poles than at present; for the same sliding of the crust that brought Greenland nearer the equator would also bring New Zealand nearer the tropics, both being on nearly the same meridian, but on opposite sides of the globe. The subject was one that deserved the attention of geologists, as it lay at the root of many important questions affecting the past history of the earth.

Professor HUGHES believed implicitly what the astronomers told him *must* be; and if observations on the distribution of life necessitated any thing more than such alterations of climate as could be accounted for by geographical changes and modification and adaptability in the forms of life, he would prefer to leave it as one of the many things he could not explain, than accept an explanation inconsistent with accepted astronomical theories. If, as explained by Sir John Herschel, the transference of large masses from one part of the earth's surface to another would disturb the equilibrium, we must remember that this action would be mostly compensative; and if the cumulative effect of many such disturbances might be a partial readjustment of the mass, we must regard such movements only as a tendency to keep the whole mass and its axis of rotation as it was in spite of the transference of portions from one place to another by denudation. Moreover he disputed the data on which the views advocated by both the present and the late President were founded. He asked whether we should say that the climate of the period of our older river-gravels was that of Egypt or of Northern Siberia, seeing that the *Corbicula fluminalis* and *Unio littoralis* were now found only much further south; while the hairy elephant and reindeer, which had once lived with them, were now held to prove an arctic climate. When we know that flowering plants and evergreens now live in Alpine regions, where they are buried in total darkness under snow for four months, shall we say that the absence of light would render it impossible for evergreens and flowers to have flourished where the arctic winter-night is four months long, even though we could account for a milder climate by geographical changes?

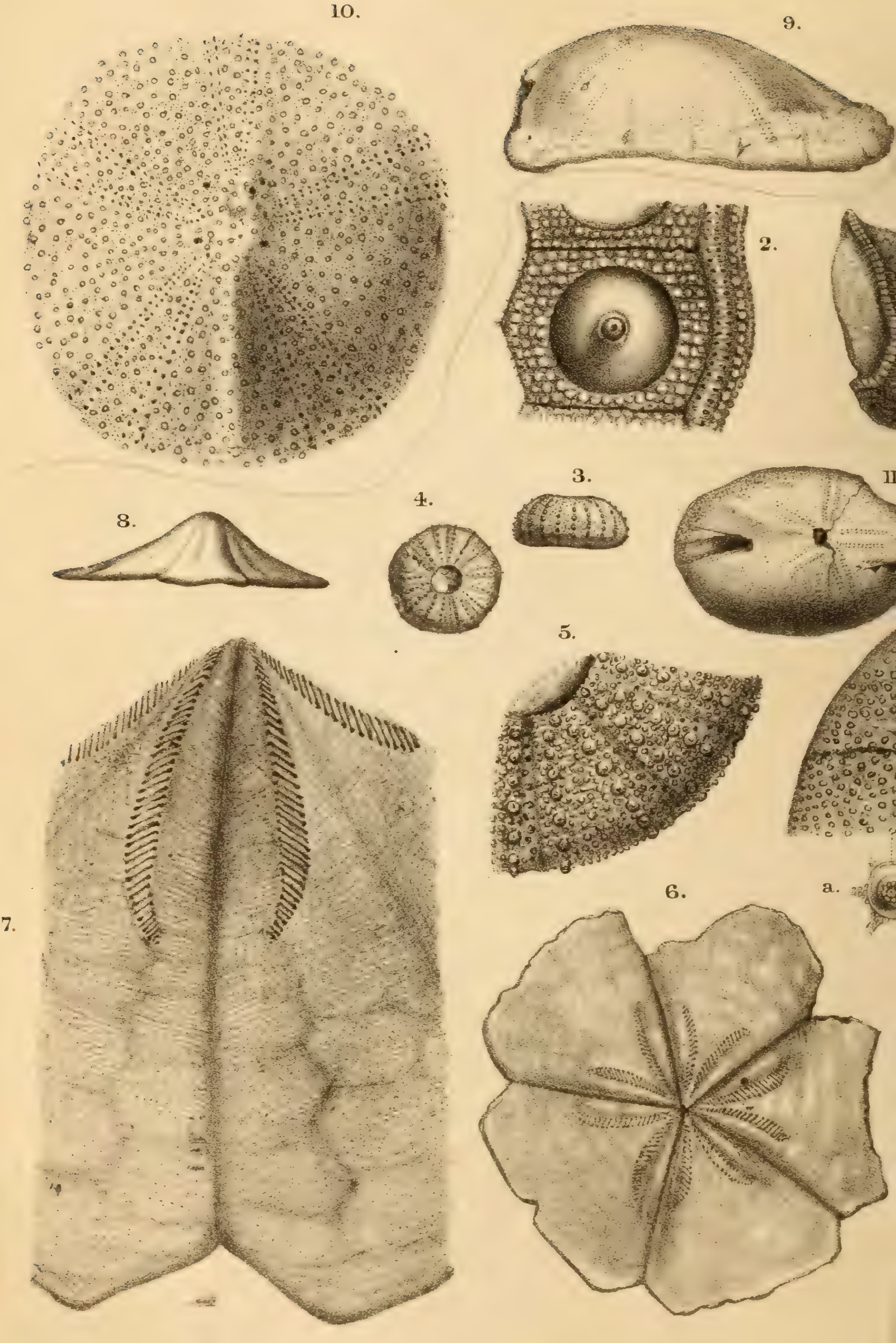
Mr. Woodward remarked that as it was not merely a question of *one* fauna and flora, Mr. Hughes's statements must be received with caution. There were evidences in northern latitudes, not only of a Miocene, but also a Carboniferous, a Jurassic, and Cretaceous flora. Nor was it a question merely of lowly organized plants which would be more likely to withstand the climate; for Prof. Nordenskiöld had found tree-trunks standing erect in the soil in which they grew; and it was impossible for them to have grown in a climate so rigorous as now exists at that latitude. If the geologists are wrong in the conclusions they have drawn from these facts, let the astronomers show them how to account for the occurrence of fossils indicative of such a warm climate in such high northern latitudes; for the absence of cold must be accounted for to explain the growth of these trees in that spot.

Prof. Ansted maintained that the geologists had certain natural-history facts on their side with regard to the occurrence of fossils near the poles; it remained, therefore, for the astronomers and physicists to find a new theory to account for these facts.

Prof. Green thought that the astronomers should be asked if the change of axis was a possible explanation, and to calculate what would be the result of a change in the distribution of land and sea, and how such a change would affect the position of the poles. The question was one of mechanics.

Mr. Sorby considered that the amount of heat and light received from the sun should also be taken into account, and the fact that this may have varied at different periods.

Sir Antonio Brady stated that there were many facts which tended to prove that the sun had varied in heat &c. But the sun had probably little to do with the warmer climate of the poles in past ages. The heat of the earth in its various stages of cooling



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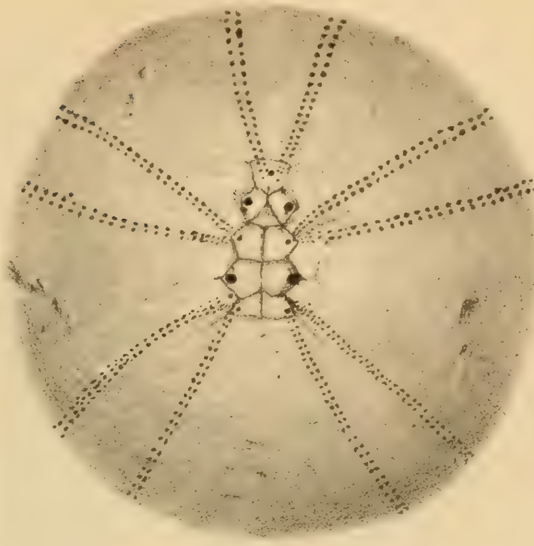

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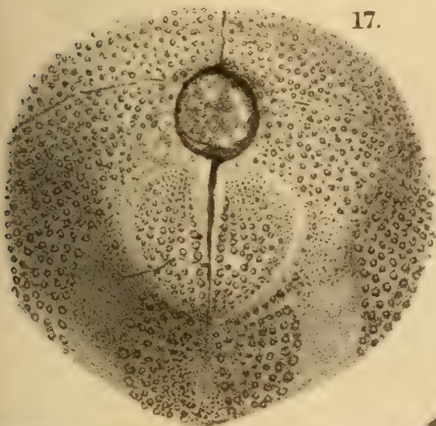

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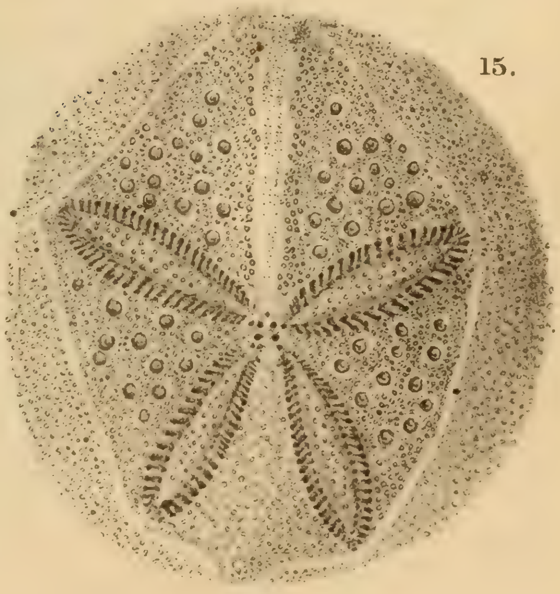

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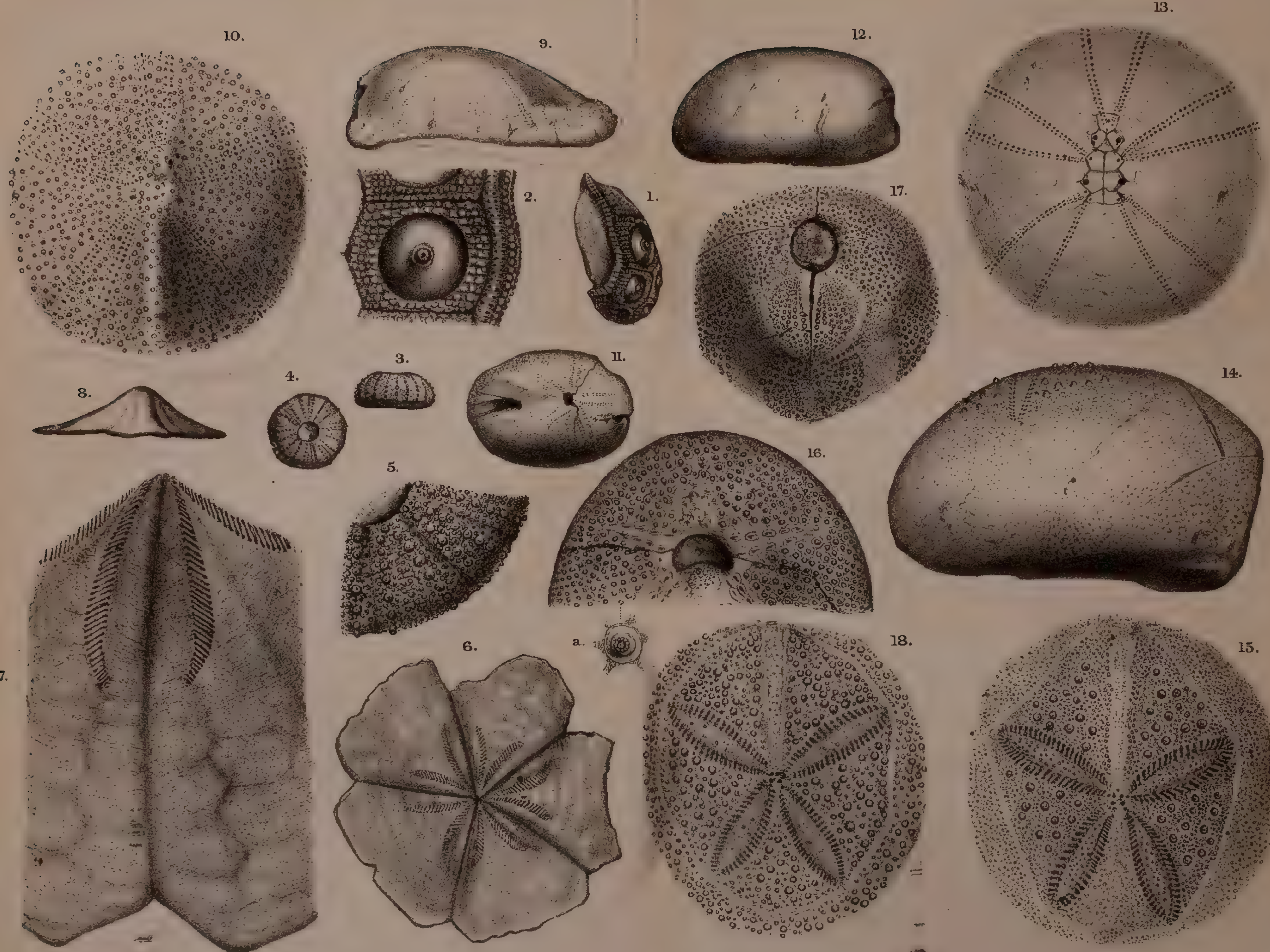

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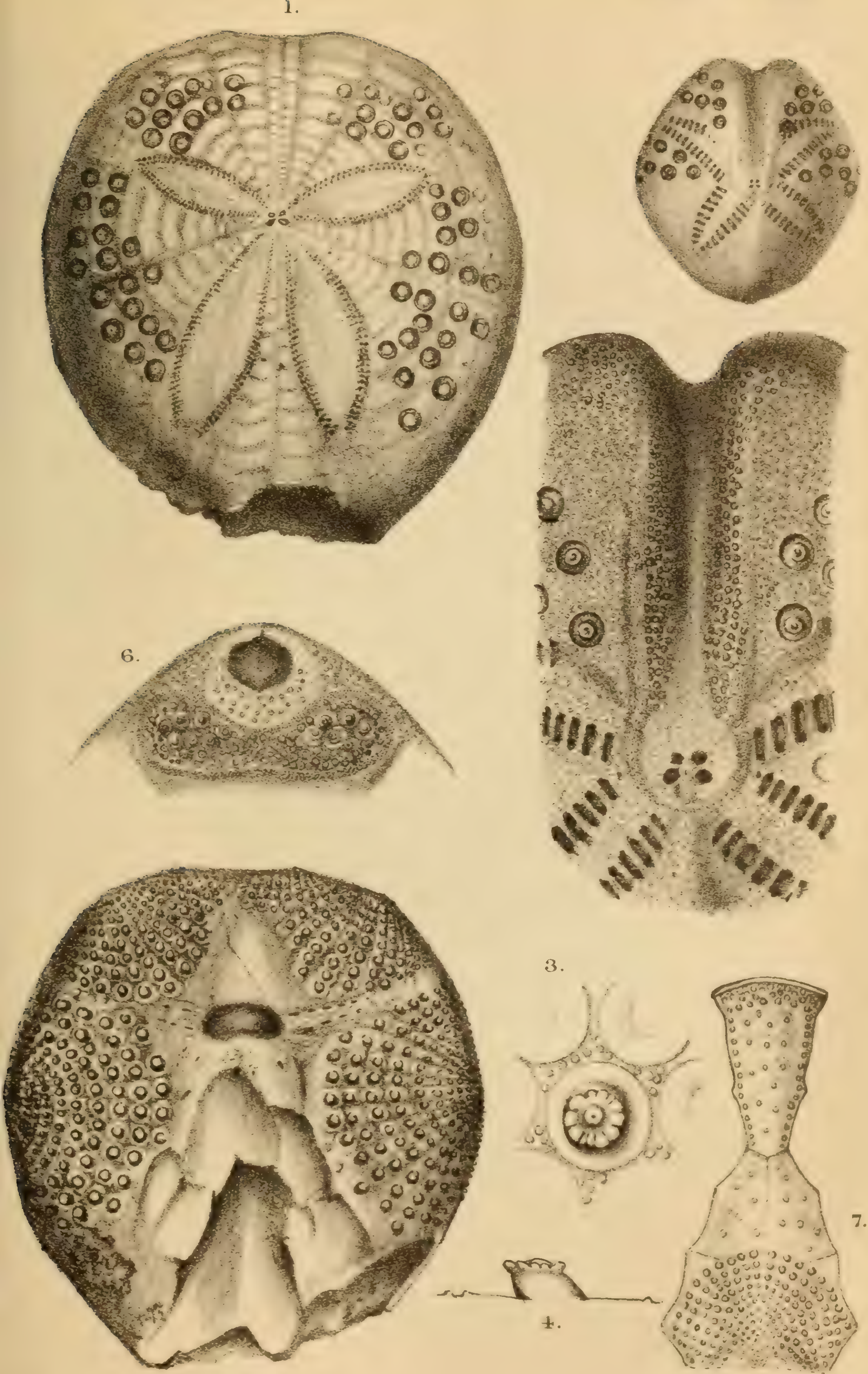

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AUSTRALIAN CAINOZOIC ECHINODERMS

would be sufficient to account for these changes of climate on the surface of the globe.

Prof. Ramsay could not agree with the last speaker in thinking that radiation in cooling would produce any palpable effect on the surface of the globe. So far from there being any proof that the climate had been gradually growing colder from the earliest times down to the present date, there was every evidence to show that glacial periods had recurred at different periods in past time. Dr. Duncan and Mr. Evans had merely given suggestions, but had not solved the problem and proved that the poles did not occupy the same position in Miocene times that they do today. Darwin and Dana were both agreed in thinking the present continents to be of extreme antiquity. Great elevations of land had taken place prior to the Miocene epoch. The Alps and the Himalayas were both pre-Miocene, and were probably higher in pre-Miocene times than at present, having been subjected to great denudation.

Mr. Gwyn Jeffreys pointed out that certain species of shallow-water mollusca now found in the Arctic Ocean had formerly in post-Tertiary times lived as far south as Sicily.

Dr. Wright remarked that there was a wonderful similarity between the Miocene echinoderms from Australia and those found at Malta.

Prof. Morris considered the abundance of Echinoderms belonging to the Spatangoid group in these Australian beds to be very interesting. The feature presents itself in the New-Zealand Tertiaries, where forms allied to *Arachnoides* occur. The distribution of these Echinoderms in New Zealand was excessively complex and difficult to understand. There was a remarkable similarity between the Miocene floras of Greenland and Central Europe; and the question to be asked was, Did they spread over a continent formerly existing between these points, or had they emigrated from some one central spot?

Dr. Duncan, in reply, stated that it was only by the united investigations of all students of geology that the question could be in any way settled. The belief in the recurrence of glacial epochs was founded on some erroneous conclusions drawn from beds in South Africa, which were really nothing more than a volcanic dyke, and from some deposits in India at the base of the Himalayas. The Miocene plants could not have existed without sufficient light, and therefore could not have extended so far north under conditions similar to the present. The Echinoderms did certainly present a striking resemblance to those found in the Miocene beds of Malta; but there were still sufficient specific differences to justify him in describing them as distinct.

5. Observations *on the* Later Tertiary Geology *of* East Anglia. By Searles V. Wood, Esq., jun., F.G.S., and Frederic W. Harmer, Esq., F.G.S.; *with a* Note by S. V. Wood, Esq., F.G.S., author of the 'Crag Mollusca,' *on some New Occurrences of* Species *of* Mollusca *in the* Crag *and Beds superior to it.* (Read November 8, 1876.)

Contents.

In writing the Introduction to the 'Supplement to the Crag Mollusca,' issued by the Palæontographical Society (for 1871), our object was, with the help of the Map and Sections accompanying it, to give only such a compressed or synoptical account of the researches on which we had for several years been engaged as would enable geologists to perceive the results at which we had arrived respecting the succession of the beds posterior to the Crag in the East of England. We considered that as the officers of the Geological Survey had commenced the examination of the district, and would eventually publish a detailed account of the sections and other evidence bearing upon that succession, we should have only encumbered scientific publications by bringing forward in greater detail the physical evidence which we had collected, and which had led us to the conclusions of which we thus gave a representation, the evidence of organic remains which we had collected being given by the author of the 'Crag Mollusca' in the tabular lists which accompany the Supplement to that work.

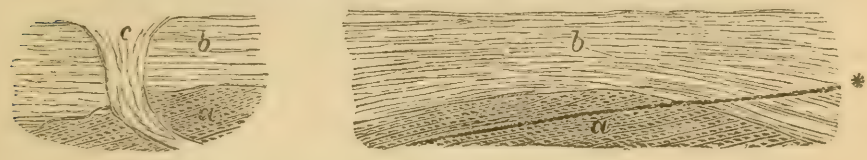
There are, however, some subjects referred to in that "Introduction" upon which we have made subsequent observations that we desire to bring forward; and there is one in particular upon which we touched only slightly, the break between the Lower and Middle Glacial deposits, which from its geological importance it is desirable should be shown in some detail, in order that while the officers of the Survey are engaged upon the district it may receive from them the scrutiny which it merits.

1. *The Unfossiliferous Sands of the Red Crag.*

The first subject on which we have to remark is that of the unfossiliferous sands overlying the Red Crag. These sands have long been a subject of perplexity to one of us; and in reference to them we observed, in the before-mentioned "Introduction" (p. viii), that "we did not think they represented the Chillesford sands, as they neither contained the Chillesford shell-bed, nor, though sometimes twenty feet thick, did they present any traces of the Chillesford Clay over them."

In some of the excavations for the extraction of phosphatic nodules (coprolites) these sands seem to pass down into the Red Crag by thin seams of comminuted shell; but in others they present an appearance which, in the case of other formations, would be regarded as clearly indicative of unconformity; for their stratification is wholly independent of the shelly crag beneath them, while the sands themselves often overlap and envelop the latter. In some instances (but these are the exception) they present the same oblique stratification which is possessed by the greater part of the shelly beds of the Red Crag. In others, such as that shown in section III. (page 81), detached and apparently disconnected portions of the shelly crag are imbedded in these sands, just as though they were transported masses imbedded while the sands were being accumulated.

Fig. 1.—*Section I., in a Coprolite-pit one mile and a half northwest of Waldringfield church.* (Scale 10 feet to the inch.)



a. Red Crag, unaltered and full of shells.
b. Red stratified sands, being *a* altered and restratified.
*. Seam of flint-pebbles.
c. Pipe filled with sand traversing both the altered and unaltered Crag.

The above section (I.) represents the usual way in which these sands overlie the shelly crag, so far as their stratification is concerned; but in that section another stratification occurs in a band of pebbles which, while conformable to that of the shelly crag where it is included in that material, cuts obliquely across the horizontal stratification of the unfossiliferous sands.

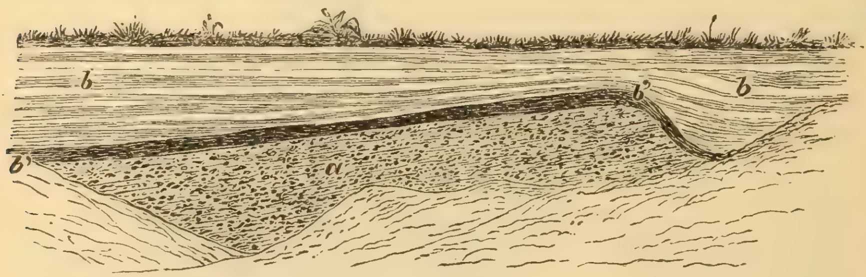
It has long been known, and it is mentioned by Mr. Prestwich in his paper on the Red Crag *, that these sands occasionally include ironstone casts of Crag shells. These we have found loose in them. Mr. Whitaker also, about two years ago, discovered in a pit three quarters of a mile N.E. of Kesgrave church, some bands of ironstone in these unfossiliferous sands which contained numerous and well-preserved impressions of Red-Crag shells, to which he called the attention of one of us, expressing his opinion that the sands in which these bands of ironstone occur had once been fossiliferous like the shelly crag, but had been deprived of their shells by the action of acidulated waters.

The difficulties in the way of that view appeared to us to be, that the line dividing the shelly crag from these sands was abrupt, no

* Quart. Journ. Geol. Soc. vol. xxvii. p. 330.

signs of any gradual disappearance of the shells by the abstracting agency being apparent, and also that the dividing line was very irregular, the shelly crag often rising in a boss or prominence (as in sections I. and II.). The unfossiliferous layers underlying in some cases detached portions of shelly material, as in section III., also presented a difficulty. In addition to these was the presence not merely of a separate and independent stratification, but the circumstance of bands of ferruginous loam at the base of the sands, sometimes, as in section II., enwrapping in an entirely unconformable way prominences of shelly crag.

Fig. 2.—*Section II., in a pit three furlongs east of Great Bealings church.* (Scale 10 feet to the inch.)



a and *b* as in fig. 1.
b'. Band of dark, partly indurated, ferruginous loam.

Notwithstanding these difficulties, however, we are inclined to think that the view expressed by Mr. Whitaker is correct; and we have been principally led to that conclusion by the detection of the band of pebbles shown in section I., which seems clearly to indicate that the original oblique stratification of the Crag once prevailed through these sands, and that the agent which abstracted the calcareous material was inoperative upon the pebble-band, which remained as part of the original stratification. If this view is correct, it is clear that in many, indeed in most, cases the material has been so far restratified in the process, that the present stratification of the sands is often as unconnected with the original stratification of the deposit as is cleavage or jointing in the cases of the old rocks.

In saying this, however, we would not be misunderstood as suggesting that there has been a rearrangment of the whole of the original material of the Crag, because, since the originally oblique bedding of the pebble-seam remains unaltered, it is evident that the arrangement of the sand particles among which this was imbedded cannot have changed, or the position of the pebble-seam would have changed with them. It is the argillaceous and ferruginous material taken up by the percolating water which has been redeposited, so as to form, in combination, the coloured threads and bands which give rise to this apparently new stratification.

It not unfrequently happens that the sands and the shelly Crag beneath are penetrated alike by sand-pipes, which cut through the stratification of the sands and the shelly Crag beneath, as shown in a detached portion of section I. It is obvious that the percolation producing this pipe must have been posterior to the abstraction of the calcareous material and restratification of the sands through which it passes ; and indeed the sharply distinct line of denudation which occurs between these seemingly stratified sands and the Middle Glacial gravel overlying them suggests that the abstraction of the shelly material and restratification of the sandy residuum preceded the deposit of this gravel.

If we rightly gather the view of Mr. Prestwich from the sections which accompany his paper already referred to, and from the remarks at (and following) page 333 of that paper, he regards these unfossiliferous sands as belonging to his upper or Chillesford division of the Red Crag ; but in this we do not agree, not merely for the reasons we have quoted from our "Introduction," but because the shells of which the ironstone casts have been preserved militate against that view. So far as we are aware, none of the shells characteristic of the newer (or Butley) portion of the Red Crag or of the Chillesford bed, such as *Scrobicularia piperata*, *Leda oblongoides, L. lanceolata, Nucula Cobboldiæ, Mya truncata &c.*, are indicated by these casts ; while, on the other hand, there occur among them numerous well-preserved impressions of such shells as *Cardium angustatum*, and the gigantic variety of *Mactra ovalis.* Now *Cardium angustatum* is an extinct form peculiarly characteristic of that portion of the Red Crag which remains unaltered beneath the sands containing these casts, and in which it abounds, and is unknown in the Chillesford bed, and, with the exception of a solitary specimen mentioned by Mr. A. Bell from Thorpe by Aldbro', is unknown also in the fluvio-marine crag. *Mactra ovalis* is common enough in the Chillesford bed, as it is also in Glacial and Postglacial beds ; but the gigantic variety of which impressions occur among these casts is peculiar to the Red Crag itself, and is unknown both in the Chillesford bed and the fluvio-marine crag. If therefore, Mr. Whitaker's view that these unfossiliferous sands represent what was once shelly crag be correct, that crag can, we think, have been none other than the same as that which still remains unchanged beneath such sands.

The uniform absence of the Chillesford Clay over the Red Crag, wherever this is exposed between the Butley creek and the Stour, and its replacement by the sands and gravels of Middle Glacial age, as exhibited in section III. (p. 81), show, when coupled with its presence to the south of the Stour at Walton Naze, that this clay suffered a considerable denudation before the deposit of those sands and gravels ; but, as we shall see in examining the evidences of the break between the Lower and Middle Glacial, the Chillesford Clay is not the only bed which was removed from this area between the close of the Crag and the deposition of the Middle Glacial ; for during this interval the Contorted Drift which once overspread the Red Crag has also been denuded from it, as outliers of that formation remaining in considerable thickness prove. Whether both the

Chillesford Clay and the Contorted Drift were removed by one and the same denudation, no evidence has as yet been found to determine, because none of the sections in these outliers of the Contorted Drift have been carried sufficiently deep to disclose it. The thickness of this Drift in one of the outliers, at Kesgrave, section XX. (page 104), would appear, from the well sunk below the bottom of the excavations made for brickmaking, to exceed 50 feet; but it is not unlikely that the lowest portion of this may be the Chillesford Clay, because, this Clay being equally a brick-earth with the Contorted Drift, there would be nothing to indicate in the workmen's report of a well-sinking its separate existence from the brick-earth of the Contorted Drift which overlay it. If therefore the Chillesford beds do remain anywhere over the area bounded by the Butley creek and the Stour, it is probable that they do so in the way suggested in sections XX. and XXI. (pp. 104, 105), carried through the Contorted-Drift outliers for the purpose of showing the unconformity between the Lower and Middle Glacial deposits which it is the principal object of this paper to describe; in which case it seems probable also that they were removed by the denudation which destroyed so much of the Contorted Drift and gave rise to the unconformity in question.

2. *The Unconformity between the Lower and Middle Glacial, and the Interglacial Valley-excavation which is connected therewith.*

In reference to this unconformity we observed, at page xx of the before-mentioned "Introduction," "that the breaking off of this deposit (the Contorted Drift) into outliers southward is evidently due to a great denudation of the Lower Glacial formation prior to the accumulation of the Middle Glacial sands, which occupy to a great extent troughs or valleys in the Lower Glacial beds; and that it is quite possible that outliers of it may be concealed under the table-lands of Middle Glacial sand which separate the East-Anglian valleys from each other;" and we added that "it was clear that the valley-system of East Anglia had its inception in that denudation."

The existence of this unconfornity in the Glacial series, and of this interglacial excavation of the East-Anglian valley-system, is of more general importance, geologically, than at first sight appears—because, if it were due to a conversion of the area into land after a considerable submergence had occurred giving rise to the Lower Glacial deposits, it indicates an arrest and reversal of the glacial subsidence which is not generally admitted, and has a bearing on one of the theories of climate which has lately provoked so much discussion.

In entering upon this subject it will be convenient first to examine how far there is any indication of the valleys of Norfolk and Suffolk having had any existence prior to the deposit of the Glacial beds.

Commencing with the long natural section afforded by the north coast of Norfolk, we find that while the surface of the country intersected by that coast is indented by deep valleys, an almost level floor of Chalk extends along the base of the cliff where these valleys occur. The surface of this floor is a few feet above high-water mark at the western extremity of the coast section at Weybourn, from whence it descends very gradually in a space of 8 miles to low-water mark at Cromer, rising again gradually to the beach-level about Trimmingham, where for a very short distance it is bent up into an arched boss, some 15 feet above the beach, and from which place it sinks gradually eastward and becomes lost under the beach. From the point where it thus disappears its place is taken by beds of the Preglacial-forest age as far as Hasboro'; so that we thus are enabled to trace the Preglacial floor for a distance of nearly 20 miles, and perceive that it is entirely unconnected with the valleys which indent the surface of the country thus intersected.

These valleys are several in number, the deepest being that in which Cromer stands, and which, measured from the top of the Lighthouse Hill, has a depth of more than 200 feet *. So far also from this valley having any connexion with the slight depression in the Chalk floor towards Cromer to which we have referred, this hill occupies the centre of that depression. The valleys thus intersected are seen by the cliff-section to be cut out of the Cromer Till and overlying Contorted Drift, which, with the pebbly sands underlying and interbedded with the base of the Cromer Till, form what we have termed the Lower Glacial series—a formation which, as proved by the height attained by some of its least-denuded portions, must before denudation have had a total thickness of nearly 250 feet in this part of Norfolk. Covering this formation in a more or less intermittent way, and resting always on a deeply marked denuded surface, occurs the sand and gravel which we have referred to Middle Glacial age. This sand and gravel along the cliff-section occupies troughs excavated in the Lower Glacial deposit below it in those parts where it extends continuously; but in places it also caps hills formed of the Contorted Drift, though not in an even way; that is to say, it hangs on one side or other of the prominence of Contorted Drift, showing that it once occupied a trough, the central part of which, having been further denuded Postglacially, does not now retain any of the sand and gravel in it.

As we have in the sections annexed to the map which accompanies our "Introduction" given one in great detail of this cliff, we refer to it in lieu of offering a representation here.

This long natural section thus shows us that the valleys are independent of the Preglacial floor upon which the Glacial beds rest, and that these valleys had their commencement in a denudation which intervened between the uppermost of the Lower Glacial series, the Contorted Drift, and the deposition of the Middle Glacial sand and gravel; and it seems to us that all the evidence afforded by

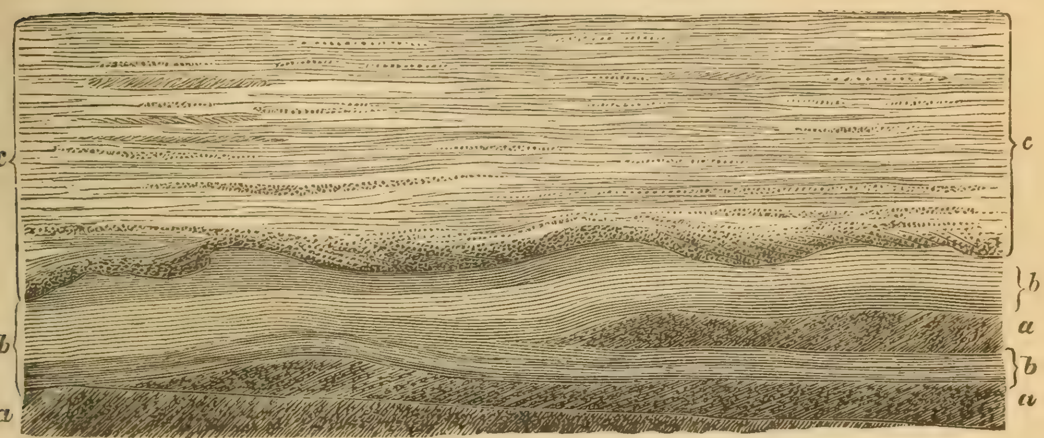
* Cromer Lighthouse-hill is given in the Book of Levels published by the Ordnance department as 248 feet above Ordnance datum, and there are still higher elevations in the neighbourhood. A small part of this elevation is made up of the Middle Glacial sand; but as this always lies more or less in a slanting position, very little deduction need be made for it.

geological mapping, and by the numerous inland sections which occur (so far as any remnants of the Contorted Drift can be traced), is entirely in accordance with the state of things thus disclosed by the Norfolk cliff, the interglacial denudation in question becoming greater southwards, so far as Norfolk is concerned, and the interglacial valleys excavated becoming deeper and deeper as this denudation increases, so that instead of forming troughs in the Lower Glacial beds only, as in the cliff-section, they are there cut through the Lower Glacial beds altogether, and down into the Preglacial floor, as we shall endeavour to show.

Before doing this, however, let us see what light the coast-section of East Norfolk and Suffolk affords upon the subject. From the point where the Forest-bed ceases, east of Hasboro', the cliff is very low, and the Preglacial floor, being beneath the beach, cannot be seen. This district, however, is low and flat, and there are no valleys beyond slight depressions of a few feet; and from Eccles to Winterton, a distance of 10 miles, there is no cliff at all. From Winterton southwards, so far as the Lower Glacial beds occur (which is but slightly, owing to the interglacial denudation they have undergone), they show no indication of having been deposited in any of the valleys which the coast-line intersects; for had they been so they would (notwithstanding that the Preglacial floor is below the beach, at an unknown depth and invisible) have exhibited a tendency to dip into those valleys; but they do not exhibit any such tendency. As far south as Yarmouth the cliff is greatly obscured by blown sand; but south of Yarmouth the Contorted Drift, denuded to a small thickness, shows itself horizontally at the base of the cliff, until that again becomes obscured. For a considerable distance inland of Yarmouth and to within about 4 miles of Norwich the Preglacial floor is concealed at an unknown depth beneath the waterline of the country, and the Middle and Upper Glacial deposits, dipping into the valley by reason of the interglacial denudation of it which preceded them, conceal much of the Lower Glacial in that part.

South of Lowestoft, along the coast-section, the Contorted Drift has been almost entirely denuded, and the Lower Glacial pebbly sands underlying it have suffered from the same cause so much as to occur but occasionally. Where they do remain, however, they maintain their horizontality, and so far confirm the general uniformity of level which we believe the Preglacial floor to have possessed in this part. So complete, however, has been the denudation of the Contorted Drift over the range of the Suffolk coast-section, that its former spread over this area would not have been suspected were it not for the thick outliers of it which remain far away in South Suffolk, and one or two nearer exposures of it inland that rise as bosses through the Middle Glacial sands which have been bedded around them. For the same reason its spread over the Red-Crag area would be similarly unsuspected, inasmuch as, in all the numerous sections of the Red Crag and its associated unfossiliferous sands that are deep enough to show any formation resting on them, this crag and associated sands are capped directly by the Middle Glacial in the way shown by section III.

Fig. 3.—*Section III., in a Coprolite-pit by Foxhall Hall.* (The actual section was in several terraces, which are here omitted. Height of section 45 feet.)



a. Red Crag unaltered.
b. Red sands and partly indurated loamy sand horizontally stratified, being *a* altered and restratified.
c. Middle Glacial, being false-bedded gravel at base and changing upwards into stratified gravelly sand.

From the uniform appearance thus presented by all the numerous sections along the flanks of the Deben, Orwell, and Stour estuaries, not only would it appear as though no formation had intervened between the Red Crag and the Middle Glacial, but also that the valleys of these estuaries had been excavated subsequently to the deposit of the Middle Glacial. The exposures of the Contorted Drift to which we shall have to refer as protruding on the summits of the tablelands dividing these estuaries show, however, as it seems to us, that this was not the case, but that the line of denudation or unconformity separating the Crag from the Middle Glacial in all these sections is due to that general interglacial denudation of the Lower Glacial formation to which the East-Anglian valleys owe their inception.

We will now take the evidence afforded by the inland sections in illustration of this interglacial denudation and valley-excavation, beginning with the northern extremity of the area mapped by us.

In the west of Norfolk and Suffolk the chalk floor, though overspread with Glacial beds, is very irregular; but with some exceptions this irregularity does not appear to correspond with the existing valleys of drainage. In the central and eastern portions of those counties, however, the Chalk and London clay, wherever exposed, indicate a similar evenness of the floor upon which the Glacial beds repose to that which we have described as being exhibited by the cliff-section of northern Norfolk.

In the Quarterly Journal of the Society for 1869 (vol. xxv. p. 446), we gave a section of the valley of the Yare at Norwich, disclosed by the sewer-works of that city then in progress.

This section, which crosses the Yare valley about 4 miles west of the point where the chalk floor rises into view above the water-line of the rivers, was very perplexing to us at the time; and we were at first driven to suppose that the deep hole in the Chalk in which the Middle Glacial sand was found in association with the chalky clay beneath the river-level (so out of their usual place) was due to some exceptional erosion by glacier or iceberg agency. A study of the way in which the East-Anglian valley-system has arisen, however, has satisfied us that, whatever may have been the eroding agency, there is nothing exceptional in this occurrence, and that it harmonizes with the general structure indicated by the unconformable relation of the Lower to the Middle and Upper Glacial deposits.

Indeed, in a foot-note to the paper just quoted, we pointed out that the erosion under consideration was connected with the conversion of the Lower Glacial formation into land, and the occupation of the valleys in it by ice prior to its depression beneath the sea which deposited the Middle Glacial.

We have here reproduced that section (fig. 4), because it is essential to the proper description of the subject-matter of this paper. The dotted lines indicate what we considered at the time, and still consider, to have been the excavation of the Yare Valley subsequently to the deposition of the Contorted Drift, and prior to that of the Middle Glacial sand.

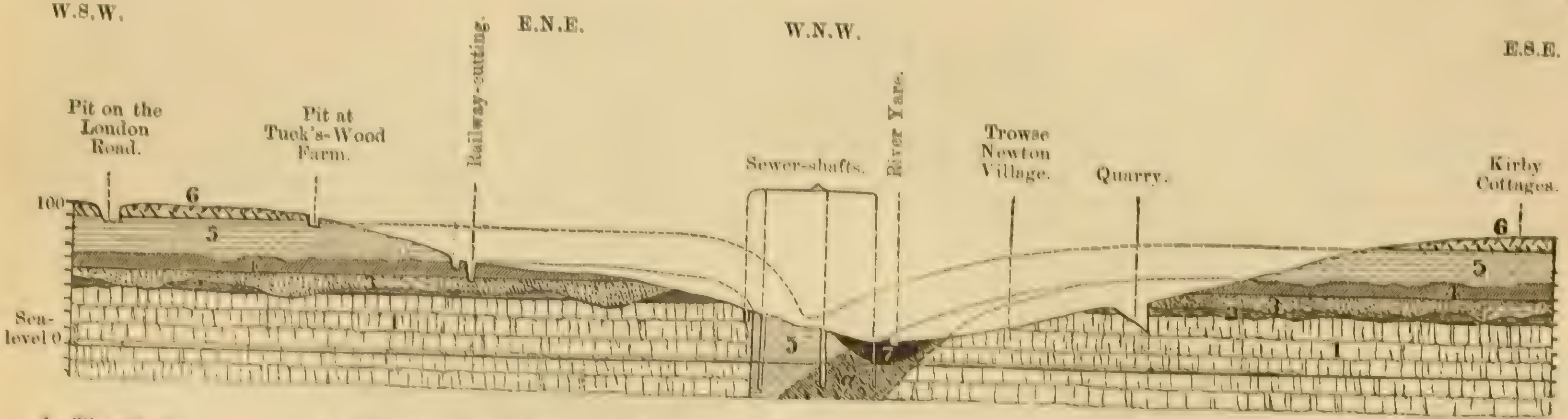
Whether the chalky clay (*a*) associated with the Middle Glacial sand in the hole beneath the level of the river be the Upper Glacial clay, or a bed of clay precisely resembling it, which occasionally occurs beneath the Middle Glacial sand in some valleys (and amongst them the upper valley of the Yare, as shown in section V., p. 85) is immaterial to the subject, because it leaves the excavation of the valley subsequently to the deposition of the Contorted Drift unaffected, the clay in question, whatever it be, being an entirely different material from this drift, which everywhere in the neighbourhood around is a red semistratified brick-earth. The sand and clay (*a* and *b*) were so bedded against each other in the sewer-excavation, and so flooded with water, that we could not satisfactorily learn which overlay the other; but, from such information as we could obtain, we understood that their relative position was as represented in the above section: we have, however, since been told by one of the workmen that the clay was over the sand, in which case it would be merely the ordinary Upper Glacial clay (6) of the high ground.

No doubt, what thus appears to be a hole below the river-level *

* The left side of the hole is drawn perpendicular, as the Chalk was very close to the sewer-shafts. The excess of the vertical over the horizontal scale of the section greatly exaggerates the slopes; but in the case of the sewer-excavation the perpendicularity may be owing to the Chalk, where the line of section traverses the interglacial valley, having formed on one side of it a cliff.

Fig. 4.—*Section IV., across the Yare Valley at Trowse.* (Vertical scale 12 times the horizontal. Length $2\frac{1}{2}$ miles.)

[Reproduced from vol. xxv. p. 446.]



1. The Chalk. 2. The Chillesford (Crag) beds. 3. The Lower Glacial pebbly sands. (These are represented in the North Norfolk Cliff by the Cromer Till and pebbly sand together—the Till being merely a deeper-water equivalent of the sands about Norwich.)
4. The "Contorted Drift," here uncontorted, and about a seventh part of its thickness in the north of Norfolk.
5. The Middle Glacial sand. 6. The Upper Glacial. 7. Postglacial valley-gravel and alluvium.
a. Bed of dark blue clay full of rolled chalk débris and identical in character with the bed No. 6 in various parts of East Anglia, but containing less of that débris than does No. 6 in the immediate neighbourhood of the line of section.

N.B. In this old section the railway-cutting is shown at too low a level, and the bed No. 3 too thin. The position of the beds Nos. 5 and 6, *relatively to those older than they*, is shown better in sections V. & VI., made for the purpose of the present paper. Lying in troughs excavated in No. 4 and part of No. 3 (as shown in section V.), they occupy somewhat different positions in nearly every separate line of section.

is merely part of the interglacially denuded valley, which was deeper than the present, and extends down the river beneath the marshes, and the Postglacial gravel which underlies them; for Mr. Samuel Woodward, in his 'Geology of Norfolk' (1833), mentions that what he calls a subsided mass of the same blue clay as that of Strumpshaw Hill (the ordinary Upper Glacial clay of the district) was found beneath the marshes of the Yare in digging the canal which joins the Yare and Waveney.

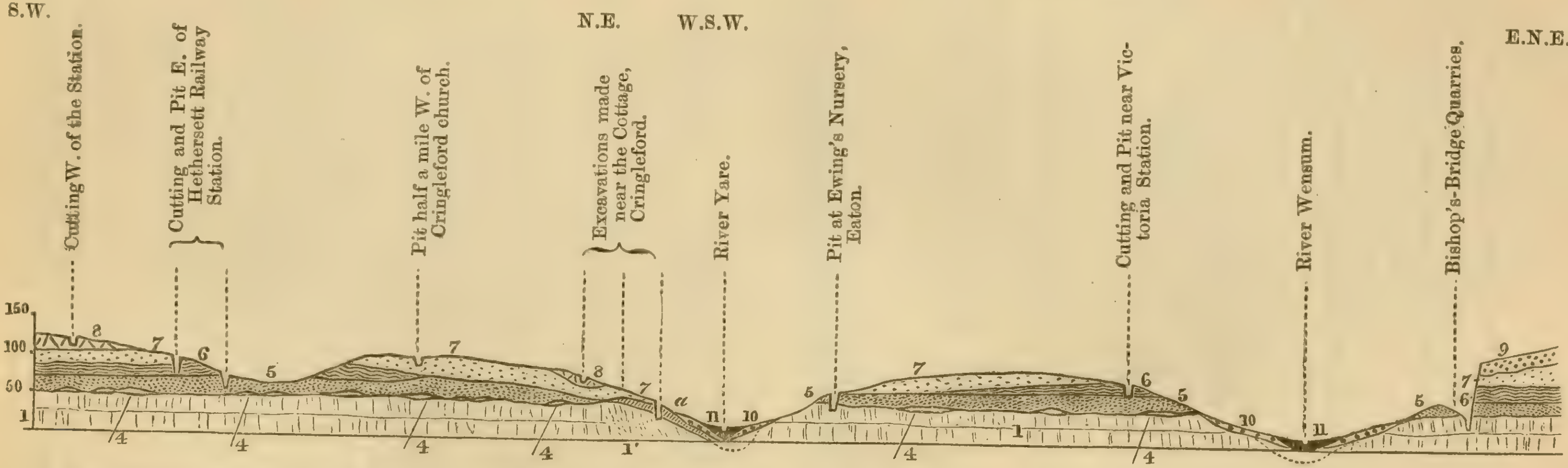
The Yare below Norwich is formed by the confluence of the Wensum (the principal stream) with it; and in describing the geological features of the two valleys we take a line of section (V.) across them near to the confluence of their streams.

The removal of the Lower Glacial sands and Contorted Drift along the slope of the interglacial valley portrayed in the cut has taken place very extensively in places along both these valleys—a circumstance which, until we came to perceive the fact of this interglacial denudation, was a source of infinite perplexity to us in mapping the beds and working out their succession in this part of Norfolk, as was also the occurrence of sections of clay with chalk débris in the bottoms of these valleys and resting on the Chalk, which resembled in their physical composition the wide-spread Upper Glacial; and it was not until one of us had the opportunity of making excavations which proved that this valley-clay in one instance at least (Cringleford, in section V.) passed under the Middle Glacial, that we could get any satisfactory evidence as to its geological position.

Thus in a paper published in the Journal of the Society for 1867 (vol. xxiii. p. 88), one of us described two exposures of a bed of clay made up chiefly of chalk débris and resting upon the Chalk in a glaciated condition in the Yare valley near Norwich (at Trowse Junction and at Thorpe Asylum); and we then interpreted this bed as being of valley-origin and posterior to the Upper Glacial; but having subsequently met with so many instances of the Upper Glacial sweeping over the sides of the interglacially denuded valleys, we were compelled to think that our original view of the valley-origin of the bed in question was erroneous, and that it could only be the Upper Glacial clay out of its usual place; and accordingly we so represented it in the map which accompanies the "Introduction" to the 'Crag Mollusca Supplement.' The crucial test applied, however, by excavations at Cringleford, and continued reflection upon the observations which we have made during more than ten years on the geological features of East Anglia, have led us to the belief that our original view of this bed being of valley-origin and unconnected with the Upper Glacial was so far correct—but that, instead of its being posterior to the Upper Glacial, it is really of interglacial age, intermediate between the Contorted Drift and Middle Glacial, and a formation belonging to the interval which is indicated by the general unconformity between those deposits, and which has become exposed by the removal from it of the Middle and Upper Glacial during the Postglacial re-excavation of the valley. We have not reproduced here the woodcuts used in the paper in the

Fig. 5.—*Section V., across the valleys of the Yare and Wensum near the confluence of the rivers.*

(Length $6\frac{1}{2}$ miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



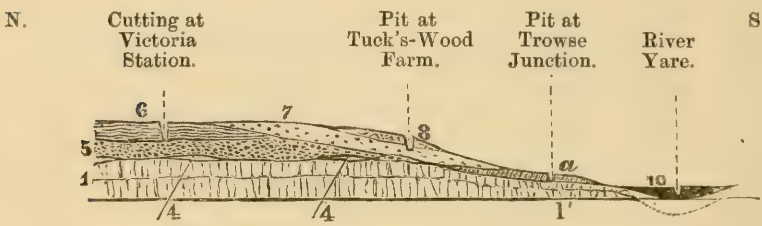
1. The Chalk. 1′. The Chalk glaciated. 4. Probably remnants of the Chillesford (Crag) Beds. 5. The Lower Glacial pebbly sands. 6. The Contorted Drift. *a*. Bed of Clay chiefly made up of chalk débris. 7. The Middle Glacial. 8. The Upper Glacial. 9. Plateau-gravel. 10. Postglacial valley-gravel. 11. Recent alluvium.

The dotted line under No. 10 indicates what probably is the continuation of the interglacial valley. It should be remembered that, owing to the very late Postglacial depression of the east of England (as, indeed, of England in general), the valleys stood postglacially at higher levels than now. Patches of No. 4 occur not far from the line of section; and it is presumed that they occur similarly along it.

N.B. This and the following sections, except Nos. XVIII. and XXIII., are drawn to the level of the Ordnance datum.

23rd vol. of the Journal, because, although the succession of all the beds out of which the valley is cut are correctly represented in them, the sweeping-down of the Middle Glacial over the edges of the Lower Glacial and Crag, such as is shown in section V. of the present paper, is not introduced, we not having then discovered it. The figure (no. 1) given in the 23rd vol. (p. 88) of the bed at Trowse shows that the clay there is partially overlain by brickearth and sand, much in the same way that the bed in the Blackwater valley (section XXIII. of the present paper, p. 111) is overlain. The sand over the brick-earth at Trowse, and the gravel over the brick-earth at Appleford bridge in the Blackwater valley, seem in both instances to show the transition upwards of this interglacial valley-bed into the Middle Glacial. The Middle Glacial sand overlain by the Upper Glacial of the pit at Tuck's-Wood farm on the hill above the Trowse section indicates, we now think, part of the infilling of the Yare valley which had been denuded interglacially out of the Lower Glacial and Crag beds and the Chalk; and fig. 6 represents what we think the relative position of the several beds is most likely to be.

Fig. 6.—*Section VI., at Tuck's-Wood Farm.* (Length 2 miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



1, 1′, 4, 5, 6, 7, and 8 as in fig. 5.
a. Bed of clay chiefly made up of chalk débris and partly overlain by thin Brick-earth and by sand.
10. Postglacial valley-gravel and recent alluvium.

The dotted line indicates the supposed continuation of the interglacial valley beneath the recent alluvium.

Pursuing now the valley of the Wensum, the following three small lines of section (Nos. VII., VIII., and IX.) are necessary to illustrate its interglacial excavation, as we are not able to give a line across both sides of the valley at any one point which can be sufficiently verified by open excavations, abundant even as these are over the country traversed by this valley.

The lines of these sections are taken at distances (following the sinuosities of the valley) of 20, 29, and 39 miles respectively above Norwich, section VII. being the lowest, and IX. the highest up the valley.

It often happens towards the upper end of the valley that the Upper Glacial rests direct on the Contorted Drift; and some good sections of the two in contact occur near Guist in the Wensum valley;

Figs. 7–9.—*Sections VII.–IX., across the Wensum Valley.* (Length of each section about 2 miles. (Vertical scale about $17\frac{1}{2}$ times the horizontal.)

Fig. 7.—*Section VII.*

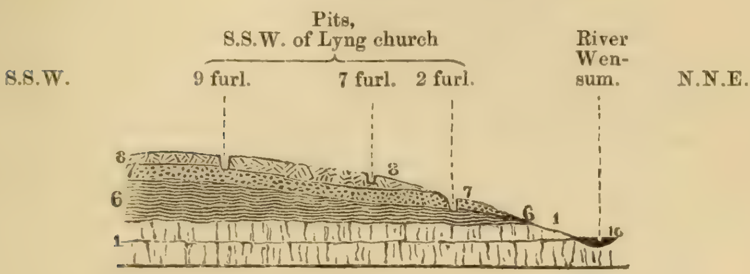


Fig. 8.—*Section VIII.*

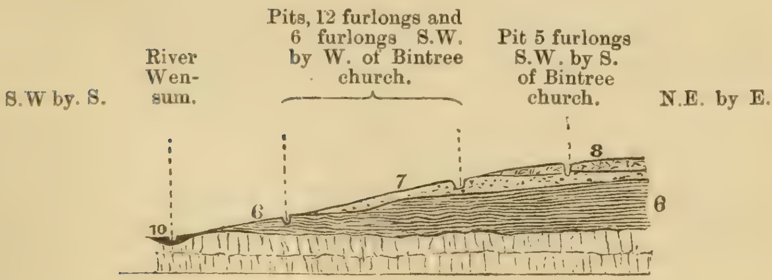
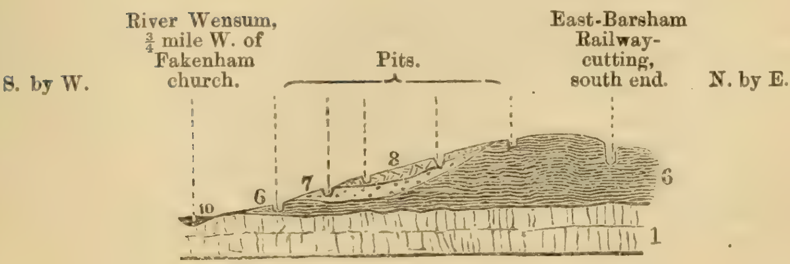


Fig. 9.—*Section IX.*



1, 6, 7, 8 as in fig. 5.
10. Postglacial valley-gravel and recent alluvium.

N.B. The pebbly sands (5) are perhaps present in small thickness below No. 6 in Section VIII., as they are so in a section (at Guist) only two miles out of the line of it.

but over the country traversed by this valley the Upper Glacial is usually underlain by the Middle Glacial, which is often in great thickness, some of the wells, as we learnt, going through upwards of 70 feet of it. As elsewhere in East Anglia, however, the Contorted Drift occasionally protrudes through the Middle Glacial and shows itself on the highest ground overlain by the Upper Glacial. At Guist also is a fine section of the Contorted Drift over the pebbly sands; but mostly in this part of Norfolk the pebbly sands have thinned out and the Contorted Drift rests on the Chalk direct.

That portion of the Wensum valley which extends on either side of the line of section VII., affords several instances of what we regard as the same bed as that marked *a* in sections V. and VI. The character of the bed in this district differs somewhat from that which it presents nearer Norwich, where traversed by the lines of the last-mentioned sections; for instead of being, as there, a tough clay full of chalk débris, it here generally consists of a greenish gritty deposit more sand than clay; but in one exposure this is overlain by clay exactly like that at Cringleford, Trowse, and Thorpe already described, with a sheet of glaciated chalk (torn from the glaciated chalk of the valley-floor) interposed between the two *. The bed in every exposure that we have met with rests on Chalk in this glaciated condition; and, indeed, the Chalk in all the Norfolk valleys, where not protected by the Lower Glacial sands, or the Crag, presents this feature, indicative, as it seems to us, of the action of the interglacial ice upon it. So completely is the condition of the Chalk changed by this action in some places that, instead of affording a porous surface of light land, it has become retentive and water-sodden, of which striking examples may be found in the bottoms on Bridgham, Roudham, and Croxton Heaths between East Harling and Thetford, where, the Contorted Drift having been interglacially denuded, the Middle Glacial sand has been deposited on this glaciated chalk, which has been again laid bare by Postglacial denudation. Where this has taken place the chalk surface holds water as well as the most tenacious clay. The explanation of the different character presented by this bed *a* about Lyng and Elsing (that is to say, in the portion of the Wensum valley illustrated by section VII.) seems to us to be found in the different condition of the beds out of which the valley is here excavated having furnished a different *pabulum* for the valley ice to degrade. Thus nearer Norwich the Chalk rises high up the valley-sides (see section V.), the Contorted Drift there has a good deal of clay in it (forming of itself a true brick-earth), and patches of the Chillesford Clay (though these

* This is to be seen at an excavation 6 furlongs S.W. by S. of Lenwade bridge, and 13 furlongs E. by S. of Lyng church. Other sections of the same bed (but without the clay capping) will be found in the same neighbourhood, as follows, viz. 3 furlongs S. of Lenwade bridge, 5 furlongs S.E. of Lyng church, 5 furlongs W. by N. of Lyng church, and 9 furlongs W. of Lyng church.

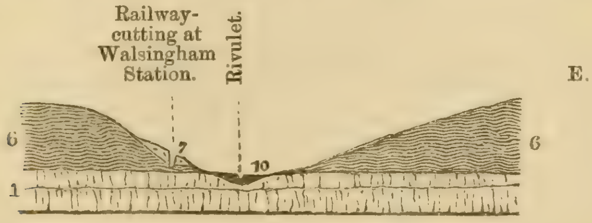
The first two of these are shown in the map accompanying our "Introduction" by dots of the same shading as the Upper Glacial Clay, to which formation we then supposed them to belong. The others lie beyond the limits of that map.

with few exceptions are now concealed) then no doubt cropped out along the valley-sides. The degradation of these formed the chalky clay shown under the letter *a* in sections V. and VI. About Lyng and Elsing, however, the Chalk only comes out in the extreme bottom of the valley, while the Contorted Drift, having lost much of its brick-earth character, usually presents the appearance of a gritty bed with but little argillaceous matter and full of grains of chalk. The degradation of this, and, in a subordinate degree, of the chalk floor also, seems to have furnished the material of the bed *a* in this part of the valley. The exposures of this bed along the Wensum valley about Lyng and Elsing all occur on the narrow strip of Chalk which crops out from beneath the Contorted Drift, and occupies the valley between it and the edge of the sheet of alluvium and Post-glacial gravel which skirts the river; and they might be mistaken, by any one not possessed of an intimate acquaintance with the geological features of Norfolk, for the Contorted Drift itself; but in the many sections of it which occur in the neighbourhood, that drift persistently maintains a different colour (tawny brown) and a less sandy composition.

The Upper Glacial does not reach north of the line of section IX., in Central Norfolk, the country lying between the head of the Wensum valley and the sea being occupied exclusively by the Contorted Drift, overlain irregularly by the Middle Glacial.

Near to the head of the Wensum valley a small stream takes its rise, and runs northwards to the sea through this Contorted-Drift area, its valley being excavated exclusively in that drift, which, in much greater thickness than near Norwich, is cut through down to the Chalk. The length of this valley is about ten miles; and the following line of section (No. X.) taken about midway of its length shows its structure.

Fig. 10.—*Section X., across the Walsingham Valley.* (Length 2 miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)

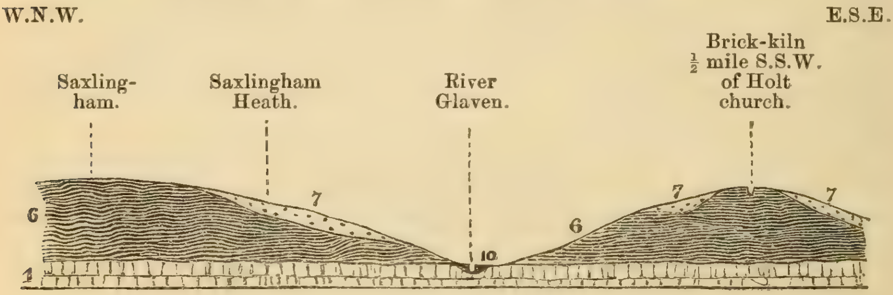


1, 6, 7 as in fig. 5.
10. Postglacial valley-gravel and recent alluvium.

The country round this part abounds in sections of the Contorted Drift, which consists of a gritty white marl, a condition which it gradually assumes westward along the coast section; so that from being a red brick-earth with included masses of marl in Central Norfolk, forming rich mixed soil, it gradually changes into this gritty marl which forms the light land of a large portion of North-western Norfolk.

About 7 miles east of the last-mentioned valley, that of another small river, the Glaven, occurs. The high land out of which this valley is cut is for the most part crowned with the Middle Glacial, which sweeps boldly down into the valley, as in section XI.; but in some places the Contorted Drift shows itself uncovered by the Middle Glacial on the highest points, proving that the Middle Glacial actually rests on the sides of the interglacial valleys which have been deepened postglacially, as described in the case of the North-Norfolk cliff-section.

Fig. 11.—*Section XI., across the Glaven Valley.* (Length $3\frac{1}{2}$ miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



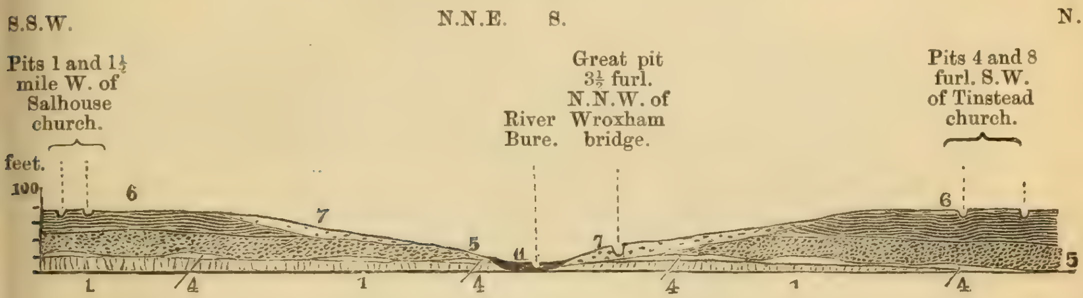
1. The Chalk.
6. The Contorted Drift.
7. The Middle Glacial.
10. Postglacial valley-gravel and recent alluvium.

The river next in consequence to the Yare in Norfolk is the Bure, the valley of which is of uniform structure throughout, being, near the sources of the river, cut out of the Contorted Drift only; but as the valley deepens in its downward course it is first cut down through this Drift to the pebbly sands, and then to the Crag (where this exists) and the Chalk. About midway in the course of the river the Chalk disappears, and the base of the Contorted Drift sinks below the water-line of the country. This is in consequence of the eastwardly dip of the Preglacial floor, the Chalk disappearing below the water-level to the east of a line drawn from a point about 4 miles east of Norwich to the coast near Mundesley*. The Crag and the Lower Glacial beds sinking with the Chalk are thus partially obscured in the lower course of the Bure, and the valley is now much below the level it possessed at a late stage in the Postglacial period, the Postglacial forest-grown land-surface having been found beneath the alluvial deposits.

* Eastward of the point where the Chalk disappears, the Lower Tertiaries no doubt come on, as proved by the Yarmouth well-boring; but we have detected no traces of them at the surface, and the dip of the Chalk beneath them takes place, so far as we are aware, at some unknown point beneath the water-level of the country.

Although the structure of the Bure valley throughout is repugnant to any Preglacial origin, it affords but slight evidence of interglacial excavation. This is partly owing to the paucity of sections along it, and partly to the difficulty of distinguishing between the Middle and the Lower Glacial sands where the one rests on the other. A section, however, of what we feel little doubt is the Middle Glacial sand, occurs at a large excavation about half a mile N.N.W. of Wroxham bridge, in the midst of the valley where the Lower Glacial sands are easily distinguishable, either from their being fossiliferous or from containing their characteristic seams of rolled pebbles; and we therefore give a line of section (No. XII) across the Bure valley at this point.

Fig. 12.—*Section XII., across the Bure Valley.* (Length 4 miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



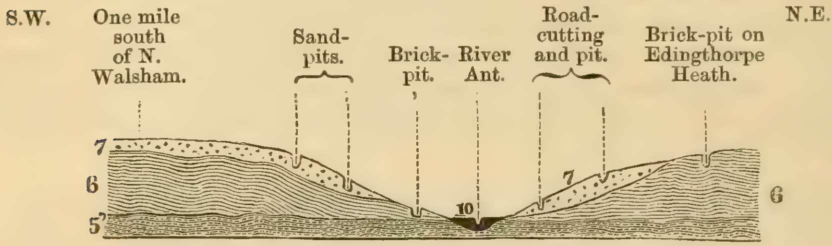
1. The Chalk-floor dipping north-eastward.
4. Remnants of the Chillesford beds (well exposed, with No. 5 over them on both sides of the river, near to, but not in, the line of section).
5, 6, 7, and 11 as in fig. 5.

N.B. The sands rise high up on the south side of the valley above the line of junction of 5 and 6; and where this is the case there can be no doubt that they belong to No. 7; but when, lower down, they rest below the level of No. 6, there is a difficulty in distinguishing between them and No. 5.

Not more than 2 furlongs from the great excavation in the Middle Glacial last referred to, and between it and Wroxham bridge, an extensive excavation in the Chillesford Clay, capped by the Lower Glacial sand, occurs at about the same level, showing the plunge into the valley which the Middle Glacial here makes. This excavation lies two furlongs out of the line of section XII.

The next river is the Ant, which falls into the Bure. The valley of this river is, in its lower part, similar to that of the Bure, as shown in the last section, the Chalk being concealed beneath the water-level, owing to the Postglacial depression before alluded to; and the original valley is now largely filled up with the alluvium that covers the Postglacial forest-grown surface. The upper part of the Ant valley, however, being cut out of higher ground formed by the Contorted Drift, which has here been left by the interglacial denudation, exhibits its interglacial origin very distinctly; and the following line of section (No. XIII.) is taken across it near North Walsham, where actual open sections afford the means of verification.

Fig. 13.—*Section XIII., across the Ant Valley.* (Length $2\frac{1}{2}$ miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



5'. The Cromer Till (probably).
The other references as in fig. 11.

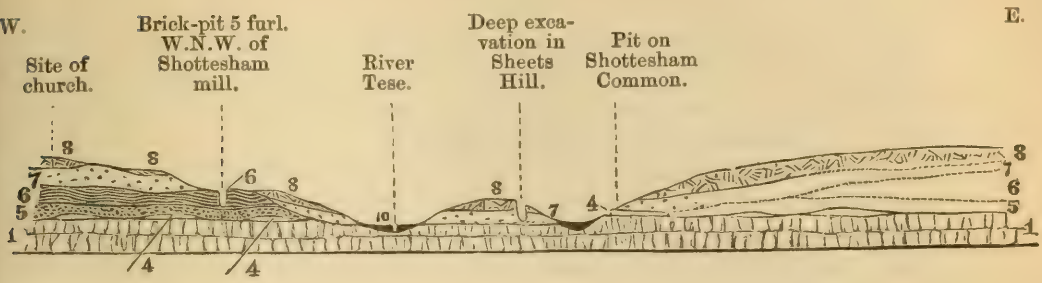
Into this valley, as into that of the Glaven, the Middle Glacial plunges boldly down; and the natural section afforded by the coast of the country traversed by them, being not far distant, serves to check the accuracy of the above representation.

The Tese is an affluent of the Yare; and its valley in a course of about twelve miles (without reckoning the windings) is cut down in its upper extremity to the Middle Glacial only, and in its lower to the Lower Glacial pebbly sands, the Crag, and the Chalk. So great has been the interglacial denudation of this valley, that we have been able to find excavations in remnants of the Contorted Drift at three places only along its course. One of these is half a mile N.E. of Shottesham-St.-Mary church, the second 6 furlongs N. by E. of Stratford-St.-Michael church, and the third one mile N. by E. of Newton–Flotman church. Assuming, as we think we are entitled to do from the presence of these remnants and from the occurrence of the Contorted Drift north, south, east, and west of this valley, that this drift once extended in full force over it, the interglacial denudation of the Tese valley was almost complete. The line of section XIV. is drawn across the principal valley, and a small one tributary to it, at the point where one of these remnants of the Contorted Drift occurs. This deposit here yielded us *Tellina balthica*, *Mactra ovalis*, and *Cardium edule*.

Just north of the above line of section, a bed of clay with chalk débris occurs in the valley-bottom, resting on glaciated chalk. There are similar occurrences at several places along this valley; and some, if not all, of these, we think, must belong to the same bed as that marked *a* underlying the middle Glacial in the Yare valley in section V.

In the case of this valley, as in that of the Yare, it is very probable that the interglacial excavation was deeper than the present one, and may be continued down into the Chalk below the level of the river, where we have represented valley-gravel (10) as present.

Fig. 14.—*Section XIV., across the Tese Valley.* (Length 4 miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



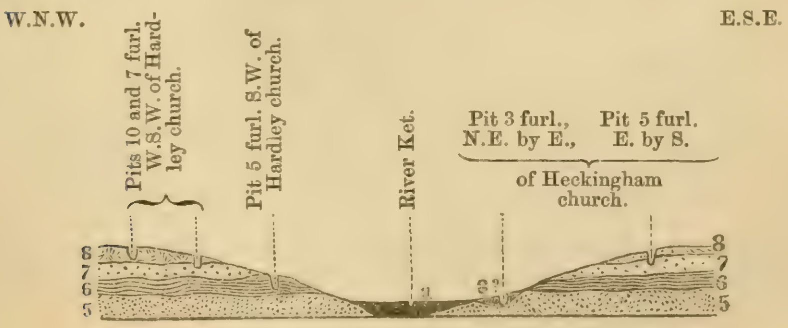
1, 5, 6, 7, 8 as in fig. 5.
4. Remnants of the Chillesford beds and Fluvio-marine Crag.
10. Postglacial valley-gravel and recent alluvium.

On both sides of the Tese valley the high ground is occupied by the Upper Glacial clay, which conceals every thing; but we feel little doubt that the Contorted Drift is present in thickness beneath it, the denudation having operated mostly along the lines of the valleys which have afterwards been re-excavated postglacially. The dotted lines which continue the line of section XIV. at its eastward extremity indicate our view in this respect; and in fact, if the section which we have given across the Tese were continued south-eastwards to the valley of the Waveney at Bungay, protrusions of the Contorted Drift thus underlying the high ground between would be encountered at Headenham.

The only river-valley of East Norfolk remaining to be noticed is that of the Ket, which river falls into the Yare eight miles west of Yarmouth. The features of this valley differ from those of the Tese in the more general presence of the Contorted Drift, which comes out pretty regularly along both its sides.

The Pebbly Sands underlying it are also in great thickness; and to the east of Loddon they form masses of shingle, which, however, are not oblique-bedded, as are the similar masses near Halesworth and Henham. The following is a section across the Ket valley.

Fig. 15.—*Section XV., across the Ket Valley.* (Length $2\frac{1}{2}$ miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



References as in fig. 5.

It is impossible to determine whether the clay with chalk débris (8?) resting in patches in this valley on the shingle of the Pebbly Sands (5) is the Upper Glacial clay of the high ground, or the bed occurring in the Yare valley under the Middle Glacial (*a* in section V.); but there are several occurrences of it in the bottom of the Ket valley resting on the Pebbly Sands. These show, however, at least that the Ket valley was excavated subsequently to the Lower Glacial, and before or during the Upper Glacial deposits.

Having passed in review all the river-valleys of Eastern Norfolk, we now come to the Waveney, the principal river of Norfolk and Suffolk, the valley of which has, since the description by Mr. Prestwich of the Hoxne brick-earth deposit containing evidence of Palæolithic man, possessed a special interest, and in connexion with which deposit, and the inferences drawn from it as to the excavation of the Waveney valley since the accumulation of that brick-earth, much controversy has taken place*. The late Mr. J. W. Flower maintained †, and, as it seems to us, with much reason, that the width of this valley at the source of its river, its confluence there with the valley of the Little Ouse flowing in the opposite direction, and the absence of any very high land near its source forbade the possibility of the river Waveney having been the agent producing the excavation of the valley through which it flows. Whatever be the case, however, as to this, it seems to us clear that the Waveney valley, like those which we have been describing, was produced by the denudation which has so largely destroyed the Contorted Drift, and which took place between the formation of that deposit and the Middle Glacial.

It may be worth observing that if the view expressed at the conclusion of this paper of the area beyond the limit of the Middle Glacial in Norfolk and Suffolk having been during its accumulation occupied by the branch of the land ice which flowed over Lincolnshire be well founded, it may serve to explain the difficulties suggested by Mr. Flower, and in this way: viz. such a glacier must have greatly denuded and lowered the area on which it rested, and thus the great level of the Fenland must have been produced by it; now if we suppose the interglacial valley of the Waveney to have been merely the eastern extremity of a far longer valley of which that of the Little Ouse formed the next portion westward, and whose head was yet further west, or north, it is not difficult to see that the slope of the Little-Ouse portion might have been reversed by the degrading action of this ice, which was of a magnitude to be independent of such small valleys, and derived its motion from the contour of the country lying between it and its source in the mountain-districts of the north of England. The abrupt termination of the Middle Glacial and of the Contorted Drift a few miles west of the confluent source of the Little Ouse and Waveney, seems to find an

* Mr. Belt has lately (Quart. Journ. Science, July, 1876) endeavoured to show that the Hoxne brick-earth is not, as hitherto supposed, newer than the Upper Glacial clay, but Preglacial.

† Quart. Journ. Geol. Soc. vol. xxiii. p. 55.

explanation in this view; that of the Middle Glacial in the way attempted to be shown in the sequel of this paper; and that of the Contorted Drift by its having been ploughed out up to that point by this great mass of glacier ice. The depth of the submergence which the structure of the Contorted Drift proves Northern Norfolk to have undergone during the Lower Glacial period renders it very difficult to suppose that the Fenland, and other low-lying country beyond it, did not participate in that submergence, and become covered with the Contorted Drift, unless their level has been greatly lowered since; but if we assume that the land ice reached to this part at the commencement of the Middle Glacial, as explained in the sequel of the paper, it is easy to account for the great lowering of the level of these districts, as well as for the destruction of the Lower Glacial deposits over them, by the degradation of their somewhat soft strata which such ice must have effected. In whatever way, however, the valley of the Waveney and Little Ouse may have been excavated and brought to its present confluent character, it seems clear to us that it must have formed a channel or strait as the land rose out of the Upper Glacial sea, and that the tidal scour through it was, as in the case of the other East-Anglian valleys, the principal agent in its *re*-excavation.

The valley of the Waveney presents few exposures of the Contorted Drift; but those that do occur seem to us sufficient to prove that this formation once spread in considerable thickness over the district through which the valley runs. The Middle Glacial, except where these remnants occur, occupies so uniformly the flank of the valley west of Beccles as to lead naturally to the inference that the valley was excavated out of this and the overlying Upper Glacial clay only, as represented by Mr. Prestwich in his well-known sections of the Hoxne bed *, and was thus of Postglacial origin. The presence of these remnants of the contorted drift, however, and the general structure of the valleys of East and Central Norfolk which we have been reviewing, appear to us to indicate that a much wider trough than that which the valley now forms was interglacially excavated in the Contorted Drift, and that the Middle Glacial overlain by the Upper Glacial was deposited in it. Moreover, at various points along the valley exposures of clay occur low down that are clearly either the bed *a* of Section V., or else the Upper Glacial clay of the high ground (No. 8), an instance of which exists at Lopham, close to the source of the river—in either case proving interglacial excavation to some extent.

A bed of clay with chalk débris exactly resembling the Upper Glacial and also the bed marked *a* in section IV. seems to underlie a great thickness of Middle Glacial sand in the cutting at Oulton two miles west of Lowestoft. The sloped and grassed condition of the cutting obscures the position of this bed relatively to the Middle Glacial sand through which the cutting is made; and instead of this bed of clay underlying the sand, it may be only a plunge of the Upper Glacial into it; but if such underlie does occur, then this

* Phil. Trans. 1860, part ii. p. 304.

seems to be of similar age to the bed in the Yare valley, and of the period of interglacial denudation discussed in this paper.

A mile and a half to the south-west of this, in the cutting of the Lowestoft branch Railway adjoining the Waveney marshes, a bed of clay occurs under a considerable thickness of Middle Glacial sand and gravel; but it is too much obscured for us to say whether it is the same bed as that at the bottom of Oulton cutting, or whether it be the Contorted Drift, or even the Kessingland fluviatile bed.

The lower part of the valley, where, instead of falling into the Sea at Lowestoft, it turns suddenly to the north-west to join the Yare, is distinctly excavated in the Lower Glacial beds, which are exposed in many places along the edge of the valley; and the line of section XVI. shows not only the extent of the interglacial denudation of the Waveney valley, but also the way in which the Middle Glacial is bedded around the least-denuded part of the Contorted Drift that rises through the high ground between the valley and the sea-cliff.

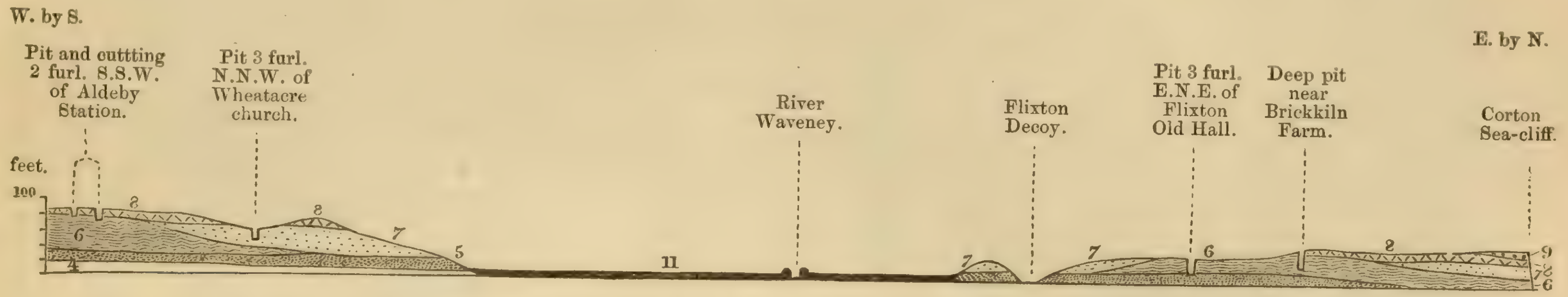
This prominence of Lower Glacial beds seems to have formed the interglacial parting between the Waveney valley and some other valley which has been destroyed by the waste of the coast line, and the slope of which is now intersected longitudinally by the cliff between Yarmouth and Lowestoft. This lost valley was probably tributary to the filled-up and now concealed continuation of the interglacial trough of the Waveney, to which we shall have presently to refer.

The features exhibited by line of section No XVI., so far as the Contorted Drift is concerned, are similar to those in sections XX. and XXI. (pp. 104, 105), which illustrate our view as to the way in which the valleys of the Deben and Orwell and other valleys of South Suffolk have been interglacially excavated.

The remnants of the Contorted Drift to which we have referred as exposed between Beccles and the source of the Waveney (where, with the exception of such exposures, the Lower Glacial beds are mostly concealed by the Middle and Upper Glacial) occur at the following places, viz.:—at a brick-kiln one mile E. by N. of Broome church and about three miles from Bungay; at the Bath Hills opposite Bungay; at Denton to the south-west of Bungay; at a pit half a mile N.E. of Starston railway-station; in several fine sections near Withersdale and Shotford bridge, in the neighbourhood of Harleston; and at Diss railway-station, where it is contorted, and overlain by the Upper Glacial. The Lower Glacial pebbly sands occur at the base of the Bath Hills beneath the Contorted Drift (which has been denuded to small thickness); but the bed of pebbles exposed in a pit within the gardens of Ditchingham House hard by, which is full of molluscan remains, appears from the specific character of such remains to belong to the Crag, though the Chillesford Clay and most of the Crag also has here been denuded in the interval between the Crag and some part of the Glacial period. The peculiar character of the contorted drift everywhere is its variability; and to this the exposures round Harleston form no exception.

Fig. 16.—*Section XVI., across the Waveney Valley near the sea and the confluence of the river with the Yare.*

(Length $6\frac{3}{4}$ miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



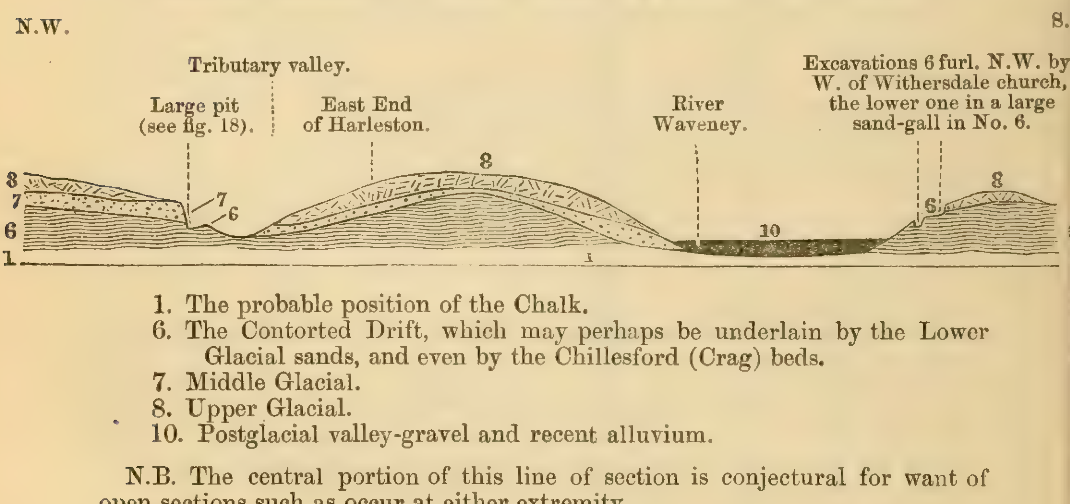
4. Probably the Chillesford beds. 5, 6, 7, 8, and 11 as in fig. 5. 9. Gravel posterior to No. 8.

The interglacial valley probably extended below the alluvium of the present valley.

N.B. The elevation of the ground by the pit near Brickkiln Farm (where No. 6 comes nearly to the surface under No. 8) ranges, according to the book of levellings published by the Ordnance Department, between 46 and 58 feet above datum, while along the base of Corton Cliff No. 6 rises from 0 to 8 feet above beach, or, say, to 15 feet above datum.

At Withersdale the uppermost layers consist of brown obscurely stratified marly brick-earth, which is the character the deposit assumes in the Norfolk cliffs near Weybourne. These are overlain very unconformably by the Upper Glacial clay, which in some of the excavations is in its turn overlain by Plateau gravel. This marly brick-earth appears, from other and not far distant excavations at lower levels, to pass down into alternations of laminated brick-earth and loamy sand, interstratified in which there occur in one of the excavations beds of rolled pebbles. On the north side of the Waveney at Starston the Contorted Drift presents the character which it possesses at Elsing and Lyng (see section VII.), of a gritty earth enclosing small flints and minute fragments of chalk. Numerous as are the excavations in the Contorted Drift around Harleston, they do not afford the means of showing in a satisfactory way the interglacial excavation of the main valley of the Waveney, but only of the small tributary valley at Starston. They, however, show abundantly the considerable thickness in which this drift originally extended across the region now occupied by that valley, along the line of section XVII.

Fig. 17.—*Section XVII., across the Waveney Valley near Harleston.* (Length $4\frac{1}{4}$ miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



1. The probable position of the Chalk.
6. The Contorted Drift, which may perhaps be underlain by the Lower Glacial sands, and even by the Chillesford (Crag) beds.
7. Middle Glacial.
8. Upper Glacial.
10. Postglacial valley-gravel and recent alluvium.

N.B. The central portion of this line of section is conjectural for want of open sections such as occur at either extremity.

It is not unlikely also that the interglacial main valley is concealed beneath the alluvium which covers the bottom of the exceptionally wide elbow in the valley at this point.

The importance of the Starston excavation consists in its having afforded, when we examined it in 1871, the only indication besides the bed *a* of the Yare valley which we have been able to discover of a land surface having existed during the interval represented by the unconformity and denudation that we have been describing.

In this excavation (section XVIII.) there occurs upon the denuded surface of the Contorted Drift, and between it and the overlying

Middle Glacial a thin bed of dark brown loam, which also fills a pothole excavated some 5 feet or thereabouts in that drift.

After what we have observed as to the action of percolating water on the Red Crag, and especially the enwrapping of a prominence of Crag by bands of dark brown loam produced from the dissolution of the Crag material by the percolating water (see section II.), we are far from sure that the loam thus spreading over the denuded surface and filling the pothole was formed as a surface soil, and the pothole excavated during the interval represented by the denudation which we have been discussing; and both the loam and pothole may be due only to percolation; but we think that as no sign appeared of the sand itself following the loam into the pothole, there is some probability of this bed really representing an interglacial land surface. It is also worthy of notice that the interglacially denuded slope of the Contorted Drift is almost coincident with the postglacially re-excavated valley-slope.

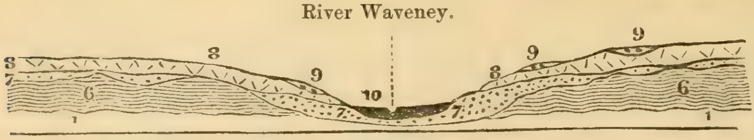
Fig. 18.—*Section XVIII., in Pit at Starston.*

6. The Contorted Drift, consisting here of a gritty earth with small flints and minute fragments of Chalk, and a sand gall at *.
7. The Middle Glacial, consisting of light-coloured stratified sands passing up into stratified gravel.
a. Thin bed of dark-coloured sandy loam covering the surface of No. 6, and filling a pothole therein.
b. Humus and rainwash (recent). *c*. Talus.

The cross indicates where a hole sunk through the talus showed *a* passing under No. 7.

Having regard to the two lines of sections XVI. and XVII. across the Waveney at distant points, and to what we have described as to the presence of the Middle Glacial along the valley-sides generally down to the edge of the sheet of Postglacial gravel which fills the valley-bottom in some parts (as for some miles on either side of Bungay), and to the edge of the alluvium sheet elsewhere, there seems to us no reason to doubt that the valley of the Waveney is of interglacial origin, like the other valleys of Norfolk which we have been describing, and like the valleys of Suffolk which we have presently to describe. The following hypothetical section (XIX.) represents what we believe to be the true, though concealed, structure of this valley.

Fig. 19.—*Hypothetical Section (XIX.) showing the general Structure of the Waveney Valley.* (Vertical scale $17\frac{1}{2}$ times the horizontal.)



1. Formations older than the Contorted Drift.
6. The Contorted Drift.
7. The Middle Glacial, including therein any valley-bed of interglacial age that may be concealed under the alluvium &c.
8. Upper Glacial.
9. Gravels posterior to No. 8.
10. Postglacial valley-gravel and recent alluvium.

It seems to us that the high ground of Central as well as much of that of East Suffolk is underlain by the Contorted Drift; but, with the exception of a very few exposures, this is concealed everywhere by the Upper Glacial, while the Middle Glacial intervenes in the same irregular way in which it occurs over the Contorted Drift in that part of Northern Norfolk to which the Upper Glacial does not extend.

It is our view that into the troughs or valleys which were interglacially excavated in the Lower Glacial and Crag and other older beds, the Upper and Middle Glacial were bedded so as to obliterate those troughs more or less. Most of the troughs thus filled in have been re-excavated postglacially, so as to form the present lines of drainage; but others have not; and among them is the supposed south-easterly continuation of the Waveney valley to which we have already adverted. The map which accompanies our "Introduction" shows that the Lower Glacial beds crop out continuously * along both sides of the Yare valley below Norwich down to its inosculation with that of the Waveney, where this bends to the north-west and where section no. XVI. is taken, as they do also along the northern side of the rest of the Waveney valley for some distance in the direction of Beccles.

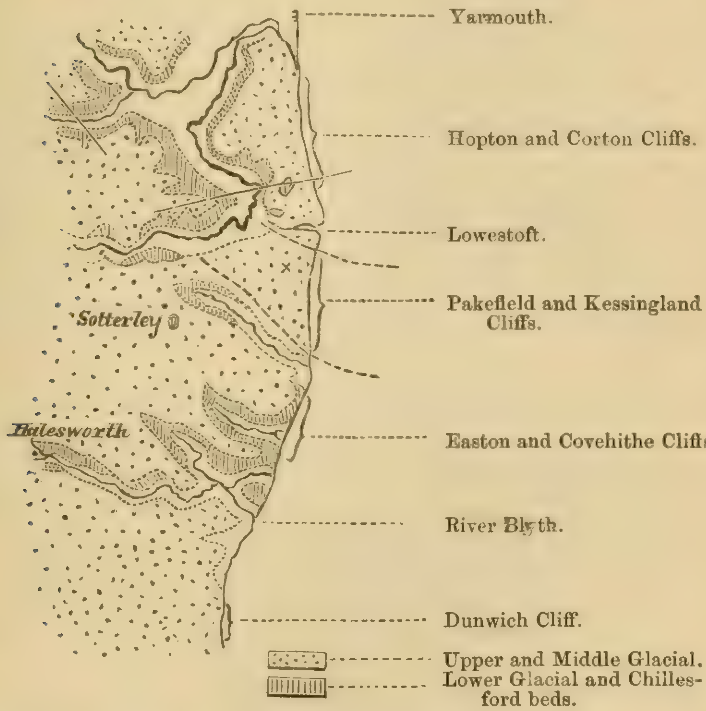
On both sides of the river at and near Beccles the Chillesford beds and Lower Glacial sands are present; but between Beccles and Lowestoft we could find no trace of either on the south side of the Waveney †, and the Middle Glacial overlain by the Upper Glacial seems to stretch along the valley-side from Beccles to near Lowestoft. Now it is through this part, south-eastward to the coast at Kessingland, that we consider the inosculated interglacial trough of

* This continuity is doubtless less than represented in the map referred to, owing to the concealment, in places, of the Lower by the Middle Glacial on the valley-sides; but this could not well be represented on the small scale of the map.

† Except, possibly, the bed mentioned at page 96 as occurring at the bottom of the cutting of the Lowestoft branch Railway.

the Waveney and Yare extended, which, having been filled in with the Upper and Middle Glacial, has not been re-excavated, remaining as a low tableland, of which the cliff between Covehithe and Lowestoft forms the natural section. It is in the centre of this trough, thus intersected by the cliff, that the well-known Kessingland deposit lies, occupying at that point a shallow valley excavated out of the Chillesford Clay and Lower Glacial sands, as the sections which accompany the separate paper by one of us on the Kessingland-Cliff section show (see p. 135). We subjoin a small sketch map to make this description more intelligible.

Fig. 20.—*Sketch Map.* (Scale 10 miles to the inch.)



The unshaded parts by the rivers are occupied by recent alluvium.
The broken lines on either side of Pakefield and Kessingland cliffs indicate the supposed continuation of the interglacial valley of the Waveney.
The two lines across rivers are those of sections XV. & XVI.

N.B. At the point marked with a cross a little way S.W. of Lowestoft, and about 10 furlongs inland from Pakefield Cliff, there occurs on low ground an excavation in mottled brick-earth resembling the Mammalian bed of Kessingland Cliff; but we are not aware whether it be that bed or the Contorted Drift.

If these views are right, there seems reason for suspecting that this Kessingland bed, containing mammalian remains and rootlets (which is directly overlain by the Middle Glacial), may belong to the period of interglacial valley-excavation we have been discussing.

The Lower Glacial beds of Easton and Covehithe cliffs, and those inland of these cliffs which are shown in the sketch map as stretching westward on the north side of Blyth, consist of the Pebbly sands for the most part resting on the Chillesford beds, though in the neighbourhood of Halesworth and Henham they have taken the place of these latter and lie up against a low cliff or foreshore of the Chillesford Clay in the condition of thick masses of beached shingle—a feature which we regard as due to the conversion of that clay together with the Crag into land between the close of the Crag and the commencement of the Glacial periods. Everywhere along the outcrop of these pebbly sands, the Contorted Drift seems to have been removed, the only remnants that we discovered between the Waveney and the Alde being at Sotterley brick-kiln (yielding traces of *Mactra ovalis* and *Tellina balthica*), and a doubtful one at the north end of Easton Cliff, which is also exposed in a pit a short way inland near Covehithe church. Along the south side of the Blyth, from a point a little east of Halesworth to the sea, we could detect no signs of the Lower Glacial pebbly sands, or of the Chillesford Clay, and the Middle Glacial seems to go down to the water-level, indicating, as it appears to us, another space of interglacial denudation; and from this neighbourhood southwards we lose trace of any thing that can be identified with the Lower Glacial sands; indeed the masses of shingle around Halesworth and Henham, into which these sands change, coupled with their highly oblique bedding, seem to show that the southern shore-line of the sea depositing such sands passed somewhere near those places. Along the coast-section southwards also we lose all trace of the Contorted Drift; but inland we found what seemed to be an immense and deep excavation in it at Blaxhall, on the tableland between the rivers Alde and Deben. Unfortunately this excavation, though dry to the bottom, was mostly overgrown, and the section obscured; but a mass of marl imbedded in red brick-earth exactly resembling that of the Contorted Drift in the Norfolk cliff, was exposed at one part, and a short way off was a small pit in another mass of marl, while good sections of the Upper resting on the Middle Glacial occurred within half a mile. Had this exposure stood alone, we should have hesitated to call it a protrusion of the Contorted Drift through this tableland; but the discovery of several such protrusions which, in our opinion, are free from all question, many miles to the south, on the tableland dividing the Deben from the Orwell, leaves no doubt in our minds that the Contorted Drift overlapped the pebbly sands, and stretched southwards in considerable thickness at least as far as the extremity of Suffolk.

This Blaxhall protrusion, like those north-west of Lowestoft, through one of which the line of section XVI. (p. 97) is carried, and those at Woodbridge and Kesgrave (sections XX. and XXI. pp. 104, 105), indicates, as it seems to us, that the tableland dividing the Alde from the Deben is underlain by the Contorted Drift, and that the valleys of both these rivers have been excavated out of it. Indeed, if we are right in this, a line of section drawn through the Blaxhall protrusion from the valley of the Deben to that of the Alde would in all respects, save that the tableland would be capped throughout with the Upper Glacial in addition, be identical in character with that drawn through the Kesgrave and Ipswich protrusions from the valley of the Deben to that of the Orwell, which is given in section XX.

Speaking of the two outliers of the Contorted Drift at Blaxhall and Kesgrave in the before-mentioned "Introduction," we observed that we thought it most probable that the tablelands dividing the estuaries of East Suffolk from each other, and through which we there gave a line of section (A), were underlain by the Contorted Drift interposed between the Red Crag and the Middle Glacial. With only a knowledge of these two outliers we did not feel justified in actually representing those tablelands as thus underlain, and, subject to such remark, preferred to represent them as occupied by the Middle Glacial only resting upon the Crag. The subsequent discovery, however, of the protrusion at Woodbridge and Hasketon, shown in section XXI., where the Contorted Drift is overlain by the Upper Glacial, and the discovery by Mr. Whitaker of similar protrusions at Kirton and Trimley, which he communicated to us, leave no doubt on our minds that what we alluded to in our "Introduction" as most probable does in fact exist.

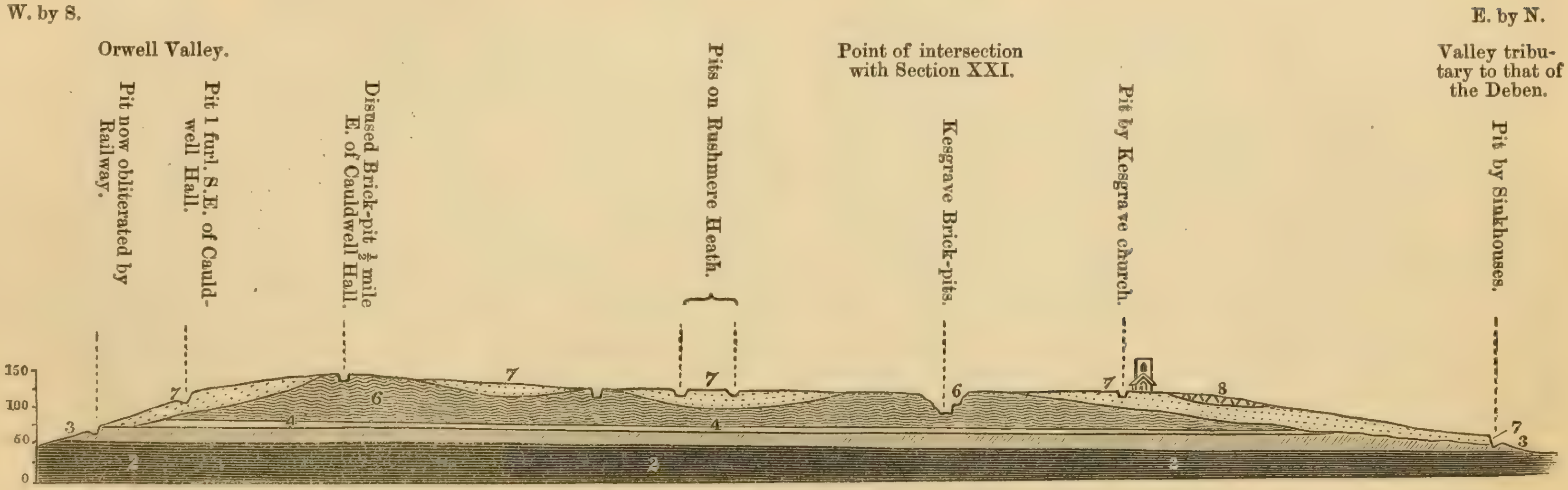
The section marked P accompanying the map given in the same "Introduction" should in a similar way be corrected by the insertion of a remnant of the Contorted Drift between the Crag and the Middle Glacial, where the height of the hill (about Crane Hall), raises the inference that it is similarly underlain to that on the opposite side of the Orwell, which forms section XX. of the present paper.

The outlier at Woodbridge is evidently of great thickness, from the height which it attains above the Red-Crag level. It consists of silty ash-coloured brick-earth in some places, and of tougher blue brick-earth in others; and in one excavation these are contorted together, the whole being capped by varying thicknesses of the Upper Glacial. At Kesgrave the outlier must, from its elevation above the Crag-level, be of equal thickness; and it consists of both light-coloured silty and tough blue brick-earth in different parts of the excavation, while one of the earlier pits now filled with water is in a mass of impure marl, of which many examples occur in the Cromer cliff. The protrusions at Kirton, Trimley, and Ipswich racecourse are in similar brick-earth; and there is little doubt that they are all exposures of the thicker and least-denuded portions of one continuous formation, out of which the valleys of the East-Suffolk estuaries were interglacially excavated. The line of section XX. is carried through the Kesgrave exposure, from one of the lateral valleys that open out to the main valley of the Deben to the valley of the Orwell, and is susceptible of verification by the numerous open sections which occur along it.

If our representation is correct, we have here, as far as regards the Contorted Drift and Middle Glacial, precisely the same kind of section as the North-Norfolk cliff affords; and a similar section of the same tableland would be afforded by a line carried parallel to, and about eight miles east of No. XX., through the Kirton and

Fig. 21.—*Section XX., from the Valley of the Orwell to that of a Tributary of the Deben.* (Length $3\frac{3}{4}$ miles. Vertical scale 9 times the horizontal.)

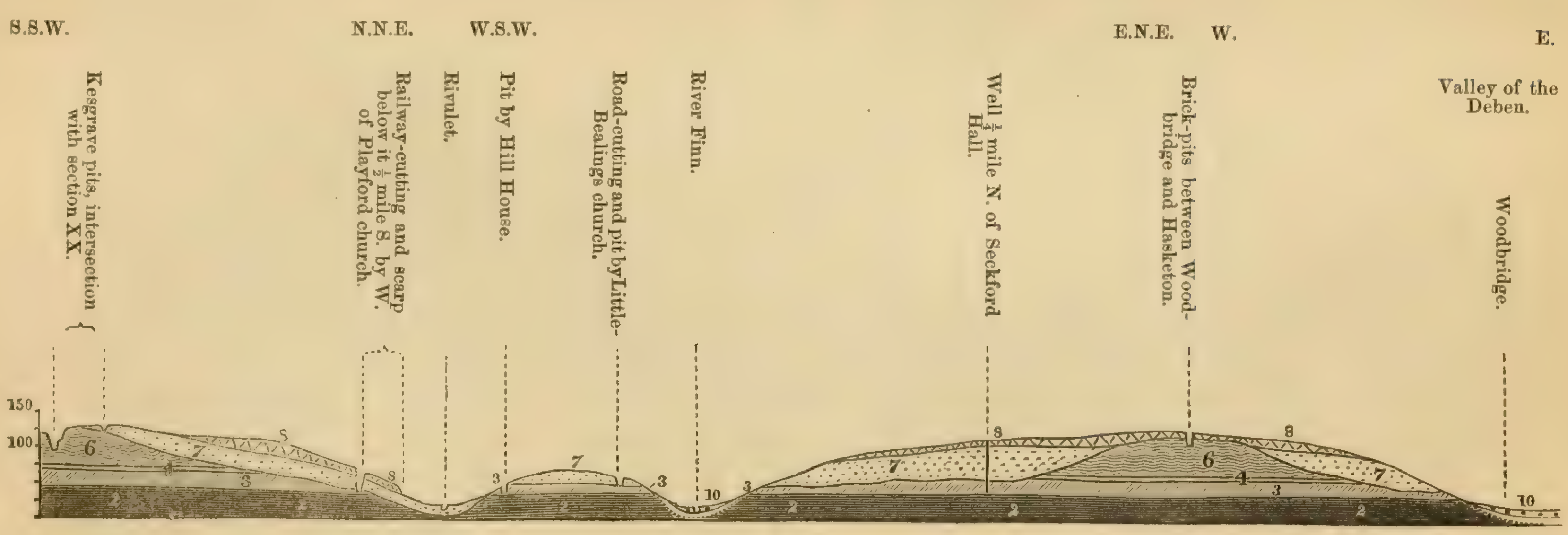
The line of section is slightly deflected southward at Kesgrave church, in a bend of about one mile and a half, in order to intersect the outlier of No. 8.



2. The Lower Tertiaries. 3. The Red Crag (both altered and unaltered). 4. The position of the Chillesford beds, if present. (N.B. If present, it is probable that, owing to the denudation between the Crag and Glacial periods, they are not continuous as represented, but in patches as in sections IV. & V.) 6. The Contorted Drift. 7. The Middle Glacial. 8. The Upper Glacial.

Fig. 22.—*Section XXI., across Valley tributary to that of the Deben and across one Side of the Deben Valley.*

(Length 6 miles. Vertical scale 13 times the horizontal.)



For references, see fig. 21. 10. Postglacial valley-gravel. The dotted lines under No. 10 indicate what may possibly be the continuation of the interglacial valley; and it is possible that No. 10 is in some cases only No. 7, or that deposit reconstructed.

Trimley outliers, the only difference being that the Kirton protrusion is partially capped with a patch of the Upper Glacial.

Looking at the lines of section, as far as they are warranted by the actual exposures, it would appear as though the interglacial valleys thus excavated were, though much wider, shallower than the present ones; but there are facts which point to the inference that in the same way that the valley of the Yare was deeper interglacially than it now is, so that of the Deben (and therefore, as an almost necessary sequence, the other valleys of South Suffolk) was somewhat deeper interglacially also. For instance, the Middle Glacial overlain by the Upper seems to plunge down so completely into the bottom of one of the principal lateral valleys which open out into that of the Deben, that, unless this were the case, the valley could have had no outlet. Section XXI. illustrates this, as well as the position of the important outlier of the Contorted Drift at Woodbridge and Hasketon, the much steeper character of the interglacial valley-slopes formed by it being proved by the great excavation in the Middle Glacial on the east, and by the well sunk through the Upper and Middle Glacial on the west side of it. In this section the sand overlain by the Upper Glacial Clay which fills the bottom of the rivulet-valley, is referred to the Middle Glacial (which is clearly recognizable where it underlies the Upper Glacial above the railway-cutting); but there is some uncertainty whether it be not the sand formed by the dissolution of the Crag; but as it descends below the general level of the London-Clay floor of the Crag (which is well exposed in an adjoining valley where the Middle Glacial sweeps down below it in the way shown in this section), we have shown it as belonging to that formation.

It is not improbable also that the bed 10, represented as valley-gravel, through which the Finn river and the Deben are represented as cutting, may be underlain by Middle Glacial gravel, or be that gravel postglacially reconstructed.

The sinking of the well, shown in fig. 22, was watched and measured daily by one of us, and was interesting as furnishing a perfectly clear scarped section of this tableland down to the Crag-level, at a point but little more than half a mile from the numerous excavations in the Contorted Drift overlain by Upper Glacial, which occur at the Woodbridge and Hasketon brick-pits; and it proved that this Drift, and any other formation, such as the Chillesford Clay, which may have existed between it and the Red Crag, had been completely removed before the deposition of the Middle Glacial. It also disclosed that the band of broken shells a few feet below the junction of the Middle with the Upper Glacial, which is so constant around Yarmouth, and from which were obtained the species given as from this formation in the Supplement to the 'Crag Mollusca,' was also present here; and we obtained from it fragments of the following species:—*Tellina crassa*, Gmel., *Mya arenaria*, Linn., *Mactra arcuata*?, Linn., *Cyprina islandica*, Sow., *Cardium edule*, Lin., *Pectunculus glycymeris*, Linn., *Pecten opercularis*, Linn. The particulars of the sinking were as follows:—

		ft.
Upper Glacial clay		6
Middle Glacial	Coarse gravel	3
	Fine gravel, containing shell-fragments and gradually changing into	3
	Buff sand	45
Red Crag with shells		6
Red Crag in water		4
	Total	67

There was nothing in this deep section answering to the sands described in the first part of this paper as altered Crag, the coarse saccharoid buff-coloured Middle Glacial sand (in the upper part of which occurred the gravel with shell-fragments) being uniform in character throughout its whole thickness, and resting directly on shelly crag. This altered crag occurs, however, in a pit at Seckford Hall, in a small valley about two furlongs from the Well-section.

In the before-mentioned "Introduction" we spoke of a brick-earth at Stowmarket, in the valley of the Gipping, as Postglacial; but Mr. Whitaker informed us that this had been by further excavation exposed as passing under the Upper Glacial clay*. Some other exposures of the same deposit occur also in the neighbourhood of the Gipping valley (which is the continuation of that of the Orwell), while on the wide tableland which divides this valley from that of a rivulet flowing into the Little Ouse, a protrusion of the same deposit occurs (as we are informed by Mr. Whitaker) at Woolpit, five miles north-west of Stowmarket. When, some years ago, we examined the many pits at Woolpit, we found one showing the brick-earth overlying the Upper Glacial, and none showing it beneath that formation; but we are told that some later excavations do show this, and that therefore brick-earths of two distinct ages, one above and one beneath the Upper Glacial, occur there. These various exposures appear to us to indicate that part of West Suffolk is, like the centre and east of the county, occupied by the Contorted Drift, overspread and concealed by the Upper Glacial, with the Middle Glacial similarly distributed

* From an account of the well sunk at the Stowmarket brewery, given by the late Rev. Professor Henslow on a tablet in the Ipswich Museum, the brick-earth of this brick-field appears to underlie the town, and to possess a thickness equal to that at Kesgrave and Woodbridge. Finding the Middle Glacial in section at the brick-field at a lower level than the section of the brick-earth, we were originally led to regard the latter as over the former, and consequently as Postglacial; but a late visit by one of us to the spot disclosed that the facts are really entirely in harmony with the general features of valley-structure which are discussed in the text, the Middle Glacial, which we had supposed to pass under the brick-earth, only lying against it as a deposit of the interglacial valley cut out of that brick-earth. On the opposite side of the river Gipping the valley-sides are all formed apparently by the Middle and Upper Glacial only, which are in section in the railway-cutting near the Station. The other exposures referred to as occurring in the Gipping valley, are one at Coddenham Old Hall (where the Contorted Drift is overlain by the Upper Glacial), and the other by Hawk's Mill, on the north side of Needham Market. This last exposure seems to extend up the lateral valley which runs between the two Creetings. In both sections the brick-earth forming this Drift was contorted when we visited them several years ago.

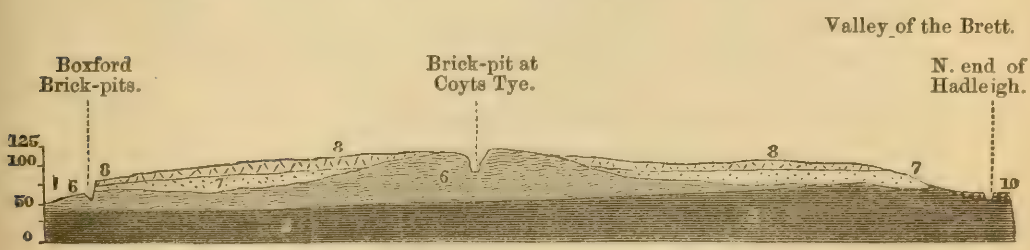
between them, and occupying valleys interglacially denuded in the former in the manner already described; for, with the exception of these few exposures, the sides of the Gipping valley are occupied by the Middle Glacial, like those of the Waveney.

The valley of the Little Ouse and parts of the valleys of some of its tributaries are the only instances in Norfolk and Suffolk which, so far as we are aware, afford any indication of Preglacial origin. In this valley, about Thetford (as also in that of the Thet, a tributary of the Little Ouse), the Middle Glacial is not present, though it sets in higher up it to the eastward. A chalky deposit, very gritty, forming extremely light land, and much resembling in aspect the Contorted Drift as it exists round Holkham, in North-west Norfolk, occurs within the slopes of the Thet and Little-Ouse valleys, as well as on the heights at and around Thetford; but whether this is the Contorted Drift, or an abnormal form of the Upper Glacial, we have not been able to satisfy ourselves. There is also at the brick-kiln on the high ground about a mile north of Thetford a laminated brick-earth overlying a bed of marl or reconstructed chalk which rests on glaciated chalk, and which we have regarded as part of the Contorted Drift. It is possible, however, notwithstanding their not being confined to the valley, that this and the gritty deposit just referred to may represent the interglacial bed (*a*) of the Yare valley which we have already described and shown in sections V. & VI. Further east, up the Little-Ouse valley, and near to the common source of that river with the Waveney, there occur some exposures of brick-earth that seem also to belong to the Contorted Drift. Of these one is 6 furlongs north by east of Garboldisham church, another about the same distance west of Knattishall church, and the third at Fen Street, Redgrave, the last of these being within the Waveney valley, whose source is a mile west of it. For this short distance, therefore, the Waveney valley is of Preglacial origin, like that of the Little Ouse. These three exposures of brick-earth are all within a valley which seems to have traversed a hill of chalk stretching north and south from the neighbourhood of Ixworth to that of East Harling, and which is now mostly covered by the Upper Glacial. Assuming this brick-earth to be the Contorted Drift, then that deposit, instead of covering a generally level floor, as it does to the eastward, here enters and lies in a valley of Preglacial origin, of which the Little-Ouse valley in this part is a re-excavation. Whether this valley was an estuary at the time of the deposition of the Contorted Drift, or merely a submarine channel, there is not evidence to show; but in view of the very considerable submergence of Norfolk during the Lower Glacial period, which the dimensions of the marl masses that are imbedded in the Contorted Drift appear to indicate, an estuarine condition of the Little-Ouse valley during the deposition of that drift is difficult to understand.

Two other small river-valleys occur in South Suffolk—that of the Brett, which flows by Hadleigh into the Stour, and that of the Boxford, another tributary of the Stour. The country between these is occupied by a tableland of Upper Glacial clay, while along the sides of each valley the Middle Glacial is exposed beneath it by the valley-denudation. In the Brett valley the London-clay floor is exposed as far up as above Hadleigh; but although some traces of the Red Crag have been found in it by the members of the Geological Survey, the Contorted Drift does not show itself as coming out on the lower slope of this valley, unless a brick-earth occurring at Layham * belongs to that drift. In the Boxford valley, however, the Contorted Drift is exposed at Boxford brick-kiln in several sections, in one of which we found it overlain by the Upper Glacial clay with a slight thickness of Middle Glacial gravel between them. Below Boxford for some miles the Contorted Drift seems to occupy the valley-bottom; and on the summit of the tableland dividing this valley from that of the Brett, and nearly midway between them, we came, at a place called "Coyts Tye," upon a deep excavation of laminated brick-earth, which we regard as most probably the Contorted Drift. It is, of course, possible that this brick-earth may be Postglacial, and occupy a hollow in the Upper Glacial clay which covers the country all round; but the depth to which it was excavated (upwards of 30 feet), and the position which it occupies on the water-parting of the district, militate against this view.

Assuming that our view as to the identity of this brick-earth with the Contorted Drift is well founded, it indicates, in connexion with the exposures in the valley at Boxford, that the excavation of these two valleys was of interglacial origin, and precisely analogous to what we have shown as obtaining in the case of the valleys of the Orwell and Deben estuaries. Section XXII. shows what, according to our view, these exposures indicate.

Fig.23.—*Section XXII., from the Boxford Valley to the Brett Valley.* (Length 4 miles. Vertical scale $17\frac{1}{2}$ times the horizontal.)



References as in figs. 21 & 22.

We have not been able to detect the presence of the Contorted Drift in Essex beyond Bulmer, near Sudbury, where we found what we regarded as that deposit overlain by 11 feet of Middle Glacial in a pit half a mile north-east of the church; but, from some sections

* The excavations at Layham seemed to us, when we examined them in 1869, to be in the Woolwich beds and London clay; but Mr. Whitaker informs us that the Survey regard them as being in a Glacial bed. They are overlain at one place by the Upper Glacial.

mentioned to us by Mr. Whitaker, it probably extended further into that county, though now probably mostly removed by the interglacial denudation which we have been discussing. Reviewing the whole case, however, it seems to us that the evidence shows that though Norfolk and Suffolk appear, with the exception of the extreme northern part, near Cromer (where the Contorted Drift, capped irregularly by the Middle Glacial, exclusively forms the country), to be occupied almost entirely by the Upper and Middle Glacial deposits, yet that this appearance is in a measure deceptive, and that the chief portion of all this area is underlain by a continuation of the Contorted-Drift deposit of North Norfolk more or less denuded throughout its range, so as to form troughs wider and deeper than the existing valleys, into which the succeeding Middle and Upper Glacial deposits have been bedded as well as spread like a mantle over the rest of the denuded surface. For a general view of the extent to which the Lower Glacial formation is exposed over the eastern half of Suffolk and Norfolk, we refer to the map which accompanies our "Introduction" before referred to.

The absence over the greater part of Essex of any traces of the Lower Glacial deposits precludes any satisfactory inference as to how far the valleys of that county may have been formed or modified by interglacial denudation. The middle portion of the valley of the Blackwater has its eastern side formed by an escarpment of London clay, which is part of a series of concentric curved escarpments to which that of the Chalk extending from Cambridgeshire to the Chiltern Hills belongs. As it is evident that all these concentric escarpments had their inception in one disturbance, we may infer that, if one of them can be shown to be Preglacial, the rest of the concentric series are Preglacial also. The Upper Glacial clay lies up to that one of the series which is formed by the Chalk, and shows that it had originated prior to that clay. The Middle Glacial also in part of Bedfordshire occurs in such a way as to indicate that at the time of its deposition the chalk escarpment had acquired much of its present configuration; but the Lower Glacial beds do not occur anywhere in such a position as to indicate whether they preceded the formation of these escarpments. It is, however, most probable that they did not; for these curvilinear concentric escarpments appear to have originated in disturbances which upheaved and terminated the older Tertiary formations; and on this assumption the portion of the Blackwater valley referred to seems to be of Preglacial origin. In this part of the valley a bed of blue clay, full of chalk débris, and undistinguishable from the Upper Glacial of the Eastern Counties, was found, in sinking a well at Witham railway-station, to underlie the Middle Glacial gravel*. Some years ago we found what appeared to us to be the same bed, in the bottom of the valley, in some brick-earth pits at Appleford Bridge, near Witham, where it passed up, *seemingly without any break*, into sandy laminated brick-earth, which was overlain by gravel resembling that of the Middle Glacial so plentiful in the neighbourhood. As this exposure cor-

* Geol. Mag. vol. v. p. 98.

responds with the level at which the clay was reached in the well at the railway-station, it seems to us that this bed of chalky clay and overlying brick-earth may probably be similar to that occurring in the Yare valley, marked *a* in Sections V. and VI., and of interglacial age; and if so, the beds at Copford, from which the late Mr. John Brown obtained an extensive collection of the remains of Vertebrata and of land and freshwater Mollusca, may possibly be of similar age. We are informed by Mr. Whitaker that the pits at Appleford Bridge were closed when the members of the Geological Survey examined the district, but that they found brick-earth in the same part of the valley, not far off, which yielded remains of freshwater Mollusca, and which they regarded as of Postglacial age. In the face of this we feel more hesitation than we otherwise should in identifying the bed at Appleford Bridge with that in the Yare valley; for the evidence available to guide us to an opinion as to its precise age (whatever we regard that as being) is, it must be confessed, obscure. Section XXIII. represents the appearance presented by the section when we examined it.

Fig. 24.—*Section XXIII., at Appleford Bridge, near Witham.*

a. Blue Clay with rolled Chalk, identical in appearance with the Upper Glacial of the neighbourhood.
b. Sandy Brick-earth passing down imperceptibly into *a.*
c. Red sandy gravel passing downwards into yellow sand.
d. Gravelly wash and humus. *e.* Water. *f.* Talus &c.

It was pointed out by one of us * that the highest elevation to which the Middle Glacial attained in East Anglia was about 360 feet, at Danbury in Essex, the usual limit being between 200 and 250 feet, the Upper Glacial overlapping it above these elevations and resting on the older formation direct; and in Middlesex, at Finchley, it underlies the Upper Glacial at an elevation somewhat exceeding 300 feet. Mr. Penning † has made this limit in elevation and this overlap the basis of an argument to prove that the submergence was, during the deposit of the Middle Glacial, confined to something like the altitude to which this formation ranges. The not unfrequent absence of the deposit, however, at low elevations within the area over which it usually occurs, and its absence over a wide area, embracing most of the counties of Cambridge, Lincoln, Northampton, Leicester, Rutland, Huntingdon, and Bedford, at elevations far below

* Geol. Mag. Feb. 1870.
† Quart. Journ. Geol. Soc. vol. xxxii. p. 194.

these altitudes and down to the sea-level, would at first sight make it doubtful how far this limit to the submergence is a sufficient explanation of the mode in which the deposit is distributed. One circumstance, however, seems to corroborate it, which is that the Middle Glacial gravel at Finchley is largely made up of pebbles derived either from the pebble-beds associated with the contiguous Lower Bagshot outliers of Essex or from those beneath the London Clay; and we must suppose that those sources were above water at the time, in order to supply the pebbles, as these do not appear to have been introduced by the action of glacier ice. The highest of any of these sources does not attain an elevation exceeding 440 feet; and most of them only reach elevations nearly 100 feet less than this, and not much exceeding that of the Middle Glacial itself at Finchley. If, however, this limit to the submergence during the accumulation of the Middle Glacial was the case, we should regard it as an indication that, so far from the glacial submergence having been an uninterrupted one, an emergence must have succeeded the Contorted Drift, because, the entire thickness of the Lower Glacial deposit around Cromer having itself exceeded 200 feet, there must have been far more than 200 feet of water over it in order to transport the bergs which, in grounding, have deposited such great masses of Marl in that Drift, contorting it in the process. Some of these masses are so enormous that it is hardly possible to suppose that a berg capable of transporting one could have grounded in much less than 1000 feet of water*; so that it seems to us that when these masses were thus introduced, Northern Norfolk had undergone a submergence far beyond what is thus supposed to have prevailed during the accumulation of the Middle Glacial. One of these masses forms the entire cliff a short distance west of Woman-Hythe Gap; and this it was our fortune once to see nearly free from the usually obscuring talus; and it seemed to be about 300 yards in length by 60 feet in height. Its breadth, of course, was concealed.

It is clear that these introductions took place before the formation of the gravel overlying the Contorted Drift in the Norfolk cliff—because the line of denudation dividing this drift from the overlying gravel is clearly defined, and cuts across the Drift and its included masses indiscriminately.

If, therefore, the land rose after the formation of the Contorted Drift to such an extent that during the deposit of the Middle Glacial the depth of water did not exceed 400 feet, we need not hesitate to suppose that it emerged altogether, and that the Lower-Glacial sea-bottom was converted into land, if other features, such as that indicated possibly by section XVIII. at Starston, and the excavation of valleys through this sea-bottom, with the formation in them of the interglacial bed of the Yare valley, point in this direction.

* Bergs of great dimensions which have acquired a pinnacled form, and therefore spread out under water with a wider base, float in a much less depth of water than those of tabular form; but, before they had time to acquire that shape, they would probably have parted with the freight of marl carried at their bottoms.

Looking at the subject in the light of the evidence at present available, the probabilities appear to be that such conversion of the sea-bottom into land did take place, and that first by tidal erosion during its emergence, and afterwards by subaërial agencies, the denudation which we have been describing was accomplished. The presence of a bed of clay full of chalk débris exactly resembling the Upper Glacial, and apparently formed by similar agency, beneath the Middle Glacial in the Yare valley, and probably in other East-Anglian valleys also, seems to us to indicate that the valleys thus interglacially denuded became, prior to their submergence, filled with ice. The interval marked by the formation of the interglacial land-surface and valley-excavation may, and indeed, if our suggestion of the interglacial age of the Kessingland bed should prove to have good foundation, must have been accompanied by a climate as temperate as that of the Preglacial Forest-bed of the North-Norfolk coast. The return of glacial climate would probably have first filled these valleys with small glaciers, and thereby for the most part caused the destruction of any river or terrestrial deposits which had been formed in them, the Kessingland bed (supposing it to belong to this interval) being one which escaped this destruction. As submergence set in, these glaciers would retreat before the sea, which would first occupy their valleys as fiords, and in so retreating would leave behind the moraine-material they produced and extruded at their terminations. Inasmuch as all the valleys in which we find a bed of clay with chalk débris that is presumptively identical with the one in the Yare valley, shown in sections V. and VI., are, in the upper portions of their courses, excavated interglacially down to the Chalk (though this is in some instances concealed), the débris of that formation would necessarily constitute a large part of the moraine of their glaciers; and we have already mentioned, as bearing upon this hypothesis, that wherever this bed of valley-clay with chalk-débris rests on the Chalk, the surface of that formation, for a few feet depth, is in a highly glaciated condition, forming a soft greasy marl, very different from the condition which it presents beneath the Crag or Lower Glacial sands through which the valleys containing this moraine bed are cut. The gradual change of clay (which, except for its bluer colour, is in all respects similar to this of the Norfolk valleys) upwards into stratified brick-earth at Appleford Bridge, in the Blackwater valley, seems to indicate the deposition of a sedimentary deposit in one of these fiords following immediately on the recession of the glacier; and, as we have mentioned, one of the sections in the Yare valley, that at Trowse Junction, shows something similar.

3. *Consideration of the Mode in which the Middle Glacial was accumulated, and of the Way in which the Sequence of the Beds posterior to the Lower Glacial is to be traced.*

The origin of the formation of sand and gravel which we have called the Middle Glacial, and its succession by the wide-spread

Boulder-clay, or Upper Glacial, which covers so much of England and Scotland, and of which only the oldest or first-accumulated portion is present in East Anglia, seems to us to have arisen from the state of things we now propose to describe.

As the submergence proceeded, and the sea, after occupying, as fiords, the interglacial valleys of East Anglia, gradually rose over the tablelands, so did the land-ice on the mountain districts of the north of England accumulate and descend over the lower ground until it formed a continuous sheet, which ultimately enveloped probably every thing as far as it extended. The thickness of that portion which descended over Yorkshire may eventually have amounted on the lowest ground to 1200 or 1500 feet, though very likely it was much less; but though enveloping high and low ground alike, its principal motion, and with it that of its *moraine profonde*, was, as it seems to us, through the greater valleys only, to their seaward termination.

Thus a part moved through the great valley of the Tees, another part through the great valley of Pickering, while a third moved through the smaller valley of the Humber. None of these three, however, concern us in relation to the East-Anglian deposits further than that we recognize in that portion of the moraine which passed through the valley of the Humber and forms the *lower part* of the Glacial clay of Southern Holderness, or that in which chalk débris is abundant, a deposit coeval with the Upper Glacial of East Anglia. The moraines of the first two branches, which were contemporaneous with this, were, it seems to us, extruded beyond the present coast-line, and some way out in the present North Sea.

The largest branch of the Yorkshire portion of the sheet is that with which we have to concern ourselves, as it is that to which the Upper Glacial clay of East Anglia owes its origin. This branch moved southwards over Lincolnshire, as is proved, not only by the profusion in that clay of Jurassic débris derived from the troughs which lie between the chalk escarpment and the respective Oolitic and Liassic escarpments of that county, but also by the occurrence in it of lumps of the red chalk * which underlies the white chalk of that county and of Yorkshire, but which ceases near Hunstanton, in the extreme north-west of Norfolk. This red chalk débris has travelled in one direction as far as the brow of the Thames valley, where it occurs in association with the hard stony chalk of Yorkshire and Lincolnshire, which constitutes the principal proportion of the débris in the Upper Glacial clay of that district as well as of East Anglia in general; and in similar association it has found its way as far as the Cotteswolds, where it occurs in gravels which probably represent both the Middle and the Upper Glacial of East Anglia, that clay dying out about thirty miles north-east of the Cotteswolds. These gravels have been traced by Mr. Lucy † to alti-

* Some of these lumps may be fragments of the pink bands which occur at certain horizons of the Chalk in Lincolnshire and Yorkshire, but are confined to those counties.

† "The gravels of the Severn, Avon, and Evenlode, and their extension over the Cotteswold Hills," Cotteswold Club, April 1869.

tudes of 700 feet in Gloucestershire, showing that the submergence over that part of England had at this time reached at least that extent.

This branch, as it seems to us, and as we shall presently explain, reached as far south as the borders of the counties of Buckingham, Bedford, Hertford, Essex, Suffolk, and Norfolk during the formation of the Middle Glacial, the sand and gravel of which we regard as produced by powerful currents washing out and searching the moraine of this branch, and distributing the insoluble residuum over the sea-bottom.

By the time when this branch of the ice-sheet reached the counties just named, not only had the East-Anglian valleys which the sea had first filled and converted into fiords become engulfed, but the whole country beyond the limit of the land-ice had become submerged to the extent of near 400 feet. South of the limit which we shall presently define, it seems to us the land ice-sheet never extended; and the formation of the Upper Glacial marks its gradual recession and disappearance.

This formation was represented in a paper by one of us* as formed by the extrusion by the ice-sheet of its moraine and the distribution of this at the bottom of bergs. Such we still believe to have been its origin. In some instances, as where the Middle Glacial passes up, as it often does, by gradual change into the Upper, this seems to have been due to the fall of the moraine-material from the bottom of the bergs in small quantities; but more generally, as where the Upper Glacial rests sharply and irregularly on the Middle, the dropping seems to have occurred in large sheets or masses. Where the latter has occurred, it has frequently happened that the clayey mass, having fallen on sand saturated with the sea-water, and therefore semifluid and yielding, has sunk into it, though without contorting it, and so given rise to the appearance which was at first supposed by us to indicate a slight fault.

Where the dropping of the mass occurred on less-fluid though still yielding material, such as the brick-earths of the Contorted Drift, it has sunk into or penetrated it to some extent, but also without contorting it†; and herein is presented a remarkable contrast to the introduction of the marl masses into the Contorted Drift, which, being invariably accompanied by contortions, was evidently due to the grounding of bergs during the accumulation of the deposit itself.

It is obvious that the hypothesis of the Middle Glacial having been deposited while the eastern side of England was submerged to the extent of about 400 feet, offers no explanation of the absence of that formation over a large district of England which lies north of it and forms low ground, unless we are prepared to suppose that a great change in the *relative* levels of this part of our island

* Quart. Journ. Geol. Soc. vol. xxvi. p. 90.

† A striking section of this is to be seen in a great excavation a quarter of a mile east of Yarrow House, and nine furlongs south of the bridge over the Wensum at Guist, a very little out of the line of Section VIII.

has since taken place. Of such a change, however, we can discover no indication, the great changes in relative level having in our view occurred in that part of England which lies south of the Thames, which was the theatre of disturbance at the close of the Glacial period, when the country rose from the sea *.

The explanation therefore which Mr. Penning has offered of the absence of the Middle Glacial from the fens of Cambridgeshire, viz. that the currents from the north that formed it were entirely excluded from the valley, seems to us altogether inadequate—because its absence is not confined to that valley, but prevails over most extensive districts, which must have become submerged by a depression of less than even 200 feet; and the explanation is, we think, rather to be sought in the position of the great branch of the land-ice to which we have adverted. We may either suppose that the original outspread of the Middle Glacial extended over this region, and that the advance of the land-ice ploughed it out and destroyed it along with much of the older formations on which it rested, or that the land-ice occupied the region during the accumulation of the Middle Glacial, and so prevented its deposit. It must be admitted that neither of these hypotheses explains the absence of the formation beneath the Upper Glacial in South Essex, where this for some miles overlaps it. It is also a perplexing feature that some denudation has occurred in the bottoms of valleys, by which the Upper Glacial (or clay undistinguishable from it) rests directly on beds older than the Middle Glacial sand, as is shown in Section XV. in the case of the Ket valley, and of which instances are also to be found in the Waveney, Blyth, and Gipping valleys. This, if the clay so occurring be the Upper Glacial, seems to have taken place either during the accumulation of that deposit, or that of the Middle Glacial, but to have been very partial or local. We are not prepared at present to offer any explanation of either of these difficulties; but, with this exception, the latter of the two hypotheses seems to harmonize with all the phenomena surrounding the question, as we will endeavour to show.

In a paper by one of us on the correlation of the Scotch and English Glacial deposits †, the sequence of the Glacial formations posterior to the Contorted Drift (that is, posterior to the interglacial unconformity already discussed) was, it was attempted to be shown, both vertical and horizontal, and much more the latter than the former. In following the South-Yorkshire coast-section this is clearly seen; for the clay which near the Humber-mouth and for some twenty miles north of it forms the lower part of the cliff, and, as proved by borings, descends to a considerable depth beneath the beach, is as full of rolled chalk as is the East-Anglian Upper Glacial, with which, indeed, we identify it. Where the Glacial beds remain least denuded this clay is seen to be succeeded upwards (in sections 100 feet and more in height) by clay containing chalk débris in less and less quantities, till in the uppermost portion of the cliff-section,

* Quart. Journ. Geol. Soc. vol. xxxii. p. 198.
† Geol. Mag. April, 1872.

below the capping of Postglacial clay (called by us and by Mr. Rome the Hessle clay *), this débris disappears altogether. Following the cliff northwards we see precisely the same change taking place in a horizontal direction, until, as we near Flamborough Head, where the chalk floor rises above the beach, this débris disappears from the clay altogether, and the clay which capped the cliff further south, and was underlain by a great thickness of clay filled with rolled chalk, rests upon the Chalk direct, save where in the old buried gorges of the chalk floor it is underlain by moraines formed purely of rolled chalk that occupy these gorges, and are evidently connected with the great mass of clay which is so full of the same material further south. Thus the clay without chalk spreads for a certain distance southwards over the clay with chalk, but gradually takes its place northwards; and this is the same kind of sequence and relation which obtains between the Upper and the Middle Glacial.

Let us now suppose that the branch of the land-ice to which the Upper and Middle Glacial of East Anglia were due extended southwards in such a way that, avoiding all but the extreme west of Norfolk, it touched the west of Suffolk a little east of Thetford (ploughing out and destroying in its course whatever beds of Lower Glacial age may have been there), and that from this point its edge trended south-westwards by Newmarket and along the chalk escarpment of Cambridgeshire to Baldock, whence, after making a little bend towards Biggleswade, it stretched to the borders of Buckinghamshire. This boundary would (except so far as the excess of altitude above 300 feet causes the absence of the formation) roughly define the westerly limit of the Middle Glacial in Norfolk, Suffolk, and Essex, and its northerly limit in Hertfordshire and Bedfordshire.

Our knowledge of the Midland Counties does not allow us to define the western continuation of this boundary with precision; but gravels and sands underlying the Upper Glacial (chalky portion) occur in Buckinghamshire, Warwickshire, and Leicestershire, west of a line drawn northwards from the termination of the already defined boundary towards Leicester, though these are frequently (and, indeed, generally in a north-westerly direction) overlapped by the Upper Glacial resting directly on the older formations. These gravels seem to represent the Middle Glacial, both in position and also in some degree in extent of outspread; but the gravels inferior to the Upper Glacial which occur within the space described by this boundary are so extremely rare and sporadic that they seem due to some local action during the accumulation of the Upper Glacial, and not to belong to our East-Anglian formation †.

* The capping bed of Hessle clay does contain chalk débris, but not of the rolled character of the Glacial clay below, being more or less subangular.

† An extensive outspread of sand occurs in Lincolnshire on the Liassic and Oolitic escarpments; but this can be traced eastwards as passing *over* the Upper Glacial. There is also a considerable sand formation in the north of Nottinghamshire; but, so far as we are able to judge, this seems connected with the later part of the Upper Glacial, viz. that of which we have spoken as taking the place of and partially overlying the clay containing chalk débris, or else with the Hessle sand.

Over the area thus defined, it seems to us, the ice rested during the accumulation of the Middle Glacial, and so kept that formation out of it; and the cause (whatever it was) which put an end to the formation of sand and gravel, at least in the neighbourhood of the land-ice, was coincident with the commencement of a recession in that ice. As this recession progressed the moraine-material, no longer washed out and distributed over the sea-bottom as gravel, was left behind in a continuous form as unstratified Glacial clay. Some of it, perhaps the greater portion, remained as extruded; but part of it was carried at the bottom of bergs as they broke off, and dropped as before described, partly over the previously spread-out gravel and partly over or onto previously extruded moraine-material which had been left undisturbed. The presence of the thin sand-bed in the midst of this unstratified clay with rolled chalk at the base of Dimlington Cliff, in Holderness, which contains *Nucula Cobboldiæ* and other Mollusca in the condition in which they lived, is thus explicable; for the Mollusca having established themselves on the surface of the submarine moraine which the receding ice had left, were afterwards covered up and destroyed by the descent from the bottom of a berg of a mass of the subsequently extruded moraine-material which such berg had carried away. Thus the formation of Glacial clay went on principally in the immediate contiguity of the ice, where it arose from the extruded material being left by the ice in its recession, and subordinately at a little further distance from it, where it arose from the same material being dropped on the sea-bottom over previously accumulated formations.

So long as the land-ice rested upon Lincolnshire and South Yorkshire this moraine-material was principally made up of the débris of the Chalk and of the softer beds of Jurassic age; but as it shrank back into Yorkshire, this débris, gradually lessening, eventually ceased, its place being taken by the débris of formations lying north of the Yorkshire Chalk Wold with which the clay without chalk débris that both overlies the clay with this débris and gradually takes its place northwards is filled. A glance at our map in the 'Introduction to the Crag Mollusca' Supplement, will show that in South-east Suffolk and in Northern Norfolk the Middle Glacial coming out from beneath the upper, extends far beyond it, a solitary patch or two of the latter occurring here and there over the former, indicating some exceptionally distant drift of the moraine-material; and a similar feature is presented by North-east Essex, and, to some extent, by Hertfordshire also. In this we get a precisely parallel feature to that presented in the overspread of the Upper Glacial clay with rolled chalk débris in Holderness, by the later clay without that débris; and in this respect and in the horizontal succession of the older deposit by the newer in a northerly direction, the relation of the Middle Glacial to the Upper in East Anglia seems identical with it. The parallel may be even pursued further; for just as the clay destitute of chalk débris is but thinly spread over the clay containing it, and assumes far greater thickness as it takes its place horizontally, so is the thickness of the Upper Glacial where it rests on the Middle, but small in comparison with what it possesses where it takes its place northwards, and rests directly on the older formations*.

It is in this way that we trace the relation and succession of the beds of the Glacial formation which are posterior to the Contorted Drift, the clay of the North of England being posterior to that of East Anglia, and the mountain-drift and high-level sands of Wales and Lancashire posterior to both, having been formed when the ice which, during the earlier stages, had kept the sea out of the deeply depressed land, had so retreated and shrunk as to leave the north of Britain a snow-capped archipelago. A comparison of the molluscan remains of the Middle Glacial, of the Upper as revealed by shell-bearing sand bands occurring in it at Dimlington and Bridlington, and of these high-level sands is in the strictest accordance with this succession. The details of the mollusca of the Upper and Middle Glacial will be found in the tabular lists of the Supplement to the 'Crag Mollusca,' with slight additions in the note at the end of this paper, while those of the high-level sands are to be found in that given by Mr. Darbishire†; and it will be seen that while several Crag species, now either unknown as living or known only as living in remote and mostly more southern seas, occur in the Middle Glacial, only one or two such have been found in the Upper, and these in association with many very arctic species; while in Mr. Darbishire's list of these high-level sands none but species still living occur, and these all, with the exception of two or three arctic forms, still surviving in British seas.

Note, by Mr. S. V. Wood, F.G.S., *the Author of the* 'Crag Mollusca,' *on* new Occurrences *of Species of* Mollusca *from the* Upper Tertiaries *of the* East of England.

Red and Coralline Crags.

Nassa conglobata, Brocchi. (Crag Moll. p. 32, *v.* Suppl. p. 15.)

The only specimen of this species known to me at the time of the publication of the Supplement to the 'Crag Mollusca' consisted of a solitary but perfect one found by Mr. Charlesworth, many years ago, at Walton Naze. Mr. Canham, however, has since found a specimen in the Red Crag of Sutton, in contiguity to the outlier of Coralline Crag; and I am now inclined to think that, like such shells as *Trophon elegans* and *Cassidaria bicatenata,* formerly supposed to be Red and not Coralline Crag shells, *Nassa conglobata* is really a Coralline-Crag species, and occurs in the Red Crag only by derivation. It may, perhaps, be objected that this is an unwarranted conclusion,

* In wells and in railway-cuttings and sinkings beneath them in Cambridgeshire and Huntingdonshire the Upper Glacial has been found to possess a thickness exceeding 150 feet. We are not aware of its having been found to have more than a third of this thickness where underlain by the Middle Glacial.

† Geol. Mag. vol. ii. p. 298, and Quart. Journ. Geol. Soc. vol. xxx. p. 40.

seeing that *N. conglobata* has not yet been found in the Coralline Crag, as have the other two shells mentioned; but such, nevertheless, is my belief.

Fusus Waelii, Nyst.

Two perfect specimens of this Oligocene species, one of which precisely agrees with fig. 2 *a* of plate vi. of Von Könen's work on the Middle Oligocene, were sent me by Mr. Reed, of York. They had been obtained from the excavations for Coprolite in the Boyton Marshes. As these excavations are, from their position, flooded with water, I am informed by Mr. Charlesworth that it is difficult to say what division of the Crag they are in; for peculiarly Red-Crag species are intermixed with Coralline Crag ones. Mr. Bell, however, tells me that in the excavations referred to, about 18 inches of Coralline-Crag are overlain by some Red Crag, and that, in working, the labourers mix the two together, so that it is only from the colour of the specimens and the character of the shell that an opinion can be formed as to the division to which they really belong. If, therefore, *F. Waelii* belongs to the Crag, it is probable that it is to the Coralline, the colour and condition of the shells of which formation it possesses. The worn specimen described in the Supplement to the 'Crag Mollusca,' p. 29, as *Fusus crispus* (Tab. xi. fig. 10) is possibly only a specimen of *Fusus Waelii*.

Murex Reedii, S. Wood.

A perfect specimen of a *Murex*, obtained by Mr. A. Bell from the Coprolite excavation in the marshes at Boyton, has been sent me by Mr. Reed. In size and general appearance it resembles the figure of *M. Haidingeri*, Hörnes, given by Dr. Hörnes in tab. xxiii. of his work on the Vienna beds, but differs in not having any transverse or spiral striæ, and in possessing some denticulations on the inside of the outer lip. I have assigned to it the above specific name. If a Crag species, it doubtless belongs to the Coralline Crag, the colour and condition of the shells of which formation it possesses.

Chemnitzia senistriata, S. Wood.

A small species of this genus was obtained by me from the Coralline Crag of Sutton. It is a quarter of an inch in length, has slightly convex volutions, and somewhat resembles the figure of *Scalaria quadristriata*, Phil., as figured by Dr. Speyer, Conch. Cassel Tert. t. xxiv. f. 9; but my shell has a vertical columella, and belongs to the genus *Chemnitzia*.

Scalaria torulosa, Brocchi (Conch. foss. subap. p. 377, tav. vii. f. 4).

A specimen of this species, obtained by Mr. A. Bell from the Red Crag of Waldringfield, has been sent to me by Mr. Reed. It is doubtless only derivative in the Red Crag; but from what bed it was derived I do not venture to suggest.

Chillesford Beds.

Abra prismatica is given in the list in the Supplement to the 'Crag Mollusca' as doubtful from these beds. An undoubted specimen has been sent me from Aldeby, by Mr. Dowson; and he informs me that he has obtained several there.

In addition to the species given in the Synoptical List in the Supplement to the 'Crag Mollusca.' I have since identified the following from specimens obtained by Mr. Harmer and my son.

Lower Glacial Sands.

Buccinum undatum, *Linn.*, var. tenerum, from Belaugh.
Melampus pyramidalis, *J. Sowerby*, from Rackheath.
Cardium islandicum, *Linn.*, from Belaugh. A doubtful identification.
Donax vittatus, *Da Costa.* One specimen from Belaugh, and two from Weybourne.
Thracia papyracea, *Poli*, from Belaugh. One perfect specimen.
Cyrena fluminalis, *Müller*, from Belaugh. Small.

Middle Glacial.

Hydrobia ulvæ, *Pennant*, from Lound, near Yarmouth. One perfect specimen.
Mactra arcuata (?), *J. Sow.* Part of the hinge of a specimen of *Mactra* occurred in the shell-band in the well two furlongs north of Seckford Hall, Great Bealings, which shows the ridged or striated markings on the lateral teeth. No other species known to me of that branch of the genus which has these markings would agree with the proportions of this fragment; so that I have little doubt, small as the fragment is, of its specific identity with *M. arcuata.* In the list accompanying Mr. Prestwich's paper on the Crag, *Mactra arcuata* is assigned by Mr. Jeffreys as a variety of *Mactra glauca* (Quart. Journ. Geol. Soc. vol. xxvii. p. 484); but this shell belongs to the section of the genus which is destitute of the striated markings, and was made the type of the genus *Mactra* by the late Dr. Gray, while those species which possessed these markings were placed by him in a new genus, which he called *Spisula,* and of which he considered *S.* (*Mactra*) *solida* the type. The fragment in question, however, does not agree in its proportions with *M. solida,* but with *M. arcuata,* which, for the reasons just given, I still consider different from any species yet known as living. Other portions of the shell also occurred with it.

Postglacial.

Trochus helicinus, *Fabr.* A perfect specimen from March. This species rarely inhabits the Shetland Seas, but is common in all Arctic seas, and is fossil in the Clyde beds.
Tapes, either pullastra, *W. Wood,* or virgineus, *Linn.* A fragment from Hunstanton.
Tellina lata, *Gmel.* A specimen from the March gravel in the Cambridge Museum.
Cyrena fluminalis, *Müller.* Numerous specimens from March.

(*For the Discussion on this paper see p.* 140.)

6. Note *on the* Red Crag. By William Whitaker, B.A., F.G.S. (Read November 8, 1876.)

(Communicated by permission of the Director General of the Geological Survey of the United Kingdom.)

My work on the Geological Survey in the Crag District has led me to think that previous observers have made a slight error in the classification of a certain ferruginous sand that is often to be seen above the shelly Red Crag, the line of junction being mostly very irregular.

This sand has been described by Prof. Prestwich as an "upper division" of the Red Crag, or, to quote his own words, "owing to the want of all fossils in the neighbourhood of Ipswich, as the 'unproductive sands' of the Red Crag"*; and he goes on to speak of the "erosion of the lower division" underneath this, afterwards classing the upper with the Chillesford sands†.

Mr. S. V. Wood, Jun., has referred the ferruginous sand in question to various horizons in the Glacial Drift, I believe with a constant tendency to lower its horizon; but his former views need not be dwelt upon, as that tendency has continued until he has accepted my classification, and now regards this sand simply as Red Crag, not separated stratigraphically or palæontologically from the shelly mass below.

The so-called "eroded" surface of the shelly Crag, noticed by various observers, is, indeed, apparently so only; but I must say that in many sections there is little or nothing to throw doubt on the reality of the appearance, which is somewhat analogous to the "mimicry" sometimes seen in insect life, though in our case one cannot see any object to be served by the delusion, unless it be the bewilderment of geologists. An examination of a large number of sections, however, and an attention to mere local details that could hardly be expected from any one but an observer who is obliged to note them as a matter of business, has conclusively shown that we have in this case not an eroded surface, worn out in a lower before the deposition of a higher bed, but an occurrence akin to the "pipes" of sand &c. so often seen piercing the top of the Chalk, and which, too, have also been taken as evidence of erosion, though their origin is now well understood: we have, in fact, an irregular underground surface, caused by the dissolving action of carbonated water in permeable beds, a surface formed after the deposition of the upper beds by the dissolving away of the shells that they once contained.

That the above is the true explanation of the irregular removal of the shells was first suggested to me by the fact that the apparently unfossiliferous sand above is, for the most part, exactly like the sand of the shelly Crag below, differing only in the absence of shells. Confirmatory evidence was given by the not uncommon occurrence in the upper sand of layers or masses of ironstone or

* Quart. Journ. Geol. Soc. vol. xxvii. p. 333. † Ibid. pp. 336, 338.

iron-sandstone, which were often found to contain impressions and casts of the shells that had been dissolved out; and these, as far as could be told, were of Crag species. They occur in the area in which the sand has been thought to be unfossiliferous; and I believe they have not been described before from thence; but in a paper read to the Society in 1874 I have noticed like impressions of shells near Sudbury and Hadleigh*.

Absolute proof, however, of the correctness of the explanation advanced was got by the observation of a few sections in which the lines of bedding, or even of false-bedding, in the shelly Crag were continued into the sand without shells. In some cases a marked gravelly layer was clearly seen to be at one spot in the Crag and at another in the sand; and in one pit a hand-specimen could be got of such a bed, half containing the actual shells, and the other half with casts only. In some pits large masses of shelly Crag are to be seen quite surrounded (in section) by the shelless sand—a fact difficult of explanation on any other view, but comparatively easy to understand as brought about by irregular dissolving action, checked in places by local hardness or slight decrease of permeability in the beds.

In many cases the dissolving away of the shells would seem to have been followed by some destruction of the lines of deposition in the sand; and, indeed, we should expect such a thing to occur on the abstraction of so much material. It is, of course, in these cases that the appearance of erosion is most deceptive.

It may be asked "What becomes of the carbonate of lime of the shells?" Some of it is doubtless carried away in the water of the many springs from the bottom of the Red Crag, thrown out by the London Clay beneath; but in places some of it is again deposited in the lower beds of the Crag as whitish marly streaks in slight fissures or open spaces. Very possibly, however, great part of the dissolution of shelly matter may have taken place under conditions somewhat different from those we now see, when perhaps the Crag was more permeated by water, or even water-logged.

Small as this subject may be, yet it is, I think, worthy of notice, and for three reasons:—because it tends to simplify our classification over an important Crag tract; because it shows a greater extension of the Red Crag than has been thought to exist, that deposit occurring in its almost unfossiliferous condition some way beyond where it is known in its shelly state; and because it draws attention to that slow metamorphism which takes place in permeable beds through the agency of water, whether as a dissolver of carbonate of lime &c., or as a depositor of iron-oxides.

Postscript.

After this Note was read, I heard from M. E. Vanden Broek, of Brussels, that he had observed an irregular junction of shelly and shelless sand, like that above described, in Belgium, and that he attributed it to the same cause as that now suggested.

(*For the Discussion on this paper see p.* 140.)

* Quart. Journ. Geol. Soc. vol. xxx. pp. 403, 404.

7. *On the* Fossil Vertebrata *hitherto discovered in* Spain. By Señor Salvador Calderon, Professor of Natural History in the Institute of Las Palmas. (Read November 22, 1876.)

(Communicated by the President.)

The fossil forms, like the living, have their zoological geography more marked in proportion to the development of life upon our planet; and for this reason, even if there were no other, it becomes a duty on the part of those who devote themselves to this branch of science in Spain, to furnish all the aid possible towards an elucidation of the problems which present themselves to the inquirer, notwithstanding the little attention paid to our scientific literature throughout Europe, already deplored by the great geologist De Verneuil*. With respect to the subject of this paper, it is necessary to bear in mind that no catalogue has ever been made, even of the summary kind which we are about to present, and that our materials have been collected from a large number of periodicals (Spanish, English, French, and German), extending over a period of about thirty years.

The palæontology of our peninsula presents many interesting features in its relations to the natural conditions of the soil. For example, the migrations of quadrupeds, which have caused the formation, in the greater part of Europe, of deposits of remains at a considerable distance from each other, must have been difficult in the Peninsula from the most remote time, and this has given rise to certain peculiarities in our mammalian fauna. Except by continuity, even in recent time, with the African continent, how can we explain the discovery of the *Hyæna brunnea*, the leopard, the serval, the lynx, and the deer of Barbary in a cave at Gibraltar?

Other important results of these studies is the discovery in the centre of Spain of remains of the *Sivatherium*, well-marked, according to Dr. Falconer, and also of *Hyænarctos*, mentioned by Paul Gervais†, it having been previously generally believed that these Mammalia had never inhabited Europe, and were confined exclusively to Asia.

The discovery of the types in question confirms the inductions which form the doctrine of modern science, and the theory of the uninterrupted development of organic beings, the Vertebrata beginning with fishes and Labyrinthodonts, and continuing with reptiles, birds, and Mammalia. It is also a confirmation in this part of the world of Owen's arrangement of the four classes of Mammalia.

But it is well known that the importance of the study of fossil Vertebrata is not limited to its palæontological and geological in-

* Coup d'œil sur la constitution géologique de plusieurs provinces de l'Espagne. Paris: 1852.

† Bull. de la Soc. Géol. de France, vol. x.

terest, but extends to the scientific investigation of the present zoological geography of this group. Whatever may be our opinion upon the theory of the specific centres which individual organic forms may have taken as their point of departure, it will always be of advantage to the student to find in every locality the prehistoric ancestors of its fauna; to use the comparison of Lyell, the connexion between the present and the fossil forms, particularly in the case of the Mammalia, is the same as that between the different dialects which proceed from one primitive language. It is no longer possible to doubt that a great number of the present forms of animal life have been in existence since the beginning of the Quaternary formation, and that there has been an almost insensible transition from the fauna of that period to that of the present, it being nearly impossible to differentiate the palæontology of the two periods. This opinion has been supported by Owen in his work on British Mammals and Birds.

From this point of view nothing can be more worthy of detailed investigation than the rich bone-deposits of Old Castile, which abound with remains of the present and immediately preceding races, and from which upwards of five hundred thousand *arrobas* (or quarters) of bones, some fossil, some recent, have been obtained for commercial purposes only. Among these bones have been discovered artificial objects, such as flint knives of the reindeer period, polished axes, and objects of metal.

The investigations in Spain are important when viewed with reference to the subject of extinction of species, particularly those that were contemporary with man in the period termed by Lubbock *Palæolithic*, and which is marked by the existence of animals that have since disappeared. Taking, for example, the Urus (*Bos primigenius*), we have clear proofs of its having existed in the Peninsula until a very recent period—among them a philological proof in the name of *Monsuri*, applied to a small hill on the banks of the Tagus*. It is also important to bear in mind that remains of the mammoth have been found in various parts of Spain—in the caverns of the Pyrenees, in the centre in Madrid, and in the south near the shores of the Mediterranean, a position further south than Rome, which has generally been considered the southern limit of the tract in in which the bones of this animal are found. The same may be said of the *Rhinoceros tichorhinus*, which has, without doubt, been discovered in two different places in the north of the Peninsula.

To sum up the results of the investigations made among the fossil Vertebrata in Spain, we may mention that they are not represented until we come to the Carboniferous formations (where we have found impressions of fishes having the tail heterocercal), in coal-shales in the province of Leon, together with many impressions of ferns, which have been carefully studied†. Consequently no

* See my 'Reseña geologica de la provincia de Guadalajara,' Madrid, 1874.

† Areitio, "Materiales para la flora fosil Española," Ann. de la Soc. Españ. de Hist. Nat. t. ii. 1873.

remains of this class have been found either in the Silurian or in the Devonian, which contain such abundance of them in other localities.

The Trias is almost barren of fossils throughout the Peninsula; and the Permian probably does not exist there at all*. We have but little information respecting the Jurassic; and all the data referring to the rest of the Secondary period are still more defective; but it must be borne in mind that in general the information respecting the vertebrate fauna of the first epoch of that period, is everywhere as incomplete as that respecting the deposits which date their origin from it.

The Tertiary formation, characterized by well marked generic and specific forms of Mammalia, is well represented in the Miocene formations of Spain, principally by Pachyderms, Ruminants, and Proboscidea; but in the other members of this series we have to lament a great deficiency of data. No objects of flint have been found similar to those collected by the Abbé Bourgeois, which gave rise to the supposition that man may have existed in the Tertiary period.

It is only in modern times that the caverns of this country have been explored, thanks to the late Don Casiano de Prado, who, in his memoir upon the geology of the province of Madrid, published an appendix containing a list of all the caverns of Spain known to him. The results obtained give reason to expect much from a detailed examination of these caverns throughout the Peninsula, as there are some which date from different epochs of the Quaternary period. A cave near Oñate, in Guipuzcoa†, has recently been imperfectly explored, and a large number of remains of hyæna and bears have been found in a good state of preservation. Four specimens exist in Madrid, in the Museum of Natural History and in that of the Propagator Athenæum of Natural Sciences. Dr. Falconer‡ has given us an account of the palæontological riches of the celebrated cavern of Gibraltar; and as this and the one above mentioned are situated at opposite extremes of the peninsula, we may reasonably conclude that all the caverns merit our interest. It is therefore unnecessary to enumerate many others equally curious.

We now know that the principal characteristics of the singular quaternary fauna of the South of Europe are well represented in the soil of Spain by the presence of cave-bears and hyænas, of the urus, the horse, and the antelopes; and we have no doubt that other species, which we are surprised to miss, will be, sooner or later, discovered to have been inhabitants of this peninsula. Discoveries of bones which have been made justify us in affirming the existence of man during the Quaternary period. For an account of the many discoveries of objects relating to his industries, we refer to the publications of Professor Vilanova §.

* Vilanova, Manual de Geol. Madrid, 1871.

† Ann. de la Soc. Españ. de Hist. nat., t. ii. Actas.

‡ Quart. Journ. Geol. Soc. vol. xxi. p. 364.

§ Origen, naturaleza y antiguëdad del hombre. Madrid, 1872.

The following Table will give an idea of the chronological distribution of the genera, more than sixty in number, and of the species, more than seventy, if we include those which are not determined, and of which we have only mentioned the genera already discovered in the Spanish peninsula, and well determined.

		Carboniferous.		Jurassic.		Cretaceous.		Tertiary.		Quaternary and Recent.	
		Genus.	Species.	Genera.	Species.	Genera.	Species.	Genera.	Species.	Genera.	Species.
Mammalia	Bimana	...	...	...	...	...	...	...	...	1	1
	Quadrumana	...	...	...	...	...	...	...	...	1?	1?
	Carnivora	...	...	...	...	...	...	2	2	5	6
	Rodentia	...	...	...	...	...	...	...	...	1	2
	Pachydermata	...	...	...	...	...	...	10	17	3	4
	Ruminantia	...	...	...	...	...	...	6	10	5	7
	Cetacea	...	...	...	...	...	...	1	1		
Birds		...	...	...	...	...	...	...	...	1	1
Reptiles	Chelonians	...	...	...	...	...	...	2	2		
	Saurians	...	...	2	2	3	4				
Batrachians		...	...	...	...	...	...	1	2		
Fishes		1	1	2	2	3	4	13	14		
		1	1	4	4	6	8	35	48	17	22

The following is a catalogue of the genera and species, with only the name of the locality where found and that of the author of the communication*.

MAMMALS.

Bimana.

Man.

Concud, in the province of Teruel (*Feijoo*, *Bowles*, *Torrubia*, *Asso*, and *Cuvier*).
Onis, in the province of Asturias (*Prado*).
Gibraltar (*Lyell*).
Totana, in the province of Murcia (*Inchaunvandieta*).
Atapuerca, in the province of Burgos (*Perez-Arcos*).
San Isidro, in Madrid (*Vilanova*).
Cave of Xarcas, in Cabra (*Vilanova*).
Cavern of Avellanera, in the province of Valencia (*Vilanova*).
Cavern of Alhama of Granada (*McPherson*).
Cavern of Albuñol, in the province of Granada; in Montefrio; in a cavern of Almeria (*Góngora*).

* The 'Commission of the Geological Map of Spain' possesses remains of other species, a list of which will appear shortly in the 'Bulletin.'

Cavern of Muriel, in the province of Guadalajara (*Castel*).
Alhama of Aragon (*Calderon*).

Quadrumana.

Peñon of Gibraltar (?) (*Imrie*).

Carnivora.

Ursus, L.

Peña de Mudá, in the province of Palencia (*Prado*); Gibraltar (*Falconer* and *Busk*).
U. spelæus, Blum.—Cabra (*Vilanova*); Guipuzcoa (*Vilanova* and *Larrimia*).

Hyænarctos, Cautley et Falc.

Alcoy (*Paul Gervais*).

Meles, L.

M. taxus, Pallas.—Gibraltar (*Busk* and *Falconer*).

Canis, L.

Argerilla, cavern in the province of Guadalajara (*Vilanova*); bone deposits of Castile (*Gil Maestre*).

Hyæna, Storr.

Concud, in the province of Teruel (*Maestre*); cave of Congostrina, in the province of Guadalajara (*Prado*); caverns of Guipuzcoa (*Larrimia*).
H. spelæa, Goldf.—Province of Segovia (*Prado*).
H. brunnea, Thunb.—Gibraltar (*Busk* and *Falconer*).

Hyænictis, Gaudry.

H. græca? Gaudry.—Concud (*Vilanova*).

Felis, L.

F. leopardus, L.—Cavern of Gibraltar (*Busk* and *Falconer*).
F. lynx, L.—Cavern of Gibraltar (*Busk* and *Falconer*.)

Machairodus, Kaup.

Madrid (*Prado*).

Rodentia.

Incertæ sedis in some caverns.

Lepus, L.

Caverns of Valencia (*Vilanova*) and Gibraltar (*Prado*).

Pachydermata.

Elephas, L.

Spain (*P. Torrubia*, *Cuvier*, &c.), Cadiz (*Buckland*); Almeria (*Ezquerra*); Madrid (*Proust* and *Prado*); Valladolid (*Pastor*).

E. armeniacus, Falc.—Province of Burgos (*Monasterio*); province of Cordoba (*Prado* and *Vilanova*); province of Santander (*Maestre*).

E. primigenius, Blum.—Spain (*Cuvier*); Madrid (*Ezquerra* and *Prado*); Almeria (*Ezquerra*); province of Santander (*Sullivan* and *O'Reilly*).

Mastodon, Cuv.

Province of Madrid (*Ezquerra*); province of Leon (*Gomez de Salazar*) Concud, in Teruel (*Maestre*); province of Toledo (*Linares* and *Calderon*).

M. angustidens, Cuv.—Spain (*Paul Gervais*); provinces of Madrid, Leon, Zamora, Valladolid, and Alicante (*Ezquerra*, *Prado*, and *Vilanova*).

M. longirostris, Kaup.—Madrid (*Ezquerra* and *Paul Gervais*).

M. aurelianensis, Cuv.—Madrid (*Ezquerra*).

M. giganteus, Cuv.—Madrid and Teruel (*Ezquerra*).

M. tapiroides, Cuv.—Madrid (*Prado*).

Sus, L.

Cavern of Gibraltar (*Busk* and *Falconer*); cavern of Cabra (*Vilanova*).

S. sp. ind.—Spain (*Hermann* and *Kaup*).

S. palæochœrus, Kaup.—Madrid (*Prado* and *Paul Gervais*); Alcoy (*Ezquerra*).

S. Lockharti, Pomel.—Madrid? (*Prado*).

S. scrofa, L.—Bone deposits in Castile (*Vilanova* and *Gil Maestre*).

Palæotherium, Cuv.

P. aurelianense, Cuv.—Madrid (*Ezquerra* and *Padro*).

P. Ezquerræ, H. v. Mey.—Madrid (*Hermann von Meyer*).

Chœropotamus, Blainv.

C. matritensis, Ezq.—Madrid (*Ezquerra*).

Anoplotherium, Cuv.

A. glaciale, Cuv.—Alcoy (*Ezquerra*).

A. murinum, Cuv.—Madrid (*Ezquerra*).

Cainotherium, Brav. et Blainv.

Provinces of Madrid, Toledo, and Guadalajara (*Paul Gervais* and *Prado*).

Equus, L.

Tertiary remains in Concud (*Maestre*); in the caverns of Gibraltar (*Busk* and *Falconer*), Valencia (*Vilanova*), and Santander

(*Naranjo*); in alluvial deposits of Madrid (*Prado* and *Bayle*), of Guadalajara (*Calderon*), and in bone deposits of Castile (*Gil Maestre*).

E. primigenius, Blum.—Concud (*Ezquerra*); Cabra (*Vilanova*).

E. fossilis, Cuv.—Guadalajara and cavern of Tativa (*Vilanova*); Vitoria (*Velasco*); Málaga (*Orueta*).

HIPPOTHERIUM, Kaup.

H. glaciale, Kaup.—Concud and Alcoy (*Ezquerra*).

HIPPARION, Crist.

Concud and Madrid (*Prado* and *Paul Gervais*).

H. gracile, Kaup.—Tarancon, in Cuenca (*Cortazar*).

H. prostylum, Gerv.—Concud (*Prado* and *Vilanova*); Vitoria (*Velasco*).

RUMINANTIA.

SIVATHERIUM, Cautley et Falc.

River-course of Duero (*Falconer*).

CERVUS, L.

Tertiary remains in Spain (*Paul Gervais*). Quaternary in Old Castile and Guadalajara (*Vilanova* and *Calderon*); in some caverns of Valencia (*Vilanova*); cave of Guadalajara (*Castel*).

C. dicrocerus, Lart.—Concud (*Vilanova*).

C. cuzanus, C. et T.—Concud (*Vilanova*).

C. matritensis, Ezq.—Madrid (*Ezquerra*).

C. capreolus, L.—Cave of Almeria (*Gongora*).

C. dama, Robert.—Gibraltar (*Busk* and *Falconer*).

C. barbarus, L.—Gibraltar (*Lesson*, *Busk*, and *Falconer*).

C. elaphus. L.—Madrid (*Prado*).

TRAGOCERUS, Belon.

T. amaltheus, Roth et Wagn.—Concud? (*Vilanova*).

PALÆOMERIS, H. v. Mey.

Spain (*Hermann* and *Kaup*); Madrid (*Paul Gervais*).

P. Bojani, H. v. Mey.—Madrid? (*Prado*).

P. Scheuchzerii, H. v. Mey.—Madrid and Alcoy (*Ezquerra*).

ANTILOPE, L.

Tertiary remains in Spain (*Paul Gervais*), in Concud (*Vilanova*). Quaternary remains in some localities of Spain (*Pictet*), in Santander (*Calderon*), in the cavern of Segovia (*Areitio* and *Quiroga*).

A. sansaniensis, Gerv.—Concud (*Vilanova*).

A. boodon, Gerv.—Alcoy (*Paul Gervais*); Concud (*Vilanova*).

OVIS, L.

Bone deposits of Castile (*Gil Maestre*).

CAPRA, L.

Bone deposits of Old Castile (*Gil Maestre*).

BOS, L.

Concud (*Maestre*); caverns of Valencia (*Vilanova*); Guadalajara (*Calderon*); bone-deposits of Old Castile (*Bos longifrons*?, Owen) (*Gil Maestre* and *Calderon*).

B. concudensis, Ezq.—Concud (*Ezquerra*).

B. primigenius, Boj.—Provinces of Madrid (*Prado*), Leon (*Prado* and *Ezquerra*), Guadalajara (*Vilanova* and *Calderon*), Seville (*Prado*), and Cadiz (*Lujan*).

CETACEA.

Remains in the Tejares de Málaga (*Ansted*).

DINOTHERIUM, Kaup.

D. giganteum, Kaup.—Spain (*Ezquerra*).

BIRDS.

FALCO, L.

F. nisus, L.—Gibraltar (*Busk* and *Falconer*).

REPTILES.

CHELONIA.

Remains in Jurassic deposits of Guadalajara (*Ezquerra*); in the Cretaceous of Navarre (*Ezquerra*); in the Tertiary of Madrid (*Prado*, *Bosia*, *Bolivar*, *Lezcano*, *Larrimia*, and *Calderon*); and in caverns of Gibraltar (*Falconer*) and Valencia (*Vilanova*).

TESTUDO, Brongn.

T. nov. sp.—Tejares de Málaga (*Orueta*).

TRIONYX, Goldf.

T. maunoir, Bourd.—Tudela? (*Ezquerra*).

SAURIA.

CROCODILUS, Laur.

C. nov. sp., Sharpe.—Cretaceous of Congostrina in Guadalajara (*Ezquerra*).

C. Rollineti, Brongn.—Province of Zamora? (*Vilanova*).

MEGALOSAURUS, Buckl.

Province of Asturias (*Egozene*).

IGUANODON, Mantell.

Utrilla, in the Province of Teruel (*Vilanova*).

ICHTHYOSAURUS, König.

Pyrenees of Navarre (*Ezquerra*).

PLESIOSAURUS, Conyb.

Province of Asturias (*Schulz*).

BATRACHIA.

Tertiary remains in the Serrata de Lorca, Province of Murcia (*Botella*).

FISHES.

SPHYRÆNA, Bloch.

Serrata de Lorca (*Botella*).

RHAMPHOGNATHUS, Agass.

R. Verneuilli, Botella.—Serrata de Lorca (*Botella*).

CLUPEA, L.

C. Gervaisii, Botella.—Serrata de Lorca (*Botella* and *Areitio*).
C. elongata, Agass.—Serrata de Lorca (*Botella*).

SERIOLA, Bloch.

S. Beaumonti, Botella.—Serrata de Lorca (*Botella*).

DAPEDIUS, Agass.

D. Colei, Agass.—Province of Santander (*Naranjo*).

PYCNODUS, Agass.

P. Münsteri, Agass.—Province of Guadalajara (*Ezquerra*).
P. complanatus, Agass.—Province of Teruel (*Vilanova*).

PALÆOBALISTUM, Blainv.

Almeria (*Ezquerra*).

CARCHARIAS, Cuv.

Provinces of Almeria (*Cortazar*) and Málaga (*Orueta*).

SQUALUS, L.

Provinces of Seville (*Lujan*), of Cadiz (*M'Pherson*), and of Tarragona (*Maestre*).

CARCHARODON, Smith.

Málaga (*Orueta*).

CORAX, Agass.

Málaga (*Orueta*).

NOTIDANUS, Cuv.

N. primigenius, Agass.—Málaga (*Orueta*).

Oxyrhina, Agass.

Jurassic deposits of Guadalajara (*Calderon*), and Tertiary of Tejares de Málaga (*Orueta*).

O. minuta, Agass.—Province of Huesca (*Mallada*).

O. xiphodon, Agass.—Province of Almeria (*Ezquerra*).

Lamna, Cuv.

Jurassic deposits of Guadalajara (*Calderon*), and Tertiary of Tejares de Málaga (*Orueta*).

L. cornubica, Cuv.—Alcoy (*Ezquerra*).

Pristis, Lath.

Tejares de Málaga (*Orueta*).

Discussion.

Prof. Duncan remarked that the presence of *Sivatherium* and *Hyænarctos* in Spain, if confirmed, would be particularly interesting, as showing a great western extension of the Sivalik fauna. He suggested that there was an error in the statement that *Elephas armeniacus* occurred in the valley of Madrid, and thought that the species would prove to be *E. africanus*. He also suggested that *E. armeniacus* was not really a distinct species, but that it and *E. namadicus* were merely local forms of *E. antiquus*.

Prof. Busk said that most of the animals the bones of which are so numerous at Gibraltar appear to have migrated from the south. He thought that there was probably some mistake as to the species of Elephants, and doubted whether remains of the Mammoth had ever occurred in Spain. He added that the bone which had been thought to belong to *Sivatherium* was an astragalus, and that it was chiefly, he thought, on account of its size that Dr. Falconer suggested such an identification.

Mr. Charlesworth stated that he had obtained from the Crag a tooth which had been pronounced by Mr. W. Davies, of the British Museum, to come nearest to that of *Hyænarctos* among known Mammalia, and remarked that this seemed to confirm the extension westward of that type of animals.

Dr. A. Leith Adams stated that molars of *Elephas primigenius* from caves in the zinc-mines at Santander had been brought to his notice. He doubted whether *E. africanus* had been found fossil. Dr. Falconer finally regarded *Elephas priscus* as a variety of *E. antiquus*. Many teeth, with thick plates, were found in the caves of Palermo; and these were clearly of *E. antiquus*; the Spanish specimens required confirmation. He confirmed the President's suggestion that *Elephas namadicus* was identical with *E. antiquus*.

Dr. Murie was doubtful about the identification of the fossil supposed to indicate *Sivatherium*. The specimen not being a bone of the head, there was a great chance of error.

8. *On the* Kessingland Cliff-section, *and on the Relation of the* Forest-bed *to the* Chillesford Clay, *with some Remarks on the so-called* Terrestrial Surface *at the* base *of the* Norwich Crag. By F. W. Harmer, Esq., F.G.S. (Read November 8, 1876.)

In the "Outline of the Geology of the Upper Tertiaries of East Anglia," given by Mr. S. V. Wood, jun., and myself in the volume of the Palæontographical Society for the year 1871, we called attention to the beds at the base of the Kessingland cliff and their relation to the Crag and Chillesford clay, and gave a section of them. Up to that time the cliff had been, at the time of our visit, more or less obscured by talus, so that some uncertainty existed as to the superposition of the different beds. After a storm in the month of November 1874, however, I was fortunate enough to find the section perfectly clear; and the result of my examination of the cliff was laid in the same month before the Geological Society of Norwich; but that body does not publish any record of its proceedings.

In all respects, so far as the sequence of the beds is concerned, this recent exposure confirmed the representation given by Mr. Wood and myself in 1871; but in one matter of detail, then left doubtful, some correction is necessary.

As Mr. Gunn has recently submitted to this Society a paper describing his view of the section*, which, in my opinion, differs entirely from what was then so clearly revealed, I think it desirable to give a short account of the facts as they then appeared to me.

The beds present in the cliff-section I take to be, in ascending order, as follows:—

1. A stratified deposit of clay and sand, which appears to be the Chillesford Clay.
2. A tough unstratified clay of a mottled slate-blue colour, shown in places to be underlain by sand and gravel, which is penetrated by rootlets, and which, with the gravel, yields mammalian remains.
3. A lenticular bed of laminated sand and clay.
4. The Middle Glacial sand and gravel.
5. The Upper Glacial, or Chalky Boulder-clay.

No. 1 occurs for the space of 400 yards to the north of the Pakefield-Lighthouse gorge, and for a short distance to the south of it. It is occasionally exposed on the beach, but is generally to be seen in section at the base of the cliff. It is horizontally stratified up to its junction with bed No. 3, and is evidently the denuded remnant of some formerly much more wide-spread deposit. It resembles the Chillesford Clay in appearance, being composed of alternating layers of fine sand and clay; and although it cannot be positively identified with that formation, owing to the absence of shells, there seems to be little question about it.

No. 2 extends from nearly the southern termination of the cliff

* Quart. Journ. Geol. Soc. vol. xxxii. p. 123.

at Kessingland for a distance of 1200 paces towards Pakefield, terminating about 500 paces south of the Lighthouse gorge*.

It is composed of an unstratified tenacious clay of a slate-blue colour, occasionally mottled with brown, and sometimes containing patches of brownish stratified sand. It is shown in places to be underlain by sand and indurated gravel; and its upper surface is throughout penetrated perpendicularly by rootlets. It contains minute particles of chalk, specks of carbonaceous matter, and a few small stones; and from it, and from the underlying gravel, mammalian remains are obtained†. At its northern termination, where bed No. 3 rests upon it, freshwater shells, chiefly *Unio tumidus*, occur at its base, and in the gravel-bed below it. Its upper surface is remarkably even; and it is occasionally overlain by a few inches of sand or indurated gravel. Its greatest thickness seems to be about 8 feet.

No. 3, which is about 6 feet at its greatest thickness, fills a lenticular hollow, cut out of beds Nos. 1 and 2, as shown in the accompanying sections. It is not penetrated by roots, as is No. 2, but contains at its base an accumulation of wood débris. It is finely laminated, and extends about 250 paces from end to end, being shown in places‡ to be underlain by sand and gravel. It varies in colour and composition, resembling at its southern end the black unstratified clay on which it there rests, while northwards its colour changes to a rusty brown. Unfortunately the section is now (March 1876) much obscured by talus, especially at the point where in November 1874 I saw the junction between beds Nos. 1 and 3 so clearly exposed. The view has been consequently advanced that the laminated clay, No. 3, is merely the continuation of the Chillesford Clay, No. 1. To this I reply, that the two beds differ widely from each other in appearance and composition; that the Chillesford Clay being a deposit remarkably *sui generis*, and easily recognizable, the supposition that the laminated bed is a local modification of it cannot be admitted. In 1874, as I have observed, the section showed most clearly the one bed resting on the other, as shown in fig. 1, which is a copy of the sketch made at the time in my note-book.

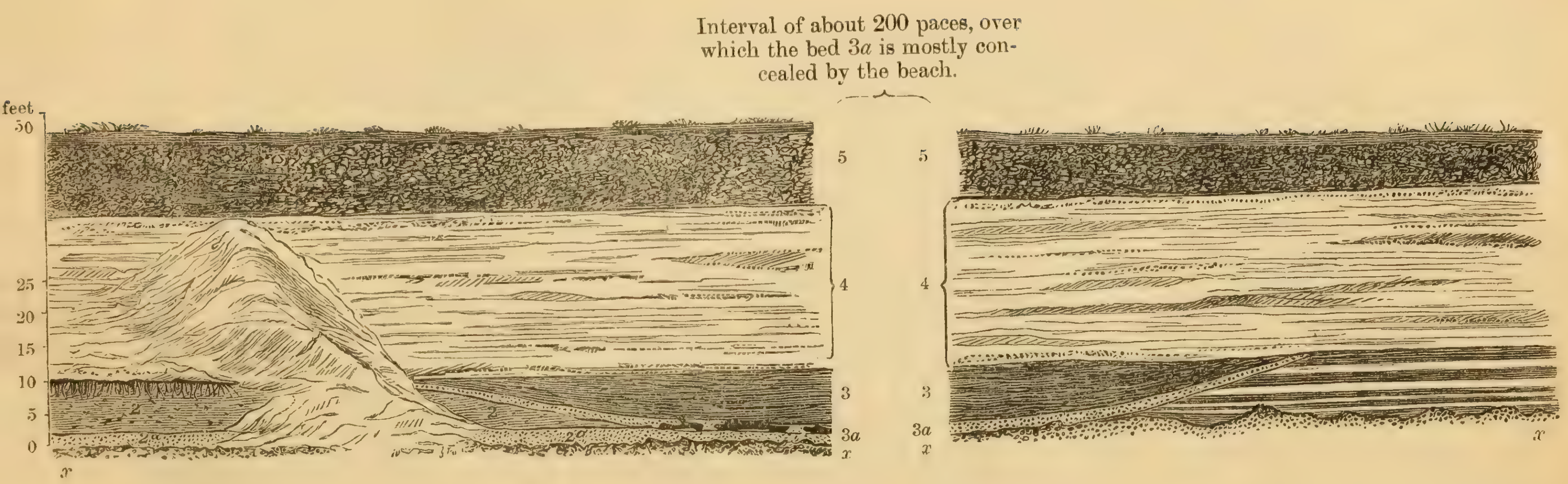
Moreover the palæontological agrees with the physical evidence. Wherever the sand and gravel at the base of the Chillesford Clay, or that Clay itself, yields molluscan remains, they are those of marine species, except that in some localities a small admixture of freshwater forms imparts a slight fluvio-marine aspect to the formation. In the gravel, however, which underlies the laminated bed in question the mollusca are entirely of freshwater species, being principally Unios with both valves united and clustered together nearly as they lived.

* These measurements are given on the authority of Mr. Henry Norton, F.G.S., of Norwich, who spent several days in examining the section.

† Mr. E. T. Dowson, of Geldeston, informs me that he has also found in it the opercula of *Bythinia tentaculata*.

‡ The representation given in the sections may perhaps give the impression that this thin and intermittent bed of sand is more regular than it really is.

Fig. 1.—*Section in Kessingland Cliff.*



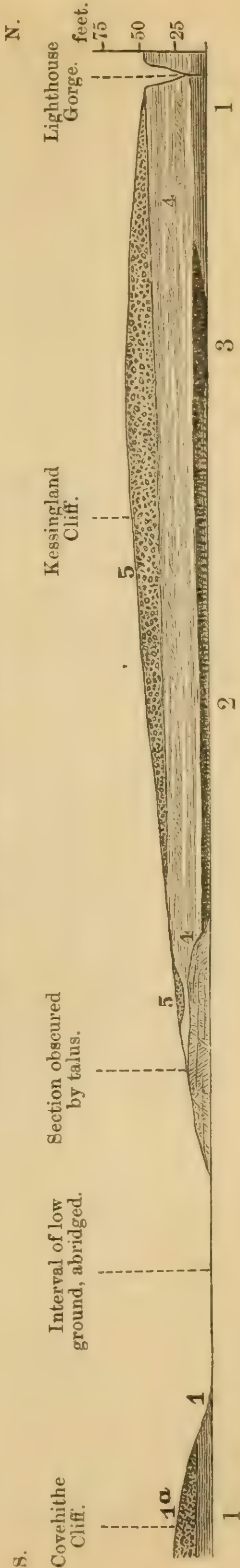
1. Laminated brown sandy clay referred to the Chillesford Clay.
2. Bluish mottled clay yielding Mammalian remains and the opercula of *Bythinia tentaculata*, and having its surface penetrated by roots.
2*a*. Thin bed of sand and of gravel underlying ditto, and containing Freshwater Mollusca.
3. Lenticular bed of dark sandy laminated silt (no fossils yet found in it); wood débris at its base.
3*a*. Bed of sand and of gravel underlying ditto.
4. The Middle Glacial.
5. The Upper Glacial.
x. The shingle of the present beach.

The bed No. 4 is the Middle Glacial sand with fine shingle bands, which is generally present in the district. It rests upon the nearly horizontal surface of the beds Nos. 1, 2, and 3, from end to end of the section, except in one place near the Pakefield-Lighthouse gorge, where it cuts through No. 1 to the beach-line for the space of a few yards. For the greater part of the distance from Kessingland to the Lighthouse gorge the Middle Glacial sands No. 4 are overlain by the chalky Boulder-clay of East Anglia (or Upper Glacial), No. 5, which here presents its usual features.

I am thus altogether at a loss to discover that sequence of beds which Mr. Gunn has recently described. The marine shells and cetacean bones mentioned, in the section given by him, as occurring in the Chillesford Clay have never yet been found in that bed in the Kessingland cliff; and I know of no evidence whatever to justify him in the assertion that the Norwich Crag, with its marine and freshwater shells, is there represented. No marine mollusca, so far as I know, have ever been found there at all.

So far also from proving that the Forest-bed is older than the Crag, the evidence of this section appears to me to point the other way. It would seem that the mammaliferous mottled clay, No. 2, was deposited either by a river or a lake whose northern bank, at least, was formed by the Chillesford Clay exposed at the Lighthouse gorge at the Pakefield end of the section, that this mammaliferous clay afterwards became sufficiently dry to allow it to be covered with vegeta-

Fig. 2.—*Section from the Pakefield-Lighthouse Gorge to the Northern End of Covehithe Cliff.*
(Length, including the abridged space, four miles).



1. The Chillesford Clay. 1*a*. The Lower Glacial pebbly sands (Bure Valley beds).
2. The beds numbered 2 and 2*a* in Fig. 1 (No. 2 having its upper surface throughout full of roots).
3. The beds numbered 3 and 3*a* in ditto. 4. The Middle Glacial. 5. The Upper Glacial.

tion, the roots of which are still preserved on it, and that afterwards, at its extreme northern edge, a shallow depression was eroded by a stream, partly in the mottled clay, No. 2, and partly in the Chillesford Clay, No. 1, into which trunks and branches of trees growing at the surface of No. 2 were swept.

In the section, fig. 2, I have reduced the scale, so as to allow of its being prolonged to the northern extremity of Covehithe cliff, where the undoubted Chillesford Clay occurs capped by the Lower Glacial pebbly sand, in order that the position occupied by the mammaliferous clay and by the lenticular laminated deposit relatively to the Chillesford Clay both north and south of them may be more clearly seen. I see thus no reason to question that they were deposited in a shallow depression or valley excavated by the removal of the latest of the Crag-beds, viz. the Chillesford Clay.

While, however, the posteriority of these mammaliferous and freshwater deposits to the Crag seems thus apparent, their age relatively to the beds newer than the Crag is obscure, since there is nothing to show whether they preceded the Lower Glacial beds, which are absent from the Kessingland section, or succeeded them—a point of considerable interest, in reference to the great denudation which, as Mr. Wood and I maintain, followed the Lower Glacial formation when the valley-system of East Anglia was, we believe, mainly excavated. The Forest-bed which appears at intervals along the Cromer coast, on the other hand, affords clear evidence of its having preceded the entire Glacial formation, since the lowest of the Lower Glacial beds, the Till and the Pebbly sand (the latter of which is shown under 1 *a* as capping Covehithe Cliff in fig. 2), rest upon it—although, as has been pointed out by Mr. Wood and myself, its relation to the Crag is obscure, owing to the absence there of any deposit that we could recognize as belonging either to the Crag or Chillesford beds.

There is another matter connected with this subject to which I desire to allude, viz. the nature of the stone-bed which underlies the Crag at Thorpe, Bramerton, Horstead, and other places, which has been regarded, erroneously as Mr. Wood and I think, as an old land-surface. It is usually of inconsiderable thickness, consisting of large subangular flints imbedded in a matrix of ferruginous sand and gravel; and in it occur mammalian remains, such as the teeth of *Mastodon arvernensis*, a species which, according to Mr. Prestwich (Q. J. G. S. vol. xxvii. p. 118), occurs similarly in the bed of phosphatic-nodule and other débris at the base of that much earlier formation the Coralline Crag. It does not present the least resemblance to such a formation as the Purbeck dirt-bed or to a freshwater deposit; and it is, I believe, merely the marine basement-bed of the formation which overlies it, the mammalian remains found in it (which are generally much worn and rolled and very imperfect) being, like those at the base of the Coralline and Red Crags, as much derivative as are the flints with which they are associated. Fig. 3 represents the way in which, I believe, this bed may have originated, viz. by the advancing waters of an estuary which washed back its chalk shore and any Tertiary bed which may have rested on the Chalk. Had the

Mastodon, Rhinoceros, and other animals whose remains occur in this stone-bed been buried in it at the time they died, or soon after, we could not fail to find a proportionally greater number of bones than

Fig. 3.—*Section representing the supposed Conditions under which the Stone-bed called Land-surface at the Base of the Norwich Crag was formed.*

1. Low cliff of Chalk with rows of flints (*a*) *in situ.*
2. Beds of Older and Newer Pliocene age, capping the Chalk and containing the remains of *Mastodon arvernensis* and other Mammalia.

b. Talus of chalk-flints, passing into *b'*, the basement-bed of the Norwich Crag, as the sea encroached on the land.

of teeth; we should sometimes meet with entire skeletons*, or portions of them, with associated bones more or less in juxtaposition, and we should often find jaws with teeth attached, as we do in the undisturbed Cromer Forest-bed and elsewhere; but the very reverse of all this is the case. The supposition, on the other hand, that these worn and fragmentary teeth were derived from the waste of some older deposit explains these facts. The bones of a skeleton, washed by waves from a cliff, fragile as such fossil remains always are, would be, as a rule, quickly destroyed, while the teeth, being harder, would be preserved and buried a second time. The cliff, of course, would be worn away as the land sank and became submerged.

A similar stone-bed occasionally overlies, and is bedded up to, the denuded remnants of the Forest (which is by no means the continuous formation it has sometimes been represented to be) on the North Norfolk coast. It often contains mammalian fossils derived from the freshwater deposit associated with the true Forest-bed in the immediate neighbourhood, and has sometimes been mistaken for those deposits *in situ*. It extends laterally beyond the limits of that formation, forming, as at Weybourne, on the surface of the Chalk, the basement bed of the Lower Glacial Pebbly sands. It contains at that place marine shells of the same species as the deposit which overlies it. The bed of flints in question at the base of the Norwich

* The statement that an entire skeleton of the Mastodon was found some years ago at Horstead, is one which rests entirely on hearsay evidence, and is, I believe, from inquiries I have made, unworthy of credit.

Crag contains, similarly, Crag-shells*. The occurrence in it of marine mollusca is hardly to be reconciled with the theory that the stone-bed represents a terrestrial surface†.

Discussion.

Mr. Charlesworth, referring to Mr. Whitaker's paper, stated that he regarded the non-fossiliferous sands as Crag. At Felixstow the London Clay is under the Crag, and without fossils; hence he argued that the fossils were not removed by chemical means, but that they never were there. He could not believe that sharks' teeth would be dissolved away by water charged with carbonic acid; but he had never seen sharks' teeth in the sands. With regard to Mr. Harmer's paper, he said that the mammalian remains in the subangular beds must of necessity be rounded, but that they are not therefore necessarily derivative. The Crag must have had a land-fauna, the remains of which would be carried down streams by floods, as in Australia. If the fossils are derivative, he asked, Whence are they derived?

Prof. Hughes, in confirmation of the view advocated by Mr. Whitaker, mentioned cases which had come under his observation in the Faluns and in the chalky gravel of Cambridge, where the removal of the carbonate of lime from the upper part by percolating acidulated water produced phenomena similar to those described by Mr. Whitaker. He pointed out that other peculiarities, such as the vertical arrangement of the pebbles dropped into the pipy hollows, the looping of the earthy residuum, the frequent coincidence of the pipes and pans with surface-features, and various other conditions affecting the collecting and passage of the acidulated water, proved that the explanation offered was the true one.

Prof. Seeley maintained that the irregularities of the gravels described by Mr. Whitaker were due to staining by iron and solution by carbonic acid, liberated by the growth and decay of vegetation and old forests. He thought that they only differed from the forest stainings which cap most Postglacial gravels in being of greater thickness. The fact of interglacial denudation as described by Messrs. Wood and Harmer seemed to him self-evident from the elevation of land after the Middle Glacial beds were deposited.

Prof. Morris remarked that the whole subject was one of extreme difficulty. He thought that the occurrence of mammalian remains at the base of each of the Crags needs further investigation. The interglacial formation of Switzerland represents the forest-beds of Norfolk.

Prof. Ramsay said that there was a growing opinion that the

* For one instance of this see Supplement to 'Crag Mollusca' in Pal. Soc. Publications for 1874, p. 151.

† Mr. S. Woodward, in his 'Geology of Norfolk' (1823), taking the same view of this stone-bed, points out that a precisely similar deposit is now forming on the Cromer coast in places where the bed of the sea is composed of chalk.

forest-beds were interglacial, and remarked that traces of man had been found in interglacial deposits in Switzerland.

Prof. Hughes, referring to the statement of Prof. Ramsay, thought that the discovery referred to was probably that of Dr. Scheuermann, recorded by Prof. Rütimeyer, of sticks apparently artificially pointed which had been found in lignite, and were considered to be of the age of the Dürnten Coal. He thought, however, that there were many sources of error in the observation, and was not inclined to accept the facts as recorded until further evidence was produced.

Mr. Whitaker remarked that the chief point of Messrs. Wood and Harmer's paper depended, to some extent, on the identification of certain inland brick-earths with the "Contorted Drift" of the coast (Lower Glacial); and he wished for further proof of this identification in many cases, as he had seen like brick-earths in the Middle Glacial beds. He thought that there was some difficulty in the use of the name "Forest-bed," as it seemed to have been applied to different horizons by different observers. Referring to Mr. Charlesworth's remarks, he denied that the London Clay of Felixstow &c. was unfossiliferous, and stated that the absence of shells in the Crag sand must have been through removal, as casts were often left, proving the former existence of the shells.

Mr. Harmer briefly explained the views advocated in his paper.

9. *On the* Ice-Fjords *of* North Greenland, *and on the* Formation *of* Fjords, Lakes, *and* Cirques *in* Norway *and* Greenland. By Amund Helland, Fellow of the University of Christiania. (Read June 21, 1876.)

(Communicated by Prof. Ramsay.)

The observations recorded in the following paper were made during two years of travel among the fjords and mountains of Norway, and during a visit to the ice-fjords of North Greenland in the summer of 1875. These travels were almost wholly undertaken with the view of seeing how far these countries confirmed the views entertained by Prof. Ramsay and other English and American geologists as to the origin of fjords and lakes.

We will first examine the fjords of North Greenland, ascend to the Inland Ice which covers the whole country, so far as is known, then visit the glaciers which descend into the fjords, measure their rate of flow, and examine the other phenomena which they present. As these are, in many respects, of the greatest importance to geology in general, they shall be described more fully than is necessary for explaining the formation of fjords and lakes.

The tract over which I travelled in North Greenland extends from the colony of Egedesminde (60° 42′ 9″ N. lat., according to Nordenskjöld) to the fjord of Kangerdlugssuak (about 71° 15′ N. lat.) in the district of the Colony of Umanak*.

Of the great ice-fjords which produce bergs of large dimensions, the following were visited, viz. those of Jakobskavn and Torsukatak; of the smaller, which produce only little bergs, those of Sarkardlek, of Alangordlek (in the district of Christianshaab), and of Kangerdlugssuak. The ice-filled valley of Ilartdlek, by Pakitsok, was traversed, and the Inland Ice here ascended. A large number of glaciers in the district of Umanak were visited, many of which, though small compared with the gigantic ice-streams of the fjord, can yet compete with the largest of Europe†.

A Norwegian geologist travelling in North Greenland will find much that is new to him, but perhaps still more that is familiar. The rocks of this country chiefly belong to the Azoic formation, granites, gneiss of various kinds, mica schists, and hornblendic schists—on the whole, rocks well known in the Azoic formation of Norway.

Disko Island, however, and Nūgssuak peninsula are composed of newer rocks—sand, sandstones, and shales, with fossil plants and

* In the orthography of Greenlandic names, I have followed that of Klean-Schmidt's Dictionary, wherever the signification was known.

† Our present knowledge of the ice-fjords and of the Inland Ice is chiefly derived from Dr. Rink's 'Grönland geographisk og statistisk beskrevet,' and Professor Nordenskjöld's 'En Expedition till Nordgrönland.' By these travellers many of the phenomena mentioned in the following paper have been already described.

layers of coal; these formations are covered by a thick sheet of basalt. From them Professor Nordenskjöld has made rich collections of fossil plants of the Cretaceous and Miocene periods; and by examining these plants Dr. Heer has shown that the climate of North Greenland must once have been subtropical, much like that now prevailing in the Canary Islands, or in Northern Egypt, with a mean annual temperature which cannot have been lower than 21° or 22° C.

In Upernivik Island, and in other places on the south side of Umanak Fjord, one sees how the great glaciers are cutting valleys through these fossiliferous strata, and dragging down to the moraine or to the sea boulders containing the half-effaced remnants of a subtropical vegetation.

Like the west coast of Norway, Greenland is intersected by many large fjords, which, when not filled wholly or partially by glaciers, pierce deep into the country. In front of the fjords near the open sea there is a "Skärgård" of larger and smaller islands, perfectly resembling the "Skärgård" of Norway. Generally the part of Greenland nearest to the sea, or "the outer land," which is not covered by eternal snow, strikingly resembles the outermost skerries and islands on the west coast of Norway, both in the rocks and in the configuration of the islands. The hills around the fjords in North Greenland vary much in height, being sometimes ridges only a few hundred feet above the sea, sometimes mountains 4000 feet, and occasionally even 6000 feet or a little more.

On the whole, the part of North Greenland here described can be geologically and orographically divided into three districts:—(1) the land around Disko Bay; (2) Disko Island, with the tableland of Nūgssuak peninsula; (3) the high land of Umanak.

(1) The land around Disko Bay consists of gneiss. It is of no great elevation, in the southern part rarely rising to 1000 feet; in the northern part, however, in Arveprindsen Island, it rises up to 2000 feet. The islands along the coast of the district of Egedesminde are small, low, and rounded. Two large ice-fjords intersect the mainland, that of Jakobshavn in the central part, and that of Torsukatak in the north.

(2) The configuration of the land round Disko Bay contrasts strikingly with that of Disko Island, which, as already said, is composed of formations belonging to the Cretaceous epoch and of basalt. The difference in rock-structure has produced a marked difference in scenery. Disko Island and Nūgssuak peninsula are less cut into islets and headlands than the more undulating tracts of gneiss round Disko Bay, but form basaltic tablelands divided into two parts by the Waigat fjord, with a generally corresponding structure on either side.

No great glacier from the Inland Ice intersects this part of North Greenland, which is connected with the ice-clad inner land only by a narrow isthmus; but very many glaciers descend into valleys from the high snow-clad interior of Disko Island and of Nūgssuak peninsula; in both these there are mountains from 3000 to 4000 feet high. The highest basaltic mountains of Greenland are probably situated in the northern part of the peninsula, where the Kelertinguak rises to 1857 metres. "Ubekjendt Eiland," lying north of Nŭgssuak peninsula, consists like it of basaltic rocks, and is thus in relation with it.

(3) The high land of Umanak consists of a line of peninsulas, divided by ice-filled fjords and with islands in front. This part of Greenland, so far as it is known, consists of gneiss and Azoic slates; everywhere, even in the islands, the mountains rise to considerable heights. The little island of Umanak, though situated in the middle of the fjord and only one geographical mile long, rises to a height of 1163 metres above the sea; and its uppermost part is quite inaccessible. The sides of the islands and peninsulas between the fjords are also steep and often inaccessible. The mountains are Alpine in character, some peaks near the sea rising to 2000 metres. The tract between Kangerdlugssuak and Ingnerit is especially conspicuous for bold peaks, lofty mountains, and numerous glaciers. The following measurements were made with a theodolite and a base-line:—three peaks, called by the Greenlanders Agpatsiait (the bird-mountain, frequented by auks), on the peninsula between the fjords of Kangerdluarssuk and Ingnerit—No. 1, 1964 m., No. 2, 2032 m., No. 3, 1930 m.; four peaks called Kioke, on the peninsula between the Kangerdluarssuk Fjord and the sound separating the island of Upernivik from the mainland, gave the following heights—No. 1, 1738 m., No. 2, 1847 m., No. 3, 1753 m., No. 4, 1878 m. A mountain in the Fjord of Kangerdluarssuk is 1958 m. Another, named Kingasima, appears to be somewhat higher; but its distance from the base was too great for accurate measurement. These mountains are the highest on the west coast of Greenland, visible from the sea-shore, although, of course, it is not improbable that others yet higher may lie further inland. Ice-fjords and glaciers abound in this part of Greenland. Of the former there are no less than eight along about 1° of latitude, the northernmost and the southernmost producing icebergs some hundreds of feet high.

The Inland Ice.—In Greenland, when a fjord is followed up into the country, the way is sooner or later barred by a glacier which has descended the valley and extends across the fjord from shore to shore, ending in a steep wall which gives rise to ice-bergs. Occasionally, indeed, the glacier does not descend the valley to the level of the water; but no large fjord or valley is known in the mainland of Greenland which does not contain a more or less imposing glacier. On gaining a commanding position, this glacier will be seen to descend from a wide inland ice-field to which no limit can be seen even from the summit of one of the mountains on its border, the ice extending inland as far as the eye can reach. This vast ice-field, called the Inland Ice, and by the Esquimaux Sermerssuak (the great ice), which, so far as we know, covers the whole interior of Greenland, occupies an area greater than the Scandinavian peninsula. I have had a view over it from five places; from each of these its appearance was the same, resembling a great sea; but it seems to rise slowly inland, forming an undulating sky-line; it lies at a lower level than the mountains near its borders, so as to be overlooked from them. This peculiarity is very strikingly exhibited at the upper end of the Kangerdlugssuak Fjord, where the mountains rise several thousand feet above the Inland Ice. Nowhere did I see mountains rising from it at any great distance from its outer edge; but it often happens that portions of land protrude like islands near the border of the sea of ice; these, however, are not be regarded as insulated peaks rising above the ice, but rather as portions of the bordering land encircled by the Inland Ice or its dependent glaciers. They resemble in appearance the bordering land, and are called by the natives Nunataks, appendages to the land. For example, at Kangerdlugssuak, where the mountains are lofty and the sides of the fjords steep, there are three Nunataks, also with steep nearly vertical sides, and equalling in height the neighbouring land; but above the Inland Ice of Disko Bay, where the outlines of the land are less abrupt, the Nunataks are lower knolls.

I observed the Inland Ice most closely above Ilartdlek, near Pakitsok, during an expedition up it on July 17, 1875. Here the mountains rise some hundreds of feet above the Inland Ice, from which a huge glacier descends almost to the sea, probably through a valley in the mountain-ridge. By ascending a mountain on the left side of this glacier and then descending some three or four hundred feet, the surface of the Inland Ice may be reached without difficulty; it forms here small undulating and gently sloping hummocks, on an average scarcely six feet high, and so is easily traversed; there are but few fissures, and these narrow enough to be crossed without difficulty. Several rivers, however, flow over the surface in various directions, some too large to be easily crossed. Their water is clear and free from mud; they have excavated canal-shaped beds, the ice at the bottom being of a bluish colour. Their size doubtless depends upon the temperature; and when it sinks to the freezing-point they probably vanish. On that day at 4 P.M., the air-temperature one and a half metre from the surface of the ice was 7° C. in the shade. The ice itself is granular at the surface; but this structure extends to no great depth; for, on cutting into it, compact ice, with air-bubbles, is soon found. The ordinary ice is often intersected by blue veins. Cones of sand and gravel with the usual icy cores occur near the border of the Inland Ice, also regular cylindrical holes of variable breadth up to one and half metre, filled with clear water and with a layer of clay at the bottom. Boulders and gravel are only found near the border of the Inland Ice; along this was a small moraine scarcely six feet high, while that beside the glacier lower down was as much as 16 metres. The above description of the Inland Ice at Ilartdlek agrees in all respects with that given by Professor Nordenskjöld of the Inland Ice above Aulatsivik (Auleitsivik); so that probably the same features would be found over the whole extent of the surface between the two places, only interrupted by crevasses where the great glaciers descend to the fjords. The surface of these is often so much fissured as to be impassable; the above crevasses, however, do not appear generally, so far as my experience goes, to extend very far up into the Inland Ice. It is very difficult, if not impossible, to determine the thickness of this mass of Inland Ice. At Ilartdlek the surface of the ice, some thousand metres from the end of the glaciers, has an elevation of 251 metres. The ice itself prevents us from seeing how much the bed of the valley beneath the glacier has risen; but if there is not a basin below, this can hardly be less than 50 metres above the sea; hence the thickness of the Inland Ice near its border cannot exceed 250 metres, and is probably not more or is even less than 200 metres; but since its surface rises as we proceed inland, its thickness may possibly increase in that direction.

As the interior of Greenland has been so little visited, not much is known of the limits of this vast ice-field, those on the west, nearest to the inhabited outer land, are best known. Here the accounts of the old Norwegians, the Esquimaux, and modern travellers agree that the Inland Ice is everywhere found in going eastwards; so we may take it as settled that its western border extends continuously from the northern colonies to the district of Julianehaab. It is evident that the Inland Ice will also be found by ascending the fjords westward from the east coast, because of the abundance of icebergs in this neighbourhood. Captain Graah * states that these are innumerable near the coast at all times. Kaiser Franz-Joseph's Fjord in 73° N. lat., discovered by the second German Polar Expedition, is an ice fjord giving rise to bergs above 200 feet high; these can only be produced by a great inland ice-field. From such observations, then, we may assume that the Inland Ice feeding the glaciers on the west coast is continuous with that from which the bergs on the east coast are derived.

The existence of this ice-sheet is, indeed, an assumption, as no one yet has travelled across Greenland; but it is in accordance with the few observations that have been made; and the existence of an ice-free district in Inner Greenland would require that its physical features should be very peculiar and exceptional †.

The amount of precipitation in North Greenland seems to indicate indirectly the great extent of the Inland Ice; for where the glaciers are largest, it is not considerable; at the colony of Jakobshavn the rainfall from July 1873 to July 1874 was 219·7 mm., from July 1874 to July 1875, 183·7 mm. In the district of Umanak, where there are a number of great ice-fjords, the rainfall seems to be no greater; yet here the glaciers are very large, one may say, the largest known; so that we can only account for them by supposing that they are supplied from a very extensive upland district on which there is a considerable snowfall, and thus that there can be little land in the interior free from ice. Be this as it may, there is no doubt that the ice-sheet extends into Greenland beyond the range of vision.

As the interior of the country is unknown, so is the configuration of the ground beneath the ice; still it may be possible to obtain from analogy an idea of this. Even in the writings of some of the most modern Arctic travellers we find the idea expressed that all Green-

* Undersögelses Reise til Ostkysten af Grönland.

† See Dr. Rink's 'Om Grönlands Indre.' Fra Videnskabens Verden, 2den Rækk. No. 9.

land is but a collection of islands,—in other words, that the Skärgård on the coast represents in miniature the whole country, except that these islands are covered up and connected by a continuous ice-sheet. With this idea any one who is familiar with a fjord and its ramifications cannot agree. Greenland is a fjord land, as is the west coast either of Norway or of North America; so that if we would form a conception of what is concealed by the ice in it, we must study what is uncovered in them. Here, then, it is obvious that large, deep, and strongly marked fjords do not intercept the country as sounds, but pierce into the land as valleys whose ramifications at last die away in the interior. We conclude, therefore, that the structure of Greenland is somewhat similar, and so that it is not a collection of islands.

The Glaciers in the Ice-fjords.—These stand in the same relation to the Inland Ice as a river does to the lake from which it flows. If the former be dammed up, the level of the latter rises; so, if the ice-fjord be blocked, the thickness of the Inland Ice will increase until it can find a new outlet. We may divide the ice-fjords into those which produce large bergs and those which only produce small bergs and "calf-ice;" the nature, however, of both is the same, the appearance of the glaciers, and their junction with the Inland Ice; but the quantity of ice which the glaciers of the larger fjords discharge into the sea as bergs is so great as to distinguish them from the rest. Of the five fjords in North Greenland of the former class, four are situated in the district here described; two of these, that of Jakobshavn and that of Torsukatak, lead from Disko Bay into the mainland; the other two, the greater Karajak and the Umiamako (the Great Kangerdlugssuak of Dr. Rink's map), occur in the district of Umanak *: the name here given is the one used by the Greenlanders, and that of Kangerdlugssuak † is applied to a fjord directly south of the Umiamako.

Of the smaller ice-fjords there are two in Disko Bay, that of Alangordlek and that of Sarkardlek. These debouch into two branches of the Tasuissak, a lateral fjord of the Jakobshavn. The following are in the district of Umanak, between the Great Karajak on the south and the Umiamako on the north—the Little Karajak, the Sermelek, the Slivdiarssuk, the Ingnerit, the Kangerdluarssuk, and the Kangerdlugssuak. Jakobshavn Fjord is filled by the great glacier (situated, according to Dr. Rink, in 69° 10′ north lat.) which produces the numerous icebergs in Disko Bay; the immense number of these of all sizes renders the fjord inaccessible to boats in the summer time, for then the ice makes it hardly possible to see the water, even from an elevation. The glacier, however, can be reached by a circuitous route, as mentioned by Dr. Rink and Prof. Nordenskjöld. I went to a place named Tivsarigssok, a creek covered with ice and blocked up by the glacier which fills the fjord. The sea, however, extends to this place, for the ice of the creek

* The fifth fjord is that of Upernivik in the district of the same name.

† This word means "a great fjord," a further reason for not prefixing "great" to it.

rises and falls with the tide: this ice enables one to reach the glacier and the side of the main fjord. The surface of the glacier is greatly crevassed, some of the ice-peaks being full fifty feet high; still the glacier can be traversed up to a distance of about a hundred paces from the side of the fjord: here, however, it is broken up into steep inaccessible crags by gaping crevasses fathoms broad, which run in all directions. To this glacier there is no continuous lateral moraine, but erratic blocks and dirty ice occur on its surface near the margin. As a rule, no boulders were seen in the middle part of the glacier.

The breadth of the fjord varies; in one place which was measured it was about 4500 metres. The length of the glacier from the place where it merges into the Inland Ice is approximately 21 kilometres. A point where the side of the fjord disappears under the Inland Ice is more than 150 metres above the sea; hence the slope of the glacier is not quite half a degree. The glacier passes evenly into the Inland Ice, which slopes slowly upwards beyond it.

The icebergs in front of the end of the glacier not seldom overtop it by as much as 30 metres, for its terminal ice-wall rises scarcely more than 40 metres from the sea. The line where the glacier ends and the bergs begin is in this case easily observed, for though its surface is much fissured, the outline of the bergs is even more confused; but the end of the glacier is indicated still more clearly by a thin layer of fine dust, which distinguishes it from the cleaner surface of the recently broken-off and overturned bergs. The sides of the Jakobshavn Fjord are not very steep or high, and so it is not difficult to traverse its south side.

The usual method of measuring the rate of motion of a glacier, by fixing a line of poles across it, cannot be applied in the ice-fjords, by reason of the inaccessibility of the glacier; it therefore has to be determined by the measurement of angles from a fixed base, the sharp peaks affording good points for observation. My measurements were made with a good theodolite, and the results are given in the following Table (p. 149).

The rate of motion, where the glacier borders upon the mountain-side, was measured by fixing sharp stones into the side of the glacier, and by laying on the rock close to the glacier similar sharp stones, so that the sharp points of the stones in the glacier were lying quite near the points of the stones on the rock. It was observed that the rate of motion close to the border of the glacier was not over 0·02 metre per day.

These numbers show that the Jakobshavn glacier flows with a velocity greater than any that has hitherto been observed *. This is the more surprising as its slope is only half a degree. The measurements were made during the daytime in summer, when the temperature rose at noon to 10° C.; perhaps the motion is slower on colder days. There must, however, be considerable motion during

* [The maximum daily motion as observed by Professor Tyndall on the Mer de Glace (Chamouni) was 33¾ inches (0·85 metre). This was in the month of June. See 'Glaciers of the Alps,' p. 280.—Ed.]

The Rate of Flow of the Glacier of the Fjord of Jakobshavn.

Name of the point.		Day and Hour when rate of motion was measured. From	To	Number of hours during which the point had moved.	Distance traversed by the point in these hours.	Hourly motion of the point.	Daily motion of the point.	Mean daily motion of the point.	Distance of the point from the border of the glacier.
I.	a.	The 7th of July, 3 p.m.	The 8th of July, 10½ a.m.	19½	11·88 metres.	0·609 metre.	14·62 metres.	14·70 metres.	400 metres.
	b.	8th „ 10½ a.m. ...	8th „ 6 p.m. ...	7½	4·46 „	0·595 „	14·27 „		
	c.	8th „ 6 p.m.	9th „ 9 a.m. ...	15	9·51 „	0·634 „	15·21 „		
II.	a.	The 7th of July, 3 p.m.	The 8th of July, 10½ a.m.	19½	14·59 „	0·748 „	17·95 „	15·36 „	420 „
	b.	8th „ 10½ a.m. ...	8th „ 6 p.m. ...	7½	3·80 „	0·507 „	12·16 „		
	c.	8th „ 6 p.m.	9th „ 9 a.m. ...	15	9·98 „	0·665 „	15·97 „		
III.	a.	The 7th of July, 3 p.m.	The 8th of July, 10½ a.m.	19½	12·13 „	0·622 „	14·93 „	15·18 „	445 „
	b.	8th „ 10½ a.m. ...	8th „ 6 p.m. ...	7½	4·97 „	0·662 „	15·90 „		
	c.	8th „ 6 p.m.	9th „ 9 a.m. ...	15	9·20 „	0·613 „	14·72 „		
IV.	a.	The 7th of July, 3 p.m.	The 8th of July, 10½ a.m.	19½	12·52 „	0·642 „	15·41 „	15·24 „	449 „
	b.	8th „ 10½ a.m. ...	8th „ 6 p.m. ...	7½	4·63 „	0·617 „	14·81 „		
	c.	8th „ 6 p.m.	9th „ 9 a.m. ...	15	9·81 „	0·654 „	15·70 „		
V.	a.	The 8th of July, 12 at noon	The 8th of July, 7 p.m. ...	7	4·97 „	0·710 „	17·08 „	19·77 „	1049 „
	b.	8th „ 7 p.m.	9th „ 10 a.m.	15	14·04 „	0·936 „	22·46 „		
VI.	a.	The 8th of July, 12 at noon	The 8th of July, 7 p.m. ...	7	5·63 „	0·804 „	19·30 „	19·54 „	1059 „
	b.	8th „ 7 p.m.	9th „ 10 a.m.	15	12·36 „	0·824 „	19·78 „		

the winter, for the icebergs "calve" from the glacier at that season also, as is stated by the Greenlanders, in so doing making cracks in the winter ice of the fjord.

The small ice-fjords of Alangordlek and Sarkardlek are situated in two branches of the Tasiussak, but are connected with each other by a glacier called Akuleakatua.

The general appearance of this resembles that of the glacier of Jakobshavn; but all the phenomena are on a small scale except the moraines, which are larger. The rate of motion also is strikingly small compared with that given in the Table above: it cannot be measured accurately in a short time owing to the small angular variation; but the glacier of Alangordlek did not move faster than 0·5 metre a day, Akuleakatua not faster than 0·4 metre a day.

The ice-fjord of Torsukatak (69° 50′ N. lat., according to Dr. Rink) sends its bergs out through the Waigat; it is difficult to get to the glacier in summer, but I succeeded in reaching it over a lake called Taserssuak. This glacier descends in four arms into the sea, being divided by several *Nunataks*: its northern arm gives rise to great bergs; the others appear to produce only small bergs and "calf-ice." The glacier ends in a level vertical wall about 15 metres high, and is about 9000 metres broad. The fjord just below is closely filled with bergs and fragments of ice. From the end of the glacier to a place where the Inland Ice covers every thing is but a short distance. Stones and erratic blocks only occur near the edge of the glacier, the middle and most crevassed part being free from boulders: the slope of its surface is less than two degrees; the rate of motion was measured as before, and the results are given below.

The Rate of Flow of the Glacier of the Fjord of Torsukatak.

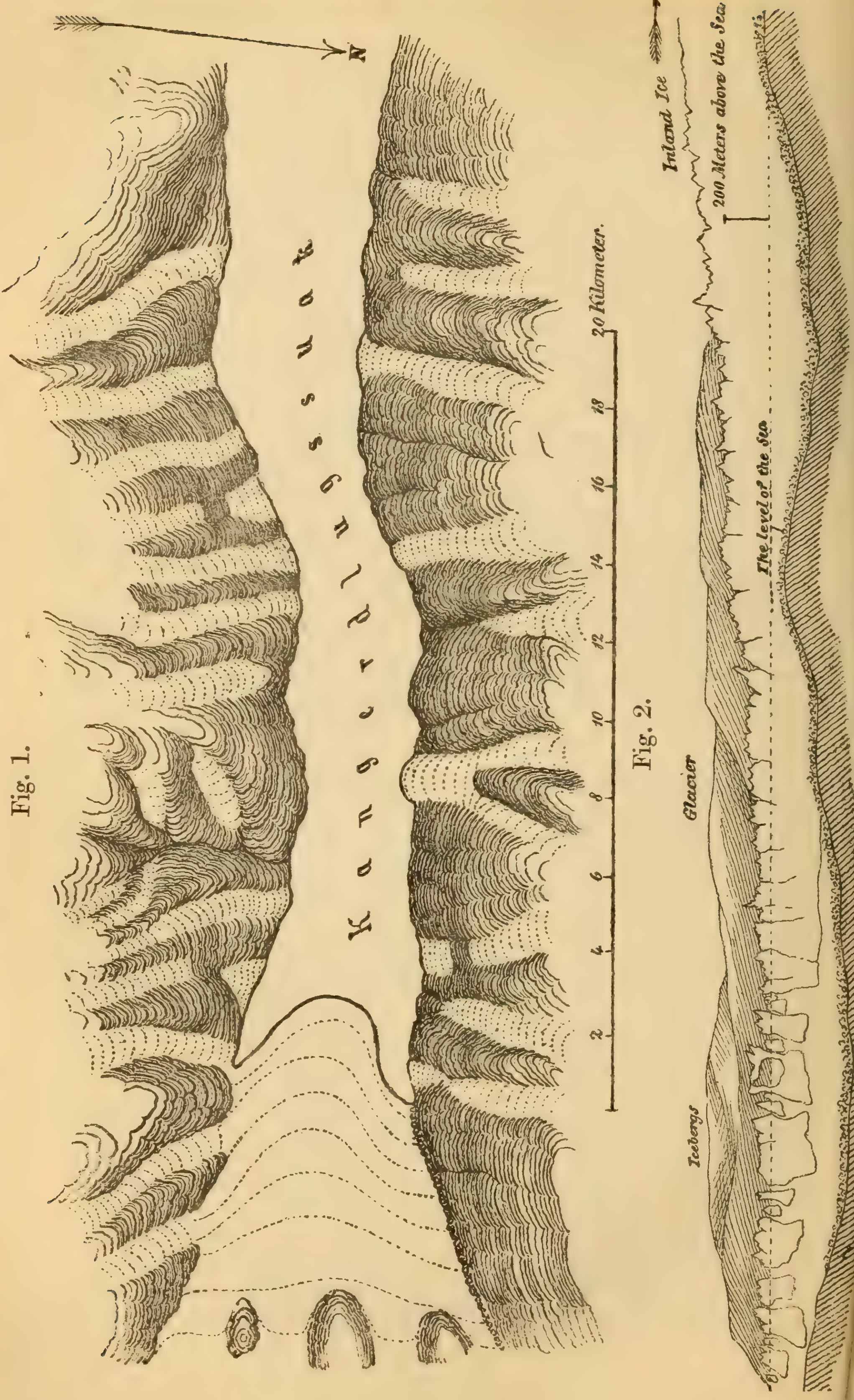
Name of the point.	Day and Hour when the rate of motion was measured.	Number of hours during which the point had moved.	Distance traversed by the point in these hours.	Hourly motion of the point.	Daily motion of the point.	Distance of the point from the border of the glacier.
			metres.	metres.	metres.	metres.
I.	From the 24th of July, at noon, to the 25th of July, 9 A.M.	21	3·28	0·156	3·75	210
II.		21	4·95	0·236	5·66	367
III.		21	7·72	0·368	8·82	1926
IV.		21	8·84	0·421	10·10	4070
V.		21	8·89	0·423	10·16	4939
VI.		21	8·18	0·390	9·35	4968

In the last three measurements there may be a fault of 1 metre, the whole variation of angles being only 7 minutes during 21 hours. It is evident from the Table that the motion of the glacier is increasing towards the central parts. The rate of motion is only half that of the glacier of Jakobshavn.

Kangerdlugssuak Fjord, situated in Umanak district at about 71° 15′ N. lat., is one of middle size, producing bergs, which, however, are not sufficiently numerous to prevent one from reaching the glacier in a boat. The scenery on the way is very fine, the mountains, as already mentioned, rising steeply from the sea to a height of 2000 metres. Their summits are often divided into sharp aiguilles, and numerous valleys descend between the peaks. There are often *glaciers remaniés*; some descend to the sea, some protrude from gloomy cirques, the steep sides of which effectually protect their snows from the effect of the arctic summer sun. It is hardly possible to imagine a landscape more thickly studded with glaciers than this. From the mouth of the sound between Upernivik Island and the mainland to the base of the Great Glacier descending from the Inland Ice at the end of Kangerdlugssuak Fjord is a long day's journey, in which not less than forty-seven glaciers are passed. The accompanying map (fig. 1, p. 152), though only sketched in without measurements, will give a general idea of the configuration of the country and the number of its glaciers.

The mountains in this fjord, though a little lower than those in the sound by Upernivik Island, descend precipitously to the water at angles of eighty degrees from heights of full 1000 metres. The glacier at the head terminates as usual in a steep wall advancing into the fjord with a convex outline, so that the end of the central part is some thousand metres in advance of that of the sides. The only landing-place which could be found near the glacier was on the moraine, and that was rendered dangerous by the "calving" of the ice.

The glacier itself is, as usual, impassable from being broken into *séracs* by crevasses (fig. 2); the moraine here rises to a height of from 15 to 20 metres, and its summit commands a very peculiar view. Near both sides of the projecting end of the glacier described above, two *glaciers remaniés* are seen high up on the mountain-side, from which ice avalanches are discharged. Down the fjord is a view of the numerous glaciers that have been passed *en route*, and looking upward towards the Inland Ice the moraine can be traced for a long distance; but the view over the Inland Ice itself is partly obstructed by three high island-like rock-masses (*Nunataks*) rising above the glacier, between which branches from the Inland Ice descend to form the glacier of Kangerdlugssuak. I had intended, if possible, to reach the great ice-fjord of Umiamako from this place by ascending the glacier of Kangerdlugssuak, and traversing the Inland Ice till I reached the elevation which commands a view over Umiamako. Partly on the moraine, partly on the glacier, and partly along its rocky side I succeeded in advancing about one geographical mile. Here, however, the moraine disappeared as the crevassed glacier came close up against the precipitous mountain-side, so I was compelled to turn back about the point where the mountain-wall bounding the glacier bends northward. It might be possible for a traveller,



Figs. 1 & 2.—*Sketch Map and Section of Kangerdlugssuak Fjord and Glacier.*

properly provided with European attendants, a ladder, ropes, &c., to traverse this part of the glacier; but the unusually numerous crevasses would certainly make it difficult. Perhaps it would be more easy to pass over to Umiamako by the north side of Kangerdlugssuak, though the steepness of the fjord side and the glaciers in the lateral glens would make the excursion toilsome.

The fact that though the climate of North Greenland, as already mentioned, is rather dry, large glaciers are numerous, is not without geological importance, as showing that a great snowfall is not absolutely necessary for the glaciation of an extensive country. It is also remarkable that the glaciers are supplied from an ice-field which, to a large extent at least, lies below the limit of perpetual snow. No doubt there is always a difficulty in determining this; for example, in the district of Umanak one may find masses of snow in summer near the sea, as in the island of Upernivik, even in the middle of August; but I ascended over the shales and sandstones* to a height of 750 feet above the sea without meeting with snow. At this elevation there is a plateau rising up to 890 metres, yet this is only dotted over with some patches of snow; so that in this island the line of perpetual snow lies above 890 metres. In the mountains on the opposite side of Umanak Fjord, east of Kelertinguak mountain, masses of perpetual snow are only found at heights above 700 metres. Above the glacier of Sermiarsut the limit was 970 metres, between the glaciers of Assakak and Umiatorfik 800 metres, and between the latter and the glacier of Sorkak 760 metres.

By comparing these numbers with the height of the Inland Ice where it has been measured, we see that the limit of perpetual snow on the outer land exceeds it: for example, at Pakitsok the Inland Ice was 251 metres above the sea, and Professor Nordenskjöld reached an elevation of 690 metres; but by looking at the bordering mountains one can see, without measurements, that the above statement is true. It is therefore doubtful if the ice-sheet and the glaciers would form again could the land be denuded of them and left to the influences of the present climate. The rate of flow, already mentioned, has an important bearing on the theory of glacier-motion. As the slope of the Jakobshavn glacier, which has the extraordinarily rapid motion of 20 metres *per diem*, is only half a degree, the fall of the bed of the valley cannot be the most important factor in the motion of glaciers. This considerable velocity must be due to the quantity of ice which has to be carried out to the fjord; or, in other words, the rate of motion is dependent on the pressure of the mass of the Inland Ice. Glaciers, therefore, fed from large districts of atmospheric precipitation, move with considerable velocity. Notwithstanding the rate of flow, the time occupied by the passage of the ice from the interior to the sea must be long. At the Jakobshavn glacier, indeed, four years would be required to transport a mass from the edge of the Inland Ice to the sea, a distance of 21 kilometres; but a much longer period would be required to transport to the sea the snow which falls on the interior

* These contain coal and fossil plants.

of the ice-sheet. From Kaiser Franz-Josef's Fjord on the east coast to that of Upernivik on the west is a distance of about 890 kilometres. If, then, a mass of ice, starting halfway, moved through the whole distance to Jakobshavn glacier at the rate of 15 metres a day, 29,666 days, or above 81 years, would elapse before it reached the fjord ; and it is not at all improbable that the Inland Ice would not move with any thing like the velocity of the glaciers.

Many Greenlanders are of opinion that the glaciers are steadily increasing. Accordingly Dr. Rink, in his excellent work on Greenland, has given a map of the south side of Umanak Fjord, showing the extent of several glaciers in the year 1850, and recording their exact distance from the sea at that date. I visited six of these, and compared their distances with those given by Dr. Rink. In the case of three I observed variations, one of which was considerable.

The glacier of Assakak is recorded by Dr. Rink to have been, in 1850, 400 ells (251 metres) from the sea ; in 1875 its end was so covered with stones that in some places we could not decide whether we were standing on the glacier or the moraine ; but it was nowhere nearer to the sea than 500 metres, so that in 25 years it has retreated about 250 metres. This glacier is interesting on account of the fossil stems of trees which it brings down. I followed them as they lay in a long row on the glacier for about one geographical mile to a height of 620 metres. If followed further they would, I think, lead to a site rich in fossil plants in the inner part of the Nŭgssuak peninsula.

The glacier of Umiatorfik, according to Dr. Rink, was from 600 to 800 ells (372 to 502 metres) from the sea ; its distance in 1875 was 322 metres, so that this one seems to have advanced.

The glacier of Sorkak is a most remarkable example of variation in a comparatively short lapse of time. Dr. Rink states that in 1850 the end was quite concealed by gravel and stones, and the ice only showed itself several hundred ells from the sea, on the site of an old homestead. When I visited this glacier in 1875 it had advanced out into the sea and ended in an ice-wall about 25 metres high. Near to its extremity it seemed to be about double that thickness. Dr. Rink also states that the Greenlanders told him that this glacier formerly entered the sea and cracked the ice of the fjord when it "calved" in winter ; so that in the course of two generations this glacier has receded and advanced several hundred ells ; hence along the south side of Umanak Fjord the glaciers do not prove a uniform increase of ice in North Greenland.

Icebergs and their formation.—The forms of icebergs are very variable ; but as these have been so often described we need not enter into details. Their surface is usually clean, but now and then one is seen with boulders upon it, and here and there little bergs occur quite covered with stones and gravel. The profile of an ice-fjord (fig. 2, p. 152) will illustrate the formation of bergs, a process which has been often explained, and so need not detain us. I have twice witnessed the formation of a berg—once in Jakobshavn Fjord, once in Torsukatak Fjord. The glacier in the former "calved" once only in three days. The "calving" was accompanied by a terrific crash, and by white clouds of spray (or comminuted ice?) hurled into the air. Simultaneously an enormous jagged mass of ice, forming part of the terminal wall of the glacier, was seen to turn over, bringing its edge, as it rotated, high above the level of the glacier. As it rose, huge towering pinnacles were shattered, and came crashing down in fragments, like a shower of gravel. The "calving," which had commenced at a place near the middle of the glacier, was continued in another. A second large mass of the solid glacier broke loose, and at first moved almost horizontally, at the rate of perhaps a metre in a second. This, like the glacier itself, was cleft into ice pinnacles, and the one group in moving past the other produced a curious effect. How many bergs were produced in this "calving" I cannot say, as they were formed simultaneously in several places; further, white clouds of spray partly concealed the glacier, and the old bergs in front of it were set in motion; there was an indescribable confusion and a continuous crashing noise, which lasted for about half an hour, then things became once more quiet. The height of one of the bergs formed by the "calving" was by measurement 89 metres.

In order to estimate the quantity of ice discharged by a fjord, we must know the thickness, breadth, and rate of motion of the glacier. The first cannot be directly measured, except so far as it rises above the sea; but if we know the proportional parts of a berg above and below water, we can form an idea of the thickness of the glacier. Taking the specific gravity of water as unity and that of ice 0·918 (according to Brunner), the volume above the water is 0·082, or about one twelfth of the whole. In the case of the bergs, however, there is not so much submerged, because of the saltness of the fjord water and the lower specific gravity of the ice, owing to the included air-bubbles. To determine this specific gravity, I took five pieces of ice from the bergs and put them into water. Into this I continued to pour alcohol until three of the pieces sank, the others still floating, and observed the specific gravity with an alcoholometer. I then placed in the mixture a piece of solid ice, and added water until it would neither sink nor rise. The difference between the specific gravity of these two mixtures is about equal to the difference between the specific gravities of the ice with bubbles and the solid ice*. From these experiments (on ice from bergs in Disko Bay) I found that the specific gravity of the bergs is decreased by 0·032 on account of the air-bubbles, or from 0·918 to 0·886. The specific gravity of the water in the ice-fjord varies; it was 1·0228 in Jakobshavn Fjord, near to the mouth of Tasiussak. From these experiments it results that 0·86 of a berg is under, and 0·14 is above

* The specific gravity of the ice when it neither sinks nor rises is not exactly equal to the specific gravity of the mixture; for the fragments partly dissolve and are surrounded by water, and so sink in a mixture of higher specific gravity than that of the ice itself: the difference, however, between the specific gravity of the mixtures is nearly, though not exactly, equal to the specific gravity of the ice-pieces.

the sea, or that the part under water is about six sevenths of the whole mass.

The heights of several bergs were measured. Of all those at the mouth of Jakobshavn, three exceeded 83 metres, the loftiest being 121 metres (according to several measurements with a theodolite), the highest which I have ever seen. I estimate the quantity of ice above the sea to have been 3,000,000 cubic metres, aud the whole mass of the berg 21,000,000 cubic metres. The depth of Jakobshavn Fjord, where the Greenlanders fish for halibut, is, judging from the length of their lines, about 390 metres. From these numbers we will endeavour to estimate the quantity of ice discharged through the Jakobshavn Fjord. According to some measurements, the height of the glacier above the sea, where it "calves," is about 40 metres. Here, then, its whole thickness must be at least seven times the above height; for if it were floating, and so less thick, there would be no "calving:" hence the thickness of the glacier must be here at least 280 metres. Its mean rate of motion is 14·25 metres a day. The breadth of the fjord is 4500 metres; its sides slope at angles of 20°, so its transverse section is a little more than 1,000,000 square metres. Hence the quantity of ice passing through this daily in summer is about 16,000,000 cubic metres. In like manner we find that the quantity of ice discharged by the Torsukatak glacier is 6,300,000 cubic metres a day. 16,000,000 cubic metres of ice represent what we may call a large berg; so we see that the daily discharge through the fjord of Jakobshavn, notwithstanding the considerable velocity of the glacier, is only equal to one large berg a day. This may, perhaps, surprise any one who has seen on a summer's day the bergs passing in great numbers out of the Jakobshavn Fjord; but it must be remembered that all the bergs produced during the long winter have to be removed during the short space of summer. True, indeed, the rate of flow of the glacier is probably diminished in winter, so that the quantity discharged on a summer's day does not enable us directly to calculate that of the whole year. If the rate of flow continued uniform, the Jakobshavn glacier would discharge annually 5,800,000,000 cubic metres; the Torsukatak glacier 2,300,000,000 cubic metres. It is not, however, probable that the quantity actually produced would be so little as half of the above, for this would require the glacier to be motionless during the three winter months. So we may estimate the quantity of ice annually discharged from the Jakobshavn Fjord to be between 2,900,000,000 and 5,800,000,000 cubic metres, and that from the Torsukatak Fjord between 1,150,000,000 and 2,600,000,000 cubic metres. Calculating in like way the discharge of the smaller fjords, as, for example, Alangordlek, we find that it hardly produces one hundredth part of that from Jakobshavn.

Large as are the quantities of ice thus yearly discharged from the fjords, they form but a small fraction of the rain- and snowfall of inner Greenland, the greater part of this passing away in rivers beneath the glaciers. Dr. Rink*, who estimates the ice yearly dis-

* "Om Vandets Aflöb fra det indre af Grönland," Naturhistorisk Tidsskrift, 3 R., i. B.

charged by a great fjord as "one or several thousand million cubic ells," states that this amount is many times smaller than that of the rain and snow which falls upon the interior of Greenland. Even if, as I am inclined to do, we read cubic metres for cubic ells in the above, still the proportion discharged as ice will be much smaller than that which passes out as water beneath the glaciers.

On the amount of mud in Rivers issuing from Glaciers in Greenland and Norway.—The sea-water of the fjords into which glaciers descend is not muddy; but where a strip of shore intervenes between the water and the ice a muddy river is seen to issue from the glacier; also along the sides of the glaciers in the fjords and along the Inland Ice, streams thick with pulverized rock are often to be seen. The rivers which discharge themselves into the fjords under the great glaciers, often far from the end of the latter, probably deposit their mud at the bottom of the sea beneath the ice.

The quantity of mud in the rivers which issue from the glaciers in Greenland is very variable, as will be seen from the following numbers (these indicate the weight of mud in grams in 1,000,000 grams of water, which is nearly the same as the quantity of mud in grams contained in 1 cubic metre of water):—

		Grams of mud in 1 cubic metre of water.
River at the glacier of Jakobshavn	9th of July, 1875 ...	104
" " Alangordlek	10th of July, " ...	2374
" " Ilartdlek	17th of July, " ...	723
" " Tuaparsuit	6th of Aug. " ...	678
" " Umiatorfik	20th of Aug. " ...	75
" " Assakak	21st of Aug. " ...	208
" " Kangerdlugssuak	11th of Aug. " ...	278

The last four glaciers are situated in the district of Umanak.

In Norway the quantity of mud in the rivers issuing from under the glaciers descending from the large snow-and-ice field of Justedalsbræen was calculated in the year 1874. The numbers were as follows:—

		Grams of mud in 1 cubic metre of water.
The western river of the glacier of Boium	23rd of June ...	88
The same river	30th of July ...	309
The eastern river of the glacier of Boium	23rd of June ...	59
The same river	30th of July ...	159
The large river of the glacier of Suphelle	24th of June ...	33
The same river	30th of July ...	113
The small river of the glacier of Suphelle	24th of June ...	72
The small river of the glacier of Langedal	6th of July ...	513
The river of the glacier of Austerdal	6th of July ...	56
The river of the glacier of Brixdal	16th of July ...	77
	Mean number	147·9

It is obvious that even the quantity of mud in the same river is very variable.

By measuring the quantity of water in the rivers, I calculated the quantity of mud carried away from all the glaciers descending from the Justedalsbræen (covering an area of about 870 square kilometres), and found it to be about 2,000,000 kilograms on a day in July. By taking account of the snow and rainfall of the above district I estimated that 180,000,000 kilograms of mud are carried away annually; this quantity is equal to 6900 cubic metres of rock, or a cube whose side is 41 metres.

Extent and thickness of the Glaciers in Greenland and Norway during the Glacial Epoch.—It is obvious that the glaciers once had a wide extension over the Outer Land of North Greenland, for *roches moutonnées*, grooves, moraines, and perched blocks are seen in places far from existing glaciers. In the Outer Land of Greenland, as in Norway, the following glacial phenomena are common:—

(1) Boulders are widely dispersed both on higher and lower levels in the two countries; (2) The mountain-sides are grooved and polished as they now are along the glaciers in the ice-fjords; (3) *Roches moutonnées* are almost universal upon the Azoic rocks on the sides of the fjords and the islands; (4) Moraines occur in places not now reached by glaciers; (5) In both countries sea-banks lie before the deep fjords, representing the old moraines in front of the rock-basins of the fjord. To these we may add (as proved in the sequel):—(6) Cirques, partly filled with glaciers, partly empty, and then covered with *débris* of a moraine; (7) Lakes, fjords, and (partly) valleys, with correspondent features in both countries.

The boulders, grooves, and *roches moutonnées* show the former extent of the glaciers, and in some cases enable us to estimate their thickness. I will give some examples from North Greenland. On the south side of the mouth of the Jakobshavn Fjord deep grooves are conspicuous between the *roches moutonnées*, which show that the glacier once filled the fjord to the mouth, was here of great thickness, and extended further out into Disko Bay.

Umanak Island, in the middle of the fjord of the same name, as already mentioned, rises to a height of 1163 metres. The gneissic rocks on the side of this show groovings and are *moutonnées* everywhere in the neighbourhood of the colony, and erratic blocks abound. Hence this fjord was also filled by an enormous glacier, from which perhaps the highest parts of the island protruded as *Nunataks*. In front of Umanak Fjord, near the sea, is an island called by the Danes Ubekjendt Eiland, and in front of the Waigat is the island called Hareöen. These I have not visited; but Giesecke states in his diary * that on the former, which consists of basalt, he found boulders from the Azoic formation which he could not discover in the mountains. Hareöen consists of basalt, with shales and sandstones containing coal and fossil plants. According to M. Steenstrup it is 1800 feet high, and large erratics of gneiss are extremely abundant. These, as he informs me, occur up to the very summit of the island †. Hence Waigat Fjord was once filled with a glacier whose thickness (supposing the configuration to be as at present) was at least equal

* Unprinted, but preserved in the University Library at Copenhagen.

† "Om de kulförende Dannelser paa Öen Disko," Meddelelser fra den naturhistoriske Forening, 1874.

to 1800 feet + the depth of the Waigat, which is unknown. The islets also near the colony of Egedesminde are *moutonnées,* showing that here also the glaciers once reached the sea.

In Norway I have investigated more closely the former thickness of the glaciers, estimating them from the heights at which I found boulders, grooves, or *roches moutonnées* on isolated mountains, on islands in the fjords, and along the sides of the fjords. The following are the results:—

Varaldsö is an island in the middle of the Hardanger Fjord, composed of clay-mica-schists and some other slates. The depth of the fjord inside this is, according to the sea-charts, 631 metres. I found a boulder of granite 3 metres long on the island at a height of 305 metres. In the northern parts there are grooves at a height of 457 metres. *Roches moutonnées* and grooves are seen at a height of 569 metres, which to the eye appears only a few metres below the highest point of the island.

The islands of Sulend lie before the mouth of the Sogne Fjord and rise to a height of 500 metres. The soundings of the Sogne Fjord inside them are the deepest known in Norway, being about 1200 metres over an extent of some 20 miles, the greatest depth being 1244 metres. The Sulends consist of a conglomerate resting on clay-mica-schists. In ascending the mountain of Pollefjeld (their highest summit) I found boulders of foreign rock on the conglomerate. The greatest height at which these occurred was 511 metres, and the summit of Pollefjeld was by measurement 529 metres above the sea-level, that is, only 18 metres above the highest boulders. *Roches moutonnées* abound in these islands; their lower parts are formed of an undulating rock-surface, and the sides over the sounds are steep and polished, and near the sea not rarely grooved. To these observations numbers from similar localities could easily be added; in short, the islets of the Skärgård along the Norwegian coast are all *moutonnées* whenever the nature of the rock has allowed this form to be preserved.

Roches moutonnées are usually found along the sides of the fjords, as well as in the islands, wherever the original surface is unweathered; this may be readily seen in travelling along the fjord at some distance from the land: by looking seawards (that is, in the direction in which the glacier moved) the characteristic smooth undulated outlines of the back of the ice-worn rocks will be at once recognized; but on looking up the fjord the steeper sides of the rocks face the spectator, rising one above the other like a series of steps. This structure is rendered most conspicuous when the country is covered by snow, which of course does not rest on the steep faces of these rocks. In the Aurlands Fjord (a branch of the Sogne Fjord) grooves occur at 391 metres and at the higher level of 606 metres above the water. *Roches moutonnées* appear to continue up to a height of 668 metres. The depth of the fjord below is 275 metres.

Along the side of the Sör Fjord, in Hardanger, Professor Sexe * observed groovings 471 metres above the sea, the depth below being

* Marker efter en Istid, p. 6.

392 metres. The mountain of Tronfjeld, in Österdalen, consists of gabbro, in which are small quantities of serpentine; the summit is 1744 metres above the sea, and 150 metres below this, on the western slope, a rounded block of granite was found. Boulders of laminated quartzite with rounded edges occurred up to a somewhat greater height, so that the upper limit of erratics is here about 1600 metres. The height of the bottom of the valley of Österdalen is about 500 metres. Erratics of serpentine, laminated quartzite, and granite are found on Sölen Mountain in Rendalen *: this mountain consists of red sandstone, paragonite schist, and conglomerate, the height of its summit being 1788 metres. According to Mr. Törnebohm's measurement, boulders occur to within 47 metres of the summit, or up to 1741 metres above the sea. The height of the country below this mountain is about 700 metres. Suletind Mountain in Valders is 1770 metres high; according to Keilhau an erratic is found on its summit. The height of Utrovand Lake (985 metres) may be taken as the general height of the country at the foot of the mountain. In South-eastern Norway, where the mountains are much lower, boulders, of course, cannot be observed at heights like the above; but on Graagalten Mountain, above Lake Soneren, I found erratics up to the summit, 756 metres above the sea, the elevation of the lake being 118 metres. On the mountain of Skrimfjeld, south of Kongsberg, erratics occur up to the summit and *roches moutonnées* near to it; this is 900 metres, the height of the country below being about 250 metres.

Assuming, then, that no important changes in configuration have taken place since the transportation of the boulders, we have the approximate *minimum* thickness of the glaciers given in the following Table:—

Thickness of the Glaciers during the Glacial Epoch.

	metres.
Height of the groovings in the isle of Varaldsö	569
Depth of the Hardanger Fjord inside the isle	631
Thickness of the glacier in the Hardanger Fjord	1200
Height of erratic boulders in the Sulends	511
Depth of the Sogne Fjord inside the Sulends	1244
Thickness of the glacier in Sogne Fjord	1755
Height of groovings above Aurlands Fjord	606
Depth of this fjord	275
Thickness of the glacier in Aurlands Fjord	881
Height of groovings above Sör Fjord	471
Depth of this fjord	392
Thickness of the glacier in Sör Fjord	863

* Törnebohm, "Om flyssblock och terasser," Geol. Föreningens Förh. vol. i.; and Schlötz," Sparagmitkvärts-fjeldet," Nyt Mag. f. Naturw. vol. xx.

	metres.
Height of boulders in Tronfjeld	1600
Height of the valley below	500
Thickness of the ice at Tronfjeld	1100
Height of boulder on Sölen	1741
Height of the country below	700
Thickness of the ice at Sölen	1041
Height of erratic boulders on Suletind	1770
Height of the lake of Utrovand below	986
Thickness of the ice at Suletind	784
Height of erratic boulders on Graagalten	756
Height of the lake of Soneren at the foot	118
Thickness of the glacier at Graagalten	638
Height of erratic boulders on Skrim	900
Height of the country below	250
Thickness of the glacier at Skrim	650

From the above we may draw the following picture of Norway in the Glacial Epoch. The fjords were filled up by glaciers, which attained a thickness of from 1700 to 1800 metres in the Sogne Fjord and 1200 metres in the Hardanger; the lateral fjords debouching into these contained glaciers 800 metres thick, supplied from an inland ice-sheet at least from 800 to 1100 metres thick. The icy mass also extended over South-eastern Norway, where it was not less than 600 or 700 metres thick.

On the formation of Cirques and Valleys ending in Cirques.—In those parts of Norway and Greenland which abound in small isolated glaciers unconnected with any large ice-field, we find a great number of recesses called Cirques, in Norsk "Botner" (bottoms). These cirques are large spaces excavated from the solid rock, bounded on three sides by an almost semicylindrical steep mountain-wall, and with a tolerably flat floor. When the upper part of a valley terminates in a *cul-de-sac*, so that its gently sloping bed comes to an abrupt end against a steep mountain-wall, this too is called a "Botn" (cirque). The latter kind of cirques may for convenience be called "valley cirques," the former "mountain cirques," though there is no essential difference between them. I shall describe the mountain cirques first.

The dimensions of these cirques are variable, their length and breadth being often about the same and varying from some hundred to some thousand metres. If the length greatly exceeds the breadth, this passes into a "valley cirque." The mountain-walls around the cirques vary from 50 to 400 metres in height, sometimes being even as much as 700 metres; and in Greenland, in the sound between Upernivik Island and the mainland, I have seen a cirque surrounded by an almost vertical wall, which rose nearly 1000 metres above the glacier which filled the cirque. The surface of this glacier was 240 metres above the sea, and the top of the mountain 1207 metres. The steep, often almost vertical, walls which enclose a cirque frequently approach each other near the mouth, so that a horizontal section is more than a semicircle. In many cirques the floor is occupied by a glacier; in other cases there is often a little lake in the middle, with a moraine in front of it. The ground is commonly covered by large shattered blocks which, near the opening, often, if not always, are collected into a moraine.

Cirques are numerous among the peaks of the Jotunfjelds, the loftiest mountains of Norway. On Glittretind and Nautgarstind they occupy half the side of the whole mountain, its physical features being due to them. The large and beautiful cirque on Glittretind is thoroughly typical. The uppermost part of this mountain consists of a semicircular crest, which slopes comparatively gently to the southern or outer side, whilst on the northern or inner side it descends precipitously into a horseshoe-shaped valley or cirque. The mountain is thus in form a cone, from a side of which an enormous cylindrical space has been excavated. The floor of the cirque is covered by a glacier, and cliffs rise above it to an estimated height of more than 350 metres, the summit of the crest being 2554 metres above the sea. Another interesting case occurs in the mountain Togga, in Sogn, where four cirques lie one beside another, like four horseshoes placed in a row. To these descriptions many others might be added; but as their form and mode of occurrence is everywhere the same, both in Greenland and Norway, we may pass on to examine their geographical distribution. Mr. Bonney * and Professor Gastaldi † have described the cirques of the Alps, and show that they resemble those in Norway. According to Mr. Drew, cirques occur in the Himalayas, where also they are often filled by glaciers or contain lakes. Professor Nordenskjöld has mentioned their occurrence in Spitzbergen.

A striking feature about them in Norway is, that they occur in parts of the country where glaciers are now or have been at work in the modern period—as, for example, near to the Justedalsbræen, the Folgefonden, and in the Jotunfjelds (Finmarken); in short, cirques are numerous in regions where small isolated glaciers now occur. Further, if we examine a landscape in which cirques abound, and count how many of them look towards the north and how many towards the other points of the compass, we find that the greater number open towards the north, north-east, and north-west, while but a few look towards the south or are situated on that side of the mountains. This can even be seen in a good map. When standing, for example, on the summit of Glittretind and looking towards the south-west and south-east, we see no less than twenty-one cirques opening towards the north, but none towards the south. Out of thirty-seven cirques in the Jotunfjelds, twenty-five have their openings towards some point of the horizon between north-west and north-east, three between north-west and south-west,

* Quart. Journ. Geol. Soc. vol. xxvii. p. 312.

† *Ibid.* vol. xxix. p. 396.

eight between north-east and south-east, one looks to south-east, and not one to south. Similarly, around the Justedalsbræen, out of forty-one cirques, twenty-five look to north, four to west, eleven to east, one to south-east, none to south.

I do not, indeed, say that no cirques in Norway look to south; but they are very rare on the south sides of the mountains as compared with the north. When a valley runs from east to west, cirques very often occur on the side which faces the north, while on the other there are none. Many examples of this might be found in districts of Norway where cirques abound.

In Greenland it is hard to say whether the cirques upon the whole are chiefly found upon the north sides of the mountains, for that country has been but little explored or mapped; still, if we look at the configuration of the land on the south side of Umanak Fjord, we see from the mountain of Kelertinguak and to the north-east a row of cirques which, as far as observed, are not to be seen on the north side of the fjord. The configuration of most of the highest mountains in Norway is due to cirques; for their summits are often only the highest point of the crest which surrounds a cirque. The same configuration is observed in the high mountains of Greenland. Glittretind may be taken as an example in Norway, Kelertinguak in Greenland.

How are these remarkable semicylindrical recesses formed? In the papers of Mr. Bonney and Professor Gastaldi we find two theories advanced. Mr. Bonney thinks the Alpine cirques have been formed by streamlets pouring down along the cirques, and gives an example of six or seven streamlets having worked out a recess only a few yards broad, yet with the form of a typical cirque. Along the fjord-sides of Norway, where rivers precipitate themselves from the mountain-wall, recesses of a form resembling that of the cirques are very often seen; but the large typical cirques are scarcely produced in this manner; for, putting aside the fact that the part of the crest surrounding the cirque and sloping to the latter is only some metres broad, so that it cannot feed even a very small stream, there is in many cirques, as above mentioned, a lake, which cannot be formed by these streams; for neither still water nor the running water of streams can erode lakes, and those in the cirques are evidently formed in the same manner as the cirques themselves.

Professor Gastaldi does not doubt that the cirques were formerly occupied by glaciers, and that glaciers are able to scoop out deep beds in soft rocks in high Alpine regions. From the above observations we can get a hint of the mode in which cirques are formed. We see, first, that on the whole they are not dependent upon the nature of the rocks; for they are found in granite, gabbro, gneiss, metamorphic schist, quartzose slates—in limestone and gypsum in the Alps, in basalt as well as in the rocks of the Azoic formation in Greenland. It is needless to remark that the above excludes the idea of cirques being old craters.

We have already pointed out their connexion with glaciers past and present in many lands; we next remark that where the line of perpetual snow lies high up, the cirques chiefly occur at higher levels; where the limit of snow descends, the cirques are also found at lower levels. According to Professor Gastaldi the Alpine cirques are found at heights between 2000 and 3000 metres; around the Justedalsbræen they are numerous at the level of 1200 metres; on the Jotunfjelds at heights above 1600 metres. The bottoms of the cirques on Istinden Mountain, in Finmark, are 800 metres above the sea; nay, in Kvalö Island, in the same district, according to Mr. Lorange, cirques lie only a few feet above sea-level. Comparing these heights with the snow-line, which is 2500 metres in the Alps, 898 to 1460 metres (according to Prof. Sexe) near the Justedalsbræen, 1600 metres (according to Prof. Keilhau) in the Jotunfjelds, and 900 metres in Seiland Island in Finmark, we see that cirques are chiefly found near the limit of perpetual snow, which is to be expected when we remember that this limit is most favourable for the formation of isolated glaciers. That the cirques also occur at lower levels than the snow-line is in harmony with the occurrence of glaciers, which, as is well known, are found much lower down than the limit of perpetual snow; and the occurrence of a cirque in Kvalö only a few feet above the sea-level harmonizes with the other observations, when it is seen that these cirques are filled with glaciers.

In Greenland, along the mainland round Disko Bay, where the mountains are low and the conditions unfavourable to small isolated glaciers, I saw no cirques; but on arriving at the Waigat and the Umanak Fjords, where the mountains are higher and isolated glaciers very numerous, cirques also are numerous; and as isolated glaciers are here capable of being formed and maintained at an inconsiderable height above the sea, the cirques also occur often at but slight elevations. The fact that the cirques are commonly situated on the north sides of the mountains or the south sides of the valleys, shows a dependence on the glaciers; for the north sides of the mountains, where the snow is less exposed to the sun's rays and to warm south winds, are favourable to the formation of glaciers. As to the way in which the glaciers excavate the cirques, I may quote another observer, Lieutenant Lorange (Norwegian Royal Engineers), who mapped the country round Justedalsbræen. He, though not a professional geologist, independently formed the opinion that the cirques and some fjord-valleys of Norway were formed by glaciers. Under the glaciers in cirques, where a space intervened between the bed of the cirque and the ice, he saw a great many stones, some of which, sticking fast in the glacier, were quite lifted up from the bed of the cirque, while others were touching or resting on it; he thinks it probable that as the temperature around the glaciers constantly varies about the freezing-point, the incessant freezing and thawing of the water in the cracks in the rock may split it, and the glaciers may do the work of transportation for the fragments thus broken loose. On examining the interior of an empty cirque, we observe that a bursting, not a scooping out, of the rocks has taken place. The high mountains of Norway often consist only of loose blocks and stones split by the freezing water. There is some difference between the exposed surface of the mountains and that beneath the glaciers; for on the latter water at 0° C. is constantly dropping down, easily frozen by every draught of colder air under the glacier, and the glacier itself is always present to remove the blocks.

In the cirques, however, there are often little lakes, and it is more difficult to account for the manner in which the glaciers have excavated these. They are not formed by moraines damming the water, but are true rock-basins; it does not seem likely that they were mainly scooped out like the great lakes, along the sides of which we see groovings and *roches moutonnées* one beside the other; for in the little lakes one often sees sharp-edged blocks covering the bottom. When the glaciers of the cirques filled these small lakes, so as to leave but little water, it seems probable that the water thus left would freeze in winter, so that the whole tarn would be frozen to the bottom, and the rocks in that way be broken loose. Whatever may be the manner in which these blocks are broken out, we see from their situation and form that a bursting has taken place in these tarns, which are the last works of the glaciers in the cirques.

The cirques which occur isolated in the mountains are not essentially different from the valleys which end in a cirque, as often they differ only in size. Thus five valleys ending in cirques and three cirques debouch into the main valley of Veitestrand, in Sogn; all these are at a much higher level than the main valley and along the same side of it. They both occur in the same way, except that the valleys are longer, their area being as much as twenty-five times as great as that of the cirques. In many cirques at the heads of valleys, both in Norway and in Greenland, there are lakes with a moraine in front, as in the mountain cirques. These moraines seem to indicate that the glaciers remained longest here; and the excavation of a cirque with a lake in it at the head of the valley was perhaps accomplished at a later time by an isolated glacier, the upper end of the valley being very well adapted for sheltering a glacier.

Perhaps it may be said that the mountain cirques were most frequently formed in the modern period, while the valleys terminated by cirques are older, dating from the close of the Glacial epoch, though some even of these are modern and still in process of formation. It is very difficult, if not impossible, to draw the line between the work of rivers before and of glaciers during the Glacial epoch; but the valleys terminated by cirques show that the present form of the valleys is due to glaciers.

The relation between the occurrence of Lakes in Norway and the different extents of Glaciers during the Glacial epoch.—In many fjord-valleys of Western Norway, and in still more flat valleys of Southern Norway, there is an intimate connexion between the extent of glaciers and the occurrence of lakes. A traveller in the districts of Hardanger, Sogn, and Nordfjord, in going from the heads of the fjords up the valleys, finds the beds of the latter, to an extent varying from 1 to 8 kilometres, covered by loose detritus lying in the form of terraces, one above the other, on both sides of the river, consisting of boulders, gravel, sand, and sometimes a little clay. After passing this tract deep lakes are met with in many places; and before the lower end of these the loose materials are often arranged in a moraine, which runs at right angles to the longer axis of the lake. By looking at the section (fig. 3) of the terrace and moraine in front of Lake Sandvenvand in Odda, in Hardanger, we see that immediately about the end of the fjord several terraces occur in quick succession, and that these are terminated in a moraine damming up the lake, which is so deep that its bottom is below the sea-level. The terraces in advance of the lakes in the fjord-valleys of Western Norway never attain an elevation of much more than 100 metres above the sea, and the height of these lakes is always less than 100 metres. If we proceed to the upper end of the lakes terraces are sometimes found there also. The same features (terraces in advance of lakes) are also found in South-eastern Norway, in front of the largest lakes in Norway. Also both east and west of Christiania Fjord the same relations between rows of moraines and rows of lakes are found to exist. I have visited and sounded more than thirty-eight lakes with moraines and terraces in front of them, and in most of them can directly demonstrate that, although dammed up by the moraines and terraces, they are also true rock-basins; and I have only some doubt in this respect in the case of a few small lakes. It would be tedious to describe all these lakes with their moraines and terraces, because it would be a repetition of the same thing in substance with slight variations in detail; so I will confine myself to a few instances. In the case of Lake Sandvenvand, already mentioned, the section (fig. 3) gives the height of the terraces and of the moraine directly in front of it. No rock is visible between the lake and the sea, the terraces covering the whole valley; the bed of the lake as shown in the section is 30 metres below the sea-level. Near Lake Öifjordvand, also in Hardanger (fig. 4), there is a series of terraces, the highest of which is situated immediately in front of the lake, without any moraine; near to where the river issues from the lake the solid rock protrudes, being here covered with groovings. Thus the lake is a true rock-basin. The deepest lake in Norway which has been sounded is Horningdalsvand, in Nordfjord (fig. 5). The solid rock is seen near the lake and the terraces.

A comparison of the measurements of the highest terraces before the lakes will show that these vary to no small amount. The highest terrace before the Horningdalsvand is only 71 metres, while that before Lake Vasbygdvand, in Sogn, is 108 metres, and the highest terraces before the lakes in South-eastern Norway extend up to 200 metres. As many of them contain marine fossils, they have evidently been formed under the sea, and the horizontal surface of the highest shows the level of the sea during their formation. How are we to explain the fact that these terraces, though repre-

Fig. 3.—Section of Lake Sandvenvand, Odda, Hardanger.

Depth 120 metres; 30 metres below sea-level.

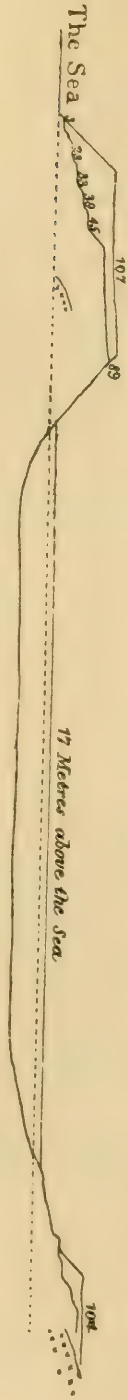


Fig. 4.—Section of Lake Öifjordvand, Hardanger.

Depth 75 metres; 58 metres below sea-level.

Fig. 5.—Section from the sea to Lake Horningdalsvand, Nordfjord, Norway.

(Horizontal scale $\frac{1}{50,000}$; vertical scale $\frac{1}{20,000}$.)

Depth 486 metres;
432 metres below sea-level

senting the level of the sea at the end of the Glacial epoch, have not the same height? We must not conclude that the land in Western Norway has risen only about 100 metres since the end of the Glacial epoch, but in Eastern Norway 200 metres. A comparison of the present glaciation of Greenland with that of Norway will show that this difference in the heights of the uppermost terraces may be occasioned in another way. Terraces are found in Greenland also at the mouth of rivers; for example, there is a terrace with marine fossils near Claushavn, in Disko Bay; its height, however, is only 30 metres. Thus the level of Greenland was once 30 metres below the present one. We should then expect to meet with a terrace of this elevation in many places in the fjords; but instead of this we find them filled with ice, which has prevented the formation of terraces. Wherever a river issuing from a glacier is now depositing the mud at its mouth a terrace is being formed at the present sea-level. Suppose, then, that North Greenland were to rise 20 metres; the terrace at Claushavn would be 50 metres high, and those now formed at the mouth of the rivers would be 20 metres high, while in the ice-fjords there would be none. Thus a difference in the heights of the uppermost terraces does not necessarily indicate that the amount of rise in the land has been different in different places. The reason, then, that the terraces in Eastern Norway overtop those in the western fjords by 100 metres may be that the glaciers in the fjords of the latter prevented terraces being formed when the land was 200 metres lower than at present; only when it had risen about 100 metres had the glaciers retreated sufficiently to allow terraces to be formed in the fjord-valleys; in these the glaciers retired at different times, and the lowest terraces are found in the valleys from which the glaciers last retired. Looking at the section of Lake Öifjordvand (fig. 4) the question naturally arises with regard to the terraces at the lower end of the lakes, how, if they are formed by the rivers from the loose detritus brought down the valleys, has this been transported across the lake? This has been explained by Professor Sexe*. The highest terrace in front of the lake clearly cannot have been formed when a thick glacier passed out into the fjord, nor can it have been formed when the glacier had retired from the lake; for then the detritus would have filled up the basin. The terraces therefore must have been formed when the glacier just reached the end of the lake. This is evident from the fact that where detritus in front of a lake is more than 100 metres above the sea (*i. e.* higher than its former level) it occurs not as a terrace, but as a moraine. The geological structure of the highest terraces is the same as that of the moraines; they are therefore only moraines made level by the waves of the sea.

* Märker efter en Istid.

List of Lakes in the fjord-valleys with Terraces and Moraines in front of them.

Names of the lakes.	Distance from the sea.	Length of the lake.	Area of the lake.	Height of the lake above the sea.	Depth of the lake.	Depth below the level of the sea.	Height of moraine (M.) or terrace (T.) in front above the sea.
	kilo-metres.	kilo-metres.	kilo-metres.	metres.	metres.	metres.	metres.
Horningdalsvand ...	7	28	58	54	486	432	71 T.
Bredeimsvand	5	18	23	56	273	217	71 T.
Stryenvand	7·5	16	23	25	198	173	?
Aardalsvand	1·5	10	8	5	186	181	40 T.
Loenvand	2·5	11·5	12	88	133	45	?
Sandvenvand.........	2	5	4	90	120	30	136 M.
Houkelivand	3	3	13	53	104	51	88 M.
Oldenvand............	4	11	7	37	90	53	65 M.
Gravensvand	1·8	4	3	29	86	57	41 T.
Öifjordvand	1·8	4	4	17	75	58	107 T.
Vasbygdvand.........	6	3	2	53	67	14	108 T.
Eidsvand	1	1·8	1	3	34	31	24 T.

The question of the manner of formation of these lakes remains. From the numbers above we see that there is a remarkable symmetry in the occurrence of these lakes. The distance from the sea varies from 1 to 7·5 kilometres; no lake has a greater height than 90 metres, and they have near their lower end a moraine or a terrace. The bottoms of all the lakes are lower than the level of the sea. Nine of them can be directly demonstrated to be rock-basins; near three of them the loose detritus of the terraces conceals the rock in front of the lakes.

Supposing these lakes to have existed before the Glacial epoch, we must assume them to have been accidentally formed symmetrically in all these fjord-valleys by forces for which we cannot account; further, we must assume that the forces which impel glaciers down the valley were in all these places accidentally strong enough to bring the glaciers to the lower end of the lake. But, on the contrary, by regarding them as having been excavated by the glaciers during the Glacial epoch, we can explain their mode of occurrence and their symmetry. The lakes, that is the rock-basins, end close to the moraines, because the situation of their valleys with regard to the mountain-region supplying the glaciers is a symmetrical one;

but as this situation is not absolutely the same in all valleys, we find some difference in their distances from the sea. Further, it is evident that the glaciers had retired from many fjord-valleys distant from the mountain-region by the end of the Glacial epoch; and in these we only find terraces, not lakes and moraines, near the sea. On the other hand, in some valleys the glaciers went further out into the fjords, and deposited their moraine on the bottom of the sea, so that the lake-basins are now parts of the fjord itself and have no separate existence.

We can constantly explain the Glacial phenomena of Norway by reference to Greenland. The ice in the latter country is not now at its greatest extent; so that Greenland at present affords us a picture of Norway about the end of the Glacial epoch, when the glaciers in some cases extended out into the fjords, in others formed the lakes mentioned above. So that, according to our theory, lake-basins must exist in many places under the glaciers in the ice-fjords of Greenland, if only the latter have been for a sufficient time in their present position. It is, of course, very difficult, if not impossible, to observe these basins; but I can bring an instance from near the ice-fjord of Torsukatak, which makes it probable that such basins exist, and will appear when the glaciers retreat. The glacier in the above fjord descends into the sea in four arms. The northern of these is separated by a mountain-range from a valley which lies symmetrically with them. In this there is at the present time no glacier; but a lake begins near the sea called Amitsok, at the side of which are the remains of a lateral moraine, like those met with along the glaciers of the ice-fjords. This moraine shows that the valley has once formed a fifth arm of the glacier, which has now disappeared, leaving a lake in its track. This lake is about 20 metres above the sea, and less than a kilometre from it. I do not know its exact length, but think it is more than 7 kilometres.

To return to Norway. The mode of occurrence of many lakes in South-eastern Norway, if possible, still better illustrates their formation. On the east side of the Christiania Fjord, from Moss to Fredrikshald, and on the opposite side from Horten to Laurveg, lie two rows of moraines; these indicate a limit of the glaciation of Norway. While moraines in the narrow fjords in different valleys are quite separated by high mountain-ranges, here, where the ground is lower, they can be followed continuously over long distances. Thus the rows of moraines extend, with some interruptions, for a length of 60 kilometres on both sides of the Christiania Fjord. Behind these are sixteen lakes, ten on the east and six on the west side of the fjord, lying on the line of the long moraines. I have visited all, and can directly demonstrate that most of them are true rock-basins. If, then, they are older than the Glacial epoch, it is a strange thing that the ends of all lie in the lines of the moraine, that the glacier advanced just as far as their southern ends, and that their longer axes are perpendicular to the line of the moraine. The phenomena are so regular that one might suppose that Professor Ramsay had propounded his theory of the Glacial formation of lakes with special reference to these; this theory elucidates the whole. The moraines, which are terminal, indicate the limit to which the the glacier has advanced during some period of the Glacial epoch; the lakes occur along this line because they have been made by the glaciers.

The occurrence of these lakes behind the moraines is so regular that many years ago Professor Keilhau, who had no idea that the banks in front of them were moraines, or their basins formed by glaciers, expressly stated that this regularity was too marked to be accidental. The above relation between lakes and rows of moraines is repeated several times in Norway. Different rows of moraines and lakes there belong to different extensions of the glaciers: for example, from 30 to 40 kilometres to the north of the aforesaid first row of lakes there is, near the town of Dröbak, another series of lakes and moraines. Further to the north is found a third series; but the largest lakes in Norway occur in the fourth row, which includes the lakes of Mjösen, Randsfjord, Spirillen, Kröderen, and Soneren. In front of these lakes, which are situated in valleys, the loose detritus takes the form of terraces, like those mentioned above in front of the lakes in the fjord-valleys of Western Norway.

The heights and depths of the above lakes are given in the following Table:—

Name of the lake.	Length of the lake.	Area of the lake.	Height of the lake above sea-level.	Depth of the lake.	Height of before-lying terrace above sea-level.
	kilo-metres.	kilo-metres.	metres.	metres.	metres.
Mjösen	99	364	121	452	195
Randsfjord	73	131	132	108	200
Spirillen	25	35	151	108	200
Kröderen	39	38	132	31	190
Soneren	10	7	118	40	—

When the first-mentioned row of moraines and lakes was formed the ice-masses were yet continuous. For this reason the configuration of the country here is without strongly marked valleys, and the moraine is, on the whole, continuous. When the last row of large lakes was formed, the ice-sheet had separated itself into distinct glaciers, owing to which the detritus in front of the lake cannot be followed from the end of one lake to another.

From these observations it results that about fifty lakes or rock-basins, among which are some of the largest in Norway, have moraines and terraces in front of their lower ends. These, in South-eastern Norway, lie in four parallel rows, following the limits of the ice-masses indicated by the moraines.

Many lakes occur in Norway without moraines at the lower end. The theory, however, does not require that all lakes should have moraines in front of them; for the motion of ice-masses over an undulating surface formed lakes in every place where their power was for some reason or other increased. The above-mentioned instances are those where the phenomena are clearest.

The Fjords, Fjord-valleys, Lakes, and Sea-banks of Greenland and Norway.—It is well known that certain districts in northern and southern latitudes abound in fjords and lakes; and, further, that this abundance is not absolutely dependent on these districts being situated in *high* latitudes, but that fjords and lakes occur in all countries once covered by glaciers.

Thus there are many lakes in Switzerland, though it is south of the general zone of lakes and fjords in Europe. This intimate connexion between fjords, lakes, and the old glaciation, first explained by Professor Dana and Professor Ramsay, led me to a closer examination of the fjords and lakes in Norway and Greenland, some of the results of which are given above. The fjords are usually regarded as valleys, or as parts of valleys, filled by the sea; so that if the land rose, the fjord would be converted into a valley.

This view is not quite correct. All strongly marked fjords are not only valleys filled by the sea, but also lake-basins. This could be demonstrated by many instances from Norway; but I will here confine myself to one. The Hardanger Fjord, in the inner part, gives soundings up to 800 metres; the depth of the sea at its mouth does not exceed 350 metres. Hence, if the land rose this much, the fjord would become a lake 450 metres deep. If Norway and the bottom of the German Ocean were elevated together, its fjords on the whole would become long and deep lakes. That the same would happen with the Greenland fjords is shown further on. Thus the fjords and the lakes are formed in the same way.

We will endeavour to follow the theory of the glacial formation of fjords and lakes to its consequences, constantly using the observations to verify the deductions. If, during a certain geological period, large portions of the land were covered with glaciers, and the fjords were formed by these, and could only be formed by these, then fjords must be confined to such portions of the land as were once covered by glaciers. Professor Dana has shown that this is the case; and Professor Ramsay has further shown that there is an intimate connexion between the occurrence of lakes and old glaciation. The fjords, if formed by glaciers, must not be confined to certain rocks, but must traverse all deposits older than the Glacial epoch. Even a rapid journey along a fjord, for example the Sogne and its branches, or a glance at the geological maps of countries with fjords will prove that fjords and lakes are, on the whole, independent of the rocks in which they occur. The inner branches of the Sogne Fjord, as the Lyster Fjord, are surrounded by clay-slates and quartzose slates; further down there is gneiss and gabbro; then at the mouth a conglomerate. The fjords in Greenland cut through both the basalt and the Azoic rocks. The large Waigat Fjord, which is a continuation of the present ice-fjord of Torsukatak, is surrounded by rocks of Cretaceous and Miocene age, which are capped by an enormous sheet of basalt; and the structure of the two sides of the fjord is symmetrical. Thus the erosion of the fjord must be posterior to the Miocene period; for, at Atanekerdluk, on the very side of the fjord, occur the well-known Miocene fossils; and as the great ejections of basalt are still later than these, but older than the fjords, the latter must be of very recent date.

Fjords are always numerous along the same coast-line. This might be deduced from the theory of their glacial formation. A great ice-sheet covering the interior of Norway or Greenland could not discharge its ice by one or a few glaciers only, but would require many of these, and along the whole coast-line. Hence the fjords are numerous along the coast, and so also are the lakes. The glaciers which formed them must have been thick enough to reach the bottoms of the lakes and, unless the land lay higher than now, the bottoms of the fjords as well; that this was the case has already been shown. If, then, the glaciers during the Glacial epoch were able to form fjords and lakes, those which now exist must also be able to scoop out the ground beneath them; and if they have been at work long enough, the depressions formed by them must be found. We have already pointed out that cirques occur near modern glaciers, being recesses formed by them. As fjords and lakes are only associated with the old glaciers, so the cirques are confined to small isolated modern glaciers. When we regard the great effects produced by these small glaciers, the enormous erosion of these ancient and thick glaciers becomes less surprising. The Norway glaciers proceeded from an extensive inland ice-sheet; if, then, the valleys and the fjords result from the erosion of ice or of water, it follows that they must start from the highest part of the country, and on the whole increase in breadth and depth in proportion to the increase of the glaciers; that is, we must be able to trace up a fjord through branch-fjords, fjord-valleys, and branch-valleys to remote glens in the mountains. The Norway fjords can be shown by numerous examples to satisfy this requirement. The Sogne Fjord is an excellent instance; it branches off, as may be easily seen, into six large tributary fjords, every one of which is continued by a fjord-valley; this is formed by other valleys into which little tributary glens debouch. Further, if these fjords and valleys are formed by the erosion of ice or water, their breadth and depth must be in proportion to the districts which once fed their glaciers and now feed their rivers. On comparing the limits of different fjords and valleys along the watershed, it is, on the whole, remarkable how their dimensions show a dependence on their districts of rain-fall. As these increase, so do the fjord-valleys. I do not mean, indeed, that the area of a transverse section through a valley can be connected by an empirical formula with the area of the district; for other forces beside the quantity of ice and water have determined the depth reached by erosion; but generally it may be said that valleys draining large districts of rainfall have a large transverse section. If a glacier fills a tributary valley, and is thinner than that in the main valley, the depth to which it erodes its bed must be less than the depth of the main valley. Hence many tributary valleys must debouch high above the bottom of the main valley. Instances abound of tributary valleys debouching thousands of feet above the beds of the main valleys, along the steep sides of the fjords of Western Norway. As mentioned above, we are unable to draw an exact line between the work of rivers before the Glacial epoch and that of glaciers during it.

The following, then, is the history of the configuration of Norway. The land is formed of rocks different in composition and origin, for which reason the country from the first has had a very uneven surface. On this thousands of rills and rivers began their work, and previous to the Glacial epoch eroded valleys more or less deep and broad. During it the glaciers followed, on the whole, the course of these, enlarging and shaping them, and excavating the fjords and lakes.

The occurrence of many large deep fjords in Western Norway is a consequence of their glacial formation and of the climate of the country; for on the west coast the rain- and snow-fall is very considerable, and the land slopes rapidly to the sea. Hence the thickness and velocity of the glaciers were probably very considerable here. Further, they seem to have remained longer on the west coast. If the fjords and lakes of Norway are formed by glacier-erosion they must be confined within the limit of glaciers. As these, however, once extended over the whole country, it has everywhere fjords and lakes. If at the end of the Glacial epoch the glaciers halted for long intervals at various places, we ought to find marks of erosion corresponding with these limits. We have already shown that we do so find them. When thick glaciers descended into the fjords and constantly deepened their beds, very peculiar relations of depth would be caused in the fjords. The glacier of the main fjord was constantly increased on its way by supply from tributary fjords, in consequence of which the depth or breadth of the fjord must have been increased. As the glacier proceeded further down the fjord the loss from melting would exceed the supply from the sides; and thus its erosive power, and consequently the depth of the fjord, would decrease; but while the glaciers deepened the bottom of the fjords, the depth of the sea in front of them would be diminished, as all the detritus would be deposited there.

Our theory, then, requires:—(1) the depths in the fjords should be greater than in the sea; (2) the depth of the fjord should increase towards the inner part and decrease towards the mouth; (3) great masses of boulders, gravel, and mud should be found in the sea in front of the fjords. These requirements are satisfied by the observed facts. It is well known that great depths occur in the Norwegian fjords. While soundings of from 400 to 500 metres are very frequent in the fjords, a depth of 200 metres is found at some distance from the shore; and in the German Ocean soundings of more than 100 metres are very rare. A few examples from the largest fjords of Norway will suffice to prove this. The depth of the Sogne Fjord in the inner part increases to 1244 metres; at its mouth, where it joins the sea, this has decreased to 158 metres. The depth of the sea 100 kilometres from land is 124 metres. The greatest depth of the Hardanger Fjord is 800 metres, while the depth of the sea 100 kilometres from land is 150 metres. The greatest depth of the Nord Fjord is 565 metres, while at the above distance from land the sea is also 150 metres deep. In the tributary fjords of the Stor Fjord the depth amounts to 721 metres, while the sea 50 kilometres from the mouth is only 100 metres deep. Some fjords along the coast of Romsdalen are continued for several miles out to sea as strongly marked deeps, much shallower, however, than in the inner parts; and in front of these large quantities of stones and sand extend, the edge of which is well known to fishermen by the name Storeggen (the large edge). With a view of examining the sea-bottom along the Norwegian coast, I made a survey opposite to the mouths of the fjords, and dredged up stones. At the mouths of those which I examined I found a great quantity of stones of different kinds mixed with clay, such as varieties of granites, gneiss, quartzose-slates, clay-slates, mica-schists—rocks, on the whole, well known as constituting the sides of the fjords of Western Norway. Some flints, however, indicated the occurrence of the Cretaceous formation, which has not been observed in the fjords. A great number of pieces of different kinds of rock, of various sizes and with rounded edges, occurring at the mouths of fjords once filled with glaciers, and in the places where their depths are decreasing, seems to prove a glacial formation of moraines under the sea. This view is confirmed by analogous facts. The row of moraines mentioned above, on the west side of the Christiania Fjord, runs at last out to sea, and continues as shoals, which in some places emerge as islands, as in the case of Jomfruland Island. As rows of moraines occur on the land with lakes behind them, so in the sea, from the fjord of Langesund towards the town of Arendal, rows of shoals lie in front of the rock-basins of the fjord. If, for example, Norway were to rise 400 metres, the shoals along the west coast and on the bottom of the German Ocean would probably appear as moraines and plains of glacial formation, widely extended in front of the lake-basins of the fjords.

Phenomena similar to the above are repeated in other countries. The fjords of Scotland are shallower at their mouths than within, and if the land rose would become lakes*. The soundings along the coast of Greenland are little known; but it is evident, from the few observations which exist, that the same peculiar configuration of the sea-bed would here also be brought to light if the land rose. The depth of the Jakobshavn ice-fjord, according to the Greenlanders, is about 390 metres; that of the Torsukatak 346 metres.

* *Cf.* Geikie, 'The Great Ice Age,' p. 519.

That all the ice-fjords are of considerable depth is evident from the existence of the bergs, which descend to a very great depth; but that the Jakobshavn Fjord is shallower near its mouth is evident from the fact that the great bergs run aground there. Opposite to the mouths of some of the Greenland fjords in Davis Strait, shoals and shallows are known just as in Norway; for example, before the Godthaab Fjord, as shown by the charts, there is a shoal of from 20 to 30 fathoms deep; before the fjords of the district of Sukkertoppen, another 30 fathoms deep; and before the Holstensborg Fjord, shoals, in some places only, from 14 to 17 fathoms deep. I proved the existence of the last by soundings as I sailed along the coast; the depths near the fjords and near to the land are considerable.

On comparing the configuration of Greenland, Norway, and Scotland, we find on the whole the same features along the coasts which are intersected by fjords, viz. beds of glaciers or rock-basins with detritus of glacial origin in front; and the lakes in South-eastern Norway, like the lakes along the south sides of the Alps, seem only to differ from the fjords in their situation above the level of the sea. I have thus summed up the most important facts which are knit together by the theory of the glacial formation of rock-basins; this throws light on a long series of facts and observations, and further investigations will certainly augment their number.

[*Note.*—The above paper was written by the author in English. This, though in general remarkably accurate as regards grammar, was not very idiomatic, and so might have repelled readers from the study of the valuable observations which he has recorded. Accordingly, at the request of the Council of the Geological Society, I undertook to prepare the paper for the press. In doing this I found it better to recast most of the sentences, and I have slightly condensed the matter by the occasional omission of clauses which were either repetitions or concerned with well-known details. As, however, I entirely dissent from some of the author's conclusions, I have been most careful to suppress nothing which was of the least importance in regard to them, and to express his argument as clearly and accurately as possible. If I have failed to do this, the cause has been that I have mistaken his meaning—a thing always possible when an author has written in a language not perfectly familiar to him. I may add that Mr. Helland appears (p. 163) to have misunderstood a part of one of my papers (Quart. Journ. Geol. Soc. vol. xxvii. p. 312). The Alpine cirques which I have described are of various sizes; some, indeed, small, but others equal, so far as I know, to most in Norway. T. G. Bonney.]

10. *On* Gigantic Land-Tortoises *and a small* Freshwater Species *from the* Ossiferous Caverns *of* Malta, *together with a* List *of their* Fossil Fauna; *and a* Note *on* Chelonian Remains *from the* Rock-cavities *of* Gibraltar. By A. Leith Adams, M.B., F.R.S., F.G.S., Professor of Zoology in the Royal College of Science, Dublin. (Read January 10, 1877.)

[Plates V. & VI.]

The Maltese fossil remains described in this memoir were collected by Admiral Spratt, C.B., and myself in various ossiferous deposits in the island. A few of the bones have been referred to in a note I communicated to the Geological Society in 1866 *. Having now, however, for the first time had an opportunity of comparing the reptilian remains from the Zebbug Cavern with my own gatherings (in consequence of the collection made by Admiral Spratt having been lately presented to the British Museum), I find the combined assemblage of Chelonian remains display so many features of interest that I have no hesitation in laying the details before the Society.

The singular characters of the associated Proboscidian, Rodentian, and Avian relics have been already described †; so that, with the exception of the *Hippopotami*, this contribution may be said to complete the palæontographical portion of the explorations up to the termination of my researches in 1865.

The following specimens are contained in the Museum of the Society and in the British Museum.

I am indebted to T. C. Archer, Esq., Director of the Museum of Science and Art, Edinburgh, for his kindness in lending me the typical skeleton of *Testudo ephippium* of Günther, to compare with the Maltese remains; and my best thanks are also due to Dr. Günther, F.R.S., for his assistance in the determination of a few of the specimens.

Although Dr. Falconer recognized Chelonian bones and fragments of shields in Admiral Spratt's collection, I can find in his writings no description whatever of their characters further than a simple reference to "two Chelonian forms," one of which, he says, is "of small size" ‡.

Shield.

Fragments of the dermal ossifications of dorsal and ventral shields are plentiful in the collection from Zebbug. They embrace pieces of costal and marginal plates of Chelonians of various dimensions, from about the size of the *Testudo græca* up to individuals which

* Quart. Journ. Geol. Soc. vol. xxii. p. 594.

† Falconer, Palæontological Memoirs, vol. ii. p. 292; Busk & Falconer, Trans. Zool. Soc. London, vol. vi. p. 227; Parker, *ibid.* vol. vi. p. 119; Adams, *ibid.* vol. vi. p. 307, and vol. ix. p. 1.

‡ Pal. Mem. vol. ii. p. 305.

rivalled in proportions the largest living and extinct land tortoises of the Mascarene and Galapagos Islands. Several pieces of plates show thicknesses varying from 2 to 20 millimetres, but present no further characters of importance, all being extremely fragmentary. They establish, however, much variability in the dimensions of their owners, which is confirmed by a study of the following bones. It may be observed that the denser outer dermal layer of several fragments belonging to the small Chelonians is marked by numerous white specks, such as are seen on the epidermis of the *Lutremys europæa*, with which, it will be seen, the humerus (Plate VI. fig. 6) and femur (Plate VI. fig. 5) agree in all particulars.

Vertebral Column.

A cervical vertebra from Mnaidra Gap and a caudal vertebra from Benghisa Gap belong to gigantic land-tortoises. Both are referred to in my previous communication *, which was drawn up in Malta during the progress of the explorations, when I had not the means of making comparisons.

The cervical vertebra is much injured: the anterior portion is lost, leaving the posterior condyle and posterior zygapophyses, with a portion of the neural arch; the last, however, is distorted and crushed. Enough remains, nevertheless, to show that it is a fifth cervical. As compared with the same bone in an individual of the large Galapagos form described by Dr. Günther † under the name of *Testudo elephantopus* of Harlan, the above represents not only a larger but also a more robust tortoise; and as the latter character will be seen to prevail in all the large Chelonian remains in our united collections, I propose to distinguish this (the largest) species of tortoise from the others by the name of *Testudo robusta*. As far as the injured condition of the fossil will allow, the following comparisons have been made between it and the typical specimen of *T. elephantopus*, as given by Günther. In both, the neural crest divides and proceeds along the dorsal aspects of the posterior zygapophyses, thereby forming a shallow triangular space between them. The following measurements are procurable:—

	T. elephantopus.	*T. robusta.*
	millim.	millim.
Breadth of condyle	33	37
Thickness of condyle	20	26
Greatest breadth of zygapophysis	10	18
Least breadth of centrum	20	22

* Quart. Journ. Geol. Soc. vol. xxii. p. 595.
† Philosophical Transactions, vol. clxv. 1875, p. 251.

The caudal vertebra (Plate V. fig. 1) has lost the posterior half of the centrum, but is otherwise entire. The anterior zygapophyses and concave centrum and transverse processes (*a*) are well preserved. The last-named present rugged articular surfaces, indicating that the costæ were not ankylosed. There is a small neural crest. Unfortunately, in the few skeletons of the large recent tortoises in collections, it is rare to find the caudal vertebræ; so that I have had no means of comparing the above with other allied forms. It clearly, however, belonged to a land Chelonian of gigantic size. It was discovered by me in conjunction with several teeth and bones of the small form of Maltese fossil elephant (*E. Falconeri*).

The length of the neck, so characteristic of *T. elephantopus*, and probably of the other Galapagos tortoises, seems to have been also a feature in *T. robusta*, if we may judge from the lengthened centrum of the cervical here alluded to.

Pectoral Arch.

The very large coracoid process of the scapula (Plate V. figs. 2, 2 *a*) is also referred to the *Testudo robusta*. The border of the distal extremity is wanting, and there is a slight abrasion on the inner border of the glenoid cavity; otherwise it is entire, and in an excellent state of preservation, as, indeed, were the majority of the remains from the Zebbug rock-cavity, owing to their investing matrix having been a firm, tenacious blue marl.

The articulating surface of the scapula (fig. 2 *a*, *b*) is triangular; its maximum length is 40 millims, and greatest breadth 45 millims, the glenoid cavity (*c*) being of about the same dimensions. The body presents the usual contorted and trihedral configuration, expanding at both the articular and distal extremities.

The internal border is sharp, and the external rounded and uneven. The superior surface of the body is also rounded, and thins out internally. The lower aspect (fig. 2) presents a triangular-shaped depression (*d*) at the distal extremity, bounded by an outer ridge (*e*) and an inner ridge (*f*). The latter forms also the boundary to the concavity (*g*) on the inner aspect of the bone. This excavation, although not seemingly apparent in *T. elephantopus*, is present to a small extent in the other Galapagos tortoise (*T. vicina*). Concerning the relations with Mascarene tortoises I am unable to say any thing.

The dimensions of fig. 2 as compared with the coracoids of Galapagos tortoises are as follows:—

	T. elephantopus.	*T. vicina.*	*T. robusta.*
	millim.	millim.	millim.
Length of coracoid	86	83	100
Least width of neck	20	33	38

The least girth of the neck in *T. robusta* is 91 millimetres. The greater breadth of the neck in *T. vicina*, as compared with *T. elephantopus*, is characteristic; and the former therefore agrees with *T. robusta*, as, indeed, generally *T. vicina* would appear to possess stouter limbs than either *T. elephantopus* or the still more gigantic *T. ephippium* *. Moreover the angle formed by the junction of the glenoid and scapular articulations (fig. 2) approaches that of *T. vicina*. I presume, however, that the great expansions of the extremities of fig. 2 (to wit, the beetling roof of the glenoid cavity and massive proportions) make the coracoid in question one of the largest as compared with recent land-tortoises.

A portion of a left scapula, from Zebbug, of a tortoise a good deal smaller than the owner of the coracoid just described is represented in Plate VI. figs. 3, 3*a*, 3*b*. The body has been sawn through the middle, and the distal portion is unfortunately not in the collection lately presented to the British Museum by Admiral Spratt. It is otherwise imperfect, the precoracoid having been broken off close to its base (*c*), which is 32 millims in length by 14 millims in breadth. The surface for the coracoid *d* (fig. 3 *a*) is triangular, and is 26 × 32 millims., and therefore much smaller than the opposing surface in Plate V. fig. 2. The glenoid cavity is slightly injured on its external border; its outline, however, seems to have been ovoid. The largest antero-posterior measurement along the curve of the cavity is 47 millims., and the maximum breadth is 28 millims.

The upper surface is flattened above the articulations, and becomes rounded towards the middle of the body, where the transverse section (fig. 3 *b*) forms a subelliptical outline different from the trihedral section at the same point in the scapula of *T. elephantopus*, and approaching rather to the greatly elongated outline of *T. vicina* †.

The lower aspect is concave at *e*, below the glenoid cavity, and becomes flattened towards the body, and finally rounded at its middle. The internal border is sharp, and the outer is thick and round. The circumference of the bone just below the lip of the glenoid cavity is 97 millims.

The coracoid, as in the last, was not ankylosed to the scapula, which appears to have belonged to a full-grown tortoise of much smaller dimensions than the owners of any of the bones yet described. For that reason, and, as will be shown in the sequel, from its relationship as regards relative size with other bones, I am disposed to consider that it belonged to a distinct form or species rather than to a small individual or female of *T. robusta*. To this smaller-sized form I provisionally give the name of *Testudo Spratti*, in consideration of the valuable collections obtained by Admiral Spratt from the rock-cavity of Zebbug.

This scapula, compared with the same bone in the typical speci-

* Unfortunately the pectoral girdle of *T. ephippium* is unknown.
† Günther, *op. cit.* pp. 265, 279.

mens of *T. elephantopus* and *T. vicina*, gives the following data. The loss of the precoracoid somewhat vitiates the determination as to the angle formed by the union of the scapula and that bone. It would appear, however, to have been more obtuse than in either of the above-named recent species. As to available dimensions:—

	T. elephantopus.	*T. vicina.*	*T. Spratti.*
	millim.	millim.	millim.
Maximum breadth at the glenoid cavity	77	77	73
Girth at the middle of the shaft	75	75	70
Length of glenoid cavity............................	50	55	45

Humerus.

The proximal extremity of a right humerus from Zebbug (Plate VI. figs. 6, 6 *a*) is the only specimen of that bone in the collections. It was picked up by me among the débris of the Zebbug rock-cavity several years subsequent to Admiral Spratt's explorations. This humerus evidently belonged to a rather smaller individual than the owner of the femur (Pl. VI. figs. 5, 5 *a*, 5 *b*), and to a tortoise about the size of *Lutremys europæa*, with whose femur it agrees closely in characters and dimensions. The large tuberosity diverging from the head expands and rises considerably above the latter, whilst the smaller tuberosity is nearly on the same level with the head. The intervening pit is deep and broad. The head is elliptical, and measures 11 millimetres along its curve, and has a deep pit under it. The least girth of the shaft is 13 millimetres. On the radial side of the head at *b*, fig. 6, is a groove with a sharp outer margin.

As compared with *Lutremys europæa* these characters are absolutely identical. In *T. græca* the great tuberosity is not nearly so much expanded, and the groove *b* (fig. 6) is wanting; the shaft, also, is stouter, and there is no pit under the head. Considering that the affinities with *Lutremys europæa* are also confirmed by the femur (fig. 5), I do not, in the absence of further data, deem it necessary to separate the fossil from this recent freshwater species, an adult specimen of which in the British Museum has a humerus of 44 millimetres and a carapace of 210 millimetres. This tortoise is still found in the lakes and muddy waters of Sardinia, Italy, and elsewhere in Southern and South-eastern Europe.

Radius.

This bone is represented by two specimens from Zebbug. The one is about a fourth part longer than the other; they agree, however, in every determinable particular; so that, admitting variability in size according to sexual and individual peculiarities, it seems probable that they belonged to the adult male and female of *T. robusta*.

The larger (Plate VI. fig. 1) has lost a portion of the outer aspect of the head and a fragment of the distal extremity; but fig. 2, also belonging to the left forearm, is quite entire.

The dimensions of these bones, as compared with one another and with the large Galapagos tortoises described by Günther *, are as follows:—

	T. robusta ♂.	*T. robusta* ♀.	*T. ephippium* ♂.	*T. vicina* ♂.	*T. elephantopus* ♂.
	millim.	millim.	millim.	millim.	millim.
Length of radius	156	110	149	122	121
Least girth of radius	76	58	51	49	50

These measurements at once demonstrate the greater thickness in *T. robusta* of the shaft as compared with the length, the girth of even the smaller being greater than obtains in any of the more gigantic recent species.

Other comparisons as regards the articular surfaces furnish equally interesting results. As compared with the radius of the immature female of *T. elephantopus* referred to by Günther † (No. 1011 of the Cat. Mus. R. Coll. Surgeons), the smaller radius (fig. 2) is precisely of the same length, whilst the girth, midshaft, of the recent bone is 43 against 58 millims. of the smaller *T. robusta*.

The dimensions of the extremities of the Galapagos radii are not given by Günther; but the typical radius of *T. ephippium* now before me furnishes the following comparisons with the two radii of *T. robusta*:—

* *Op. cit.* p. 280.

† Phil. Trans. vol. clxv. p. 261.

	T. robusta ♂ & ♀.	*T. ephippium* ♂.
	millim.	millim.
Largest diameter of the humeral articulation	{ 43 40	35
Largest diameter of the carpal articulation	{ 55×28 45×18	36×19
Largest diameter of the proximal radial articulation	{ 37 25	30

It would be interesting to establish comparisons between the Maltese specimens and the recent and extinct Mascarene species, or, in fact, any of the recent gigantic species I have been unable to examine; the materials, however, as regards the latter are rare in public collections.

In general characters the radius of *T. robusta* presents large and expanding articular surfaces. The humeral is concave, and of the outline shown in fig. 2 *a*. The distal ulnar facet is very prominent, thus enlarging the concavity on the ulnar aspect of the bone. The gnarled surfaces for muscular attachments contrast with the general smoothness of the same parts in *T. elephantopus* and *T. ephippium*, to a less extent in *T. vicina*, whilst they at the same time prove that both fig. 1 and fig. 2 belong to fully adult, if not aged individuals.

The shafts in the fossil bones are round in the middle and flattened on their upper and outer aspects. The distal extremities are convex in front (fig. 2) and concave behind (fig. 1). The extensive distal ulnar facet is similar to that of *T. ephippium*, which appears to be relatively larger than that of *T. elephantopus*.

A few TARSAL and CARPAL bones were found in Mnaidra Gap; but these are too much broken to be useful for comparison.

The very large UNGUAL PHALANGES (Plate V. figs. 5, 6, 7) from Zebbug attest to the dimensions of their owners, and may be safely referred to *T. robusta*.

PELVIC GIRDLE.

PUBIS.

The following pelvic fragments referable to *T. robusta* are contained in the Zebbug collection:—

1. A portion of a right pubis, extending from the obturator foramen outwards (including the process), is 87 millimetres in length,

the maximum breadth of the process being 24 millimetres. The same measurements of the pubis of *T. ephippium* are 76 and 18 millimetres.

2. A mutilated process of another pubis presents about the same measurements.

3. A fragment of the symphysial end of a right os pubis indicates a tortoise as large as the owner of the preceding, but shows no important characters.

Femur.

Two proximal extremities of femora of gigantic tortoises were found by me in Mnaidra Gap. The left, being the more entire, is represented in Plate V. figs. 4, 4 *a*, 4 *b*.

It shows the head, trochanters, and a small portion of the shaft. There is a loss of substance on the outer side of the head and great trochanter, which, however, is preserved in the other specimen of the right side. There is also a small abrasion on the inner side of the head. Otherwise the fragment is entire and well preserved. It will be seen from the figures that the head is elliptical, and does not rise above the summit of the great trochanter.

The conspicuous notch (fig. 4 *a*) is also present in the recent *Testudo ephippium*, and is apparently wanting in *T. elephantopus* *: thus the femur of the former and that of *T. robusta* agree so far. Moreover the cartilaginous capping of the trochanters is apparently confined to the latter by a smooth dividing groove, whereas in *T. elephantopus* the cartilage extends along an unbroken ridge from trochanter to trochanter.

The condition of the fossil renders it impossible to state whether or not one or other of these two conditions existed.

The pit embraced between the head and the trochanters is about as broad as long; and the notch between the head and small trochanter is broader than between the former and the great trochanter, but it is relatively smaller than in *T. elephantopus* and *T. ephippium*. And whilst the head in the former and in *T. robusta* assimilate, *T. robusta* and *T. ephippium* consort as to the intertrochanteric notch and the configuration of the intervening pit (fig. 4 *b*).

A detached left femur of a recent tortoise (No. 1021 B in the Osteological Collection of the Royal College of Surgeons) agrees with the characters of *T. ephippium* and *T. robusta*; but the cartilaginous covering dips into the notch, and is continuous from one trochanter to the other.

The locality from which this specimen was obtained is unknown; but it evidently belonged to a very large tortoise, and an individual of nearly the dimensions of the fossil. The greatest length and breadth of the heads in the three (by callipers, and along the curve) are as follows:—

* Günther, *op. cit.* pp. 267, 274.

	T. robusta.	R. C. S. No. 1021 B.	*T. ephippium.*
	millim.	millim.	millim.
Length by callipers	66	60	43
Length by tape	92	82	60
Breadth by callipers	55	50	35
Breadth by tape	72	70	52

I have given the chief measurements of fig. 4 in my former paper. Suffice it to state, as to the comparative dimensions, that the fossil exceeds in size any recent femur I have been enabled to examine, and shows that the owner was a gigantic tortoise, but possibly not quite so large as the owner of the coracoid just described.

A distal extremity of a right femur, comparable as regards dimensions with the form to which I assign the name of *T. Spratti*, is also from Mnaidra Gap. It is relatively small as compared with the same part in the immature skeleton (No. 1011 of the Museum of the Royal College of Surgeons) referred by Günther to *T. elephantopus* *. The breadth of the condyles in the last is 78 millimetres, whereas it is only 56 in the fossil. In the latter there is a shallow depression above the condyles superiorly, and a deep pit at the same point on the opposite or inferior side. The condyles are stouter relatively and more confluent than in *T. ephippium*, and more like what obtains in *T. vicina*; the specimen, however, is too fragmentary for precise determination.

The small right femur from Zebbug (Plate VI. figs. 5, 5 *a*, 5 *b*) has lost its distal extremity. The head is elliptical, and confluent with the great trochanter, and is at the same level. The great trochanter (fig. 5 *a*), as in the large femur, is separated by a deep notch from the lesser trochanter, the enclosed pit (fig. 5 *b*) being almost circular. The largest diameter of the head is 12 millimetres, and the least girth of the shaft is 18 millimetres. In *T. græca* there is no notch, the shaft is less bent, and the trochanters are more convergent. Although somewhat larger than a femur of *Lutremys europæa* (46 millimetres in length), it agrees with it in every respect, in common with the humerus (fig. 6), both of which therefore may be accepted provisionally as belonging to that species.

Tibia.

The two tibiæ, right and left (Plate V. figs. 3, 3 *a*, and Plate VI. figs. 4, 4 *a*) are from Zebbug. The larger, or right tibia (Plate V. fig. 3), is not entire, having lost portions of the head on its outer

* *Op. cit.* p. 261.

and inner aspects, and also a portion of the distal end in front. As regards size, it is about a third longer than fig. 4, and, as will be seen presently, differs from it morphologically. Both bones represent aged individuals, as is well shown by their gnarled appearances. Moreover, relatively, they are stouter than the tibiæ of *T. elephantopus* and *T. ephippium*, and come closer in that respect to *T. vicina*. I conceive that the larger (fig. 3) belonged to *T. robusta*, and the smaller (fig. 4) to *T. Spratti*.

The following establishes their proportional greater thickness as compared with certain recent species that I have been enabled to examine :—

	T. ephippium.	*T. elephantopus.*	*T. vicina.*	*T. robusta.*	*T. Spratti.*
	millim.	millim.	millim.	millim.	millim.
Length of tibia..........................	150	136	129	115	85
Least girth of tibia	72	60	57	73	53

Thus it appears that the smallest girth of the shaft in *T. robusta* is greater than that of the tibia of the more slender *T. ephippium*, which is 2·2 inches longer, and that, whilst the antero-posterior diameter of the femoral articulation is 41 millimetres in *T. robusta*, it is 38 millimetres in *T. ephippium*; but their distal articulations are about equal in size.

The tibia of *Testudo Spratti* has the groove on the astragalo-calcaneal aspect deep (Plate VI. fig. 4 *a*), whereas it is barely indicated in *T. robusta* (Plate V. fig. 3 *a*). There are two prominent muscular tuberosities about midshaft in *T. Spratti*.

The anterior aspects in both are more concave than appears to be the case in the recent species named above; and there is greater dilatation at the articular surfaces; otherwise they do not appear to present further characters to distinguish them from the tibiæ of recent species and from one another.

Fibula.

The distal half of a left fibula from Zebbug represents a tortoise considerably larger than the owner of the tibia, Plate V. fig. 3, but not apparently of greater dimensions than the individuals to which the large femora and coracoid belonged. The tarsal articular surface is trihedral in outline and somewhat convex, whereas it is even in *T. ephippium*. There is the usual expansion of the articulation as seen in the other large bones with prominent rugosities. The shaft is flat below, becoming rounded towards the middle. In *T. ephippium* the shaft is rounded posteriorly and flat, with a concavity close to the articulation on its tibial aspect. The circumference at midshaft is 60 millimetres in the fossil, and only 45 millims. in *T. ephippium*. A prominent rugosity for muscular attachment occupies the anterior border near the distal extremity, whilst a well-defined ridge runs up the posterior border and is lost about midshaft. Altogether this bone presents different characters from the fibula of *T. elephantopus* and *T. ephippium*, and bears a closer resemblance to that of *T. vicina*, and perhaps also of *T. ponderosa*, as far as I have been enabled to compare it with a specimen of the fibula of the latter in the possession of Dr. Günther, to whose masterly determinations we are indebted for the only lucid descriptions yet given of the osteology of the gigantic land-tortoises of the Galapagos Islands.

The foregoing Testudinea and Emydea must be admitted as interesting additions to the already goodly list of remarkable animal remains from the rock-rents of Malta.

The gigantic land Chelonians and their freshwater congener, when considered in relation to the gigantic Dormouse and water-birds and the small Pachydermata, furnish further proofs of the physical conditions requisite for the maintenance of such a varied fauna. This subject, however, deserves special consideration, not contemplated in the present communication.

The vertebrated and invertebrated animals hitherto recorded from the Cavern and alluvial deposits of Malta may be enumerated as follows:—

Mammalia.

Equus, sp. Horse, sp.?
Hippopotamus Pentlandi. Pentland's Hippopotamus.
Hippopotamus minutus. Pygmy Hippopotamus.
Cervus dama. Fallow Deer.
Cervus vel *Capra.* Deer or Goat, sp.?
Canis. Fox, sp.?.
Elephas mnaidriensis. Large Maltese Elephant.
Elephas melitensis. Smaller Maltese Elephant.
Elephas Falconeri. Pygmy Maltese Elephant.
Myoxus melitensis. Great Dormouse.
Myoxus Cartei (?). Carte's Dormouse.
Arvicola amphibia. Water-Vole.

Aves.

Cygnus Falconeri. Falconer's Swan.
Cygnus musicus (?). Wild Swan.
Bernicla vel *Anser.* Bernicle or Goose, sp.
Anas, sp. Duck, sp.?

REPTILIA, AMPHIBIA.

Testudo robusta. Gigantic Maltese Tortoise.
Testudo Spratti. Spratt's Tortoise.
Lutremys europæa (?). Speckled Tortoise.
Lacerta, sp. Lizard, sp.?
Batrachia, sp. Frogs or Toads, sp.

MOLLUSCA *.

Helix aspersa.
Helix vermiculata.
Helix candidissima.
Helix aperta.
Helix Sprattii.
Helix striata.
Bulimus acutus.
Cyclostoma, sp.
Clausilia syracusana.

The stratigraphical conditions under which these animal remains were discovered varied considerably. On that account it may be inferred that all were not conveyed into the rock-cavities and hollows at the same time and under exactly the same conditions; and it is not wholly improbable that a redeposition of remains may in one or more instances have taken place. At all events, a contemporaneity may be claimed for the Elephants, Hippopotami, Myoxi, Anatidæ, Chelonia, Lacertilia, and certain Helicidæ, inasmuch as their remains were intimately associated.

I exclude the remains of Horse, Fallow deer, Deer or Goat, and a canine tooth referable to a small *Canis*, also the remains of the Water-rat, Frogs, and several species of land shells, on account of the following circumstances connected with their discovery:—

The exuviæ of the Horse, Fallow deer, and of a small carnivore of about the size of a Fox were found together in a rock-rent containing red soil and fragments of the parent rock. The other ruminants' teeth, also the canines of a small *Vulpes*, *Arvicola*, and Frog-bones, were met with in close proximity to the larger quadrupeds; but the deposits being composed of closely packed red soil, it may not be improbable that, in the case of the two last-named and several species of land Snails, they had made their way into the bed after its deposition. At all events, the *entire* absence of large Carnivora is not the least remarkable feature of the collections.

NOTE *on* CHELONIAN REMAINS *from the* ROCK-FISSURES *of* GIBRALTAR.

As far as yet ascertained, the mammalian and avian remains from the rock-cavities of Malta and Gibraltar belong to different faunas, the Maltese being the more ancient.

* The Mollusca were determined by the late Dr. S. P. Woodward.

In the collections made by Captain Luard, R.E., in the Gibraltar caverns are two bones of Chelonians which Mr. Busk has kindly permitted me to inspect.

The larger is a much mutilated humerus or femur; which of the two it is difficult to say, from injuries, it having lost the proximal and a portion of the distal extremity. It belonged, however, to a large Chelonian, inasmuch as the remaining length is 130 millimetres, and least girth of the shaft 71 millimetres. A deep circular pit on the anterior and inner aspect of the shaft near the head seems peculiar as compared with the larger recent marine and land species. To which of the two groups it belongs is not evident; but possibly, from the prominent ridges, it may have belonged to the latter.

The small right radius (Plate VI. figs. 7, 7 *a*) has lost its distal articular aspect, but is otherwise entire. The surface is remarkably smooth, and without the rugosities of the humerus of the larger Maltese Testudinea.

The above is clearly the radius of a land or freshwater tortoise of larger dimensions than any recent European species.

The humeral aspect (fig. 7 *a*) is slightly concave; but, excepting the dimensions, the specimen does not present other noteworthy peculiarities; the least girth of its shaft is 28 millimetres.

The two bones represent species differing very much in size, and are of interest with reference to further discoveries in connexion with the fossil fauna described by Mr. Busk, F.R.S., in a paper read before the Zoological Society of London on May 2, 1876.

EXPLANATION OF THE PLATES.

Plate V.

Fig. 1. Caudal vertebra of *Testudo robusta*, natural size.
Figs. 2, 2 *a*. Right coracoid of the scapula of *T. robusta*, natural size.
Figs. 3, 3 *a*. Right tibia of *T. robusta*, natural size.
Figs. 4, 4 *a*, 4 *b*. Proximal third of the left femur of *T. robusta*, natural size.
Figs. 5, 6, 7. Phalangeal bones of *T. robusta*, natural size.

Plate VI.

Fig. 1. Left radius of *Testudo robusta*, natural size.
Figs. 2, 2 *a*. Left radius of *T. robusta*, natural size.
Figs. 3, 3 *a*, 3 *b*. Portion of a left scapula of *T. Spratti*, natural size.
Figs. 4, 4 *a*. Left tibia of *T. Spratti*, natural size.
Figs. 5, 5 *a*, 5 *b*. Portion of a right femur of *Lutremys europæa*?, natural size.
Figs. 6, 6 *a*. Portion of a right humerus of *L. europæa* ?, natural size.
Figs. 7, 7 *a*. Right radius of a Tortoise from the rock-cavities of Gibraltar, natural size.

Discussion.

Prof. Ramsay inquired what was the probable geological age of these remains, as this seemed to him a point of much interest.

The Author stated that his paper was purely palæontological, and that he had not touched upon any geological questions in it. No judgment could be formed from Sicilian deposits, as there seemed to have been no connexion between the islands; and with regard to the Maltese deposits, he stated that remains of *Hippopotamus* were found in breccia and in conglomerates in rock-cavities which appeared to have been caves, and also in fissures with red soil like that of the surface, containing angular fragments of the parent rock. In one cavity he found whole carcasses of Elephants, just as if they had been carried in suddenly, and filled in with earth by a wave. The remains might have been derived from a Pliocene deposit broken up and swept into the cavities.

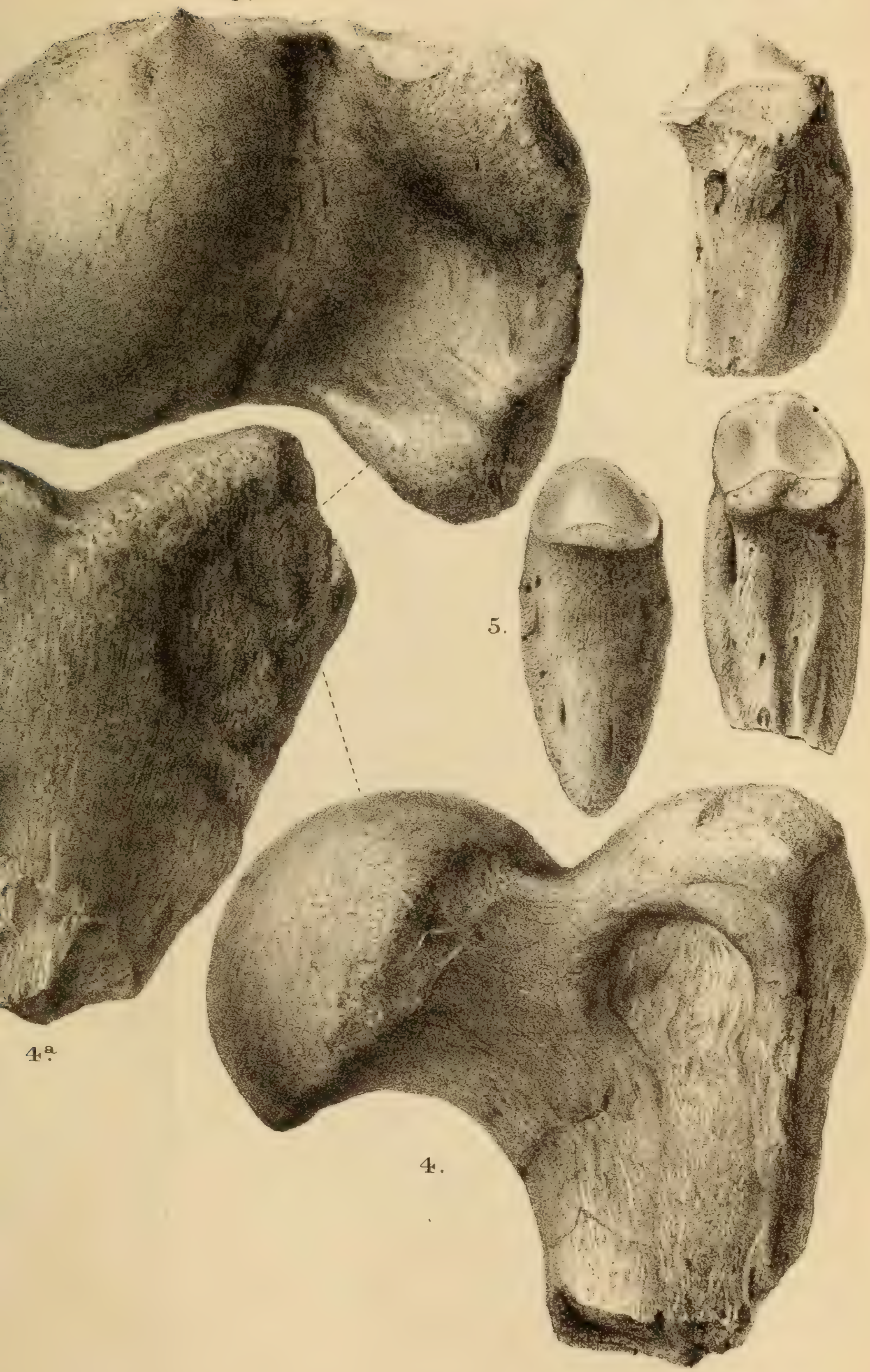
Prof. RAMSAY remarked that when the small Maltese Elephants were first described he thought they were generally spoken of as Miocene; but this might be a misunderstanding. It was, however, confirmed by the prevalence of Miocene rocks in Malta; but the *gisement* of these remains might be of later date. He was much struck by the number of Tortoises, but regretted that it could not be decided whether those from Gibraltar were land or freshwater species. If the latter, their presence was exceedingly interesting, fresh water being now so scarce in Gibraltar; and such remains occur in Gibraltar high up in the rock, where there is now no water. This, it seemed to him, would indicate an enormous change in the physical geography of the region. In a late visit to the north coast of Africa, near Tangier, he had found what were probably Jurassic strata very much contorted, and above them Coralline sands, half consolidated at their junction with the Jurassic rocks; and here on the old land surface he obtained a jaw of an Elephant, containing a molar tooth which proved it to belong to *E. antiquus*. This was interesting, from the alliance of that species with the existing African Elephant. From his point of view, he said, the chief interest of the paper was its bearing upon the changes in the physical geography of the Mediterranean and Aralo-Caspian areas.

Prof. T. RUPERT JONES remarked that some of the Maltese gravels contain rock-matter not now existing in Malta. This indicates a great lapse of time, a great depth of rock having been washed away.

Prof. SEELEY inquired whether the author had examined into the affinities of the large Maltese Chelonia and those from the Siwaliks. He noticed differences in the form of the femur, reminding one of the Indian forms, but perhaps indicating a still closer relationship to American types. He inquired whether there was any apparent relation of descent between the Miocene and later forms, and remarked that it seemed to him there was evidence proving the migration of animals and plants, with specific modification, from east to west. With regard to the thickness of the plates of the carapace and plastron, he said that this was no evidence of size. Thus *Emys crassus*, although but a small species, has plates at least as thick as those from Malta; and he had seen a Kimmeridge-clay species which illustrated the same fact.

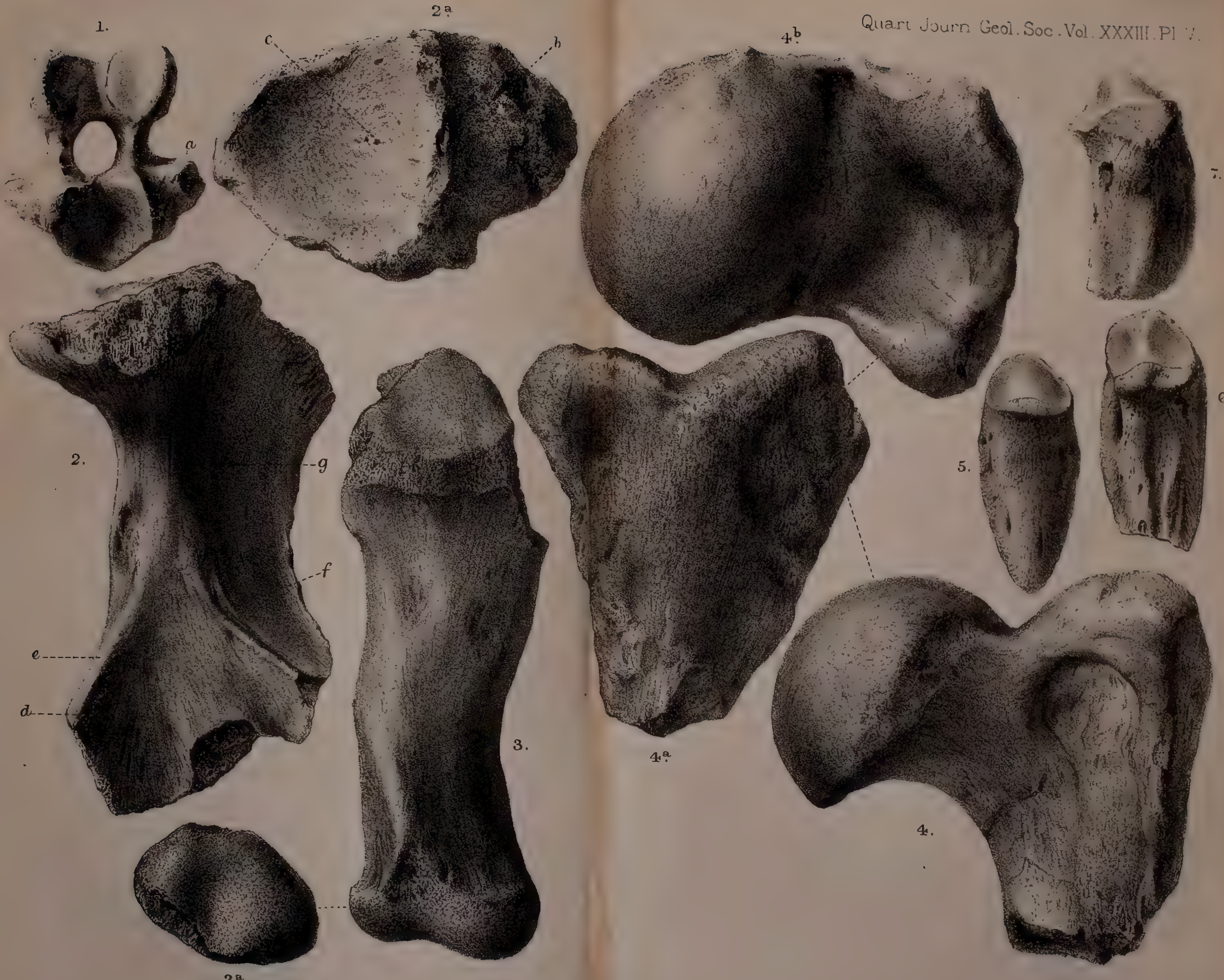
C.L. Griesbach.

MALTESE GIG



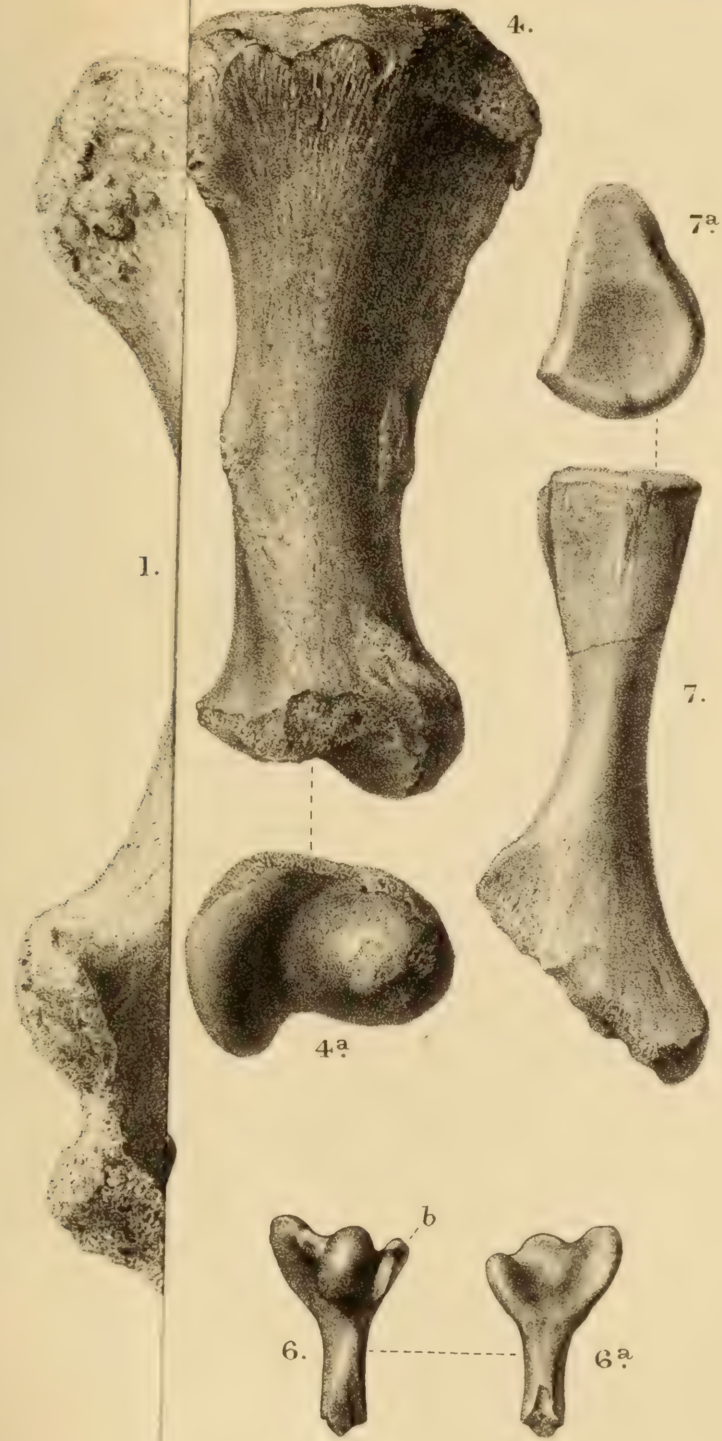
TORTOISES.

Mintern Bros. imp.



C.L. Griesbach. Mintern Bros. imp

MALTESE GIGANTIC TORTOISES.



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Mintern Bros. imp.

J. L. Griesbach

Mintern Bros. imp.

MALTESE AND GIBRALTAR TORTOISES.

The Author, in reply to Prof. Ramsay, said that it was impossible to tell whether the remains from Gibraltar belonged to a land or freshwater species, as the parts of the skeleton preserved did not furnish the necessary evidence; but the characters of the radius showed that it was not a marine Turtle. In reply to Prof. Seeley, he said that the head of the femur of the large Maltese Chelonian was quite different from that of *Colossochelys atlas* from the Siwaliks, and added that he quite agreed with him that the thickness of the carapace was by itself no evidence of gigantic size.

11. *On* British Cretaceous Patellidæ *and other Families of* Patelloid Gastropoda. By J. Starkie Gardner, Esq., F.G.S. (Read January 24, 1877.)

[Plates VII.–IX.]

A study of this group of Cretaceous Gastropoda, commenced some twelve months since, brought to light unexpectedly so many forms new to our Cretaceous series, some of the genera to which they are referred having, indeed, never before been found fossil, that I have deemed the result of sufficient importance to form the subject of a paper which I now lay before this Society. Conical or patelloid shells make their appearance amongst the earliest known Mollusca; and from them seem to have been differentiated the convoluted forms represented by *Bellerophon*: in the earliest times these two typical forms can hardly be separated one from the other, being linked together by spirally twisted capuliform shells. So impressed does Pictet seem to have been with this that he, in his great work the 'Terrains Crétacés de Ste. Croix,' includes *Bellerophina* in the Fissurellidæ. The families, species of which are here noticed, have been unusually persistent in form, having come down, in some cases, almost unchanged, even specifically, to the present day. The aspect of the group is therefore more recent in appearance than that of any other group of Gastropods from rocks of the same age. Although a considerable advance is here made in our knowledge of these families, from these particular rocks, yet the number of species described from single specimens tells us unmistakably how much more remains to be learned, and the inference is forced upon us that we must still possess, though undiscovered, a far greater variety of representatives of these mollusca. By the absence of many genera from our Cretaceous rocks which are found in earlier rocks, such as *Rimula*, or in contemporaneous rocks of other countries, such as *Fissurella*, *Parmophorus*, *Infundibulum*, *Galerus*, and the upper valves of *Hipponyx*, this inference is greatly strengthened.

The study of these families is perhaps of more importance to the geologist than that of most others of the Gastropoda, as the depth at which each form lived is approximately defined, and their presence or absence is therefore of assistance in understanding the physical conditions under which marine strata have been deposited. For instance, from the complete absence of fissured forms from the Gault and Greensand of Folkestone, Cambridge, and Blackdown, while they are abundantly represented elsewhere in rocks of approximately the same age, we may infer that these seas were shallow. Further remarks are appended to some of the specific descriptions; especially noteworthy are some remarkable cases of mimicry among the Calyptræidæ. A table of genera and species is appended. In this table the * signifies that the genus is altogether new in Cretaceous rocks; †, new to Europe; N, that the species is new. In the columns an I denotes that the species is described from not more than two specimens, × that the species is comparatively abundant.

	Neocomian.	Gault.	Upper Greensand.	Chalk.
PATELLIDÆ.				
Tectura tenuicosta, *D'Orb.*	......	×	I	
—— tenuistriata, *Seeley*	......	I		
—— formosa, N	I			
—— plana, N	I			
*Helcion Meyeri, N	I			
†Anisomyon vectis, N	I			
*Scurria calyptræiformis, N	I			
—— depressa, N	I			
FISSURELLIDÆ.				
Emarginula neocomiensis, *D'Orb.*	×			
—— valangiensis, *P. & C.*	I			
—— puncturella, N	×			
—— Gresslyi, *P. & C.*	......	......	×	×
—— divisiensis, N	......	......	×	
—— sanctæ-catharinæ, *Passy*	......	......	×	
—— affinis (?), *Sby.*	......	......	......	I
—— ancistra, N	......	......	I	
—— Meyeri, N	......	......	I	
—— unicostata, *Seeley, MS.*	......	......	......	I
*Puncturella antiqua, N	......	......	I	
CALYPTRÆIDÆ.				
Calyptræa Cooksoniæ, *Seeley* (C. sanctæ-crucis, *P. & C.*)	......	×		
—— concentrica, N	......	×		
—— Grayana, *Tate*	......	......	......	I
Crepidula gaultina, *Buv.*	......	×		
—— alta, *Seeley*	......	I		
—— chamæformis, N	I			
*Crucibulum giganteum, N	I			
CAPULIDÆ.				
Pileopsis neocomiensis, N	I			
—— dubia, N	......	I		
—— Seeleyana, N	......	......	I	
Hipponyx Dixoni, *Desh.*, N	......	......	I	×

PATELLIDÆ.

TECTURA FORMOSA, sp. n. Lower Greensand. Pl. IX. figs. 10, 11, 11 *a*.

Shell depressed, thin; apex minute, situated $\frac{1}{3}$ anterior; sculpture consisting of about fifty very finely tuberculated ribs, between which are slight, radiating, simple, parallel striæ. Neither the ribs nor the striæ are regularly equidistant; the shell near the base possesses short oblique striæ (fig. 11 *a*).

This shell differs from *T. tenuicosta* in being more regular and elevated—and by its ribbing, which is more uniform, closer, and most delicately tuberculated. It was found by Mr. Meyer in the Folkestone beds of the Lower Greensands at Shanklin.

The specimen has apparently a perforated apex, and might at first sight be regarded as a *Fissurella*; but even the most careful examination leaves it doubtful whether the perforation is or is not due to accidental abrasion; but the ornamentation, consisting of tuberculated striæ, is so characteristic of *Tectura*, and so different from that of *Fissurella*, which is almost invariably cancellated, that there can be practically little doubt as to which family it belongs to. *Fissurella* is still unknown from British Cretaceous rocks.

TECTURA PLANA, sp. nov. Lower Greensand. Pl. VIII. figs. 27–29.

Shell minute, laterally compressed, very elongated, cup-shaped; apex recurved; posterior region without ribs, but with lines of growth; surface smooth, but under the microscope rugose or weathered. L. 4 millims., b. 2 millims., ht. 2 millims. Unique. Found, by Mr. Meyer, at East Shalford.

The shell could with equal probability be assigned to the Lepetidæ, some of which it much resembles; but there are also smooth forms of *Tectura* still existing.

TECTURA TENUICOSTA, D'Orb. Gault. Pl. VII. figs. 19, 20.

Shell oval, depressed, thin; apex acute, subcentral, or $\frac{1}{3}$ anterior; sculpture fine, radiating, irregular ribs, almost absent on the anterior region, crossed by still finer striæ, and occasional lines of growth. The cast is smooth.

This shell seems to characterize the Gault, where it is not uncommon. Sowerby, 'Min. Conch.', figures a cast of this shell from Folkestone, together with a Lias cast, as *Patella lævis*. Michelin, in 1834, figured the species in the 'Mémoires Soc. Géol.' vol. iii. pl. 12. fig. 2. D'Orbigny describes it fully, with figures, in the 'Paléont. Franç.' Pictet and Roux have described it as *Acmæa gaultina*, distinguishing this form from *T. tenuicosta* "par son angle apicial plus ouvert, et par la position plus antérieure du sommet."

There is little doubt that some smooth limpet-like casts from the Cambridge Greensand are of this species. A rather larger specimen than the average is figured (Pl. VII. fig. 20). It also occurs at Devizes.

Amongst living shells, *T. tenuicosta* most resembles *T. testudinalis*, Müll., Greenland, and *T. Candeana*, D'Orb., from St. Vincent, both of which are extremely variable in height.

TECTURA TENUISTRIATA, Seeley. Gault. Pl. VII. fig. 18.

Minute, thin, higher than the last species, very finely striated. The specimen, still unique, is in the Cambridge Museum. It was described and figured in the 'Ann. and Mag. Nat. Hist.' for April 1861. The figure is unfortunately not very accurate.

HELCION MEYERI, sp. nov. Lower Greensand. Pl. VII. figs. 8–11.

Cap-shaped, depressed, anteriorly convex, posteriorly excavated; apex recurved, posteriorly projecting beyond the margin; sculpture, about twenty-two strong, rounded, imbricated ribs.

This unique shell was found by Mr. Meyer in the Folkestone beds of the Lower Greensand at Shanklin. It is an undoubted *Helcion*, and represents the earliest known appearance of that genus, which had not previously been found fossil. It bears a distant resemblance to *Emarginula Desori*, P. & C. The figure should have represented the shell as symmetrical.

ANISOMYON VECTIS, sp. nov. Neocomian. Pl. IX. figs. 3, 4, 5.

Oval, slightly quadrate, elevated, thin; apex small, pointed, subcentral, placed rather anteriorly; surface smooth or polished, without radiating ribs or lines, but with concentric, parallel, undulating lines of growth.

This species resembles *Helcion (Acmæa) conicum* of D'Orb., from the Upper Gault, and *Tectura elevata**, Forbes, figured by Stoliczka in the 'Pal. Indica,' but is thinner and more delicate than either.

Anisomyon is a Cretaceous genus, founded by Meek and Hayden †. The specimens just described cannot be examined interiorly; so that the form of the muscular scar is unknown; but the smooth aspect, thin shell, and minute apex leave little doubt they are correctly placed in this genus.

Two specimens are known, which were obtained from the Cracker Rocks of Atherfield, and are now in the Woodwardian Museum.

SCURRIA CALYPTRÆIFORMIS, sp. nov. Lower Greensand. Pl. VII. figs. 15, 16.

Shell ovate, or suborbicular, elevated, convex posteriorly, rather flattened anteriorly; apex anterior, slightly obtuse. The cast near the margin retains traces of fine radiating ribs, but is otherwise smooth, with irregular lines of growth.

The specimen, now in the British Museum, has a *Calyptræa*-like aspect, but resembles most strongly *Scurria mitra*. It is from the Lower Greensand of Seend.

SCURRIA DEPRESSA, sp. nov. Lower Greensand. Pl. VII. fig. 17.

Of the same form as the last species, slightly more depressed, but with an entire margin without the least trace of ribbing; more specimens may establish their identity. Two specimens are in the British Museum, which were found with the last.

* Geol. Soc. Museum.

† 'American Journal of Science and Arts,' May 1860 (2nd ser.), vol. xxix.

FISSURELLIDÆ.

Emarginula neocomiensis, D'Orb. Neocomian. Pl. VIII. figs. 1–6.

Shell oblong, twice as long as high, solid, conical, convex anteriorly, slightly concave posteriorly; apex small, recurved, about $\frac{2}{3}$ posterior; sculpture, 26 to 30 strong narrow principal ribs, and the same number of intermediate ribs, the last varying in prominence in different specimens, and not appearing at all until the shell is well advanced in growth; the ribs are cancellated in full-grown specimens by 25 to 30 elevated lines of growth, which pass over the secondary, but not over the principal ribs (fig. 6*a*). In two very perfect specimens in the Leckenby collection, Woodwardian Museum, there is a node at every intersection (figs. 1, 2, 2 *a*). The slit is short, and placed rather to the right of the median line. D'Orbigny's figure in the 'Pal. Franç.' has this character rather exaggerated; and it usually occupies a more symmetrical position. Pictet and Campiche had five examples under examination, in all of which the fissure deviated. Amongst the number of specimens which I have examined, the fissure, I find, usually deviates; but the character is not constant. The slit is bordered on each side by a principal rib; the scar forms, between two of the principal ribs, a narrower region than the space occupied by an intermediate rib, and is imbricated transversely. There is no trace of spiral growth in any of the specimens. The cast is smooth, except at the margins, where it bears impressions of all the ribs. The line of fissure presents a broad furrow, extending from near the apex to the margin, in the centre of which is a slightly raised region terminating at the fissure (Pl. VIII. fig. 2).

Although very distinctly characterized, it has been confounded with *E. Guerangeri*, D'Orb., of the Chloritic Marl, from which it is readily distinguished by its greater number of ribs.

Pictet and Campiche, 'Terr. Crét. de Ste.-Croix,' mention a variety which has the primary and secondary ribs equally prominent; there is a similar example in the Woodwardian Museum, from Donnington, Lincolnshire, which has about 54 ribs and a median fissure, and may prove distinct when more specimens are available.

There is apparently no specific difference between the specimen from the Atherfield clay, and one from Speeton, in the Jermyn-street Museum, named *E. fissaria*, Forbes.

The largest specimen I have seen is from Seend, and is in the British Museum (figs. 3, 4), measuring l. 25 millims., b. 18 millims., ht. 13 millims., these dimensions being considerably in excess of those usually met with.

E. neocomiensis, D'Orb., was first described as *E. reticulata* by Leymerie, in 1842, and was figured the next year by D'Orbigny in the 'Pal. Franç. Terr. Crét.' vol. ii. p. 392, pl. 234. figs. 4–8, and again by Pictet and Campeche, 'Terr. Crét. de Ste.-Croix,' pl. xcvii. figs. 9–11.

The species is very generally distributed throughout the Lower Greensand, which it characterizes, and has, no doubt, as wide a range on the Continent as it has in England. Many specimens have been found at Atherfield, others at Redcliffe, Isle of Wight, Devizes, East Shalford, Sevenoaks, Seend, Donnington, Specton, Furze Hill, Farringdon, &c.

Stoliczka, in the 'Pal. Indica,' remarks that the furrow in *Subemarginula*, Blainv., is lateral, and that this and the other species possessing the lateral emargination might form a subgenus. The character, however, is seen in this species to be inconstant.

Emarginula valangiensis, Pict. & Camp. Lower Greensand. Pl. VIII. figs. 7–9.

The species is described by Pictet and Campiche as being somewhat quadrilateral, and possessing 26 ribs, with intermediate striæ, only the accessory ribs of *E. neocomiensis* being absent. The form of the scar on the cast figured by them differs from that of the species last described. Mr. Meyer has found specimens at East Shalford which may probably belong to this species, but which are unfortunately too imperfect to determine with any degree of certainty.

Emarginula puncturella, sp. nov. Lower Greensand. Pl. VIII. figs. 10, 11.

Shell minute, oval, cap-shaped, elevated, compressed laterally; apex sharp, recurved, overhanging posterior margin; sculpture, 30 strong ribs, cancellated by transverse lines; each interspace possessing two pits, arranged horizontally in pairs.

The cast shows a fissure extending about $\frac{1}{3}$ the height of the shell, leaving a deep, sulcated scar on the remainder. This scar possesses an elevated median region, with strong imbrications resembling the teeth on a cog-wheel (fig. 11 *b*). The dimensions are, l. 7 millims., b. 5 millims., ht. 4 millims.

This species very much resembles *E. neocomiensis*; and the pits on the cast might be supposed to represent, in but a very slightly modified manner, the more quadrate interspaces between the ribs and striæ of that species. The shell, however, is higher and more compressed, the fissure is relatively longer, and the scar approaches much nearer to the apex. It appears to present certain affinities with *Rimula*.

The specimens figured are selected from several found by Mr. Meyer at East Shalford, and represent the shell natural size and magnified; the ornamentation being drawn from a cast, is shown in elevation instead of depression.

Emarginula Gresslyi, Pict. and Camp. Upper Greensand to Grey Chalk. Pl. VIII. figs. 12, 13, 16–18.

Shell ovate, or rounded, rather depressed; apex subcentral or $\frac{2}{3}$ posterior, slightly recurved; sculpture, about 200 fine ribs, crossed by still finer transverse lines, and marked also by lines of growth. The reticulations, which are very delicate, have no nodes at the intersections. The fissure is long, extending one fourth or more between margin and apex, and leaving on the rest of the distance a raised, ridge-like scar, which is sometimes depressed centrally.

This species is very variable in general form. The largest specimen figured measures, l. 25 millims., b. 19 millims., ht. 8 millims. and was obtained from the cast-bed of the Grey Chalk near Dover (figs. 12, 13). Another from the Chalk Marl of the Isle of Wight is proportionally higher, measuring 19, 14, and 9 millims. respectively (figs. 16, 17). Other specimens more nearly resembling Pictet and Campiche's figure (Terr. Crét. de Ste.-Croix,' pl. xcviii. fig. 10) are from the Cheddington Chloritic Marl (fig. 10); whilst another from Devizes is nearly orbicular. These differences of form are, no doubt, partly caused by pressure.

The excellent figure of *E. pelagica*, in Passy's 'Géol. de la Seine Inférieure,' is, if any reliance can be placed on figures unaccompanied by descriptions, taken from a specimen of the same species as that here figured from the Grey Chalk; but D'Orbigny's figure of *E. pelagica* has an altogether different appearance. I have not seen the original specimens; but should they be identical, Passy's name, published in 1832, would have priority. *E. flexuosa*, De Ryckh., resembles our species, but has the ribs flexuous.

EMARGINULA DIVISIENSIS, sp. nov. Upper Greensand. Pl. VIII. figs. 19, 20.

Shell ovate, convex anteriorly, flattened posteriorly; apex subcentral. The cast, which alone is known, bears traces of numerous ribs, reticulated by lines of growth, the ribbing being coarser than that of *E. Gresslyi*. The fissure is very short, leaving a deep and wide depressed region, very different in appearance from the raised fissural scar of the species last described.

From Devizes, now in the British Museum.

EMARGINULA SANCTÆ-CATHARINÆ, Passy. Upper Greensand. Pl. VIII. figs. 21, 22.

Shell in form like a Phrygian cap, compressed laterally, convex anteriorly, much hollowed out posteriorly; apex beak-like and recurved, overhanging the posterior margin; sculpture, about 28 ribs, two or three of which are stronger than the rest, reticulated by finer transverse lines. The fissure is short, narrow, and very distinct; fissural scar broad, depressed, with a narrow central ridge. The dimensions of the figured specimens from Whitenore are, l. 12 millims., b. 9 millims., ht. 10 millims. There is no doubt that our shell is identical with the *E. sanctæ-catharinæ* of Passy, described in the 'Géol. de la Seine Inférieure,' 1832, p. 335, pl. xvi. fig. 1, the figure, however, being extremely obscure; and in the 'Pal. Franç.' vol. ii. p. 395, D'Orbigny describes the species as possessing 14 or 15 elevated ribs, alternating with others less prominent.

In England it occurs in the Chloritic Marl of Wilts and Dorset; and specimens are in the British and Jermyn-street Museums. In France it is common to the Mediterranean basin and the Gulf of the Loire, and has therefore a wide range. The European *E. rosea* appears to be its living representative.

Emarginula ancistra, sp. nov. Upper Greensand. Pl. VIII. figs. 23, 24.

Very elevated, Phrygian-cap-shaped, compressed laterally, hollowed out under the beak in form of a semicircle; apex much recurved, pointing downward and projecting considerably beyond the posterior margin; sculpture, 8 principal and about 14 subordinate ribs, reticulated by fine transverse lines of growth, the sculpture being most distinct anteriorly, whilst the posterior region is nearly smooth. The fissure is long and narrow; the fissural region nearly flat, slightly depressed, smooth, and bordered by two raised ribs.

This well-marked form is quite distinct from all others of our Cretaceous rocks. *E. dubisiensis*, P. & C., resembles it slightly, but has a more inrolled apex, and differs in its ornamentation.

The species is described from a unique fossil from Roundway, near Devizes, in the Bowerbank collection at the British Museum. *E. capuliformis*, now living in the Mediterranean, is of smaller size, but identical in form with this species.

Emarginula Meyeri, sp. nov. Chloritic Marl. Pl. VIII. figs. 14, 15.

Shell cap-shaped, very elevated, laterally compressed, the sides being almost flat, convex anteriorly, much hollowed out posteriorly; apex sharp, beak-like, recurved, overhanging posterior margin. Fissure short; the fissural scar is broad and depressed, but with a very slight median elevation or ridge. The cast has traces of rather coarse ribs reticulated with transverse lines, which are closer together than the ribs.

In general form this shell rather resembles *E. stenosoma*, De Ryckholt, but is more concave in front and rather longer in proportion to its elevation; *E. stenosoma* has 36 ribs and 16 transverse lines, which produce a vertically elongated cancellation, with nodes at the intersections.

We are indebted to Mr. Meyer for the discovery of this and many other interesting forms. It is from near Lyme Regis.

Emarginula unicostata, Seeley, MS. Upper Chalk. Pl. VIII. figs. 25, 26.

Thin, ovate, Phrygian-cap-shaped, compressed laterally, hollowed out posteriorly; apex acute, recurved, overhanging posterior margin; sculpture reticulated, consisting of ribs and lines of growth, the ribs being most strongly marked on the anterior region, whilst under the apex they are hardly visible. The fissure is very short; the fissural scar is in the form of a ridge, between two narrow depressions.

This species very strongly resembles *E. sanctæ-catharinæ*, but is more depressed and more finely ornamented, and the ribs are about twice as numerous. They both have affinities with *E. loculata*, De Ryckh., which, however, has fewer and less regular ribs, and with *E. Desori*, P. & C.

It was discovered in the Upper Chalk, at Norwich, and is preserved in the Woodwardian Museum at Cambridge.

EMARGINULA AFFINIS, Sby.

This is probably identical with *E. sanctæ-catharinæ*. It is figured in Dixon's 'Geology of Sussex.'

PUNCTURELLA ANTIQUA, sp. nov. Upper Greensand. Pl. IX. figs. 6–9.

Conical, cap-shaped; apex blunted, excentric; anterior region inflated, posterior hollowed out; shell thick, ornamented with about 60 radiating ribs, which become finer towards the posterior region. The cast presents posteriorly a central groove or depression extending from margin to summit. In this depression is a longitudinal, narrow, fissure-like scar, extending from the margin about $\frac{2}{3}$ of the way up, and terminating above, at the deepest part of the depression, in a small, raised, pipe-like protuberance, which has filled in the perforation. The second specimen figured does not show the depression so prominently; but in this case the shell is not completely removed, and still partly fills it up; the scar, however, is present. The depression has been caused by the internal shelly plate, characteristic of the genus, which answers probably a somewhat similar purpose to that of the internal septum in other genera. Some of the Eocene *Fissurellæ* are also thickened at the foramen, which is then excentric; but in *Fissurella* the fissure, if not apical, is immediately under and in *front* of the apex, whilst in *Puncturella* it is always placed *behind* the apex.

These specimens, which are from Devizes, are of especial interest, as they carry far back into Cretaceous times a genus which had hitherto not been met with fossil except in Glacial deposits. There are but few living *Puncturellæ*; *P. cucullata*, from Oregon, is the nearest known representative of our species. The specimens are in the British Museum.

The genus *Fissurella* is not represented; and its absence is the more remarkable as nine species are recorded from foreign Cretaceous rocks, and it is well represented in the Tertiaries. It may be noticed, as a possible explanation of the absence of both *Patella* and *Fissurella*, that the strictly littoral habits of these two great genera may have precluded their being buried, under ordinary conditions, with other Mollusca, in the deeper Cretaceous seas. The genus *Emarginula*, on the contrary, is a deep-water form, and is found more or less abundantly in most of the divisions of the Neocomian, Upper Greensand, and Chalk. Its absence in the Gault is confirmatory evidence of the shallowness of that sea, whilst its presence in the Upper Gault of Switzerland agrees with the character of the associated fauna. The scarcity of living species of *Emarginula* and their former abundance, has led to the idea being expressed by several authors that it is dying out and being replaced by *Fissurella*. The genus *Rimula*, not uncommon in the Oolites, is still unrepresented in subsequent rocks until it is met with in the Tertiaries.

The family of Siphonariidæ is only represented in Cretaceous times by *S. antiqua*, Binkhorst, from the Upper Chalk of Limburg.

CALYPTRÆIDÆ.

CALYPTRÆA COOKSONIÆ, Seeley. Gault.

Shell elevated, cap-shaped, wider than high, longer than wide, inflated, rounded anteriorly, flattened posteriorly; apex posterior, recurved; septal scar variable, rectangular or U-shaped, narrow. The cast only is known, which is marked by fine lines of growth.

This shell is known only from Cambridge, where it is frequently found inside the last chambers of Cephalopoda.

It was figured in 1861 by Seeley, in the 'Ann. and Mag. of Nat. Hist.' as a *Crepidula*, and almost at the same time by Pictet and Campiche as *Calyptræa sanctæ-crucis*. Seeley's name would seem to have priority, as that part of Pictet's work was published after 1861.

The form of the scar indicates a relationship with *Calyptræa* rather than *Crepidula*. Pictet's figures, if really of one species, show the shell to be variable in height and in the form of the scar. Further specimens may unite it with *Crepidula gaultina*, Buv.

CALYPTRÆA CONCENTRICA, sp. nov. Gault. Pl. VII. figs. 27–30.

Unsymmetrical, cap-shaped, irregular, elevated; sulcated concentrically, like an *Inoceramus*, without radiating marks; apex recurved, acute, projecting beyond, and overhanging, posterior margin.

This shell bears so great a resemblance to *Inoceramus concentricus* that it has been hitherto overlooked by all collectors. The mimicry by this and other Calyptræidæ of the prevailing Monomyarian bivalves of the age in which they lived, is continued at the present day, as in the cases of *Calyptræa niveata*, *Lessoni*, *plana*, *dilatata*, *squamosa*, *fimbriata*, and many others, which can hardly be distinguished from small species of oysters. This mimicry, we may suppose, is protective, and enables the mollusk, which from the thinness of its shell might otherwise be selected by the boring carnivora in preference to the thicker-shelled *Ostreæ*, to escape. Other *deep-water* limpets are peculiarly open to attacks of this kind.

Specimens are not uncommon in the nodule-bed of the Gault at Folkestone.

CALYPTRÆA GRAYANA, Tate. Chalk. Pl. VII. fig. 25.

"Shell ovate, conical, elevated, summit slightly recurved, ornamented by numerous angular raised ribs, decussated by flexuous and inequidistant lines of growth."

The description is taken from the 'Quart. Journ.' vol. xxi. (1865), p. 38, pl. iii. figs. 8, 8 *b*. These figures are twice nat. size, and are inaccurate in this respect, that they represent the lines of growth which decussate the ribs too regularly arranged, there being in reality only occasional and very irregular lines of growth. The ribs or, more properly, striæ are almost invisible without the aid of a lens, there being as many as thirty to every 5 millims. breadth of shell, with interspaces between them of about three times the width of the ribs. The scar, which is immediately under the apex, is very open, and is unsymmetrical.

The specimen is from the Upper Chalk of Kilcorrig, Lisburn, and is preserved in the Jermyn-street Museum.

Crepidula gaultina, Buvignier. Gault. Pl. VII. figs. 21–23.

Shell small, thin, suborbicular, inflated and rounded, sometimes as high as wide, more frequently depressed; smooth, without radiating lines, but with irregular folds of growth; apex minute, posterior, in front of the septum, spiral, easily detached, marked with strong lines of growth. The scar seen on the casts is directly under the apex, and resembles a widely opened V, or, more correctly, a distant bird in flight. The position of the septa can be traced externally on the shell itself by slight ridges. The fry was perfectly helicoid and finely ribbed.

It is found in the Gault of Folkestone, and at Cambridge, attached to shells of Ammonites, and has been met with in the Gault of France and Switzerland.

It has been figured by Buvignier, in the 'Stat. de la Meuse,' by Pictet and Campiche, and by Jukes-Browne (Quart. Journ. Geol. Soc., May 1875).

The depressed form only has been met with as yet at Folkestone; but the amount of depression, depending entirely, as it does, on the position in which the shell, when living, was fixed, has no specific value. A larger series may unite the species with *Calyptræa Cooksoniæ*.

Crepidula alta, Seeley. Gault.

Shell smaller, and relatively higher than that of *C. gaultina*, with the septal scar less open.

This is the *Galericulus altus* of Seeley, a genus founded on a unique specimen in the Woodwardian Museum. The genus *Galericulus* is characterized, according to Seeley, by a second septum near the base of the shell. The scar considered to indicate this septum, however, is very much to the right of the median line, and, as already pointed out by Jukes-Browne, is probably an accidental indentation, as it is difficult to see the use of a second septum in the economy of the living mollusk, and nothing analogous exists in recent genera. The figure and description are in the 'Ann. and Mag. Nat. Hist.' for April, 1861. It may, probably, be only a variety of *C. gaultina*, and should, I think, be eventually removed from our list.

Crepidula chamæformis, sp. nov. Lower Greensand. Pl. VII. figs. 12–14.

Unsymmetrical, capuliform, depressed; apex posterior, recurved, spiral (?), projecting beyond the margin; posterior region much excavated under the apex; aperture irregular; surface rugose, with lines of growth.

This shell is very like *C. grandis*, from Japan, and resembles a

Chama in aspect; its mimicry of the Neocomian *Exogyræ* is almost as remarkable as that of the common Gault *Inoceramus* by *Calyptræa concentrica*. A unique specimen, from Donnington, is preserved in the Cambridge Museum. *Crepidulæ* first appear in Cretaceous rocks.

Crucibulum giganteum, sp. nov. Lower Greensand. Pl. IX. figs. 1, 2; Pl. VII. figs. 3, 4.

Orbicular, patelliform, depressed, height equal to $\frac{1}{5}$ the length; apex obtuse, central or subcentral; posterior region slightly hollowed out, anterior very slightly concave; surface irregularly marked with lines or folds of growth, without ribs. The scar is deeply impressed, and extends sinuously from near the margin, about half-way to the apex, forming a sharp bend, something like a Greek epsilon.

The larger specimen shows only a slight depression along the scar-line, but appears to be specifically the same as the one from Shanklin, although it has the apex less central. The larger specimen is from Hythe, and in my collection; the smaller, from Shanklin, is in the Jermyn-street Museum.

The genus is here, for the first time, recorded as Cretaceous.

CAPULIDÆ.

Pileopsis neocomiensis, sp. nov. Lower Greensand. Pl. VII. figs. 1, 2.

Orbicular, depressed; rather compressed laterally, giving the aperture a slightly pentagonal aspect; apex small, acute, recurved, not spiral, about $\frac{5}{6}$ posterior; surface irregularly marked with concentric lines of growth, with a texture similar to that of *Ostrea*.

The shell is from the Tealby limestone of Donnington, and is in the Woodwardian Museum; the surface is pitted by the pisolitic iron-stained grains which largely compose the matrix of the stone in which it was found. It is an undoubted *Pileopsis*, and strongly resembles the British *P. ungarica*.

Pileopsis dubia, sp. nov. Gault. Pl. VII. fig. 24.

Shell thin, orbicular, scutiform, very depressed, with minute flexuous striæ; apex subcentral, spiral (?). The muscular impression can be traced; and there is no sign of septum.

The specimen upon which the present species is founded is unique. It was obtained at Folkestone, and is in my collection. It resembles *Patelloidea*, which has not hitherto been noticed fossil.

Pileopsis Seeleyana, sp. nov. Upper Greensand. Pl. VII. figs. 5–7.

Shell rather thick and suborbicular, scutiform, depressed; apex subcentral, slightly anterior; margin entire, laminated; shell very finely and evenly striated, the striæ being only visible by aid of a strong lens.

This is the only patelliform Gastropod from the well-known Blackdown beds, and is unique. The original is in the British Museum.

The shells of *Pileopsis* are very variable, attaching themselves to foreign objects, of which they frequently take the impression, as in the case of strongly radiated bivalves &c. *P. squamæformis,* from the Paris-basin Eocene, takes the crescentic form of the aperture of *Fusus longævus* when fixed inside the aperture of that shell. The genus is peculiarly interesting geologically, being the nearest representative of the Silurian cap-shaped shells, which range upwards to the Lias. Although absent in the Jurassic, it is well represented in the Lower Cretaceous rocks, Pictet and Campiche enumerating ten species in their list.

Hipponyx Dixoni, Deshayes. Upper Greensand and Chalk. Pl. IX. figs. 12, 13.

Shell-base in the form of a solid cylinder of irregular growth, at the extremity of which is apparent the peculiar muscular impression special to the genus *Hipponyx.*

The name was suggested by Deshayes for the irregular body figured in Dixon's 'Geology of Sussex,' pl. xxvii. fig. 8, without specific description or name. Similar specimens are not uncommon in the White Chalk, and are preserved in most collections. Eocene and Recent forms alike sometimes deposit a series of bases, one over another, but none to the same extent, or so shiftingly, as appears in the Cretaceous form. It may be that, as at the bottom of the Chalk sea stones or rocks were rare, the excessive and heavy deposit served the animal in lieu of them, and formed an anchorage; the shifting may have taken place to escape burial or silting-up. The Greensand specimen from Cambridge, in the Woodwardian Museum, is very solid, the last base being deeply hollowed out, like a basin.

The genus makes its first appearance in Cretaceous rocks, and is met with in the Chalk of Normandy and the Maestricht limestone. *Capulus dunkerianus*, D'Orb., is the only upper valve yet discovered which could belong to these bases.

EXPLANATION OF THE PLATES.

Plate VII.

Figs. 1, 2. *Pileopsis neocomiensis,* sp. nov. Lower Greensand. Tealby; Woodwardian Museum.

Figs. 3, 4. *Crucibulum giganteum,* sp. nov. Neocomian. Shanklin; Jermyn-street Museum.

Figs. 5, 6, 7. *Pileopsis Seeleyana,* sp. nov. Blackdown; British Museum. (Fig. 5, magnified.)

Figs. 8, 9. *Helcion Meyeri,* sp. nov. Magnified. Lower Greensand; Mr. Meyer's collection.

Figs. 10, 11. The same, natural size.

Figs. 12, 13, 14. *Crepidula chamæformis,* sp. nov. Neocomian, Seend; British Museum.

Figs. 15, 16. *Scurria calyptræiformis,* sp. nov. British Museum.

Fig. 17. *Scurria depressa*, sp. nov. Same locality.
Fig. 18. *Tectura tenuistriata*, Seeley. Gault, Cambridge; Woodwardian Museum.
Figs. 19, 20. *Tectura tenuicosta*, D'Orb. Gault, Folkestone; Gardner collection.
Figs. 21, 22, 23. *Crepidula gaultina*, Buvignier. Gault, Folkestone; Gardner collection.
Fig. 24. *Pileopsis dubia*, sp. nov. Gault, Folkestone; Gardner collection.
Fig. 25. *Calyptræa Grayana*, Tate. Upper Chalk, Ireland; Jermyn-street Museum.
Fig. 26. *Helcion*, sp.? Buck Hill, Bedfordshire, probably derived from the Kimmeridge Clay.
Figs. 27, 28, 29, 30. *Calyptræa concentrica*, sp. nov. Gault, Folkestone.

Plate VIII.

Fig. 1. *Emarginula neocomiensis*, D'Orb. Neocomian specimen from the Leckenby collection. Atherfield.
Fig. 2. Ditto, side view.
Fig. 2 *a*. Part of same, enlarged.
Fig. 3. Ditto, specimen from the British Museum. Seend.
Fig. 4. Ditto, side view.
Figs. 5. 6. Specimens from the Jermyn-street Museum. Atherfield.
Fig. 6 *a*. Part of same, enlarged.
Figs. 7, 8, 9. *Emarginula valangiensis*, Pict. & Camp. Neocomian. Mr. Meyer's collection. East Shalford.
Figs. 10, 11. *Emarginula puncturella*, sp. nov. Neocomian. Mr. Meyer's collection.
Figs. 11 *a*, 11 *b*, 11 *c*. The same, enlarged.
Figs. 12, 13. *Emarginula Gresslyi*, Pict. & Camp. Grey Chalk. Gardner collection.
Figs. 14, 15. *Emarginula Meyeri*, sp. nov. Chloritic Marl, Lyme Regis. Mr. Meyer's collection.
Figs. 16, 17. *E. Gresslyi*. Lower Chalk, Isle of Wight.. Jermyn-street Museum.
Fig. 18. Ditto. Upper Greensand, Devizes. Jermyn-street Museum.
Figs. 19, 20. *E. divisiensis*, sp. nov. Upper Greensand, Devizes; British Museum.
Figs. 21, 22. *E. sanctæ-catharinæ*, Passy, from the Chloritic Marl of Whitemore; Jermyn-street Museum.
Figs. 23, 24. *E. ancistra*, sp. nov. Upper Greensand, Roundway, near Devizes; British Museum.
Figs. 25, 26. *E. unicostata*, Seeley, MS. Upper Chalk, Norwich; Woodwardian Museum.
Fig. 27. *Tectura plana*, sp. nov., nat. size. Neocomian. Mr. Meyer's lection.
Figs. 28, 29. The same, enlarged.

Plate IX.

Figs. 1, 2. *Crucibulum giganteum*, sp. nov. Neocomian, Hythe; Gardner collection.
Figs. 3, 4, 5. *Anisomyon vectis*, sp. nov. Neocomian, Atherfield; Woodwardian Museum.
Figs. 6, 7, 8, 9. *Puncturella antiqua*, sp. nov. Upper Greensand, Devizes; British Museum.
Figs. 10, 11. *Tectura formosa*, sp. nov. Lower Greensand, Shanklin. Mr. Meyer's collection.
Figs. 12, 13. *Hipponyx Dixoni*, Deshayes. Chalk; Jermyn-street Museum.

Discussion.

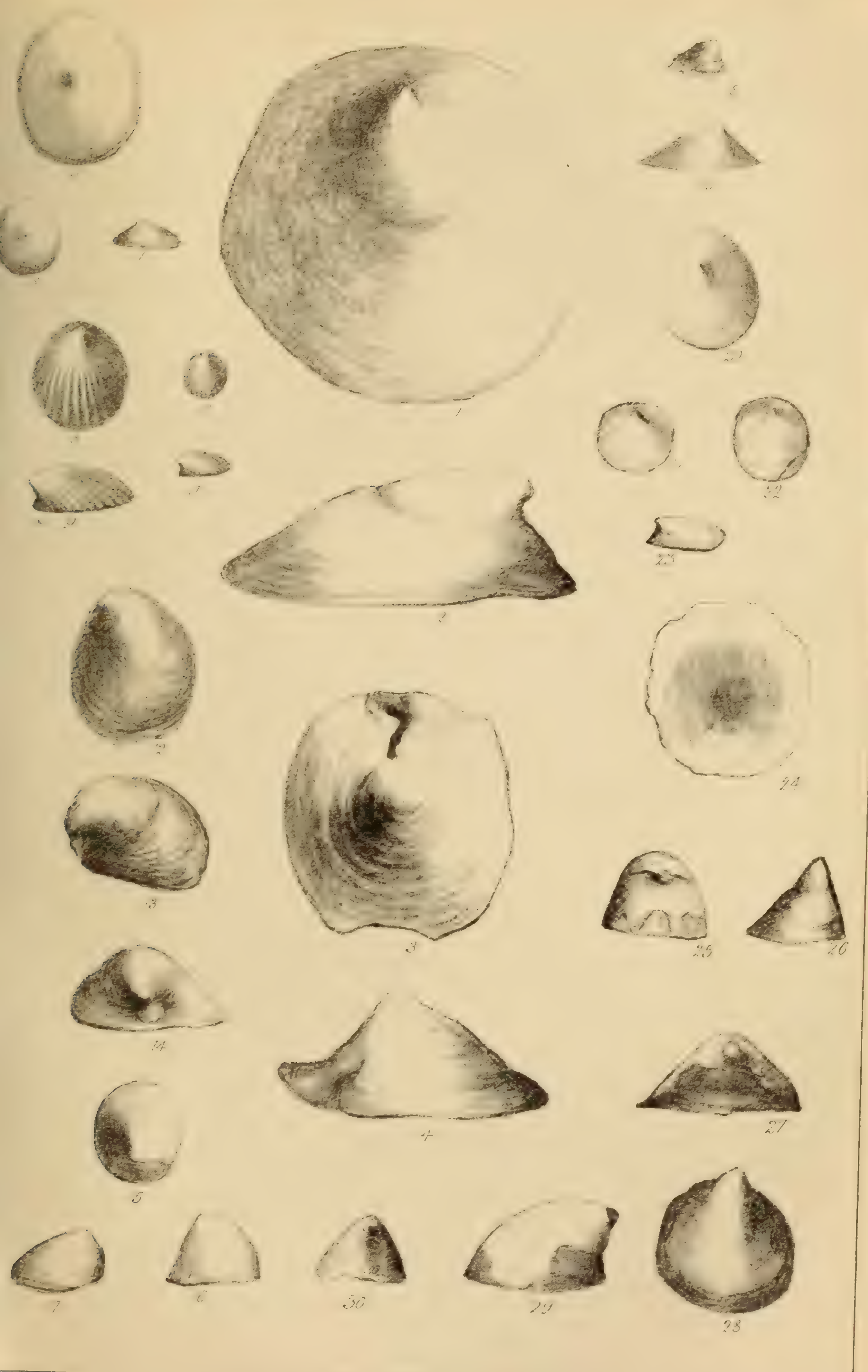
Prof. Seeley remarked that the paper raised questions both large and small. The author's inferences with regard to depth of seas and questions of old physical geography were of great importance, if they could be established. He infers, from the presence of certain shells, that the Gault was deposited in shallow, and the Greensand in deep water; but this was opposed to all evidence of a physical kind, and was therefore untrustworthy. Coarse deposits are formed near the shore, and finer ones at greater distances; therefore the Gault must have been formed in deeper water than the Upper Greensand. Prof. Seeley also maintained that the occurrence of similar species did not necessarily imply similarity of conditions, and that therefore no inference as to physical conditions could be drawn from extinct species of marine fossils.

Mr. Charlesworth made a comparison of the old limpets with those of the present day, and, in connexion with the author's remarks upon the apparent mimicry presented by the Cretaceous species, stated that neither in the later Tertiary deposits which he had especially studied, nor on existing beaches, had he ever found a limpet bored by carnivorous Gastropoda after their well-known fashion.

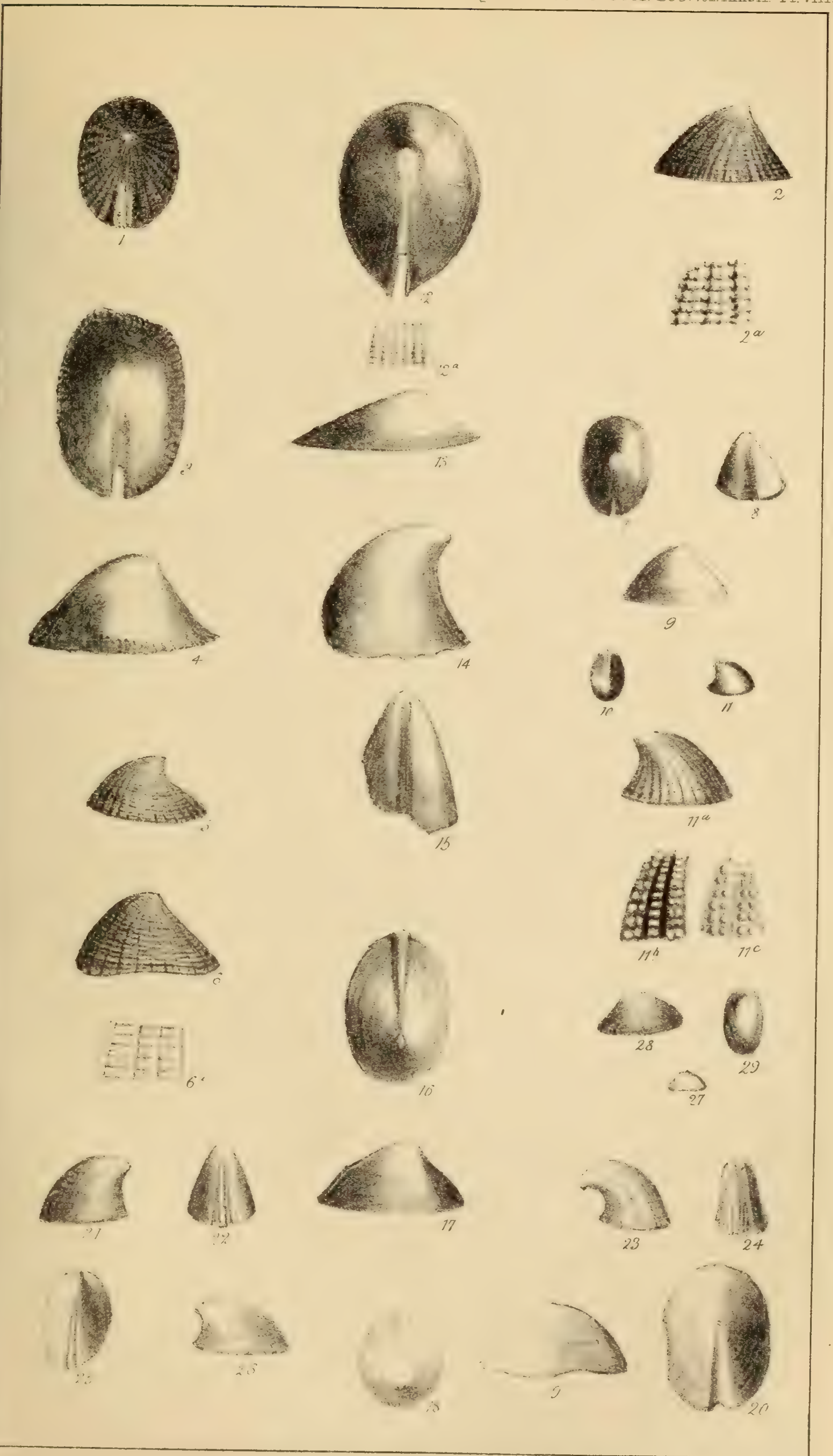
Mr. Meyer said that, with respect to the comparative depths of the Gault and Greensand seas, he agreed with the author, for two reasons:—one derived from the fauna, namely that Brachiopoda, which are usually held to be inhabitants of deep water, abound in the Greensand, but are almost entirely absent in the Gault; the other from the mineral condition of the two deposits, as he believed that while the immediate shore-line of the Greensand was rocky, in part Portlandic, yielding sand rather than clay, the shore-line of the Gault was mainly Kimmeridgian, yielding clay rather than sand. This would partly account for the difference in mineral condition.

Mr. Price said that in estimating from palæontological data the approximate depth of the Gault sea, he found that the lower part of the formation was deposited in shallow water, the middle in deeper, and the upper part in still deeper water, until the oceanic conditions of the Chalk were nearly reached.

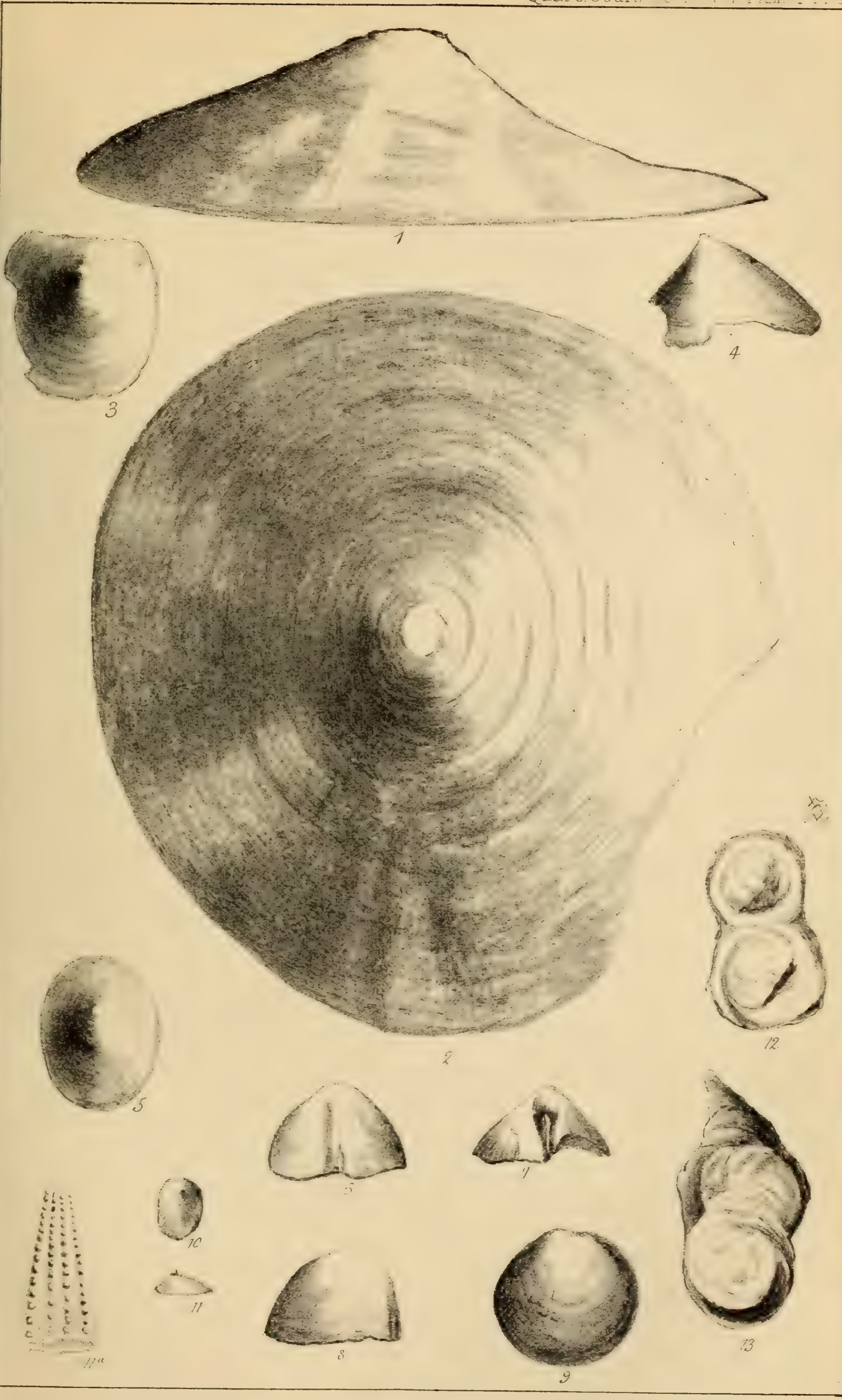
The Author, in reply, said that he could not agree with Prof. Seeley. The Greensand of Cambridge and Blackdown possess none of these Mollusca; and the Greensand of Warminster, with its numerous Echini, is certainly a deep-water formation. The Gault is known to be a shallow-water deposit. At the same time it was to be admitted that our knowledge of the Cretaceous Limpets is exceedingly imperfect, a great number of the species described being founded on unique specimens. He regarded the Limpets as representing the most ancient form of the Gastropod shell, the simple capuliform shell gradually passing into the convoluted form, such as *Bellerophon*, which Pictet had included among the Limpets. The persistence of the type is therefore exceedingly remarkable.



BRITISH CRETACEOUS PATELLIDÆ &c



BRITISH CRETACEOUS PATELLIDÆ &c.



BRITISH CRETACEOUS PATELLIDÆ &c.

12. *On the* SILURIAN GRITS *of* CORWEN, NORTH WALES. By Prof. T. McKENNY HUGHES, M.A., F.G.S. (Read December 20, 1876.)

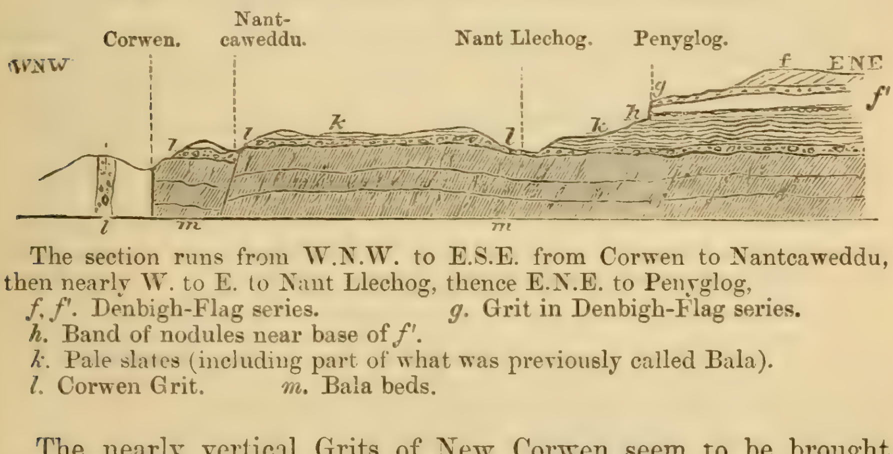
I BEG to offer a few notes, made chiefly in the summer of 1876, while endeavouring to correlate the base of the Silurian rocks of North Wales with the corresponding beds in the Lake-district and South Wales.

I found that some important changes in the mapping and consequent classification of the rocks in the neighbourhood of Corwen were necessary. These corrections being made, I obtained a key by which I was able to detect, over the whole of the district I then examined, a very variable but yet a more satisfactory and easily recognized base for the Silurian rocks.

It will be seen by reference to the Geological-Survey map of the Corwen district, that the Denbigh Grits are represented as thrown down by a fault (running W.S.W. and E.N.E.), while no Grits are are shown on the map between this and Pennyglog Quarry.

I found, however, that the Grits at Corwen were not the Denbigh Grits, as seen *e. g.* on top of the Flags at Penyglog Quarry E.S.E. of Corwen, but that the Corwen Section is as follows (fig. 1):—

Fig. 1. *Diagram Section from Corwen to Penyglog.*



The section runs from W.N.W. to E.S.E. from Corwen to Nantcaweddu, then nearly W. to E. to Nant Llechog, thence E.N.E. to Penyglog,

f, f'. Denbigh-Flag series. *g*. Grit in Denbigh-Flag series.
h. Band of nodules near base of *f'*.
k. Pale slates (including part of what was previously called Bala).
l. Corwen Grit. *m*. Bala beds.

The nearly vertical Grits of New Corwen seem to be brought in by faults, two of which are pretty clear. South and east of these faults there are two large quarries near the church—one in Bala beds, which have yielded *Stygina latifrons*, *Illænus Davisii*, *Glauconome disticha*, *Atrypa marginalis*, various species of *Orthis*, and corals.

The other quarry is a little further west. In it the Grits, to which I propose to give the name of the "Corwen Grits," are worked, chiefly for road-metal. These are obviously thrown down by a small fault from the grits seen in the cliff immediately to the south.

In this cliff I picked them up, and traced them S.W. for some distance in the bed of the stream that runs down Nantcaweddu. Here they begin to show a very variable character. In one place just south of the moorland boundary-wall, they contain quartz pebbles from the size of a pea to that of a hen's egg. In another they run into fine sandstones. I here obtained one fossil from the coarser part, which, though not well preserved, can with great probability be referred to *Favosites alveolaris.* At about one mile south of Corwen a slight fold throws the Grit outcrop about $\frac{1}{4}$ mile to the east, beyond which I followed it west of the shooting-box known as Liberty Hall, and lost it south of Moel Ferna. Along this line it is frequently very thin and is generally of a finer texture than in Nantcaweddu, being very often a grey-and-white sandstone with wavy lines of bedding and subordinate patches and lines of slate.

To return to Corwen. The Grit runs along the cliff south of the rectory to Nant Llechog, where it may be seen rolling towards the north, the stream following the face of the beds along some of the folds for a considerable distance. It is then lost under the drift and talus north of Penyglog. Nearly south of Bonwmuchaf the Grit, which is rather coarse, weathering yellow or white, contains what look like fragments of cleaved slate; but this is not clear, as elsewhere it certainly contains small pans and lenticular patches of mud; and these, when pinched up in a bed of different lithological characters, such as sandstone or grit, might often appear like included fragments, and have cleavage produced in them alone. In such cases there is generally a kind of uniformity in the direction of the cleavage-planes; but when the cleavage-planes of the included pieces of slate lie in all directions, the probability is that they are fragments of a previously cleaved rock.

Along this line of section the Grits are frequently seen overlying Bala Shale, in which, immediately below the Grit, I found, in one place, *Orthis Actoniæ.* In the Grit itself here I have found only some undeterminable fragments of *Orthis* and *Petraia.*

In Nant Llechog the Grit is represented by a white saccharoid sandstone, sometimes ripple-marked and false-bedded, sometimes with black lines and bands of slate in it, at others quite homogeneous. In several places along this line of outcrop I noticed in the Bala beds a kind of double cleavage, to be referred to two successive movements causing lateral pressure, not in the same direction, and giving to the rock, when viewed across the broken edges of the cleavage-planes, an elongated lozenge-shaped structure. In the series overlying the Grit there seemed to be but one cleavage. I could not make out the original directions of these several movements, as it was clear that there had been many subsequent disturbances in that area which had affected both the singly and doubly cleaved rocks—such as, for instance, the great movements which let in the Hafodycalch Mountain-limestone, which, with its associated shale, is not cleaved. This test of double and single cleavage cannot be expected to hold everywhere, as it must frequently happen that the direction of the second pressure may coincide with that of the first; and though perhaps the result may be more intense cleavage in the previously cleaved rocks, no crossing of cleavage-planes could be produced; and, moreover, in cases where the second cleavage is very intense, or the rock very susceptible of cleavage, this would entirely obliterate all previously existing divisional planes, as notably in the volcanic slates of the Lake-district, where we find joints and faults quite healed, and the rock splitting along the cleavage-planes only.

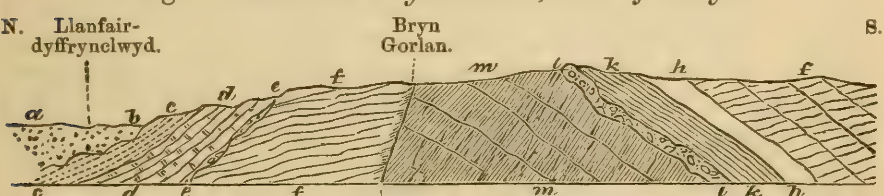
The beds below the Grits are, as a rule, bluish rab, *i. e.* a shivery mudstone breaking along bedding, joints, and imperfect or double cleavage into irregular, often somewhat prismatic fragments. Frequently, however, these beds have, especially where much weathered, a pale grey colour, much resembling that of the beds above the Grits. This may perhaps be because they are derived directly from the felspathic ash of some volcanic district, while the Silurian beds above the Grits have been formed later on from the waste of such beds.

These pale beds above the Grits pass up into the "Pale Slates" of the Survey, which in turn pass up into the striped flaggy Slates of Penyglog, on the top of which come Grits to be referred to the true Denbigh Flag- and Grit-series, and which I traced for about two miles to the N. side of Moel Ferna. In the flaggy Slates I found *Graptolithus priodon*, *Cyrtograpsus Murchisoni*, and *Retiolites*, sp., with *Orthoceras primævum* and *O. subundulatum*. I again found some Graptolites in a small watercourse N.E. of Moel Ferna, on what seemed to be the same horizon. The dip is here about 10°, N.E. to N.N.E., and the cleavage 30° N. I would here acknowledge much useful information which I got from Mr. Phillips, of the Penyglog Quarries.

I then tried to apply this key to other districts.

First, then, there is a patch of Bala coming in south of the fault near Bryn Gorlan, at the south end of the Vale of Clwyd, as shown in the section (fig. 2).

Fig. 2. *Section at Bryn Gorlan, Vale of Clwyd.*



a. New Red. *b.* Basement bed of New Red, sometimes conglomeratic.
c. Carboniferous Sandstone, generally stained red. *d.* Mountain Limestone.
e. Basement bed of Mountain Limestone (shale, sandstone, and conglomerate).
f. Denbigh Flags.
k. Pale slates (including part of what was previously called Bala).
l. Corwen Grit. *m.* Bala beds.

Here I found at the north end the Denbigh Flags. These may be examined along the road to Llanfairdyffrynclwyd, where Graptolites (chiefly *G. priodon*) occur. South of the Bryn-Gorlan fault we find the Bala beds in places highly fossiliferous, as *e. g.* near Cerrig-oerion, where I found *Leptæna sericea*, *L. transversalis*, *L. scissa ?*, *Strophomena depressa*, *Palæarca*, &c.

On the top of the hill, sticking out through the flat peaty surface soil, runs a ridge of whitish Grit about 50 feet thick, which becomes finer as we follow it west, until it is represented by a set of nodular striped sandy beds.

The beds below the Grit have the same kind of double cleavage, noticed in some cases near Corwen in beds below the Corwen Grit.

The beds above the Grit are pale imperfectly cleaved slates, passing up into the beds mapped as "Pale Slates" by the Survey, which are, in turn, overlain by the Denbigh Flags.

On the west the same beds might be expected at a short distance below the Pale Slates; but I have only hastily run over some of the ground between Llanfihangelglynmyfyr and Cerrigydrudion since I made out the Corwen Section; and though I came upon fragments which I believe should be referred to this rock, I did not find it in place. Mr. Etheridge informs me that he has *Pentamerus oblongus* recorded from Cerrigydrudion.

On the east, after crossing the Llandegla and Bryneglwys faults, we come to rather a difficult bit of ground about Cyrnybrain. I will, however, give the results of a very imperfect examination, as it may save time if any one should go over the ground more carefully before I can offer any thing better.

Following up the stream by Penycae to the south-east, about one third of a mile south-east of Penycae we find some crushed Sandstone in the bed of the stream, but no clear section. If we proceed straight on, climbing the hill on the north-east of the gully, we soon come upon a long line of fragments of white Grit, nowhere seen in place, but, as far as it can be traced, keeping a uniform distance from the Pale Slates, as if they were portions of a rock broken up along its outcrop. It is true that there are also scattered along the hillside many boulders of felspathic rocks from the high mountains to the west; but they do not occur in a line like the fragments of Grit. In this Grit there are a good many fossils, generally in the form of casts, among which I was able to make out *Petraia subduplicata*, *P. crenulata*, and *Meristella crassa*; and *Pentamerus oblongus* is recorded by Mr. Salter from Cyrnybrain.

The character of this rock is like that of Corwen; the position of the line of fragments relative to the Pale Slates is the same.

To the E. and E.S.E., however, I was unable to follow it into the ravine near Plasuchaf; but up that dingle a thick series of fossiliferous sandy mudstones occur, dipping at a high angle (50° to 70°) to the south.

In these beds the following fossils occur—*Meristella crassa*, *Orthis sagittifera*, *Petraia subduplicata*, and *P. crenulata*.

I would suggest a comparison of these beds with those in the tramway-section at Llansantffraidglynceiriog; while the beds on the hill about half a mile to the N.W. of Plasuchaf seem to be exactly like those in the valley south of Llansantffraid, on the road to Llanarmon.

Along the strike of the Llansantffraid mudstones toward the S.E. we find a curious bed, indicated by a blue line in the Survey Map. This consists of alternations of bands of Limestone and fine Sandstone with wavy lines, very like that into which the Corwen Grit passed in several places. In this I saw several traces of fossils. The only ones I was able to make out were *Favosites alveolaris* and a large form of *Orthis calligramma.*

Both the Limestone and the tramway mudstone pass under the Pale Slates; and these are overlain by the Denbigh Flags, which are worked in the large quarries near Llansantffraid. A bed of Sandstone seen on the hillside north of the village may represent the Grit of Penyglog, near Corwen.

The points that seem to me clear are:—that the Corwen Grits are distinct from the Penyglog Grits; that there is more evidence of a discordancy at their base than at the base of the Pale Slates or of the Penyglog Grits; that there are generally some beds of conglomerate, sandstone, or limestone with sandstone on the horizon of the Corwen Grits; that the general facies of the few fossils obtained from these beds in the district examined is that of the May-Hill rocks; that the mudstones of the ravine north of Plasuchaf are the same as those of the tramway-cutting south-west of Llansantffraid.

Other questions remain to be worked out. Are these mudstones (which have not yet been found immediately underlying the Corwen Grits) merely a local development of those Grits? or are they a lower part of the same group locally developed to a greater thickness? or are they a higher part of the underlying Bala series here and there overlapped by the Silurian Rocks?

I have thought it better to bring forward what I have done, and invite cooperation along the same line of investigation, rather than to wait till I could offer more definite results.

Discussion.

Prof. Ramsay said that about Builth and all round the Longmynd area, and, indeed, over a great part of South Wales, we find Cambrian and Lower Silurian rocks overlain unconformably by the *Pentamerus*-limestone or Upper Llandovery rocks, upon which, north of the Builth country, and also in part of South Wales, come the Tarannon shales and the Denbigh grits with Wenlock fossils, overlain again by the ordinary Wenlock shales. He was particularly pleased, therefore, to hear that *Pentamerus oblongus* occurred in the beds where Prof. Hughes said it was present, as this was strongly in favour of his own opinion that the Upper Silurian strata were transgressive in the Corwen district.

Mr. Hicks considered the Lower (or Corwen) Grits to be the equivalents of the grits at the base of the Lower Llandovery rocks in South Wales. The Upper (or Penyglog) Grits are nearer to the horizon of the May-Hill Sandstones. There was no visible unconformity in the Corwen area between the Lower Grits and the underlying Bala beds in any of the sections he had examined; and he was inclined to believe that this area remained under water during nearly, if not quite, the whole period that the more central parts of Wales were above sea-level. No one had attempted to deny that there was marked unconformity in the Longmynd and some other districts between the May-Hill Sandstones and the underlying rocks; but the beds which could in any way be classed with the Llandovery rocks attained there only to a few hundred feet in thickness at the most, whilst thousands of feet represent that period in South Wales, and apparently also in parts of Denbighshire.

Mr. Hopkinson gave a list of Graptolites he had found in the flaggy slates, which included forms characteristic of beds at the summit of the Coniston Mudstones or the base of the Coniston Flags, and stated that a similar series occurred in equivalent beds in Scotland.

Prof. Hughes, in reply, pointed out that the Graptolites found in the slates of Penyglog were not those of the Graptolitic Mudstones or Stockdale Shales, but agreed exactly with those of the Coniston Flags. So also near Austwick, on the borders of the Lake-district, the Graptolitic Mudstones had not yet been discovered, though they were well developed not far to the north in the Sedbergh district. He had not himself succeeded in finding *Pentamerus oblongus* in the Corwen beds; but Mr. Salter recorded it from Cyrnybrain. He thought the Corwen beds were on the horizon of the calcareous conglomerate of Austwick, and that the Penyglog grit was the equivalent of the Austwick grit, while the flaggy slates of Penyglog represented the flags between the Austwick conglomerate and Austwick grit.

The President insisted strongly on the necessity of studying both the Palæontology and the Field-geology of any district, before attempting to come to any definite conclusion as to its geologica structure and the relative age of the deposits forming it.

13. *On the* Discovery *of* Plants *in the* Lower Old Red Sandstone *of the* Neighbourhood *of* Callander. By R. L. Jack, Esq., F.G.S., and R. Etheridge, Junr., Esq., F.G.S., of the Geological Survey of Scotland. (Read June 21, 1876.)

(Communicated by permission of the Director-General of the Geological Survey).

1. *Introduction.*—Before proceeding to describe the plants from the localities in question, and their geological horizon, we append a brief historical outline of the vegetable remains of the Scotch Old Red Sandstone. The gradually accumulating evidence of a terrestrial flora in the Old Red Sandstone of Scotland since the first discovery of plants in that formation by the Rev. Dr. Fleming and Hugh Miller, and the reference of many of them to land rather than aquatic forms, by Charles William Peach, leads all observers interested in the subject to hope that ere long botanists may be in possession of sufficient material to enable them to illustrate the flora of that remote period in a more satisfactory manner than can be done at present, and to restore, in some degree at least, the bygone vegetable organisms which then existed. As a slight contribution to this end, we have now the pleasure of announcing the discovery by one of us (R. L. J.) of land plants in the Old-Red-Sandstone series of the neighbourhood of Callander, during the progress of the Geological Survey of that district under the direction of Prof. Geikie, F.R.S.

2. *Bibliography.*—One of the earliest notices which has come under our observation is a short paper, in 1811, by the Rev. Mr. Fleming, entitled, 'A Mineralogical Account of Papa Stour, one of the Zetland Islands'*, wherein it is stated that in Bressay, near Lerwick, "the sandstone includes beds of slate-clay, and contains vegetable impressions similar to those common in the sandstone of the coal-fields of the Lothians."

In 1831 the same author describes, in a paper "On the Occurrence of the Scales of Vertebrated Animals in the Old Red Sandstone of Fifeshire"†, with the scales obtained at Parkhill, near Newburgh, and Arbroath, circular flat patches, composed of numerous smaller, contiguous, circular pieces, as probably the conglobate panicles of extinct species of *Juncus* or *Sparganium*. It is probable that these are the Crustacean remains now known as *Parka decipiens*, Flem.

In 1841 Mr. Hugh Miller published his 'Old Red Sandstone,' in which he described the vegetable remains of that series in the north of Scotland as obscure, consisting mostly of carbonaceous markings such as might be formed "by comminuted seaweed." He further noticed the bifurcating nature of some of his specimens, and that one exhibited scars resembling those of *Stigmaria*, whilst the branches of

* Mem. Wernerian Nat.-Hist. Soc. i. p. 175.

† Cheek's Edinb. Journal of Nat. & Geogr. Science, iii. p. 86, pl. ii. fig. 5.

another terminated in hooks. One example showed the remains of ligneous fibres; and this only was regarded by Miller as of terrestrial origin. In Fife, he says, the vegetable remains are "dark impressions of stems . . . . . . confusedly mixed with what seem slender and pointed leaflets"*. In the Carmylie-Parish Quarries, "irregularly grooved stems branching out into boughs at acute angles were also noticed."

In 1853 Dr. J. D. Hooker published a "Note on the Fossil Plants from the Shetlands, collected by the Right Hon. Henry Tufnell," which are provisionally referred to two species of *Calamites* †.

In 1855 Mr. C. W. Peach presented two short notes to the Royal Geological Society of Cornwall (namely "A Notice of the discovery of Land Plants and shells in the Lower Old Red Sandstone of Caithness," and "A Note on the Fossil Flora of the Lower Old Red Sandstone of Wick, Caithness")‡, in which he respectively notices the occurrence of wood at several localities near Thurso and Dunnet Head, and records the discovery of land plants at Kilmster, near Wick.

The Rev. J. Duncan described and figured, in Jeffrey's 'History and Antiquities of Roxburghshire and adjacent Districts'§, published in 1855, plant-remains from Denholm-Hill Quarry, consisting of dichotomizing stems, regarded by the author as fucoidal, another specimen with more or less alternate branches, which he supposed to be a land plant, and, lastly, an organism described as "the radical portion of what we cannot hesitate to call a species of Calamite."

In 1855 Hugh Miller read before the British Association a paper "On the less-known Fossil Floras of Scotland"||, in which reference was made to the bituminous nature and dark colour of the Caithness Flagstones, the latter arising chiefly from the vegetable portion of the contained organic matter. He further notices the discovery of a *Lepidodendron* in the Caithness Flagstones at Clockbriggs Quarry, and a form resembling the maiden-hair spleenwort, in the Orkney Flags. At the same meeting, Mr. J. Miller, of Thurso, exhibited a collection of plants from the Caithness Flagstones similar to that described by Mr. H. Miller ¶.

In 1857 the 'Testimony of the Rocks' appeared**, with the author's figures of many of the previously mentioned plants. Three sectional figures of the Cromarty Conifer, examined by Prof. Nicol, are given, magnified 40 diameters††, and two vignettes of the supposed fucoidal remains ‡‡, regarded by Mr. Salter, however, as roots. Reference is made to a "curious nondescript vegetable organism"

* Afterwards pronounced by Prof. Nicol to be coniferous in character.

† Quart. Journ. Geol. Soc. ix. pp. 49, 50.

‡ Trans. Royal Geol. Soc. Cornwall, vii. pp. 230 and 289.

§ 2nd edit. 8vo, p. 123, pl. vii.

|| Brit.-Assoc. Rep. 1855, Trans. Sect. p. 83.

¶ *Ibid.* p. 85.

** Testimony of the Rocks, or Geology in its bearings on the Two Theologies, &c., 8vo.

†† *Ibid.* p. 11.

‡‡ Figs. 118 and 119.

found at Stromness by Dr. Fleming, provisionally named by him *Stroma obscura*, " in all probability a plant of the sea"*. It consisted of a " flattened cylinder traversed above and below by a mesial groove extending to the extremities." A figure is given of a fine *Lepidodendron* from Thurso †, and a description of the Clockbriggs specimen, which was four feet in length, and threw off two branches at an acute angle. The specimen was covered with a brittle coal, and internally was converted into a brown calcareous substance similar to that of the celebrated Granton and Craigleith trees ‡. Mr. Miller describes some supposed Calamites from Thurso §, 9 inches to 1 foot in length, and figures a plant discovered by Dr. Fleming, with the usual thick rachis of palæozoic plants, and pinnules even smaller than those of our true Maiden-hair ‖. Not the least interesting of the plants figured in the 'Testimony' is the *Palæopteris* (*Cyclopteris*) *hibernicus*, Forbes, from the Upper Old Red Sandstone of Prestonhaugh, near Dunse ¶.

We are indebted to the late Mr. J. W. Salter for one of the first connected accounts of these old plants. His paper "On some Remains of Terrestrial Plants in the Old Red Sandstone of Caithness" was published in 1858**. He there describes and figures "Coniferous wood" allied to *Dadoxylon* of the Coal Measures, "Rootlets," and two plants to which specific names were assigned, *Lycopodites Milleri*, Salter, and *Lepidodendron nothum*, Salter (non Unger).

In the same year also (1858) appeared a short paper by Dr. J. A. Smith, "Notes of Fossils from the Old Red Sandstone of the South of Scotland"††, in which plants similar to those previously discussed by the Rev. J. Duncan are noticed from Denholm-Hill Quarry, Roxburghshire.

To his original description of the genus *Psilophyton* in 1859, Dr. J. W. Dawson ‡‡ appended a few remarks on Scotch Old-Red-Sandstone plants. He considers the dichotomous roots described by Salter, and the bifurcating plants noticed by Hugh Miller, to belong to his genus *Psilophyton*, and probably to *P. princeps*, Dn., or *P. robustius*, Dn.

1859.—Appended to the late Sir R. I. Murchison's paper "On the succession of the older Rocks in the Northernmost counties of Scotland"§§, are a series of figures by Mr. J. W. Salter, identical with those given in certain editions of 'Siluria,' with an additional figure of a large stem with subalternate lateral branches found at Thurso by Mr. C. W. Peach, and named after him by Mr. Salter *Caulopteris Peachii* ‖‖, and another representing the young shoot of a coniferous (?) plant with leaves from Duncansby Head ¶¶.

In 1862 Prof. R. Harkness communicated to the Geological Society a paper "On the Position of the *Pteraspis*-beds, and on

* Testimony of the Rocks, p. 430.
† *Ibid.* p. 432.
‡ *Ibid.* p. 447.
§ *Ibid.* pp. 433, 434.
‖ *Ibid.* p. 445, fig. 122.
¶ *Ibid.* p. 454, fig. 124.
** Quart. Journ. Geol. Soc. xiv. pp. 72–76.
†† Proc. Royal Phys. Soc. Edinb. ii. p. 36.
‡‡ Quart. Journ. Geol. Soc. xv. p. 482.
§§ Quart. Journ. Geol. Soc. vol. xv. p. 407, fig. 13.
‖‖ *Ibid.* p. 408, fig. 14*a*.
¶¶ *Ibid.* fig. 14*b*.

the Sequence of the Strata in the Old-Red-Sandstone series of South Perthshire" (Quart. Journ. Geol. Soc. xviii. p. 253, read 16 April, 1862). This paper will be afterwards referred to.

In the fourth edition of 'Siluria,' published in 1867, Sir R. I. Murchison gave figures of the chief vegetable remains of the Scotch Old Red*. The longitudinally fluted stems mentioned by previous writers as common throughout the formation were microscopically examined by Prof. Quekett, and found to exhibit true coniferous structure, approaching that of the Araucarian group.

Mr. W. R. M'Nab communicated† his researches into the structure of Hugh Miller's Cromarty lignite, which had been previously examined by Prof. Nicoll. Mr. M'Nab pronounces the structure exhibited by these sections to be allied to the Coniferæ, but not referable either to *Dadoxylon* or *Dictyoxylon*, as surmised by Mr. Salter: he proposes the name of *Palæopitys Milleri* for the Cromarty lignite, and pronounces it distinct from the coniferous wood examined by Prof. Quekett for Sir R. I. Murchison.

The welcome appearance, in 1871, of Dr. J. W. Dawson's monograph of the Devonian and Silurian plants of Canada ‡, published by the Geological Survey of Canada, not only afforded botanists an opportunity of becoming acquainted with the British-North-American fossil flora of those periods in a collective form, but, what was of equal importance, put us in possession of Dr. Dawson's notes on Mr. C. W. Peach's extensive collection of Scotch Old-Red plants. In the latter, Dr. Dawson noticed two species of *Psilophyton*, one allied to *P. princeps*, Dn., the other to *P. robustius*, Dn. There are three species of *Lepidodendron*: one, perhaps *L. nothum*, Salter, Dr. Dawson considers closely allied to his *L. gaspianum*; the second is allied to *Cyclostigma densifolium*, Dn.; and the third, that described by Salter as *Lycopodites Milleri*, he considers an herbaceous plant. The collection also contains a *Cyclopteris* (allied to *C. Brownii*, Dn.), a *Calamites* (near *C. transitionis*, Dn.), *Stigmaria*, bark of *Sigillaria*, a plant probably allied to *Anarthrocanna*, and pieces of Coniferæ §.

In 1872, Mr. C. W. Peach delivered a Presidential Address to the Royal Physical Society of Edinburgh, "On the Fossil Flora of the Old Red Sandstone of the North of Scotland," when drawings of all the discovered forms were exhibited. In the 'Journal of Botany' for 1873 Mr. Carruthers gave a paper "On some Lycopodiaceous plants from the Old Red Sandstone of the North of Scotland." He there refers the fragments figured by Miller, on plate vii. of the 'Old Red Sandstone,' to Dawson's *Psilophyton*, and proves that the coniferous rootlets of Salter are really the upper branches of his *Lepidodendron nothum* and *Lycopodites Milleri*, all of which Carruthers considers identical with *Psilophyton* (*Haliserites*) *Dechenianus*, Göppert; further, *Caulopteris Peachii*, Salter, is probably a fragment of a large plant allied to *Psilophyton robustius*, Dn.

* *Op. cit.* p. 269, foss. 73. † Trans. Bot. Soc. Edinb. 1870, x. p. 312.

‡ The Fossil plants of the Devonian and Upper Silurian Formations of Canada, pp. 92, pls. xx. 8vo. Montreal, 1871.

§ *Op. cit.* p. 77.

In the foregoing notes we have endeavoured to give a short and concise sketch of the literature of the Old-Red plants of Scotland. We have not thought it necessary to refer to the general accounts to be found in various manuals.

3. *Description of the Specimens.*—Plant-remains in various states of preservation, but chiefly of the most fragmentary nature, have been met with by one of us [R. L. J.] at no less than twelve localities; and specimens have also been collected by Mr. A. Macconochie, one of the fossil-collectors of the Geological Survey. Those to which the greatest interest is attached, now to be described, and fortunately the best-preserved, occur in a fine-grained blue-grey micaceous sandstone near Braendam House, near Callander (group C. of the following Table, p. 220).

The specimens, as we now find them, appear as elongated flattened stems, on an average about one inch wide, and are either casts in the

Fig. 1.—*Psilophyton* (?), sp.

Portion of a simple stem, with the cellular tissue destroyed at one end, leaving the vascular axis, from the Quarry near Braendam House, Callander.

Fig. 2.—*Psilophyton* (?), sp.

Portion of a stem showing bifurcation, from the south-west corner of Muir Plantation, near Braendam House, Callander.

fine-grained matrix, or thin carbonaceous black films left by the soft cellular tissue. They are ornamented either with a series of pucker-like depressions, when viewed from the interior, or with a number of wart-like eminences, when seen externally. These are the scars of the points of issue of the vascular bundles passing to the leaves. Along the margins of the stems are a series of spine- or thorn-like projections, which may be the leaves themselves or only their persistent bases, and are apparently arranged in spirally oblique rows. They appear to be impunctate, although Mr. Carruthers thinks he has detected a cicatrix in one or two of them. In some of the specimens, around and near the scars, are a series of indistinct longitudinal more or less parallel lines, or perhaps wrinkles. Either as a faint impressed line on the surface of the micaceous matrix, or as a slender flattened carbonaceous band, is seen the internal axis of the stems, probably scalariform, and longitudinally striated. In fig. 1, this axis may be seen extending beyond that part of the specimen from which the cellular tissue has been removed; fig. 2 represents what appears to be a dichotomously branching stem.

After submitting the specimens to a careful and close examination, we were convinced of their great resemblance to and affinity with Dawson's genera *Psilophyton* (especially *P. princeps*), and *Arthrostigma**, our own conclusion being that the closest affinity was with the latter genus. With the view of receiving support in this opinion, or, on the other hand, correction, if necessary, the best specimens were submitted to Mr. R. Etheridge, F.R.S., and Mr. W. Carruthers, F.R.S. The latter has been kind enough to furnish us with some notes which we now append, with his permission. We take this opportunity of thanking Mr. Carruthers for his assistance.

In *Psilophyton princeps*, Dn., the leaves are described as rudimentary, or short, pointed, and rigid, becoming hard, spinous and prominent; in *Arthrostigma gracile*, Dn., as linear and rigid, with circular bases, and nearly at right angles to the stems, sometimes resembling spines. The spinous character is exhibited in our specimens, the spines more closely resembling those of *P. princeps* in their slightly curved form than those of *A. gracile*, which are almost at right angles to the stem, and much less crowded and inequidistant than in *P. princeps*. We at first thought that the scattered scars were impunctate; but Mr. Carruthers has detected what he thinks may be a cicatrix scar in one or two of them. The following are his remarks on the specimens submitted to him:—

"They have a true Lepidodendroid structure. The axis consisted of a slender column of vascular tissue; the soft cellular tissue left an undefined carbonaceous stain, except where the opening for the passage out of the vascular bundles existed, the scars of which are well seen from the inside. These are like *Cyclostigma*-markings; but in this specimen they are certainly the markings on the inner surface of the false bark of these plants. The spines are, I believe, the persistent bases of the leaves, not the leaves themselves, though that is possible. But I see, I think, indications of their being bases

* Dawson, *op. cit.* pp. 37-42, pls. ix. & xiii.

from which the leaves have disappeared. The leaf is not clean-cut on the upper margin, but has something like a cicatrix scar.

"As to their name, it is probably the larger stem of a plant like Dawson's *Psilophyton princeps*, with which it agrees in structure &c. No doubt his *Arthrostigma* and *Cyclostigma* are the same things; but we yet want light as to the true nature of these Devonian Lycopods."

The preceding facts comprise all the information we at present possess bearing on these interesting fragments. Beyond the probable dichotomous method of branching, we are unacquainted with any of the broader characters; neither do we know any thing of the fructification. The plentiful manner in which the matrix is traversed, gives rise to the hope that the discovery of more perfect specimens is only a matter of time and careful search. Under these circumstances we content ourselves with appending a short provisional description under the name of *Psilophyton* (?), sp., in accordance with the suggestion of Mr. Carruthers, as given above.

Psilophyton (?), sp.

Stems branching dichotomously, and covered with spirally oblique lines of short, rigid, pointed and slightly curved thorn- or spine-like projections, the persistent bases of the leaves, or perhaps the leaves themselves. Axis composed of a slender column of vascular tissue, surrounded by a cylinder of cellular tissue.

4. *Geological Notes on Horizon.*—It now only remains for us to indicate the horizon of the plant-bearing flagstones within the limited district where these have been met with. This region is but the smaller end of the largest Scottish area of the Lower Old Red Sandstone formation; and the structure of the greater part of that area has yet to be mapped out. It is not improbable that similar flagstones containing similar fossils may yet be discovered in other places and at various horizons. It would be premature in the mean time to correlate the divisions of the strata, within the limited area in question, with those of separate and distant contemporaneous areas, considering the paucity of fossil and other evidence.

If we traverse a line parallel to the course of that part of the river Teith lying between Callander and Stirling, and about four miles to the north-east of that river, we meet, in a great synclinal trough, with an immense thickness, though by no means the whole, of the Lower Old Red Sandstone strata. The highest or axial beds of this trough cap horizontally the tableland of Uamh Mhor and Uamh Bheag, while the subjacent beds crop out on the south-east, with a dip gradually increasing to about 30° at the Sheriffmuir, and on the north-west with a dip which rises rapidly to very near the vertical at the heads of the Keltie and Ruchil Waters, where a great fault brings up the Silurian rocks of the Highlands.

As will be readily understood, from the trappean and conglomeratic nature of a large portion of the formation, especially in its lower parts, the strata vary very widely in character and in thickness, within a short distance. The following is a rough *ad interim* Table of the strata occurring in the trough cut by the section-line above referred to. It will be seen that the conglomerate beds of the series are thicker to the north-west of the axial line, while the finer deposits thicken out in the opposite direction.

Centre of Trough, Uamh Mhor &c.

A. Fine red conglomerate, with matrix of siliceous sand, enclosing pebbles of white quartz, porphyrite, and Silurian grit. The pebbles frequently angular .... 300 ft.

North-west side of Trough. Heads of Keltie and Ruchil Waters.		ft.	*South-east side of Trough. Braes of Doune, Allan Valley and Sheriffmuir.*		ft.
B. Red pebbly sandstone, matrix mainly siliceous		500	B. Red pebbly sandstone		550
C. Greenish-grey flags and thin-bedded sandstones		500	C. Greenish-grey flags and thin-bedded sandstones		750
D. Conglomerate, stones up to 2 inches in diameter, mostly of white quartz, some of porphyrite, and various Silurian rocks	3300 ft.		D. Fine-grained brown sandstones and dull brown shales	1700 ft.	
Red Shales, conglomerates, and grey sandstones	1100 ,,		Crumbling felspathic shales	500 ,,	
Brown gritty sandstones and brown shales with calcareous nodules and crustacean-tracks	(?)800 ,,		Chocolate-coloured sandstones with calcareous nodules and a few pebbles	8400 ,,	
	——	5200		——	10,600
			E. Bedded porphyrites of Wharry Burn		200
F. Very coarse conglomerate with well-rounded blocks, up to 2 feet in diameter, of porphyrite and quartzite, chiefly porphyrite		1500	F. Course trappean conglomerate		1100
G. Bedded porphyrites abutting against fault about a mile south of the section-line.			G. Bedded porphyrites, melaphyres and ashes of the Ochils, their base masked by a fault.		

In the paper by Prof. Harkness, of 1862, above referred to, the "grey sandstone passing upwards into red sandstone," and overlying the trappean conglomerate (F in above Table), is stated to have yielded remains of *Pteraspis*. These *Pteraspis*-beds are probably inferior in position to those marked C in the above Section. Professor Harkness remarks, "no traces of plants, so far as I am aware, have been found in this [Bridge of Allan] neighbourhood; nor are there any remains of Crustaceans."

It is in the flagstone group marked C that the plant-remains above described are found. No large quarry or natural section in the group fails to furnish at least a few traces of plants; but here and there surfaces are to be met with which are quite black with felted vegetable remains. In one or two places (notably Cameron Plantation near Balloch) lenticular patches of anthracitic coal a few lines in thickness have been observed. The flagstones are generally grey, with a more or less distinct greenish tinge, and contain pellets of shale and sparsely scattered pebbles of white quartz. Felspathic and siliceous granules contribute in about equal proportions to the composition of the flagstones. The flags, which are divided by green, grey, blue and purple shales, are extensively used for building-purposes in the neighbourhood (the Duke of Montrose's principal seat, Buchanan House, for example, being built of them), and occasionally for pavement, although they are less hard and durable than the Arbroath and Caithness flags. In former days they were frequently employed as tilestones; but this heavy roofing-material has entirely given place to the slates of the Highland border.

We may now shortly trace the flagstone group from the Braes of Doune southwestward to the Clyde.

The fall of the ground from the Braes of Doune to the river Teith at once denudes the flagstone group of the overlying sandstones and conglomerates, so that in the valley the centre of the trough is formed solely by the flagstones. This continues to be the case till the raised beach-deposits of the Carse of Forth to the south of Thornhill obscure the solid geology.

South of the Carse of Forth, the Lower Old Red Sandstone area is rapidly narrowed by the south-westward continuation of the fault which bounds the Ochils on the south side. Extending from Kippen to Cardross Park on the Firth of Clyde, this fault brings, on its south-eastern side, the Calciferous Sandstones down against the Lower Old Red Sandstones. On the south side of the Carse of Forth, brown felspathic sandstones, probably representing those of group B, overlie the Flagstone group, which here dips to the south-east. The Flagstone group thickens considerably towards the Clyde, and between Geilston and the foot of Loch Lomond (where no other member of the Lower Old Red Sandstone formation is seen) it cannot be less than 2000 feet in thickness. Here the axial beds of the synclinal trough are concealed by the fault which throws down the Calciferous Sandstones against the Lower Old Red Sandstone. The Lower Old Red Sandstone does not reappear on the southern shore of the Firth of Clyde.

5. *Locality.*—Quarry, 2½ miles S. by W. of Braendam House, E. of Callander, and S.W. corner of Muir Plantation, near Braendam House.

6. *Other Plant-remains.*—Fragments of plants have been found in the Lower Old Red Sandstone at the following localities:—

(*a*) *Buchanan-Castle Quarry*, near Drymen, Stirlingshire, in a thin-bedded sandstone. A small stem (?), nearly three inches long by two or three lines wide, with portions of the black carbonaceous matter into which it has been converted adhering, and a good deal wrinkled.

(*b*) *Old Quarry at Small Reservoir, near Kilmahew*, north of Cardross, Stirlingshire, in a light-coloured thin-bedded sandstone. A stem three inches long by about two and a half lines wide, with a lateral branch one inch long. The substance of the specimen is converted into a similar material to the foregoing, but is brown in colour, instead of black. Along the margins of the stem and branch are a series of delicate horizontal processes given off at right angles. We believe this to be a *Psilophyton* allied to *P. princeps*, Dn.

(*c*) *Green Burn*, *Keltie Water*, 1½ miles S. of Gartmore, Stirlingshire. A micaceous sandstone full of linear vegetable fragments, one specimen not unlike some examples of *Pinnularia*, Dn.

(*d*) *Keltie Water, above Chapellarroch*, 1 mile S. by W. of Gartmore, Stirlingshire. Portions of plants, probably stems, one having a very Lepidodendroid appearance, although leaf-scars were not discernible.

(*e*) *Keltie Water below Brackland Linns,* 1½ mile E. of Callander, Perthshire. Fragmentary remains.

(*f*) *Quarry at Kames Farm*, 4 miles S. by E. of Callander. Fragmentary remains.

(*g*) *Quarry at Easterhill*, 1½ mile E. of Gartmore, Perthshire. A stem three and a half inches long, giving off subalternate branches, two on each side, and in general appearance very closely resembling *Psilophyton robustius,* Dn.

(*h*) *Quarry in Cameron Plantation,* near Alexandria, Dumbartonshire. A grey flaggy sandstone crammed with plant-remains varying from mere comminuted fragments up to large specimens. There is one specimen in the collection, probably a stem, nine inches long by nearly one inch and three quarters broad, and at one end between four and five lines thick. Internally it is a sandstone cast; externally the vegetable matter is converted into the usual black bituminous substance. There is also a small stem of *Psilophyton* resembling that from locality *b*.

(*i*) *Turnpike road at Overballoch,* Loch Lomond, Dumbartonshire. Sandstone resembling that at the last locality, and similarly yielding fragmentary remains.

14. *On the* Remains *of a* large Crustacean, *probably indicative of a* new Species *of* Eurypterus, *or allied Genus* (Eurypterus? Stevensoni), *from the* Lower Carboniferous Series (Cement-stone Group) *of* Berwickshire. By Robert Etheridge, Jun., Esq., F.G.S., of the Geological Survey of Scotland. (Read December 20, 1876.)

1. *Introduction.*—Of the genus *Eurypterus*, so largely represented in the Upper Silurian rocks of Great Britain, and much more sparingly in the Old Red Sandstone, we have but a single Carboniferous species, *Eurypterus Scouleri*, Hibbert, from a freshwater limestone of the Lower Carboniferous Limestone series at Kirkton, near Bathgate, Linlithgowshire. The bibliography of this species is not heavy. We have first Dr. Scouler's original description under the name of *Eidothea* *, next the memoir of Dr. Hibbert † wherein the specific name is suggested, then a notice by the late Mr. J. W. Salter ‡, and lastly Mr. H. Woodward's more detailed description and magnificent figures §.

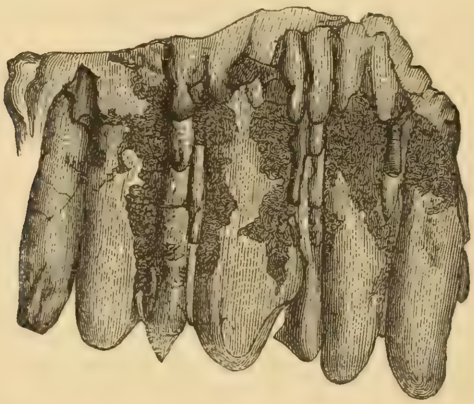
Last year Mr. W. Stevenson, of Dunse, presented to the collection of the Geological Survey of Scotland three fragmentary specimens of great interest, which he had collected at Kimmerghame quarry, near Dunse. I at once saw, as had previously been surmised by Mr. Stevenson, that these specimens were, in all probability, portions of a very large *Eurypterus*, of far larger size than *E. Scouleri*, Hibbert. A rough drawing of one of the fragments was sent to my friend Mr. H. Woodward, F.R.S., who, so far as he was able to form an opinion from the drawing, confirmed my view. Since Mr. Stevenson presented his specimens to the Survey Collection, one of the fossil-collectors of the Scotch branch of the Geological Survey (Mr. A. Macconochie) has visited Kimmerghame quarry in the course of his duties, and succeeded in obtaining five more specimens, similar, speaking generally, to those found by Mr. Stevenson. I have this year been favoured by Mr. Smith of Preston Farm, near Dunse (through Mr. Macconochie), with two additional fragmentary specimens from the same locality, both very interesting, but one more particularly so, as it appears to represent a considerable portion of a body-segment. Lastly, we are again indebted to Mr. Stevenson for six further specimens which have only lately come to hand; they represent portions, I believe, of body-segments. Irrespective of counterparts, Messrs. Stevenson, Smith, and Macconochie, have thus obtained from the Dunse neighbourhood no less than thirteen specimens, which, although fragmentary, and differing a little in size amongst them-

* Edinb. Journ. of Nat. and Geograph. Sc. 1831, p. 352, pl. 10.
† Trans. Royal Soc. Edinb. 1836, xiii. p. 280, pl. 12.
‡ Quart. Journ. Geol. Soc. 1863, xix. p. 82.
§ Mon. Brit. Foss. Crustacea, Pal. Soc. pt. 4, 1872, p. 133, pls. 25–27.

selves, appear to indicate a species of far greater proportions than those of *E. Scouleri*, Hibb. In 1867 Professor Page exhibited at a meeting of the Edinburgh Geological Society* portions of *E. Scouleri* from the Lower Carboniferous beds of Berwickshire. Unfortunately no description of these has appeared; they were, I believe, also found by Mr. Stevenson.

2. *Description of the Specimens.*—In his remarks on *E. Scouleri*, Mr. H. Woodward states that the "two anterior body-rings are ornamented with a single row of narrow, acute, well-defined, spine-like squamæ." The posterior free margin of the abdominal somites "is ornamented on its dorsal border, with a series of blunt, rounded, equidistant spines, and the surface itself encased with squamæ, whilst the ventral border is roundly dentated, and that of the penultimate segment more acutely so. The ventral surface is not covered with squamæ, but is finely punctate"†. In the fine fragment represented by fig. 1, may be observed five elongated

Fig. 1.—*Eurypterus* (?) *Stevensoni.*



Spines probably from the dorsal posterior margin of an abdominal somite. From Kimmerghame Quarry, near Dunse, Berwickshire.

and bluntly pointed spines. The two outer on each side are about equal in size, and united one with the other until near their free extremities; they appear to have been separated from the middle and largest spine by a smaller one on each side, now only partially preserved, making in all seven spines. I take these to represent those bluntly rounded spines described by Mr. Woodward in *E. Scouleri* as ornamenting the free dorsal posterior margin of the abdominal somites. The anterior portion of both the spines, in the specimen (fig. 1), and the concavities between them are covered with narrow, acutely inclined, spine-like squamæ, much resembling those figured by Mr. Woodward on the carapace and two anterior body-

* "Notes on some New Fossils (*Eurypterus Scouleri*?) from the Tuedian or Passage Beds of Berwickshire," Trans. Geol. Soc. Edinb. i. p. 57.

† *Op. cit.* p. 137.

rings of *E. Scouleri* *. The following are the measurements of this specimen (approximately):—

	in.	lin.
Length	1	7
Breadth	1	11
Length of central spine	1	2

In another specimen (fig. 2) there are five spines of nearly equal size, although smaller than in the preceding (with perhaps indications along each lateral margin of another indistinctly preserved spine), separated as in the former case by other narrower

Fig. 2.—*Eurypterus* (?) *Stevensoni.*

Spines and scales. From Kimmerghame Quarry, near Dunse. In the collection of Mr. Smith, Preston Farm, near Dunse.

spines. Similarly, the spines are overlain by narrow spine-like squamæ, which gradually, towards the anterior edge, become flat (and partially imbricating?) scale-like squamæ, approaching in form and appearance those on the abdominal somites of *E. Scouleri*, but of far larger size. The measurements of this specimen are:—

		in.	lin.
Length		1	$2\frac{1}{2}$
Breadth		1	3
Length of spines	(about)	0	7

Size of scale-like squamæ, 1 to $1\frac{1}{2}$ line square.

One of the specimens collected by Mr. Macconochie consists of a few of these detached squamæ, one or two measuring four by three lines. Of specimens resembling this there are in the collection several examples. They all, I think (although the outline of each is more or less different, owing to its fragmentary condition), represent portions of the general surface of a body-segment †, with the

* *Op. cit.* pl. 25. figs. 1 *a* and *b*, and pl. 27.

† Or, on second thoughts, fragments of some very large jawfoot (?).

blackened squamæ in various stages of preservation. In one specimen there are a number of casts of squamæ still retaining in the deeper portions the remains of the blackened test. In this instance they are smaller than in the former cases, measuring only about one line by one line and a quarter. Another seems to be a portion of an abdominal somite, and, if this view is the correct one, that of a very large specimen indeed. As compared with any of the abdominal segments of *E. Scouleri*, the length of the specimen (more than three inches), in relation to the breadth, is excessive. The anterior is clearly discernible from the posterior portion by the direction of the flat squamæ wherever they are preserved. If an abdominal somite, the Crustacean of which it formed a part must have possessed an abdomen of very different form from that of *E. Scouleri*. On the other hand, could it be one of the narrower somites near the telson of a large species, similar to the smaller terminal somites in *E. scorpioides*, H. Woodward, from the Upper Ludlow *? Another suggestion offers itself: Is it an ordinary somite of large size bent down laterally, along the median line? I scarcely think so, from the apparent absence of all disturbance of the squamæ, where preserved. Or, on the other hand, is it a segment of one of the smaller appendages? Whichever way this specimen may be interpreted, there is this difficulty, that, as determined by the direction of the squamæ, the anterior end is the smaller, and the posterior the larger of the two—just the contrary to what we should have expected if the specimen, as we now find it, really represents an abdominal somite, but as it should be if it is one of the segments of the smaller appendages as represented in Mr. Woodward's restoration of *E. Scouleri*. In the posterior cross section, below the outer black crust there is visible in the fine-grained matrix another black line; the intermediate space, about two lines thick at the median line of the specimen, may represent the thickness of the test. The measurements are (approximately):—

	in.	lin.
Length	3	5
Breadth	1	0

Length of largest squamæ, 3 to 4 lines.

Of the specimens collected by Mr. Macconochie, two only call for special notice. The first is a cast, 1 in. 7 lin. broad, by 2 in. 6 lin. long, showing spines similar to those of fig. 1, succeeded anteriorly by several series of the spine-like squamæ, gradually passing into the ordinary flattened scale-like squamæ. The second specimen is similar, but not so well preserved. The material composing all the specimens, wherever preserved, is in the form of a blackened shining crust or film, which is easily rubbed off and destroyed, unless the specimens are immediately covered with a protective preparation. Prof. James Hall † has remarked on the imbricating

* *Op. cit.* pl. 29.
† Pal. New York, iii. p. 396.

scale-like sculpture covering some portions of American species, and adds that "the texture appears to have been elastic or leathery, and the substance very thin." These remarks equally apply to the present examples.

A due consideration of the foregoing facts has led me to the conclusion that the large bluntly pointed spines of the above specimens represent those on the posterior dorsal border of the abdominal or body-segments of *E. Scouleri*, of which Mr. Woodward has given an enlarged figure in his Monograph on the Fossil Crustacea *; but in the present instance we also have spines of an intermediate size. The narrow, acutely pointed spine-like squamæ which succeed and partially overlap these large spines, most nearly approach those seen on the head-shield and two anterior segments of *E. Scouleri* †. The scale-like squamæ are larger than those of the latter, although evidently constructed after the same plan, and are much closer together; I also suspect that there is a tendency to imbricate from before backwards. From whatever point of view we look at the elongated and compressed specimen above referred to, either as an abdominal segment bent down along the median line, or as one of the terminal and consequently narrower segments near the telson, or as a segment of one of the smaller appendages, we can arrive at only one conclusion—namely, that it formed part of an animal far larger than, and, in all probability, of very different form from *E. Scouleri*. If fig. 3, represented on the twenty-sixth plate of Mr. Woodward's monograph, is an enlarged view of a portion of *E. Scouleri*, what must have been the size of the individual or individuals of which the present fragments are the remains?

Should further discoveries bear out the view here advocated, that these specimens represent a form specifically distinct from *E. Scouleri*, Hibbert, I would suggest that the name of the gentleman, Mr. Stevenson, to whom the Survey is indebted for the presentation of specimens to its collection, and who first brought them under my notice, should be assigned to them, and name the species *Eurypterus? Stevensoni*. At the same time I also heartily beg to thank Mr. Smith for the loan of his valuable specimens, and Mr. Macconochie, through whom they were placed in my hands.

3. *Locality and Horizon.*—Kimmerghame Quarry, Blackadder Water, near Dunse, Berwickshire; in a light-coloured micaceous sandstone of the Cement-stone group, Lower Carboniferous, or Calciferous Sandstone series.

4. A reference has been made to the exhibition, by Professor Page, LL.D., F.G.S., at a meeting of the Edinburgh Geological Society, of fragments of a *Eurypterus*, also obtained by Mr. Stevenson in Berwickshire. Prof. Page was kind enough to inform me that he gave these specimens to Mr. J. Powrie, F.G.S., of Reswallie, Forfarshire, to whose courtesy I am indebted for the loan of two of them. Their resemblance to the previously described specimens is at once apparent. One of them corresponds remarkably

* *Op. cit.* pl. 25. fig. 3.

† *Ibid.* pl. 26. figs. 1 *a* and *b*, and pl. 27.

well with fig. 1; and although nearly the whole of the blackened crust has disappeared, still the casts of the seven spines preserved exhibit their form and length in a marked degree; and, what is more, we have in this specimen a view of the bluntly rounded ends of these spines; for fortunately they terminate on the immediate edge of the matrix, or, perhaps, rather, the latter has been fractured there. The other specimen is the largest fragment of all, but has only three spines preserved, two of which, the outer ones, are of very considerable size; the elongated spine-like squamæ between them are also well marked and larger than those in any of the other specimens. It is not improbable that both these specimens, with Nos. 1 and 2, may even be the posterior portion of the dorsal surface of the carapace itself, rather than that of one of the somites, a suggestion which is borne out by the size attained by one of Mr. Powrie's specimens.

5. *Locality and Horizon.*—Preston Quarry, near Dunse, on a similar horizon to the last.

Discussion.

Mr. H. Woodward remarked that the remains of *Eurypteri* from the Carboniferous rocks are so distinct from the Upper-Silurian *Eurypteri* of America, Shropshire, Lanarkshire, and Russia, as probably to entitle them to be placed in a distinct genus; and, indeed, at some future day, when more remains are obtained, they may perhaps have to be arranged among the Arachnida, along with many curious fragments which have been called *Arthropleura*, discovered by Mr. M'Murtrie in the Radstock Coal-field, by Mr. Jordan in the Saarbrück Coal-basin, and by Mr. Gibbs in the Manchester Coal-field. *Eurypterus Scouleri* occurs at Kirton with *Sphenopteris Hibberti* in a remarkable siliceous deposit, probably thrown down by an old thermal spring in the Carboniferous period.

Prof. Ramsay remarked that the rock from which the fossils were derived seemed to him to be pretty nearly the equivalent of the Burdie-House Limestone, which he had long ago thought might be to a considerable extent formed by calcareous deposits from thermal waters, probably during a period of great volcanic activity. This would be in favour of Mr. Woodward's opinion.

15. *On the* Pre-Cambrian (Dimetian *and* Pebidian) Rocks *of* St. David's. By Henry Hicks, Esq., F.G.S. (Read November 22, 1876.)

[Plate X.]

Introduction.

In the Geological-Survey Map of North Pembrokeshire, published in 1857, there is in the promontory of St. David's a wide band, coloured as a mass of intrusive syenite and felstone, with altered Cambrians on the north of it, and on the south Cambrians unaltered. In the year 1864, when making a section from this so-called syenite to the south through the Cambrians, I noticed that a considerable portion of it was made up of altered rock, in which the bedding was quite distinct. This portion I then believed to be altered Cambrian, like that marked on the north, and to be quite distinct from the central mass, to the influence of which I thought possibly this change might have been due. On further examination, however, it seemed clear that the syenite did not penetrate any of these beds, and hence that the alteration was in no way due to it. Moreover the masses of rock forming the Cambrian conglomerate appeared to have been derived from rocks apparently identical with those forming this ridge. This discovery led Mr. Salter (whom I guided over the section in that year) and myself to suspect that the ridge of so-called syenite therefore was a portion of what had previously been a "Pre-Cambrian island;" and these views were communicated for the first time by Mr. Salter to the British Association in 1864. At that time no lines of bedding had been discovered in the central or more crystalline part; and we were satisfied to look upon this portion as a great mass of eruptive rock, but Pre-Cambrian in age. In our report to the British Association in 1866 I ventured, however, to suggest that this also for the most part was not of volcanic origin, and that it was chiefly made up of altered sedimentary rock.

In a paper communicated by Prof. Harkness and myself to the Geological Society in 1871, other facts were mentioned tending to prove not only the Pre-Cambrian, but also the sedimentary origin of these rocks, viz:—that the bedding of the central portion had an invariable strike from N.W. to S.E., and hence discordant with that of the overlying rocks; that the chemical composition of the rock proved it not to be true syenite; and that it had associated with it bands of hard greenish-coloured ashy-looking shales, considerably altered in character, but in many instances possessing distinct traces of foliation. In subsequent papers I added a few additional facts; but hitherto the subject has been dealt with imperfectly, as I then devoted most of my time to the immediately overlying series, to which those papers chiefly referred. During the last two years, however, I have given a good deal of time to the further and special examination of these rocks, and I have obtained much additional and valuable information in regard to their distribution and mineral composition.

General Description.

The ridge formed by these rocks attains its greatest breadth near the city of St. David's, where it is rather over a mile wide. It extends in a direction from St. David's to the N.E. for about 4 miles, with an average width of rather less than a mile, and is then cut off by a fault running nearly east and west. To the south of St. David's it is greatly reduced in width by faults on either side. The portion immediately under St. David's is thrown down to some extent to the S.E. by two faults; and hence this part is not entirely in line with the remainder of the ridge. Except in the immediate neighbourhood of the faults, which cross it, the ridge stands boldly out, with a tolerably even rounded surface, the highest points being at least 300 feet above the level of the sea. Low marshy ground marks the lines of the three chief faults. In my map of St. David's (Quart. Journ. Geol. Soc. vol. xxxi. pl. viii.) the width in some places is understated, as I find it necessary, after further examination, to include as Pre-Cambrian all the beds below the Lower Cambrian conglomerates, and to which the latter are unconformable.

I propose now to divide the Pre-Cambrian rocks into two distinct series under the local names of Dimetian (*Dimetia* being the ancient name for a kingdom which included this part of Wales) for the lower, and Pebidian (*Pebidiauc* being the name of the division or hundred in which these rocks are chiefly exposed) for the upper series. Up to the present time no name has been given to rocks in England or Wales which occupy an earlier position than the Cambrians; and as there can be no doubt that these two series of rocks are overlain unconformably at St. David's by the lowest Cambrian rocks hitherto known in Wales, I think I am justified in giving them local names in preference to attempting at present to correlate them with rocks in other countries which may appear to hold a somewhat similar position, but which may nevertheless indicate separate periods in the world's history.

The rocks composing the ridge consist chiefly of compact quartziferous beds, altered shales, and limestones in the lower series, and of altered conglomerates and shales in the upper. The two series are everywhere unconformable to one another, the strike of the beds in the lower being from N.W. to S.E., and in the upper from S.W. to N.E. The Cambrian conglomerates overlap them irregularly, in some places entirely covering over the upper series. The conglomerates of the Cambrian also are almost altogether made up of pebbles derived from the underlying rocks. It is difficult to give a correct estimate of the thickness of either series, because of the faults in the lower, and of the overlapping by the Cambrians of the upper; but it is certain that the lower (Dimetian) cannot be less than 15,000 feet in vertical thickness, as shown by the sections near St. David's; and the upper (Pebidian) have a thickness of over 3000 feet exposed at several points, and undoubtedly are of very much greater thickness, only that they are everywhere more or less hidden by the Cambrians.

Dimetian.

The portion of the ridge formed by these rocks gives an average width of from 2000 to 3000 feet from St. David's northward to the position where they are cut off by the great E. and W. fault at Treglemais and Carnymyl. To the south of St. David's, and especially about midway between St. David's and the coast, the width is greatly reduced by faults on either side. Here only the more central portion of the ridge seems to have been left; and the faults which have so reduced the thickness have in addition dropped the immediately overlying Pebidian beds, as well as some of the lower Cambrians. At the bend in Porthclais Valley the conglomerates of the Cambrian rest immediately on the Dimetian rocks, and a little further east in the harbour still higher beds of the Cambrians. On the coast to the south the highest rocks of the Harlech group strike up against the ridge. With these exceptions, and that of another small area at the north-east end of the ridge near Carnymyl, which is again covered immediately by Cambrian conglomerates, both sides are flanked throughout by the Pebidian rocks. The rocks which compose the Dimetian series are chiefly compact quartz schists, chloritic schists, and indurated shales. Sometimes these shale-bands, as under St. David's, alternate frequently with the quartzose beds; but usually the latter predominate to a very great extent. In section I. (Pl. X.) apparently, there are but few bands of shale; but as there are only a few exposures of the rocks in this section, I am unable to speak with confidence on this point. In the direction of section II. I have had frequent opportunities of examining the rocks in deep wells, in addition to the numerous quarries open; and I have almost everywhere found bands of shale associated with the quartzose beds along this line. The most highly crystalline beds which I have yet seen occur to the north of St. David's. In these the quartz seems to be nearly perfectly crystalline. Other beds between this point and St. David's are also very much altered; but as we go further south the rock seems to be less highly metamorphosed. In section III. there are several bands of shale at the base; but in the exposures along the side of the valley further south, and until we reach near the coast at Porthlisky, the quartzose schists again are very greatly in excess. The portion of this section which extends along the east side of Porthlisky harbour is the most important part, geologically, of the whole ridge, as it not only shows the bedding very distinctly, but the quartzose beds are less altered*, and a change also takes place in

* Mr. T. Davies, F.G.S., of the British Museum, has kindly given me the following report of a microscopical examination of a section of this rock:—

the character of the beds which are associated with them. Instead of the ashy shales as at St. David's, we now find massive beds of calcareous shale and chloritic schists, and associated with them also dolomitic limestone beds several feet in thickness. The limestone beds I only discovered for the first time last year. None of the shales at St. David's contain much calcareous matter, and they do not effervesce with acid; but these shales and schists at Porthlisky, including some of the more compact quartzose schists, effervesce most freely, and on analysis show the presence of frequently over 20 per cent. of carbonates. The rocks are sometimes flaggy, and split easily in the line of the bedding; but usually they are more schistose in nature. The beds vary in thickness from 2 to 15 feet. In addition to the carbonate of lime in these beds, I have detected in them about 0·5 per cent. of phosphoric acid; hence it is more than probable that the lime was deposited by organic aid.

I have not as yet discovered any thing in these beds of a decidedly organic nature. There are markings on some of the surfaces where the rock is split along the line of bedding, which may possibly be organic; but at present, and until further specimens have been found, I would speak with doubt as to their nature.

The quartz schists have generally a greenish or a purplish tint, and the surfaces of the bedding and joints a soft greasy feel.

In this section there are five distinct bands of impure limestone, separated from each other by compact beds of quartz schists. They vary in thickness from 1 to 3 feet, and show considerable differences in their composition. The three lower bands are fine-grained and compact in texture, of a greyish colour, and contain occasionally scattered bits of quartz, serpentine, pyrites, galena, &c. The two upper bands are darker and more ferruginous in character, and usually contain more serpentine *. Occasionally in both are seen

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"It consists of quartz, orthoclase, and an anorthic felspar, with small specks of chlorite; the quartz, however, forms by far the greater part, and is intercrystallized with the felspar in a peculiar manner, somewhat resembling that of graphic granite on a very small scale, recalling to mind very forcibly the intergrowth (if it be such) of the felspar and quartz in the Mull granites. Both of the felspars appear to be considerably altered—so much so that, except in a few instances, the two felspars are not distinguishable from each other. To me its position would appear to be among the metamorphic crystalline schists. Further examination of the rock-specimens, although parts of the same mass, show great variety in the proportions of the constituents. In all of them quartz is by far the predominating mineral; indeed some of them consist almost entirely of it, though it varies from medium crystalline to cryptocrystalline in texture. The chlorite is present in them all, and appears to vary less in amount than the other minerals. In some no calcite or dolomite is visible, whilst in others both occur in large quantity. Only one of the specimens shows undoubted crystals of a felspar. It is evident that no two analyses or microscopic examinations of fragments of such a rock, taken from a few feet apart, could agree."

* The following are analyses of two specimens of these rocks, by Mr. W. H. Hudleston, M.A., F.C.S.:—

bituminous-looking stains; but nothing definitely fossiliferous in character has yet been found in them.

It is evident that the beds in this section at Porthlisky are the highest of the series to be found in this neighbourhood; for the dip is invariably towards the south-west in at least three fourths of the whole ridge. The only place where I have yet found them dipping in the opposite direction is at the north-east end of the ridge. The faults north and south of St. David's do not seem to have caused a repetition of the same rocks, but a slight down-throw to the south-east only. It is evident, therefore, that the thickness of the series must be enormous; but at present I only estimate it at about 15,000 feet. Section III. might have been continued out as far as the Bishop's rock, since at low water I have walked to the Crow rock, and have found the beds still dipping in the same direction. The dip throughout is also high, being generally about 80°. In this section there are several dykes of igneous rock, which appear to have

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I.

A greyish-white sparry mass, with a moderate amount of greenish silicate enclosed. Specks of metallic sulphides, chiefly galena and pyrites. Hard and compact. Sp. gr. 2·801.

Omitting small quantities, the following is the composition:—

Portion soluble in hydrochloric acid.

Water	2·20	
Alumina (including dissolved silica and slight traces of phosphate)	2·40	
Ferrous oxide (traces of ferric)	1·30	
Lime	20·90	
Magnesia	12·50	
Carbonic acid	28·20	
		67·50

Portion insoluble in hydrochloric acid.

Silica	26·00	
Alumina (traces of iron oxide)	3·10	
Lime	1·25	
Magnesia	1·00	
Soda and potash	1·15	
		32·50
		100·00

The bulk of the mass therefore consists of sparry carbonates, viz. crystalline dolomite, with some calcite. It is probable that there is also a small quantity of amorphous carbonate of lime. In the soluble portion there is a small excess of lime and magnesia beyond what is necessary to satisfy the carbonic acid; this, together with some of the alumina and a portion of the ferrous oxide, is in combination with part of the silica. Some of it goes to form the serpentinous or chloritic mineral which imparts a greenish tinge to the mass. In the insoluble portion of the analysis, the abundance of silica points to the presence of free quartz, which, indeed, may be recognized in the hand-specimen; and there is also probably some fine felspathic débris, partly kaolinized, which would account for much of the alumina of this part of the analysis. The insoluble lime and mag-been intruded into the series before they were elevated out of the horizontal position, and before metamorphism had taken place; they are probably fine-grained altered dolerites, being columnar in structure and the columns at right angles to the plane of the dyke*.

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nesia form part of some pyroxenic matter, which is evidently distributed throughout the mass.

II.

A greyish green rock with a gritty feel and very uneven fracture; is pervaded by much brown-coloured spar. Sp. gr. of particular fragment 2·774. No metallic sulphides noticeable.

As in the previous case, omitting smaller quantities, the following is the composition:—

Portion soluble in sulphuric acid.

Water	3·50	
Alumina (very slight traces of phosphate)	4·10	
Ferrous oxide (traces of manganese)	6·09	
Ferric oxide	2·50	
Lime	20·60	
Magnesia	6·70	
Carbonic acid	20·60	
Dissolved silica	3·10	
		67·00
Insoluble portion (principally silica)		33·00
		100·00

The insoluble portion was not estimated in this case; but the same fibrous pyroxenic mineral may be seen, whence there can be little doubt that small quantities of lime and magnesia would be found.

There is less sparry carbonate in this than in No. I.; indeed much of the carbonate of lime would seem to be amorphous. The brown spar is a ferriferous dolomite, which in some specimens exhibits the curved cleavage of that mineral very distinctly. The rest of the soluble magnesia goes to form the chloritic matter, which is uniformly disseminated, and which, along with the quartz, and probably some fine felspathic débris, constitutes a large portion of the rock.

However we might hesitate about No. I., there can be very little doubt that No. II. has all the appearances of having been a mechanical aggregate.

The following is a description of some sections of this dolomitic rock, by Mr. T. Davies, F.G.S:—"In thin sections the principal mass of the rock is seen to consist of a crystalline rhombohedral carbonate (either calcite or a dolomite), varying somewhat in texture. The numerous interstices and cavities have been lined with distinct rhombohedral crystals of the mineral constituting the mass. These interspaces have subsequently been filled up with quartz, in a few instances accompanied by clear calcite, easily distinguishable from the rock-mass. The rock is but semitranslucent when prepared very thin, which is owing to the presence of a grey opaque minutely divided substance, which pervades pretty evenly the whole mass; its nature is entirely unrecognizable by the microscope. The quartz encloses, in cavities and minutely diffused, a considerable amount of a fine-grained granular material, probably of the same nature as that pervading the remainder of the rock: some of the cavities also contain a structureless substance, apparently a chloritic mineral, varying in colour from a grass-green to grey."

* In general appearance these altered dolerites are scarcely distinguishable at

One of these dykes may be examined just above the last limestone-band in section III., and another in the Porthclais valley on the east side near the lime-kilns.

Pebidian.

These rocks everywhere rest unconformably on the Dimetian, the beds being usually at a very high angle, almost vertical and sometimes even slightly inverted. As may be seen by the map (Pl. X.), they extend all along both sides of the ridge, with the exception of a small area at the north-east end and where they are cut off towards the south end by faults. The strike is for the most part from W.S.W. to E.N.E., or parallel with the ridge. They vary considerably in thickness, showing at some places less than 500 feet, and at others over 2000 feet, the thickness being chiefly regulated by the amount of the overlap by the Cambrian conglomerates, which have a strike nearly in a line with them, but dip usually at a lower angle. These rocks, like the Dimetian, are always greatly metamorphosed, and consist chiefly of indurated shales, often porcellanitic in character. In the more compact masses the stratification is generally indicated by narrow dark lines, which give the rock a rather pretty banded appearance. The beds are also frequently intersected by closely approximated joints.

The lower beds of the series, or those resting immediately on the Dimetian axis, are hard compact conglomerates, in which, however, from the great change which they have undergone, the distinctive outline of the pebbles is for the most part lost. The conglomerate seems to be chiefly composed of masses of quartz and altered shale, or such masses as might have been derived from the underlying rocks, afterwards very closely cemented together. The best-exposed sections are at Nun's Well, on the coast south of St. David's, to the east of the fault, and on both sides of the Caerbuddy valley to the east of St. David's. They may also be seen in the St. David's valley to the north and south of the Cathedral; but here superficially they differ somewhat in their appearance from those in the sections to the south of the ridge, being less compact, and decomposing more readily. The more solid portions, however, when examined, indicate a rock of the same texture as that in the other

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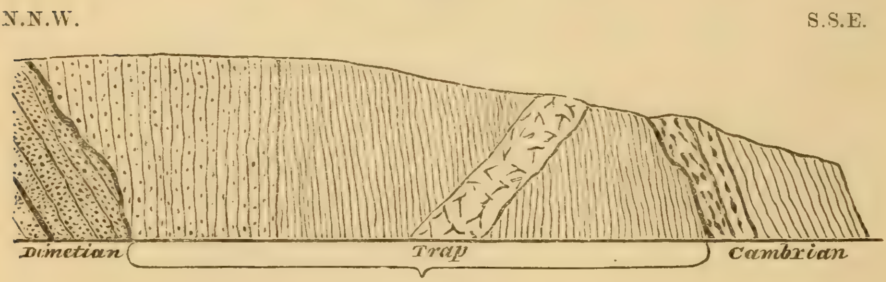
first sight from some of the extremely altered schists; but when seen, as they sometimes are, associated with and penetrating the schists, the columnar structure, always very marked, at once points them out. They were intruded into these rocks at a very early period; hence they have also suffered from the great changes to which the rocks have been subjected. This alone might account for some of the appearances, and for the similarity in character. Prof. Judd, F.G.S., has kindly examined two specimens of this rock for me microscopically; and he reports as follows:—"The base and enclosed minerals are both pseudomorphous. The rock now consists of zeolitic minerals, calc-spar, and 'viridite;' but the forms of the original felspar crystals can clearly be traced, and there is very little doubt that the rock is a greatly altered 'dolerite.' It would be called by continental writers a 'melaphyre.'"

sections. Most of the harder compact conglomerates have been dropped in the hill north of the Cathedral by a fault running in a N.E. direction almost at the junction there of these beds with the Dimetian axis. It is more than probable, however, that the conglomerates on the west side of the St. David's valley are these conglomerates repeated, as they have none of the usual appearances of the Cambrian conglomerates. A tolerably thick series may also be seen in section in the valley between Llanhowell and Carvoriog; and the hard conglomerate beds creep up above the general surface near the road-side between Llanhowell and Treglemaish, and near Bryn close by the fault. To examine the series generally, however, the first two sections mentioned, viz. Nun's Well and Caerbuddy Valley, offer the best opportunities. The lower conglomerates are well seen on the St.-David's side of the valley just above Clegyr Bridge, and the fine compact porcellanite beds in some quarries in the valley about midway between the bridge and the mill. Immediately above the mill the conglomerates of the Cambrian rest unconformably upon the porcellanites; and masses of the latter may here be seen in the conglomerates. At Nun's Well Cliff the porcellanite beds are seen in section perfectly vertical, with the conglomerates again resting upon them unconformably. A thick dyke of compact quartz porphyry cuts across the beds at this point, but does not penetrate the Cambrian above *. This is shown in the following section:—

Section at Nun's-Well Bay, extending from above the Well to the Coast.



* Prof. Judd reports as follows of these porphyries, the best specimens of which are found in the Clegyr valley near Trepuet:—"The base shows little besides zeolitic minerals and patches of 'viridite,' the latter probably derived from some hornblendic constituent. But the quartz veins are numerous, and of large size, and exhibit the stone and (liquid?) enclosures so common in quartz-porphyries. Some of the large quartz grains are beautiful double pyramids, with the intervening prism scarcely, if at all, developed. There are large felspar crystals, some of which are very little altered; and the latter are certainly *plagioclase*. There cannot be the smallest doubt, therefore, that this rock was a *quartz-porphyrite*.

"The rock presents the most remarkable identity of character with the gold-bearing quartz-porphyrite of Cstatye, near Vöröspatak, in Transylvania, which is an eruptive rock of Neogene age. It is probably the oldest quartz-porphyrite yet noticed."

Besides flanking the Dimetian axis as already described, the Pebidian rocks are again exposed supporting the Cambrians at several places in the neighbourhood. The part coloured as intrusive greenstone in the Survey map, running nearly parallel with Ramsey Sound, is made up of these rocks with a few intrusive dykes; and the bedding isf or the most part quite distinct. The width, however, is greater at the upper part than that which is coloured as greenstone, since it includes here in addition the part coloured as altered Cambrian, which extends on the west side from Rhosson to the fault at the Burrows. It seems tolerably evident also that the space intervening between this patch and the St.-David's ridge will be found to be occupied entirely by these rocks, as wherever an exposure is seen the rocks have more the character of the Pebidian than of the Cambrian beds.

The appearance of the rocks in this exposure is much like that at St. David's; but there is a larger proportion of greenish and purplish schists alternating with the compact porcellanitic shales. As the beds lie at a high angle, seldom under 70°, there is probably exposed here at the widest part a thickness of no less than 3000 feet. The Cambrian conglomerates, entirely unaltered, rest unconformably on them to the west of Rhosson rock, and can be traced almost continuously along the western side. On the eastern side, in Porthlisky harbour and at Trevithan, some of the conglomerates at the base may be seen. They seem identical in character with the conglomerates in the St.-David's valley; so there is every probability that we have a repetition of the whole series in the intervening space, and that the altered beds here do not belong to the Cambrian series, as marked on the maps and sections. Another patch may be seen at the south-western side of Ramsey Island, a triangular mass rising up into a bold hill about 400 feet in height. This is coloured as greenstone intruded into the Arenig rocks in the Survey maps. The beds composing this hill are compact porcellanites, like those near St. David's; and the bedding is also easily traced. The Cambrian conglomerates are to be seen resting unconformably upon the beds along the north-east edge.

The fault in Ramsey Sound, along with the numerous ones to be traced in the island, have so altered the position of this portion that the line of strike of the beds has here been quite changed as compared with that in the other, greater masses more inland. There are but few beds of the Lower Cambrian series exposed in the island; but fortunately the conglomerates at the base are well seen at the spot already mentioned, with a strike from W.N.W. to E.S.E., and, as in the other places where they rest on the Pebidian rocks, in an unaltered state. On the east side of this mass is a great fault, which has brought the upper beds of the Arenig series down upon the Pebidian rocks.

The faults in Ramsey Island are highly instructive; for the results usually are of enormous importance, and such as would be productive of almost insurmountable difficulties in an inland or covered district. Here, however, they can be traced in precipitous coast sections; and frequently the line can be followed right across the island from side to side, as the surface is almost entirely barren. The fault on the east side of the hill has a downthrow of at least 14,000 feet, as the Arenig beds found here are the highest in stratigraphical position in that group. The fault which meets it at the N.E. end has also a downthrow of nearly equal extent, since the Arenig beds are again brought down against the very lowest beds of the Cambrian.

About eight miles to the east of St. David's, on the coast near Newgate Sands, there is an oblong patch coloured as granite in the Survey map. This, again, is made up of these Pebidian beds, in somewhat the same state of alteration as in the other places mentioned; and the Cambrian conglomerates again rest upon them unconformably. It is more than probable that there are other exposures of these rocks to the east of the areas already described, and that portions at least of the so-called granites of Brawdy and Hayscastle, and of the felstones to the north of Llanrithan, will prove to be made up of these metamorphosed Pebidian beds. My researches in these neighbourhoods hitherto, however, have not been sufficient to enable me to speak decidedly on this point, though I have recognized in these masses rocks of like character to those at St. David's, and have already obtained facts which tend to show that the unaltered Cambrian beds overlie these also unconformably.

The Pebidian rocks, in consequence of having a strike frequently nearly identical with that of the overlying Cambrians, have been included with the latter in some of my former papers, though even in these I always pointed out that they formed a distinct group in that formation. Finding on further examination, however, that the two groups are everywhere unconformable to one another, that the rocks in the one are throughout always highly metamorphosed, and in the other unaltered, and, what is still more important, that the true Cambrian conglomerates undoubtedly contain masses of the underlying rocks in their altered state, very frequently as pebbles, I have thought it necessary to distinguish them from one another by a stronger line, and hence have in this paper classed these lower beds under the new name of Pebidian. It is certain that some of the boundaries of these rocks will yet have to be enlarged, and that most of the patches coloured as altered Cambrian will prove to be made up of these rocks. In this paper my endeavour has chiefly been to point out spots where the unconformity between them and the Cambrians above, or the Dimetians below, is well marked, rather than to give the superficial areas.

Conclusions.

From the foregoing remarks it will be seen that nearly all the large so-called intrusive masses associated with the lower Cambrian rocks in the promontory of St. David's are only highly metamorphosed sedimentary rocks—and that, instead of being intruded into the Cambrian rocks, the latter really rest upon and have been for the most part derived from them. One mass in Ramsey Island, which was supposed even to have been intruded into the Arenig rocks, consists only of these altered beds with the Arenig rocks brought down against it by enormous faults.

In these metamorphosed rocks are found two distinct formations unconformable to one another. Moreover the rocks belonging to these formations not only show clear evidence of having undergone the several changes of depression, elevation, and metamorphism, previous to the deposition of the Cambrian rocks, but also that the one had undergone all these changes before the deposition of the other. It is evident, therefore, that these Dimetian and Pebidian rocks formed portions of islands or continental lands in Pre-Cambrian times, and that they were subsequently depressed to receive the sediments now known to us under the name of Cambrian.

The various and frequent changes to which these rocks must have been subjected since they were deposited, and which produced the very high state of metamorphism in which they are now found, would doubtless also be more than sufficient to have removed all traces of any organisms that may have been present in them at first. Therefore the absence of fossil evidence, when the high state of metamorphism is taken into consideration, does not in any way tend to the conclusion that the seas or continents during the early epochs represented by these rocks contained no animal or vegetable life. Indeed it would be most unnatural if such were the case; for the mode of deposition and character of the sediments indicate suitable marine conditions, and also that there was nothing in the chemical character or heat of the water which could be detrimental to life. Moreover the limestones, and the large proportion of carbonate of lime found in some of the indurated shales and quartz schists, seem strong evidence of the presence of life at the time they were deposited—indeed, to my mind, are sufficient proof of there having been the direct intervention of life itself.

As far as can at present be made out, these rocks seem to hold the same position in regard to the Cambrian series as do the Laurentian rocks in Canada; and there are many points of resemblance in the rocks themselves. The Malvern rocks described by Dr. Holl, and some altered beds mentioned by Mr. Maw as underlying unconformably the Cambrians in the Llanberis slate-quarries, probably belong to one or other of these series, as also the gneissose rocks in the west of Scotland and in Norway, Sweden, &c. Still, as there is an entire absence of fossil evidence, and frequently of successional evidence also in some of these places, I feel at present that any attempt at a general correlation would be premature.

EXPLANATION OF PLATE X.

Map and Sections of Pre-Cambrian Rocks near St. David's.

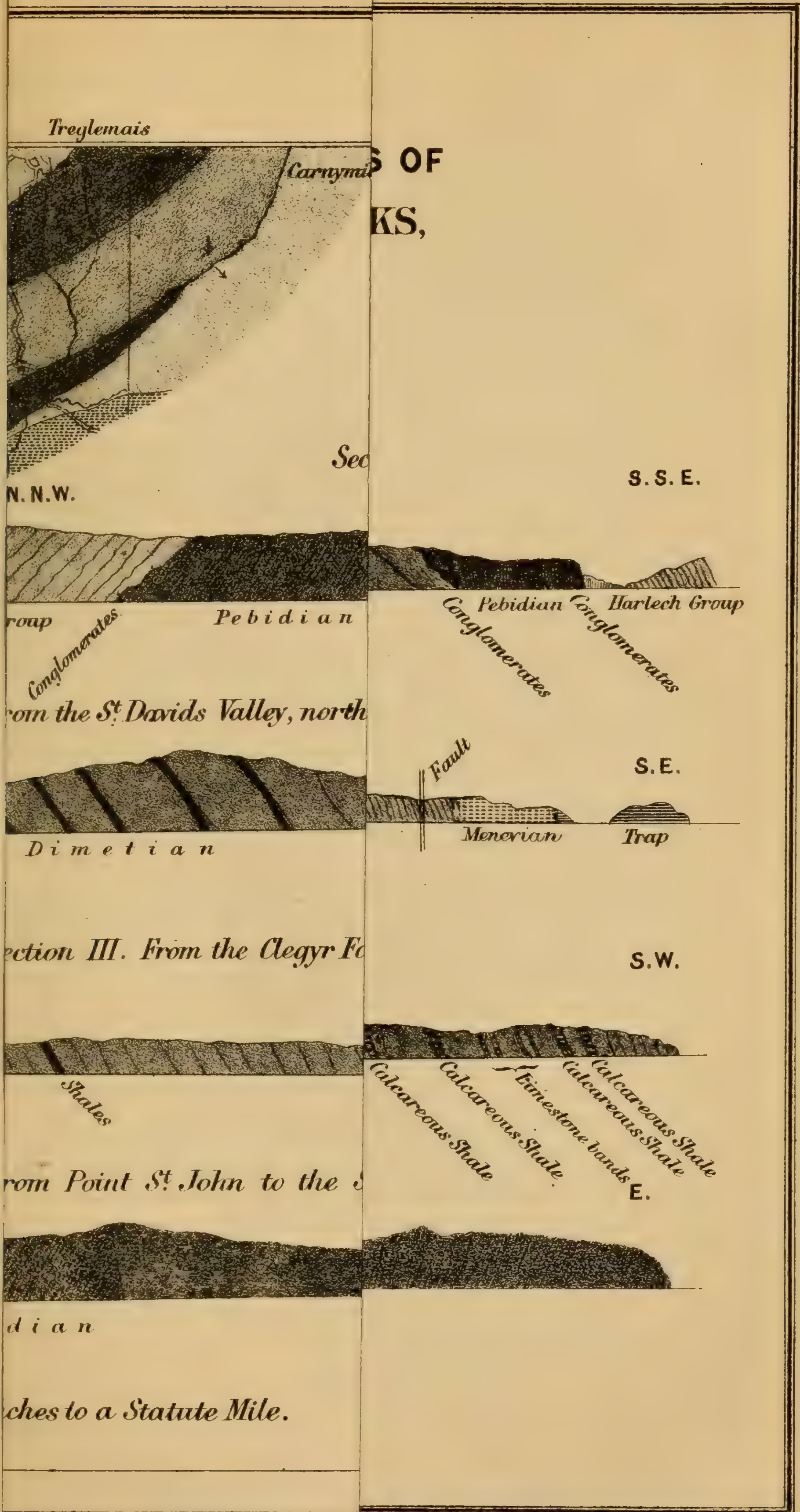
Discussion.

Mr. Judd thought that Mr. Hicks had proved that there were at St. David's two series of rocks older than the Cambrian, but that whether these were of volcanic or of sedimentary origin was doubtful. He thought the author was right in not attempting to correlate the rocks described by him with any foreign formations; for, in the total absence of palæontological evidence, the mere fact that both in America and Europe the Cambrian strata were found to be unconformably underlain by other rocks, was no proof whatever of the contemporaneity of the latter in the two areas.

Mr. Forbes had heard Mr. Hicks's paper with much interest, and the more so from his having studied in Norway a series of rocks so closely resembling the specimens shown on the table that it would be impossible to distinguish them by the eye. Like the rocks of St. David's, those in Norway were, from their stratigraphical position, evidently older than the Cambrian; but not being fossiliferous, nothing definite as to their geological age could be determined. He thought Mr. Hicks had done well in applying new names to these rocks, rather than, as has been too often the case, calling all rocks below the Cambrians Laurentian, especially as these rocks, as well as those very similar to them which he had met with in Norway and Sweden, were very different in petrological character from the original Laurentian rocks of Canada.

Prof. Seeley objected to the adoption of such names as had been employed by the author, as standing in the way of the recognition of the probable correlation of these beds with the older rocks of the north of Scotland. The northern crystalline rocks under altered conditions of pressure might acquire the same structure as those of Wales.

Prof. Hughes, in reply to a question of Mr. Blake's, pointed out that the strike of the Dimetian was nearly at right angles to that of the overlying series, so that, although the breadth of the patch shown in the map was small, there was quite a sufficient distance exposed across the edges of the beds (with a dip of 80°) to give the thickness assigned to the series by Mr. Hicks. The thickness might have to be corrected for other reasons, as it was difficult in such a highly metamorphosed series to determine whether the most conspicuous divisional planes were in every case to be referred to bedding. He thought there was much value in the suggestions of Prof. Seeley, though they did not weaken the case brought forward by Mr. Hicks. It was most unsafe to try to identify these rocks in separate districts by lithological characters alone; and it was true that conglomerates at slightly different horizons near the base of one and the same group might, especially when metamorphosed, be mistaken for the commencement of a new series. But in the case before them other tests also had been applied, and other proofs of unconformity were adduced, such as discordancy of strike, the occurrence of fragments of the immediately underlying group in the overlying conglomerates, &c. He was unable to recognize any thing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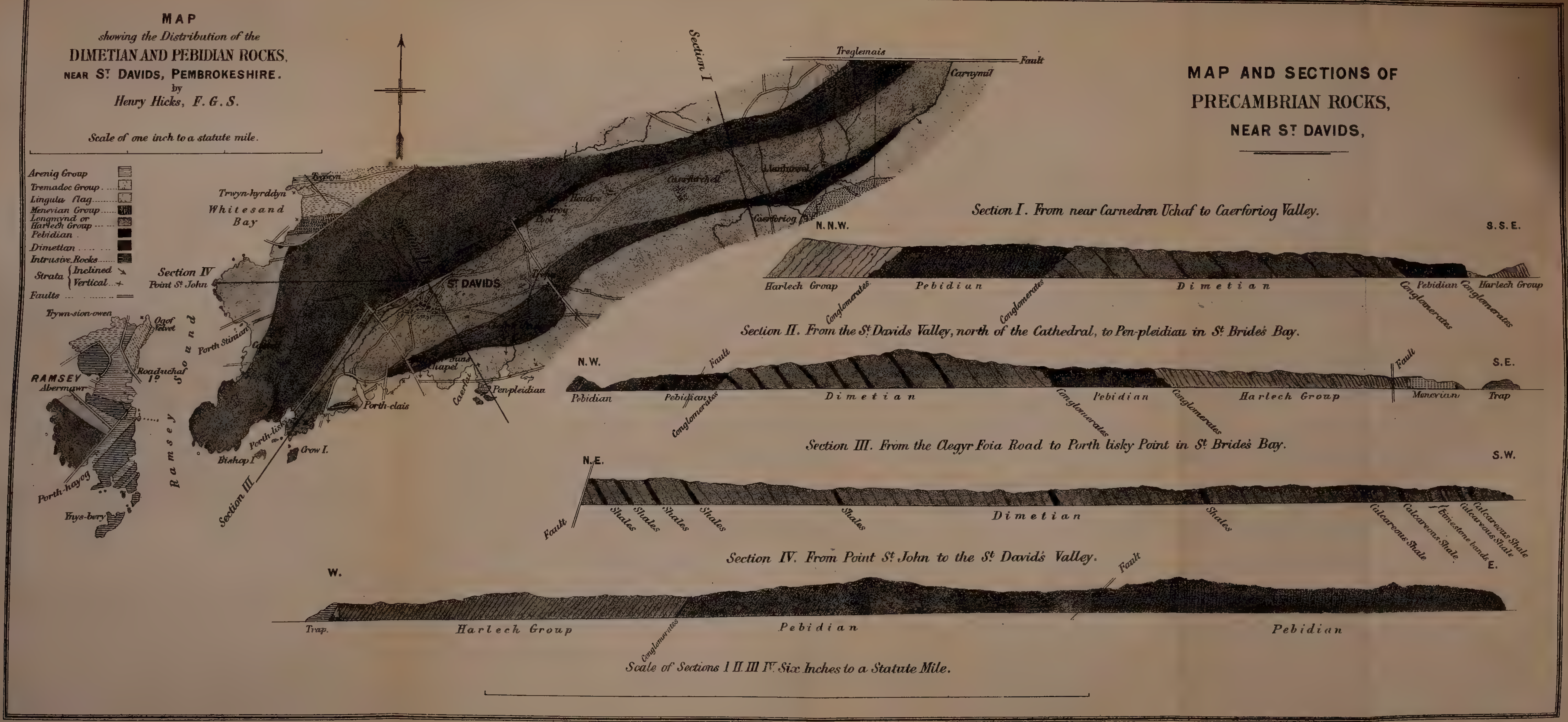

MAP
showing the Distribution of the
DIMETIAN AND PEBIDIAN ROCKS,
NEAR ST DAVIDS, PEMBROKESHIRE.
by
Henry Hicks, F. G. S.
Scale of one inch to a statute mile.
Arenig Group
Tremadoc Group
Lingula flag
Menevian Group
Longmynd or Harlech Group
Pebidian
Dimetian
Intrusive Rocks
Strata Inclined
Vertical
Faults
MAP AND SECTIONS OF
PRECAMBRIAN ROCKS,
NEAR ST DAVIDS,
Section I
Treglemais
Fault
Whitesand Bay
Trwyn-hyrddyn
Section IV
Point St John
ST DAVIDS
Trwyn-sion-owen
Ogof Velvet
Ramsey Sound
Porth Stinan
RAMSEY
Abermawr
Porth-clais
Penpleidiau
Porth-lisky
Grow I.
Bishop I.
Porth-hayog
Ynys-bery
Section III
Section I. From near Carnedren Uchaf to Caerforiog Valley.
N.N.W.
S.S.E.
Harlech Group
Conglomerates
Pebidian
Dimetian
Section II. From the St Davids Valley, north of the Cathedral, to Pen-pleidiau in St Brides Bay.
N.W.
S.E.
Fault
Menevian
Trap
Section III. From the Clegyr Foia Road to Porth lisky Point in St Brides Bay.
N.E.
S.W.
Shales
Calcareous Shale
Limestone bands
Section IV. From Point St John to the St Davids Valley.
W.
E.
Trap.
Scale of Sections I II III IV Six Inches to a Statute Mile.

like organisms in the specimens referred to by Mr. Hicks, but thought that fossils would probably be found in the series by and by. He described the beds passed through in the adit to the slate-quarry on Moel Tryfaen, south of Caernarvon, and thought there was much reason for considering them Pre-Cambrian; but they appeared to him to resemble more the Dimetian of Mr. Hicks than the Pebidiauc beds.

Mr. Etheridge said that these rocks of St. David's are so special that the author was justified in proposing new names for them. He confirmed the author's statement as to the extent of the faults in Ramsey Island.

Mr. Hudleston wished to call attention to the character of some of the rocks to which Mr. Hicks had alluded, and more especially to a class of rocks called "dolomites," which occurred in beds of moderate thickness. The specimen examined was not a true dolomite, but rather a calci-dolomite, the proportion of lime being too great. Moreover, with the carbonates were mixed silicates of probably no very definite constitution. With these was associated a moderate amount of a serpentinous or chloritic substance which pervaded the rock, and was more plentiful and better defined in some other specimens. Such a rock was evidently now much altered from its original state; and there were two alternatives which seemed to present themselves; either we had here a rock which had, perhaps, been broken down from a highly crystalline state; or, what was far more likely, its present condition was the result of alteration from a marly and gritty mud, whose original constituents had arranged themselves into crystalline forms more or less complete according to their several affinities.

Rev. H. H. Winwood objected to the term Pebidian as being merely derived from the name of a Hundred, and not possessing any generally intelligible connexion with the locality in which the rocks in question occur.

The Author, in reply, stated that the names used by him were local and applied to the district. He considered that the succession of the Scotch rocks was not well determined, and that therefore they could not yet be correlated with the Welsh deposits.

16. *On* Pharetrospongia Strahani, Sollas, *a* fossil Holorhaphidote Sponge *from the* Cambridge "Coprolite" bed. By W. J. Sollas, Esq., B.A., F.G.S., Scholar of St. John's College, Cambridge. (Read December 20, 1876.)

[Plate XI.]

In the collection of Cambridge-Greensand fossils exhibited in the Woodwardian Museum, Cambridge, may be seen some rather large and irregular fossil sponges bearing the name of *Chenendopora*, sp. These are the sponges referred to under this name by Mr. Bonney, in his Text-book of Cambridgeshire Geology (p. 41), and included, also with the same generic designation, by Mr. Jukes-Browne * in the lists of fossils given by him at pages 311 and 313 of his paper "On the Relations of the Cambridge Gault and Greensand." The responsibility for the name rests, however, solely with the Museum authorities, the authors cited having simply quoted from the labels attached to the specimens in the Museum, the correctness of which they naturally took for granted. Why the sponge is named "*Chenendopora*" I do not know; certainly it does not possess the characters of that genus as founded by Lamouroux, nor does it correspond with any of the subsequently described species of the genus with which I am acquainted; it is, though long known to Cambridge collectors as an abundant form, an undescribed species, and, from the very important features it presents, merits a detailed investigation.

Outer Form.—The Sponge consists essentially of a somewhat thick plate, which, by folding in various ways, and by uniting with itself wherever its sides are folded into contact, gives rise to a great diversity of forms; thus it is sometimes merely a curved plate, sometimes more or less cup-shaped, while often it is contorted into an intricate pattern, which is made still more intricate by the anastomosis of the plate at every point of contact.

The Plate.—This in its present condition is a solid mineral plate, the two faces of which are, on the whole, parallel to each other and connected by rounded edges; its thickness is constant in the same specimen, or nearly so, and varies only within narrow limits in different specimens; numerous measurements give $\frac{1}{3}$ of an inch for the mean thickness.

From the constancy in thickness of the plate we may infer that it increased chiefly by additions to its edges; thus its growth was marginal.

The Sponge.—The plate, by the more rapid growth of one surface, becomes curved, sometimes to such an extent as to form bowl-shaped or cup-like sponges; in this manner the general curvature from *a* to *g* of the specimen represented in Pl. XI. fig. 1, has been produced. The diagram, Fig. 1, is a section showing this curve.

If the rate of growth of the peripheral portions progressively

* Quart. Journ. Geol. Soc. vol. xxxi. (1875).

increase, the edge will undulate on each side of an imaginary median plane, and thus the gentle folds *a b c*, of Pl. XI. fig. 1, shown in the diagram, Fig. 2, may have arisen.

Fig. 1.—*Section of curve of Sponge.*

Fig. 3.—*Section of recurved fold.*

Fig. 2.—*Section of undulated form.*

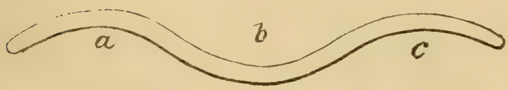


Fig. 4.—*Diagram of approximated sides of a fold.*

The folds so produced become more marked, and one or more may increase so as to become recurved, as at Pl. XI. fig. 1 *c*, here represented in profile (Fig. 3).

The recurved fold, continuing its growth, may reach the surface towards which it tends, and then, by union with it, form a tubular process; the latter, however, more usually arises from the union of the sides of a fold which have grown towards each other, *e. g.* Pl. XI. fig. 1 *e* (and in the diagram, Fig. 4).

The foregoing changes may be observed in most of the stages described in one and the same specimen, *e. g.* that represented in Pl. XI. fig. 1; and thus the originally simple plate may develop into a very complex whole; and since the form, proximity, size, and complexity of its foldings differ in different specimens, the sponge well deserves to be described as "polymorphous."

In most of the specimens from the Greensand the hollow tubular processes and nearly closed folds are filled up with hardened chalk-marl, which must be removed before one can analyze into its elements a form which at first sight appears to be almost inextricably complicated.

General Structure.—The plate is composed, as may readily be seen on breaking it, of an irregular or vermiculate network, consisting of white calcareous fibres imbedded in a solid matrix, either of hardened calcareous or compact phosphatic material. The ordinary intermeshes of the network are not markedly modified either for the outflowing canals or for their oscular openings; hence the oscules are small (the earlier writers on fossil sponges would have said "absent"), and the excurrent canals are scarcely indicated in the skeleton.

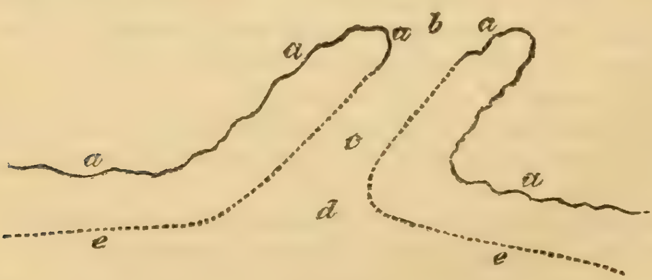
Nevertheless there is a clear distinction between the two surfaces of the sponge, accompanying a differentiation by which the one is specially set apart as an oscular face and the other as originally a poriferous one.

Oscular Surface.—This (Pl. XI. fig. 2) is smooth all over and much more even than the other face; the fibres of its network are broader than those of the interior skeleton; and their exposed outer sides are flattened so as to lie in the same plane as the general surface of the plate, which thus acquires its noticeable smoothness; the intermeshes are more or less circular in outline; and some of them increase at the expense of their neighbours, indicating a tendency towards the formation of more specialized oscular openings.

This surface is always found in the interior of the tubular processes or closed folds of the sponge, and on that side of the plate which is continuous with the interior of the tubular processes through their proximal openings (fig. 5, *e*). The other surface occupies just the opposite position, covering the face which extends over the exterior of the tubular processes (fig. 5, *a*). It is from this relative position of the two surfaces that we are able to determine which is the oscular and which the poriferous one—since in all recent tubular sponges the oscules are confined to the inside of the tube, while the outer side is occupied by the pores; and hence it is clear that the surface we have described above must be the oscular one, while the one to which we now proceed and which covers the exterior of the tubular prolongation, must be the poriferous layer.

Poriferous Surface.—This (Pl. XI. fig. 3) is rough and irregular, owing partly to the fact that the fibres of its network retain the form of those in the interior, and do not undergo any expansion in the plane of the surface, and partly also to the fact that the network is produced irregularly in places above the general surface of the plate, rising and falling in minute ridges and furrows. In addition to the minor inequalities so produced, there are inequalities on a larger scale, such as the long and rounded ridges and furrows, the pits and dimples which mark the surface of the specimen represented in Pl. XI. fig. 1 at *r* and *p*. The poriferous surface is continued over the edges of the plate, and sometimes intrudes to a slight extent on the oscular face, as is well seen at the mouths of the tubular prolongations, where the poriferous surface covers not only the lips but dips for a short distance into the interior of the tube, as is exhibited in the following section (Fig. 5).

Fig. 5.—*Diagram section of a tubular prolongation.*



a, *a*. Poriferous surface. *b*. Distal opening or mouth. *c*. Tubular process. *d*. Proximal end. *e*. Oscular surface.

In using the term "poriferous" surface, we do not, of course, mean thereby to imply that the intermeshes of the network of this surface really represent the pores of the sponge, but simply that the surface is now antoscular and was originally in close proximity with a poriferous layer. The intermeshes, in all probability, represent the openings of the incurrent canals that proceed from the "intermarginal cavities" of the living sponge, of which intermarginal cavities we seem to have indications in those minute furrows which we have mentioned as giving a characteristic irregularity to the poriferous surface. If this is the meaning of these furrows, they ought, according to all analogy, to have been roofed over in the living sponge by a delicate network for the support of the pores; and that we do not observe this now, is due to its disappearance after death, either by decay or by attrition on the sea-floor.

Such a superficial network would be connected with that which originally formed the floor of the intermarginal cavities (and which now lies exposed as the poriferous surface) by transverse fibres passing from one to the other: the outer ends of these fibres would disappear along with the network they supported; but the internal or basal ends might be expected to remain attached to the network from which they spring. Of this nature appear to be certain conical spines produced approximately at right angles from the network of the poriferous surface, and contributing to its general asperity: it is true these spines might possibly be the free ends of growing fibres which were never attached to the outer network; but since the sponge grew marginally, and these are found on the wide surface of the plate, this latter view seems less likely, and I think we may safely regard the spines of the poriferous surface as the remains of fibres which once supported a poriferous network which has now wholly disappeared, and the poriferous surface itself as being actually the floor of intermarginal cavities, now unroofed and converted into pits and furrows.

Minute Structure.—For the investigation of the minute structure, transparent slices were prepared by Mr. Cuttel, taken from the fossil in two directions, one parallel to the surface of the sponge-plate, and the other at right angles across it—parallel and transverse sections. The transverse section alone exhibits the distinction between the primary and secondary fibres alluded to further on, as well as traces of canalicular passages; but as, with these exceptions, there is no difference between the two sections worth mentioning, we shall not require to speak separately of them again.

The sections reveal the same irregular calcareous network which is to be seen in roughly broken fragments.

The primary fibres, or those which radiate towards the margins of the plate in the direction of its growth, are not markedly different in size from the secondary fibres which join them together, and which, having formed conformably to successive growing edges of the plate, naturally join them transversely. The distinction between the primary and secondary fibres is most clearly seen in specimens from the Upper Chalk from which the friable matrix surrounding and infilling them has been removed, so as to leave the skeletal fibres exposed and bare, as in a deciduous recent specimen.

The thickness of the fibres varies very considerably. The smallest measure about 0·0025″, and the largest 0·025″ in diameter, the average thickness being 0·006″.

The superficial aspect of the oscular network shows that its fibres are wider than those of the interior, while these sections prove that they are also thicker; and although no definite canals can be traced in the transparent sections, there is yet observable a general tendency of the intermeshes to open more freely into one another, and thus to form more open and less obstructed passages, in a direction crossing obliquely outwards from the poriferous to the oscular surface; and as these passages seem to become confluent in certain of the intermeshes of the oscular network, to the exclusion of others that have become nearly or quite obliterated by an enlargement of the oscular fibres, we may conclude that the excurrent canals found their way along these more open paths, and drifted together to open into the intermeshes of the oscular network, which thus, though minute, are really oscular openings.

The Fibre.—Under a power of 60 diameters and by transmitted light, the fibres present a transparent and colourless ground of crystalline calcite, which is finely striated in a direction more or less parallel to the general direction of the fibre by fine black lines about 0·00035 of an inch apart. The apparent blackness of these lines is due to their opacity, since, when viewed by reflected light, they shine brightly with a pure white colour.

Examined by a higher power (say from 150 to 500 diameters, though with a very careful examination an enlargement of 60 diameters will suffice) these striæ are resolved into a perfect spicular structure; one sees clearly that the fibres of the sponge are composed of a number of transparent acerate spicules which lie side by side, overlapping at their ends and separately defined by the fine granular opaque white material, which coats them externally and produces the black lines seen by transmitted light (Pl. XI. figs. 5, 6, 7, 8).

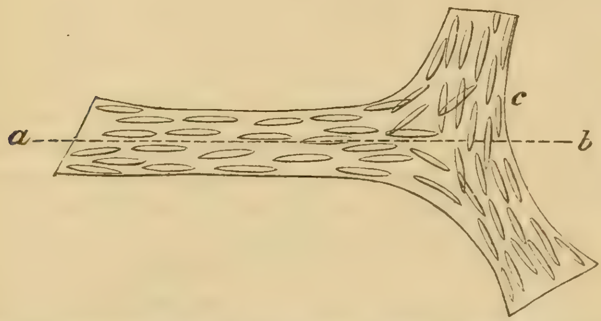
This is the appearance produced when the fibre happens to have been sliced along its length; when the section cuts the fibre transversely, so that it appears as an isolated round transparent space instead of a broad band, the striation vanishes and is replaced by a "dotting" of minute transparent circles, defined from each other by the fine opaque material before mentioned, which either thinly invests each of them or may be present in sufficient quantity to produce a black ground with the transparent circular areas set in it (Pl. XI. fig. 6, *t*).

Since the spicules lie with their long axes in the same direction as the length of the fibre, it is evident that a slice transverse to the axis of the fibre must also cut the spicules transversely; and since the spicules are more or less cylindrical in form, the circular spaces observed can be nothing else than the spicules seen in transverse section.

This explanation is supported by such appearances as that represented in Pl. XI. fig. 6, where a fibre is longitudinally striated throughout except at its rounded termination, where the striæ are replaced by circles.

This is due to the section crossing a fibre which at one part of its course lies in the plane of the transparent slice, but afterwards bends somewhat abruptly at right angles to it, and so presents us with a transverse section of the fibre, in obvious continuity with a longitudinal one (diagram, Fig. 6); and as the longitudinal section

Fig. 6.



Lateral view of a fibre bending at *c*, at right angles to the plane of the section, *a*, *b*, thus producing the appearance shown in the section Plate XI. fig. 6.

of the fibre passes into the transverse one, the longitudinal acicular section of the spicules passes correspondingly into the transverse circular one.

It is noticeable that the spicules are not confined to the axis of the fibre, as in the recent Chalinidæ, but are uniformly crowded throughout it; the spicules, indeed, *are* the fibre, the granular material which fills the interstices being no greater in amount than that required to fill up the spaces between a number of cylindrical rods closely pressed together. Nor do the spicules differ in size to any important extent; they are all, so far as one can see, of the same size and shape; nor do they follow two chief directions, one transverse and the other longitudinal to the fibre, as in the Echinodermata, but are bound together in parallel bundles like the Roman fasces.

It is difficult to find an example of a complete spicule sufficiently isolated from the rest to determine its dimensions and the nature of both its ends, though there are a few very exceptional cases in which this can be accomplished. At the place, for instance, where two or more fibres anastomose, the contained spicules cross one another at various angles, and so become separately visible to a much greater extent than when they all lie in a sheath side by side (Pl. XI. fig. 12, example from a recent sponge); occasionally also a single spicule deviates from the general trend of the rest, sometimes even to the extent of lying athwart them at right angles; and then also one has an opportunity of examining a spicule separately. In specimens where the matrix of the network consists of the phosphatic material called "coprolite," we find that this amber-coloured substance has in places penetrated the fibre and stained the exterior of the spicules of the same colour as itself, thus rendering them more than usually distinct on the unaffected transparent ground of crystalline calcite.

The exceptional preservation of a group of spicules (Pl. XI. fig. 8) so stained at the point of anastomosis of three or four fibres in the section Pl. XI. fig. 5, gives an excellent opportunity for drawing and measuring the individual spicules, some of which are represented in Pl. XI. fig. 9, magnified 435 diameters. These spicules are all acerate, very sharply pointed, straight or curved, from 0·007 to 0·009 * of an inch long, and about 0·00035 of an inch in diameter; this latter measurement has been checked by a comparison with the diameters of the circles which represent transverse sections of the spicules, and with concordant results.

From the preceding it will appear that the calcareous fibres of this sponge do not consist simply of homogeneous carbonate of lime, as has hitherto been supposed, but are composed of a vast number of acerate spicules, overlapping at their ends and lying parallel with each other in the direction of the fibre.

From this character we assign *Pharetrospongia* (*pharetra*, a sheaf of arrows) as the generic name of the sponge; its specific name, *Strahani*, is in honour of Mr. Strahan, of H.M. Geological Survey, who showed me a similar structure in an undetermined sponge from the Upper Greensand of the south-west of England, some years ago, before I had commenced the study of this so called *Chenendopora*.

Affinities.—The only sponges of the present day whose skeleton consists wholly of acerate spicules are siliceous ones and belong to the Holorhaphidota, an order established by Mr. Carter, and defined by him as follows †:—"Possessing a skeleton whose fibre is almost entirely composed of proper spicules bound together by a minimum of sarcode. Form of spicule variable."

This order is divided by Mr. Carter into five families, of which the first or Renierida is distinguished from the rest by having its "spicules more or less arranged in a fibrous form," the very structure which we described as characteristic of our sponge; so far then we have no difficulty, and *Pharetrospongia* must evidently be referred to the Renierida.

When we come to its nearer relations we find a wonderfully close agreement between it and an unnamed sponge from Australia, which Mr. Carter showed me for comparison, and of which, with his usual generosity, he gave me notes and a specimen. The notes are to the effect that the sponge is "massive, lobulate, with whitish fibre crammed with stoutish acerate spicules, $\frac{44}{6000}''$ long by $\frac{1\frac{1}{2}}{6000}''$ broad, with very little sarcode." The specimen I imbedded in par-

* It will be seen in the supplement that numerous isolated spicules have since been exposed to view by a new process. These have for a maximum length as much as from 0·01 to 0·011 of an inch.

† Ann. & Mag. Nat. Hist. ser. 4, vol. xvi. 1875, p. 130.

affin, cut thin slices from it, and mounted them in Canada balsam; the fibre so prepared exhibited the structure represented in Pl. XI. fig. 12, which, it will be observed, is exceedingly similar to that figured from *Pharetrospongia*, Pl. XI. figs. 5 to 8, of course making due allowance for the fact that fig. 12 is magnified 140, and figs. 5 to 7 only 60 diameters. A close examination of the two sponges, the fossil and the recent, fails, indeed, to reveal any essential difference between the structure of their fibre. Minor distinctions of course exist: thus the spicules of the Australian form are 0·0073″ long by 0·00025″ broad, while, as we have already stated, those of *Pharetrospongia* are from 0·007″ to 0·011″ long by 0·00035″ broad, and thus are slightly the larger; the recent spicules (Pl. XI. fig. 11) are also more abruptly pointed than the fossil ones.

We have already assigned *Pharetrospongia* to its family, we now go a step farther and place it amongst the Thalyosa, the third group of the Renierida, first because its spicules are all of one kind, next because they are arranged in a fibrous form, and finally because their dimensions are those which distinguish the spicules of the Thalyosa from those of the other allied groups, to which otherwise *Pharetrospongia* might belong; for the same reasons the Australian sponge goes with it and is included in the same group; and thus the association of the two is only separated by one step from generic identity. Here, however, the agreement ceases; for the Australian sponge possesses a well-marked canal-system, with large and distinct vents; in this it agrees with the rest of the Thalyosa and differs widely from *Pharetrospongia*, which, as we have seen, is characterized by the absence of clearly specialized oscules and of distinctly defined canals.

Order HOLORHAPHIDOTA, *Carter*.

Family RENIERIDA, *Carter*.

Group Thalyosa, *Carter*.

Genus Pharetrospongia (mihi).

Description.—A plate-like sponge, variously plicated, contorted, and anastomosing; growth marginal; skeleton composed of an irregular or vermiculate network, the fibres of which consist almost wholly of acerate spicules lying parallel with each other, with overlapping ends; oscules small, oscular surface smooth, with a network of thickened fibres; poriferous surface rough, undulating, ridged and furrowed, furrows probably exposed intermarginal cavities; canal-system indefinite.

Species Pharetrospongia Strahani (mihi).

Sponge about one third of an inch thick, other dimensions very variable; spicules 0·007 to 0·011 of an inch long, by 0·00035 of an inch broad; fibre 0·006 of an inch in diameter on the average.

Formation.—Coprolite-bed at the base of the Chalk-marl *.

Locality.—Cambridgeshire.

State of Fossilization.—The intermeshes of the network are filled up with the material of the bed in which the fossil happens to occur; thus specimens from the Chalk have their network imbedded in chalk, and from the Cambridge Greensand in the heterogeneous mixture of calcareous silt, fragments of crystalline calcite, coccoliths, "green grains," Foraminifera, entire and fragmentary, and other débris which characterizes that stratum, and which may be best defined as impure chalk-marl. This chalk-marl usually forms a hard compact mass in the intermeshes of the network, more or less opaque and white; but sometimes it is coloured brown, owing to an infusion of phosphatic matter, so that the fibres of the fossil stand out as a white network traversing a brown ground.

In the best-preserved portions of the fibre the spicules are converted into clear and transparent calcite, while the spaces between them, at one time filled with animal matter, are now occupied by the finely granular opaque white substance which we have before mentioned. In a less perfect state of preservation the fibre consists wholly of crystalline calcite, which often exhibits a radiate crystalline arrangement, diverging from various centres, either in the midst of the fibre or from the sides of its walls. Between the complete preservation and the complete obliteration of the spicular structure there exists a whole series of transitions: a fibre full of spicules at one end may consist of mere crystalline calcite at the other; and between the two extremes will be found a number of intermediate stages produced by the gradual disappearance of the granular coatings of the spicules as these become converted into the crystalline form.

The total replacement of the silica of the spicules, which has taken place as well when the outline of the spicules is preserved as when it is not, can be most readily demonstrated by dissolving specimens of *Pharetrospongia* from the Chalk in hydrochloric acid, when, save for a green grain or two and a little structureless flocculent material, no trace of a residue is left behind. We have here renewed evidence of that preservation of anatomical details in a structure which has undergone a complete chemical change, which I have before called attention to in the case of *Stauronema* (Sollas), the only difference between the two cases being that in *Pharetrospongia* the anatomical structure is more delicate, and its replacement total instead of incomplete.

The spicules are sometimes subject to another change not yet noticed; and that is the appearance in their interior of minute structureless spherules of a clear brown colour, often deepening into black, and of about the same diameter as the spicules themselves. Sometimes there are but one or two such spherules in a single spicule; sometimes a continuous series occurs along a considerable length of spicule (Pl. XI. fig. 13), looking like bullets filling a tube

* The genus is common in the Chalk; but whether the same species occurs there I have not now the opportunity of determining.

of the same interior diameter as themselves; while, finally, in rare cases it happens that these spherules join together into a cylinder, and so replace the spicule for a great part of its length.

Precisely similar spherules, but more variable in size, occur also scattered through the matrix of the fossil, of which one is represented in Pl. XI. fig. 14; and associated with them are a number of round, almost spherical bodies (Pl. XI. fig. 15), about 0·005 of an inch in diameter on the average, and of the same clear transparent brown colour, with which colour also the chalk-marl immediately surrounding them is faintly stained. On careful examination these are seen in many instances to consist of aggregations of smaller spherules (Pl. XI. fig. 16). What these bodies and the spherules may be appears very doubtful; but they certainly have very much the appearance of standing to each other in the relation of spores and sporangia *. In specimens where the matrix is coloured with phosphatic matter, this substance sometimes penetrates the fibre of the sponge, and, occupying the space between the spicules once filled with animal matter, stains the exterior of the spicules of its own brown colour.

Thus, to sum up, we find that the spicules are generally replaced by carbonate of lime, and sometimes infested by minute spherules of an unknown nature; that the animal matter of the fibre is also replaced by carbonate of lime, but in a granular condition, and by phosphatic material; and, finally, that the intermeshes are filled up by the material of the stratum in which the fossil is imbedded. From this last fact we may infer that our Cambridge *P. Strahani* is generally contemporaneous with the bed in which it is found, and not derived from the subjacent Gault.

Observations on the Classification of fossil Sponges.—The proposal of D'Orbigny to separate all the fossil sponges, except *Cliona*, from all the recent ones, as an extinct order ("Amorphozoaires à squelette testacé") characterized by a hard and resisting calcareous network, had much at the time to justify it; for those recent sponges to which the fossil ones are chiefly allied were then unknown; the Lithistina and Hexactinellidæ had first to be discovered before the fossil forms could be said to belong to the same groups as the known sponges of existing seas. The great mistake of D'Orbigny lay in his assigning an original calcareous composition to the skeleton of all the fossil sponges, of which the skeleton itself furnishes no proof, since it exists in very various mineral states, and since even when it is actually calcareous, is so, as we now know, as a result of mineral replacement (see page 250).

The recent discovery of the Hexactinellidæ, especially of the Vitreohexactinellidæ, and, above all, of the living species *Myliusia Grayi* (the skeleton of which agrees essentially with that of Toulmin Smith's *Ventriculites*), has given us the means of proving that the distinction between the fossil and living sponges does not hold for one of the largest of the fossil groups, that, namely, which is charac-

* These and some fossil Saprolegneous organisms, common in the "coprolites" of the Cambridge bed, will form the subject of a separate paper.

terized by lattice-like ("gitterförmig") tissue, and which clearly belongs to the existing Hexactinellidæ. The other great fossil group, distinguished by vermiform ("wurmförmig") fibres, or the Vermiculata, is sometimes regarded as closely related to the Lithistina. The structure of the genus *Pharetrospongia*, which is repeated with modifications in various species of sponges belonging to the genera *Scyphia* and *Manon*, together with the fact that *Siphonia*, *Polypothecia*, and other fossil genera are true Lithistid sponges, shows, however, that the Vermiculata are not at all a natural group, but simply a mixed assemblage of such sponges as are not Hexactinellids, and which belong, some to the Renierida, others to the Lithistina, and the rest probably to various other orders of recent sponges.

The separation of the fossil from the recent sponges, which has been made since D'Orbigny by almost every palæontologist who has written on the subject, now that we know more about the structure of both of them, appears to have been a great mistake in classification.

The simple fact is that we do not want a separate classification for the fossil sponges, any more than we require a separate classification for the fossil Foraminifera; and hence all such elaborate attempts as that, for instance, made recently by Pomel, are works of supererogation, which the modern spongiologist is obliged to ignore if he sets any value on economy in nomenclature and time. What we do now greatly need is knowledge of the exact structure of the fossil forms; that once definitely determined, but little difficulty need be expected in the work of correlation; the grouping of the petrified sponges will then follow naturally upon the lines already laid down for existing species.

Supplementary Note, April 26, 1877.

It has been suggested to me that the taxonomic position of *Pharetrospongia* cannot be regarded as demonstrated till its spicules have, in some instances at least, been found to exist in a siliceous state. This, however, is a view which I must confess myself unable to accept; the arguments as to the affinities of the genus which have already been adduced, are, to my mind, and will be, I believe, to most spongiologists, conclusive. At the same time, since one might naturally expect to find some of the spicules of a siliceous sponge still retaining their original composition even in a fossil state, and since it is impossible to demonstrate a fact too fully, I have now made a fresh search by a method I had not previously employed to see if the evidence which had been demanded was forthcoming, and with affirmative results.

My first experiments were conducted on specimens which had been filled in with chalk-marl. The polished face of a thin section taken from one of these was etched with dilute acid, and, after washing with distilled water and drying, examined both as an opaque and as a transparent object by powers of 75 and 140 diameters. It was then found that the skeletal network had dissolved freely and uniformly; and the undissolved remainder, still exhibiting a spicular structure, presented a smooth even surface sunk considerably below the level of the surrounding interstitial matter; here then spicules and fibre alike consisted solely of carbonate of lime. The interstitial matter, however, presented an interesting difference: part, being calcareous, had dissolved; but another part of a different composition had resisted solution, and remained behind as an insoluble network, imbedding green grains, silicified Foraminiferal shells, casts, and other foreign particles in a siliceous cement. Thus the original calcareous composition of the infilling material has been in this case, to a great extent, exchanged for a siliceous one; but precisely the same alteration has occurred to the interstitial matter of every specimen of *Pharetrospongia* which I have examined; and since siliceous infiltration is a very rare phenomenon among the fossils of the Cambridge Greensand, while in *Pharetrospongia* it is a constant occurrence; and since, again, we have already shown that the fibres of *Pharetrospongia* once possessed a siliceous composition, which they have since exchanged for a calcareous one, it seems not unfair to conclude that the silica under consideration found its way into its present position from the fibres of the sponge itself—that, in fact, there has been an interchange of material between the interstitial substance and that of the sponge-fibre, an outflow of dissolved silica from the one being compensated by an influx of calcic carbonate from the other.

It is scarcely possible within the limits of an appendix to discuss this change fully; and, reserving that for another place, I must now proceed to describe the more important results which have been obtained chiefly, though not exclusively, from an examination of specimens in which a phosphatic infiltration has taken place in addition to a chalk-marl infilling. On etching the surface of one of these specimens with acid the same results follow as with the calcareous examples, with one exception, however; for in these specimens the skeletal fibre, though almost wholly converted into carbonate of lime, is not altogether so, but leaves behind on solution a number of beautifully preserved spicules having a siliceous composition beyond a doubt, and present in such abundance as to furnish plenty of examples perfect enough for accurate measurement; at the same time they are exclusively restricted to the borders of the skeletal fibre, and do not occur in its central portions, since they are not only absent from the latter position, as seen on the eroded surface of the fossil, but are also not to be detected in the sediment which, after solution, is collected on washing with distilled water. Connected with this fact is the observation that in some cases the dissolved silica of the spicules has been deposited about the exterior of the spicular fibre to such an extent as to form a thin siliceous envelope to it.

Thus the siliceous spicules to be sought for have been found, and just that particular evidence which was thought to be needed to render the demonstration of the affinities of our sponge complete has been supplied.

I take this opportunity of explaining more fully certain difficulties which had only been touched upon in the body of the paper. The silica of sponge-spicules is a very different substance from the mineral silica of quartz. The latter is to all intents perfectly insoluble in carbonated waters and most other solvent fluids ; it is crystalline with a comparatively high refraction-index, and is composed solely of oxygen and silicon. The former, on the other hand, is colloidal, with a comparatively low refraction-index, is soluable in caustic potash and in carbonated waters, and consists of silica (probably one of the silicic acids) in intimate combination with organic matter. With substances so widely different it is not wonderful that a replacement by calcic carbonate should be common with the one, and unknown if not impossible with the other. The subject of the replacement of organic silica is a new one, and requires independent working out ; next to nothing has hitherto been known about it, partly because siliceous organisms are less abundant than calcareous ones, and partly because they have been less studied. I need here only remark that while *Siphonia* exhibits the structure of a Lithistid (siliceous) sponge, *Stauronema* of a Hexactinellid (siliceous) sponge, and *Pharetrospongia* of a Thalyosian (siliceous) sponge, yet the fossil skeletons of all three frequently occur now in a calcareous state; and it would be singular if these three structures, so different from one another, and so similar to their existing allies, should all have had their "doubles" in past time resembling them in every respect except in the one important particular of chemical composition—and this the more especially since each of them still presents cases in which it even now exhibits a siliceous composition. If chemical composition and morphological structure are invariably associated in the living organisms of the present day, we may depend upon it that they were not divorced in the past.

EXPLANATION OF PLATE XI.

Fig. 1. *Pharetrospongia Strahani* (Sollas), natural size.
2. Portion of oscular surface, magnified 1·6 diam.
3. Portion of poriferous surface, magnified 1·6 diam.
4. Section across a tubular process, showing the character of the network, nat. size.
5. Longitudinal section of fibres: *c*, point of anastomosis; *s*, spicules in longitudinal section (×60).
6. Mixed section of the fibre: *s*, spicules in longitudinal section; *t*, transverse section of spicules in the transverse section of the fibre (×60).
7. Longitudinal section of fibre from the oscular network: *m*, intermesh, which in many instances becomes obliterated by an enlargement of the surrounding fibre (×60).
8. Group of spicules from the point of anastomosis of several fibres, similar to that shown at *c*, fig. 5, occurring in the section shown in fig. 4 (×140).

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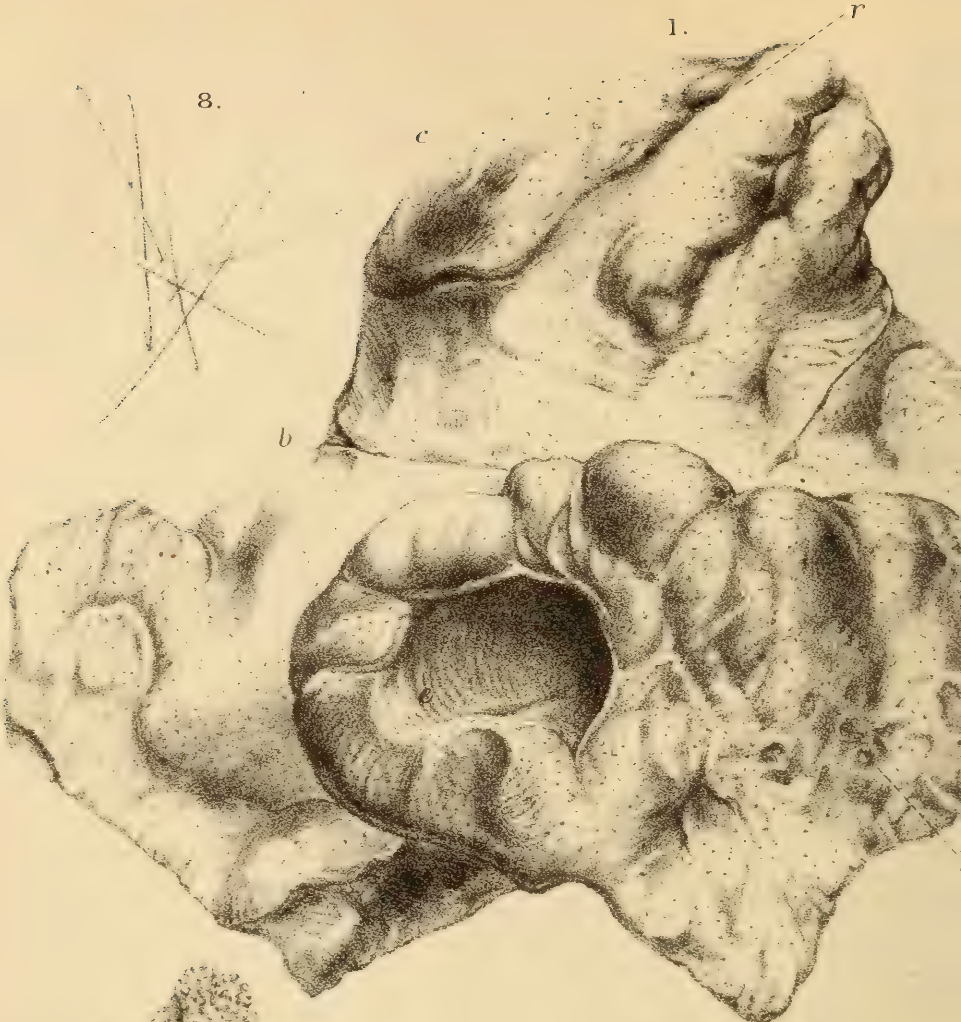

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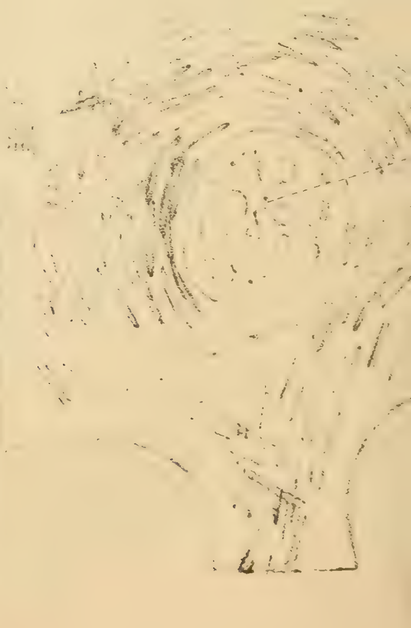

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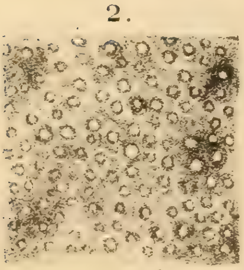

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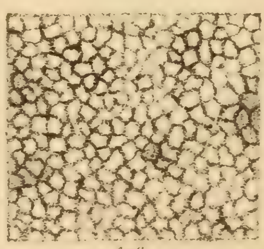

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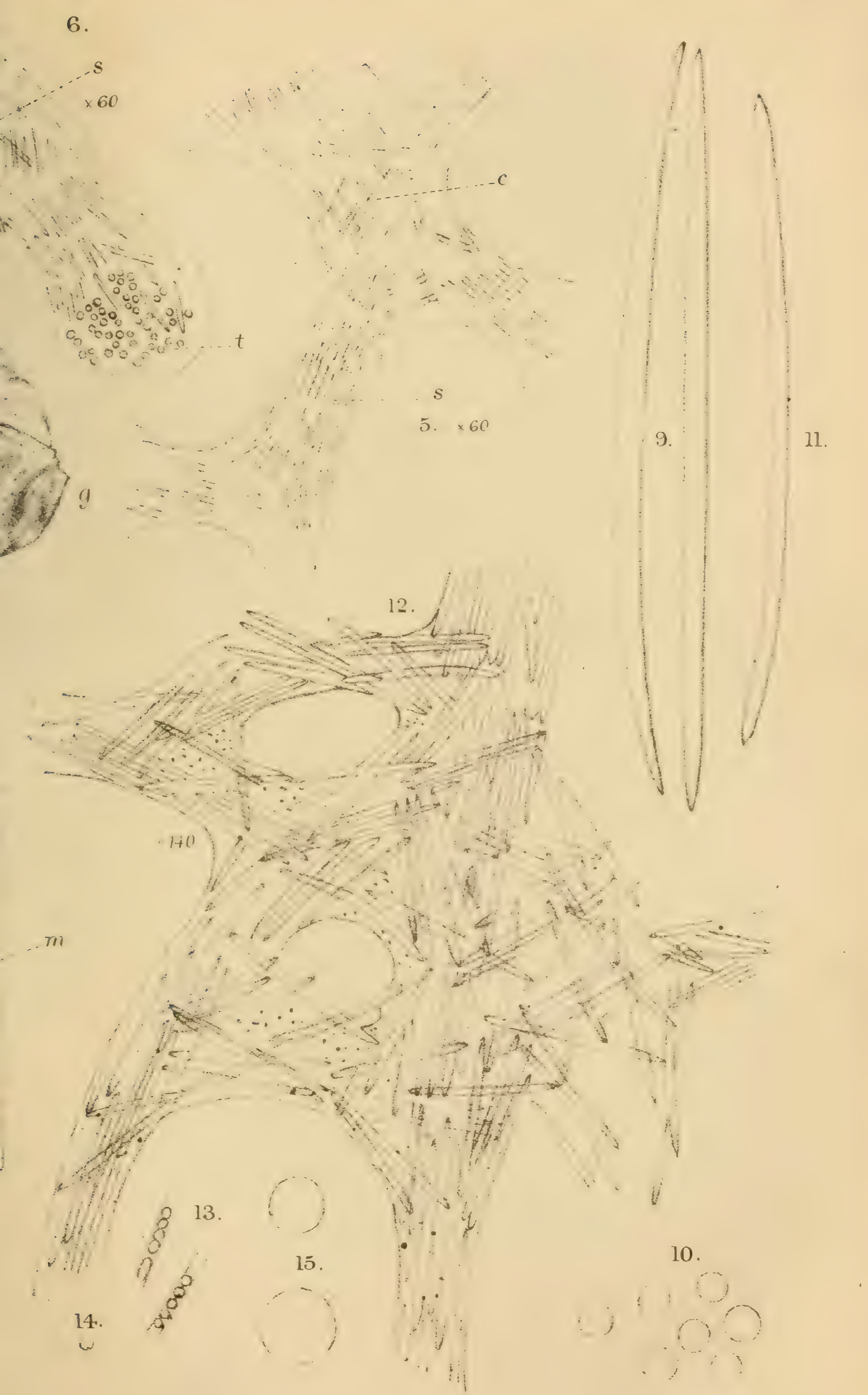

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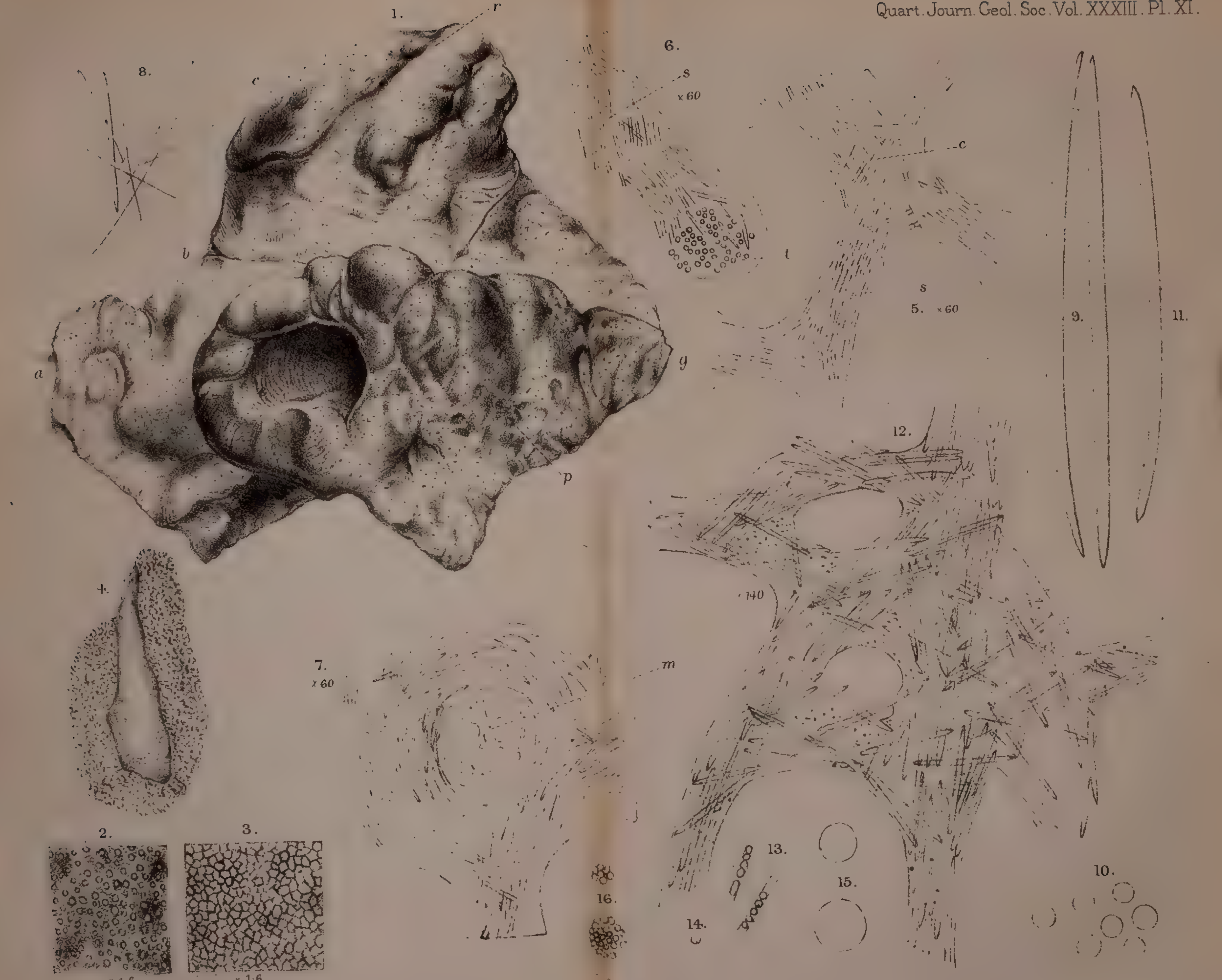

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PHARETROSPONGIA STRAHANI.

Fig. 9. Individual spicules of fig. 8 ($\times 435$).
10. Transverse sections of spicules ($\times 435$).
11. Spicule from a recent Australian sponge, for comparison with fig. 9 ($\times 435$).
12. Section of fibre of Australian sponge ($\times 140$).
13. Fragments of spicules containing small spherules of an unknown nature ($\times 140$).
14. Isolated spherule from the infilling chalk-marl of an intermesh ($\times 140$).
15. Outlines of spheroidal bodies composed of the same material as the preceding spherules ($\times 140$).
16. Section of the preceding, showing component spherules ($\times 140$).

Discussion.

Rev. T. G. Bonney remarked that the question of fossilization was one of great difficulty, but it seemed to him to be rather an unusual process for silica to be replaced by carbonate of lime.

The President thought it was more probable that the sponge described was one of the Calcispongiæ. The spherules observed by the author were exceedingly interesting to him, as he had observed in silicified corals what seemed to him to be similar bodies, which, however, he regarded as being dusty infillings of minute cavities; at least the appearance presented by them when carefully examined under polarized light seemed to justify such a conclusion.

17. *On* New Species *of* Belemnites *and* Salenia *from the* Middle Tertiaries *of* South Australia. By Ralph Tate, Esq., F.G.S., Assoc. Linn. Soc., Professor of Natural Science in the University of Adelaide. (Read February 7, 1877.)

Contrary to my determination not to publish any facts connected with the Middle Tertiaries of South Australia until I could present a detailed account of them, and of their palæontological characters, I herein communicate to the Geological Society the discovery of the presence of two genera in these rocks, which, on account of their distribution in time in European strata, must be regarded as of especial interest.

A species of Belemnite (*Belemnites rugifer*) has been recorded from the Older Tertiaries of Ronca, in Northern Italy; but the occurrence of the genus in the South-Australian Tertiaries greatly extends its duration, inasmuch as the epoch of the deposition of the River-Murray beds is generally regarded as not older than Miocene, and by some is placed in the Pliocene period. I refrain from offering an opinion on this question, as hitherto the corals and echinoderms only have been critically examined. At this time I am engaged in comparing the fossils of the South-Australian Tertiaries with existing forms, particularly those inhabiting the South-Australian shores. This task is rendered great from the circumstance that there is no available collection in this colony for study, and I have been obliged to supply the deficiency by my own labour. But this has borne good results, as I have added 78 unrecorded marine shells to Mr. Angas's list (Proc. Zool. Soc. 1867), some of which occur in the Middle Tertiary beds, and I have made several important additions in other departments of marine zoology.

The discovery of a Tertiary *Salenia* very happily bridges over the hiatus that separates in time the newly discovered living example obtained by Sir Wyville Thomson during the cruise of the 'Challenger' ('Academy,' June 3). Though much good work has been done by Professor Duncan and Dr. Laube in making known the Echinoderm-fauna of our Tertiaries, yet the number of species recorded by them does not represent a moiety of those which I have met with. The additional genera represented are *Fibularia*, *Laganum*, *Brissus*, *Cardiaster*, *Cidaris*, *Echinanthus*, *Hemiaster*, *Pygorhynchus*, *Echinobrissus*, *Glyptocrinus*, *Meoma*, *Arachnoides*, *Astrogonium*, *Pentacrinus*, and *Comaster*.

The locality at which the new species herein described have been collected is Aldinga, 26 miles south from Adelaide, on the east coast of St. Vincent's Gulf. The general assemblage of fossils in the very diversified strata displayed in the long stretch of sea-cliffs about 150 feet high at this place, is identical with that of the River-Murray beds.

Belemnites senescens, spec. nov. Fig. 1.

Guard elongated, slender, gradually tapering to an acute apex, cylindrical, but inclined to subquadrangular in section, especially

Fig. 1.—*Belemnites senescens*, Tate.

a. View of the most perfect specimen obtained, natural size.
b. Its proximal end.
c. Section of another specimen, enlarged.

Fig. 2.—*Salenia tertiaria*, Tate.

a. From above, enlarged.
b. From the side, enlarged.
c. An ambulacrum, still more enlarged.

towards the alveolar region; without grooves or furrows. Length from 12 to 15 times the width. Alveolus imperfectly known, apparently shallow, with a broadly obtuse base (?).

Dimensions of longest example—length $4\frac{1}{2}$ inches, diameter $\frac{3}{10}$ of an inch.

No perfect specimen has been obtained; and the guard is usually in a fragmentary state, often incrusted with Polyzoa and mined with galleries of a boring animal. But the physical features of the stratum in which they occur, a calcareous sand full of débris of Polyzoa, and often exhibiting false-bedding, serve to explain their present condition, which is not derivative beyond the circumstance that they have been drifted in shoal water. *Belemnites senescens* occurs also in the River-Murray cliffs, associated with their common fossils.

I have a Belemnite from the interior of this province which resembles *B. gingensis* of the European Oolite, and is consequently unrelated to *B. senescens*, and a new species allied to *B. australis*, Phillips, obtained with other Jurassic (?) fossils from Stuart's (formerly Cooper's) Creek, on the line of the transcontinental telegraph.

SALENIA TERTIARIA, spec. nov. Fig. 2.

Form with the characters belonging to the genus, hemispherical, depressed, moderately inflated below, base concave; mouth not large, nearly circular; anus subhexagonal, disk with shagreen-like ornamentation, suranal plate smaller than the genital plates. Each *interambulacral area with* 12 crenulated *tubercles* in two vertical rows. *Poriferous zones straight*, *ambulacral areas margined with large granules*, between which are two rows of smaller ones, amongst which are scattered granulations.

Diameter of largest specimen $\frac{6}{10}$ of an inch, height $\frac{5}{10}$.

DISCUSSION.

The PRESIDENT remarked upon the interest attaching to the discovery of this Belemnite, which added another to the curious examples of the survival of older forms of life in Australia. He thought it could hardly have been derived from Secondary strata. The *Salenia* was evidently Tertiary; and as it was somewhat Cretaceous in its aspect, it added another to the list of Cretaceous forms which outlived the Cretaceous period. This and similar discoveries showed the impossibility of comparing Australian and English strata on purely palæontological data.

Mr. J. S. GARDNER remarked that the discovery of Belemnites at so late a period as the Miocene was of extreme importance, as adding another to the list of Cretaceous forms found still surviving at a late period. If Belemnites &c. lived on until the Miocene, might not Ammonites have lived on until the Eocene? In America there are Cretaceous beds, known as Cretaceous from the presence of Ammonites and other forms, but the *facies* of whose fauna mainly resembles that of our Eocene. Floras mingled with these are known as Cretaceous floras. Should the presence of the incoming Eocene mollusca be taken to fix the age of the beds, and the Ammonites be considered to have survived in those regions to a later period, the floras would no longer be considered Cretaceous, and the arguments for and against evolution in Dicotyledons based upon the age of these plant-types would be greatly modified.

Mr. A. W. Waters said that two years ago he exhibited to the Society Belemnites from Ronca. Since then it has been shown by M. Bayan and Prof. Hébert that in the deposit at Ronca there are rolled fossils from the still older Tertiary beds; but the Belemnites are not rolled. Although there is every possibility that they may be Tertiary, it is by no means certain. Some geologists think that they resemble Liassic forms; but they certainly are not similar to Mr. Tate's Belemnites.

Rev. J. F. Blake remarked that Mr. Tate's Belemnites were more like Oolitic than Cretaceous forms; and they certainly did not belong to the genus *Belemnitella*. The interest of the case, as the President had pointed out, consists in the carrying on of Cretaceous life into Tertiary times; and this favours the idea of a non-uniform deposition of beds, and a more continuous succession of life in Australia than in Europe.

Prof. T. Rupert Jones said that, in 1857, Belemnites found in a Tertiary deposit of North-west Germany were exhibited at the meeting of the Naturalists' Association at Bonn.

Prof. Seeley remarked that it was impossible, from the material before the Society, to determine the species to which the *Belemnites* might belong. The characters were not sufficiently clear to show whether it was a true *Belemnites*, or ought to form a distinct but allied genus. He agreed with Mr. Gardner with regard to the resemblance of American Cretaceous shells to those of the English Tertiaries.

18. *On the* Corallian Rocks *of* England. By the Rev. J. F. Blake, M.A., F.G.S., and W. H. Hudleston, Esq., M.A., F.G.S. (Read January 10, 1877.)

[Plates XII.–XVII.]

Table of Contents.

Introduction.

Whatever may be the value of the grounds on which the ordinary line of separation between the "Middle" and "Upper" Oolites is drawn, there can be no denying that from the Oxford to the Kimmeridge Clays, in some parts of England, we have one continuous deposit, which, from a physical point of view, has been aptly termed a great "pelolithic" formation. During the period when this was being quietly laid down, at a quicker or slower rate, in these areas, other portions of the same great region were at various times subject to alterations of the physical conditions, in consequence of which the deposits were changed in character; they became Grits or Limestones, and supported coral reefs, with their accompanying Oolites. The very fact of these changes being local—a fact proved as much by the discontinuous as by the variable nature of the deposits—prevents our assuming that they were all contemporaneous, even in a large sense, as has been done by those who have used the term Corallian, as indicative of a period, for all or any of the coral deposits that have been formed between the commencement of the Oxfordian and the close of the Kimmeridgian epoch.

In England, however, these rocks, originally called "Coral Rag" by Smith, from their development in that form in the area studied by him, have been divided into *Upper Calcareous Grit*, *Coralline Oolite*, and *Lower Calcareous Grit*, the classification being originally derived from Yorkshire; and it has been too hastily assumed that rocks of similar lithological character are the equivalents of each other in different localities. To determine the true relations of the various Corallian beds to each other, as developed in different parts of the country, we have examined them consecutively, and are now attempting to present a general history of their formation. Geologists, indeed, are already possessed of valuable information on several isolated districts; but their correlation has scarcely been at all attempted, and several areas have never, or but very imperfectly, been described.

In the study of no other series of rocks, perhaps, is it more necessary to remember the influence that physical conditions have upon the contained fauna. The close resemblance, not to say identity, of some of the species with those of similar beds belonging to the Great or the Inferior Oolite proves that much of the peculiarity of the Coralline fauna is due, not to the lapse of time, but to the conditions of deposit, as we hope to indicate in the sequel. Nevertheless palæontology does not fail us as a guide, and there are still a sufficiency of forms, above the influence of physical conditions, which indicate satisfactorily by their association the relative age of the deposits. At the same time it is possible that if we were to eliminate all the influenced forms, the remainder might indicate but two well-marked faunas, the Oxfordian and the Kimmeridgian—the one ending and the other commencing during the period of the deposition of the Corallian deposits with their additional fauna due only to physical conditions. This may be the case, though we are scarcely prepared to assert it without a careful examination of the great uniform clay series in which no Corallian beds are found. Our aim at present will be to take such note of the physical conditions under which each deposit was formed as will enable us to estimate the contained fossils at their true chronological value, as well as to study the history of the beds for its own sake.

The Corallian rocks, as traced across the country, are separated into several areas, not simply by denudation, but by their original form, as we judge by a certain general similarity and connexion, under the cover of minor diversities, which characterize each, and separate it from the others. These areas are of very unequal magnitude and importance; but this is just the very feature of the series. They may be distinguished as follows:—

I. The Weymouth district.
II. The North-Dorset district.
III. The North-Wiltshire and Oxfordshire range.
IV. The Cambridge reef.
V. The Yorkshire basin.

In our description of these areas we shall endeavour to remember that our study is the development, physical conditions, and correlations of the Corallian beds, and not their stratigraphy, except so far as it may throw light upon the former points.

I. The Weymouth District.

The geological structure of South Dorsetshire is well known; and it affords us three distinct opportunities of studying the Corallian beds. We have first the neighbourhood of Weymouth itself, with the rocks extending on the west to the Fleet near Wyke, and also the two ends of the series on the northern side of the anticlinal as exposed on the east at Osmington, and on the west near Abbotsury.

The rocks in the immediate neighbourhood of Weymouth were early described by Prof. Sedgwick, in the 'Annals of Philosophy' for 1826, when he divided the series between the harbour and Sandsfoot Castle into 11 groups, and remarked on the similarity of some of them to the rocks at Filey Brigg; and later this same series was more minutely studied by Prof. Buckland and Sir H. De-la-Beche *, and divided into 33 groups. They did not, however, touch the palæontology, or assist in the correlation of the beds with those of other areas. In the maps of the Geological Survey the whole is simply coloured as "Coral Rag." Mr. Damon's valuable little work †, however, makes this area familiar ground, and contains very useful lists of fossils. More recently Dr. Waagen has called the Sandsfoot-Castle beds the "Upper Calcareous Grit" ‡. Some notice, nevertheless, even of previously described rocks, appears necessary for the completion of our view of the whole deposits of this area and its comparison with others.

Speaking generally, the Corallian beds of this area are a lenticular mass having its greatest thickness near Weymouth—a result

* Trans. Geol. Soc. 2nd series, vol. iv. p. 1.
† Geology of Weymouth and the Island of Portland.
‡ Versuch einer allgemeinen Classification, &c.

due to the greater development of particular beds there than elsewhere.

Beginning at the base near Weymouth, we find that the series commences with a considerable thickness (about 30 ft.) of calcareous sand, with hard bands of grit. These are well exhibited beneath the Nothe Fort at the end of Weymouth Pier, where the curious interlacing bands, due probably to decayed fucoids, have long been noticed. The whole has, however, undergone much alteration since its original deposition, by the action of chemical and other agencies, as is the case with similar beds in Yorkshire.

The change into these beds from the Oxford Clay below is by no means so gradual as it is in many other areas. Mr. Damon says that "the junction at the Nothe, now no longer visible, is sharp and well-defined;" and certainly on the western side, in the Fleet, it is remarkably so. The uppermost bed of clay there is surmounted by a thick layer of *Ostrea dilatata*, associated with *Ammonites cordatus*, *Ostrea gregaria*, and *Serpula tricarinata*, which is immediately covered by the sands, with great abundance of *Perna quadrata*, a very characteristic fossil of the beds throughout this district. In a brickyard between these two localities the change at the base is also sudden, though the overlying sands are more argillaceous and support abundance of *Myacites* and *Pholadomyæ*. The beds of calcareous grit become more strongly developed at the top; and the uppermost one is somewhat ferruginous. In order to avoid any undue assumption in the names used, we think it best to employ local designations for each series of beds; and this series we call the "Nothe Grits."

The fossils that have occurred to us in these beds near Weymouth are the following:—

Ammonites cordatus (*Sow.*).
Belemnites hastatus (*Blainv.*).
Cerithium muricatum (*Sow.*), var.
Chemnitzia, sp.
Pleurotomaria Münsteri (*Sow.*).
Opis Phillipsi (*Mor.*).
Cyprina tancrediiformis (*Bl. & H.*).
Trigonia perlata (*Ag.*).
Myacites decurtatus (*Ph.*).
Pholadomya æqualis (*Sow.*).
—— concinna (*Ag.*).
Perna quadrata (*Sow.*).
Pecten fibrosus (*Sow.*).
Avicula ovalis (*Ph.*).
Anomia radiata (*Ph.*).
Ostrea solitaria (*Sow.*).
—— gregaria (*Sow.*).
—— dilatata (*Sow.*).
——, sp. (deltoid form).
Exogyra spiralis (*Goldf.*).
Serpula sulcata (*Sow.*).
—— tricarinata (*Sow.*).
Millericrinus echinatus (*Ph.*).

This is not an entirely distinct fauna from that of the Oxford Clay below; but there are some species, such as *Trigonia perlata*, *Pecten fibrosus*, *Avicula ovalis*, and *Millericrinus echinatus*, which are very characteristic forms and assist much in correlation.

The development of the Nothe Grits on the northern side of the anticlinal from Osmington to Abbotsbury shows, like most of the series, a considerable diminution. At the former place their thickness is only 12 feet, and their colour is darker. The fossils are tolerably numerous, and remarkable for their large size, especially the *Trigonia perlata* (both valves) and *Ostrea dilatata*, which are immense. We note also, in addition to the forms met with at Weymouth, *Ammonites perarmatus* (Sow.), *Belemnites abbreviatus* (Mill.), *Ostrea dilatata* (large var.), *Turbo Meriani* (Goldf.), *Myacites jurassi* (Brongn.), and *Lucina*, sp. (cf. *lirata*). Traced westward from Osmington, these grits are thinning out, till at Broadwey, due north of Weymouth, they are scarcely discoverable, unless represented by a single 2-ft. block of ferruginous sandstone, lying in the midst of clays ; and only a thin band can be identified in the valley south of Abbotsbury, which is excavated down to the Oxford Clay. This restriction of the deposit is a feature worthy of attention.

The series of beds which follow the Nothe Grits are again argillaceous, though containing bands of hard calcareous grit towards the base. We include in this series, which we call the "Nothe Clays," about 40 ft. of beds at Weymouth, which are spread out in the bay to the south of the town. They are of less thickness in the other localities ; but they present no particular feature, except at Wyke, where they are separated from the Nothe Grits by a few feet of a *fissile* calcareous sandstone, surmounted by rubbly limestone with fragments of shells—the débris possibly from some coral-reef to the west, now removed from our sight. These usurp the place of some of the lower grit bands at Weymouth.

The fossils from the Nothe Clays are :—

Ammonites cordatus (*Sow.*).	Modiola bipartita (*Sow.*).
Nautilus hexagonus (*Sow.*).	Lima elliptica (*Whit.*).
Alaria trifida (*Ph.*).	Pecten fibrosus (*Sow.*).
Cucullæa contracta (*Ph.*), var.	Anomia radiata (*Ph.*).
Arca æmula (*Ph.*).	Exogyra nana (*Ph.*).
Trigonia perlata (*Ag.*).	Ostrea dilatata (*Sow.*).
Perna quadrata (*Sow.*).	—— gregaria (*Sow.*).
Thracia depressa (*Sow.*).	Serpula tricarinata (*Sow.*).

It is interesting to note that this list has on the whole more of an Oxfordian than of a Corallian type, very few of the more peculiar forms of the latter appearing in it—a proof that in this district at least the fauna of the sands and grits makes its appearance rather on account of physical changes than on account of the lapse of time. We can scarcely find a parallel to this reintroduction of clay elsewhere, unless it be in the Clays overlying the Elsworth rock.

Succeeding to these Clays is another series of Grits and Sands, which from their being well developed at Bencliff, east of Sandsfoot Castle, we call the "Bencliff Grit Series." They consist here, in descending order, of

	ft.
1. Calcareous grit, with dichotomizing branches, very hard in the upper part, passing down into softer calcareous sands, with a band of compact argillaceous limestone at the base	10
2. Sandy shales, becoming loose "foxy" sands, which contain towards the base huge tabular doggers of indurated calcareous sandstone	11

The first bed alone is fossiliferous, and that only locally, the remarkable feature of the series being the large doggers of the lower sands. These are due to the subsequent action of mineralized waters, which, percolating through the loose sands, were stopped by the impervious clays below. A more abundant supply of the cementing materials might have formed a continuous bed. By these the series may be best traced inland, as at Broadwey, Rodwell Station, &c. and near Abbotsbury. To the east of Osmington the grits encroach on the sands below, and finally appear to drive them out, the marly beds above becoming at the same time thicker, the total being in this instance less than at Weymouth, namely about 18 ft.

The fossils of the Grit are *Cucullæa corallina* (Ph.), *Pecten qualicosta* (Et.), *Gervillia aviculoides* (Sow.), *Cerithium*, sp., *Lucina*, sp., *Exogyra nana* (Ph.), and *Trigonia corallina* (Ag.)—a fauna which, though small, has relations both above and below, but mostly with the beds above.

At Wyke, by the Fleet, this series can scarcely be recognized, it being stratigraphically represented by false-bedded calcareous sandstones with their slope to the west—that is, lying on the edge of beds on the same parallel to the east.

The next series in the ascending order is an important and interesting one. It is composed of marls and oolites in varying proportions. At Osmington it contains a beautifully compact and uniform single bed of white, fine-grained oolite, of a thickness of 12 ft., which we call the "Osmington Oolite." This, in physical character, is not unlike some of the Great-Oolite beds of Minchinhampton, being remarkably uniform in its structure. It is a tolerably pure limestone for this district, but still somewhat sandy; it is highly fossiliferous at Osmington, though the thicker beds (22 ft. seen) near Abbotsbury (where they are quarried for building), which are on the same stratigraphical horizon and resemble them in lithological character, scarcely contain a single fossil besides *Myacites*, the only others noted being *Pecten fibrosus* and a *Chemnitzia*.

At Weymouth this series has a less marked character, being split up by marls and clays, and showing the oolitic structure less clearly, shell-limestone being partially substituted.

Here it consists, in descending order, of:—

	ft.	in.
1. Blue marly clay, with oolite grains	6	6
2. Small-grained sandy oolite, weathering hummocky, by its having shell-limestone substituted towards the base	2	0
3. Marly clay with doggers..................................	5	6
4. Oolite, gritty in the centre and marly below, with *Amm. perarmatus* (var.)	6	0
5. Blue sandy marls, partly argillaceous	4	0

In the Rodwell railway-cutting the oolite commences in abundant grains in the underlying marls; and at Wyke the whole oolitic series of this and the beds above are united into one great false-bedded mass.

The fossils of the Osmington Oolite are very interesting, partly from their peculiarity as compared with those of the other beds of the same district, partly from their similarity in facies to those of the older beds which this series so strongly resembles in structure, and partly from the assistance they afford in the correlation of the series with those of other districts, especially Yorkshire. They are as follows:

Chemnitzia heddingtonensis (*Sow.*).
Phasianella Buvignieri (*D'Orb.*).
Natica corallina (*Damon*).
—— clytia (*D'Orb.*).
Opis corallina (*Damon*).
—— Phillipsi (*Mor.*).
Lucina Moreana (*Buv.*).
Trigonia clavellata (*Sow.*).
—— Hudlestoni (*Lyc.*).
Sowerbya triangularis (*Ph.*).
Tancredia planata (*M. & L.*).
—— disputata (*Bl. & H.*).
—— curtansata (*Phil.*).
Cucullæa contracta (*Ph.*).
Lima subantiquata (*Röm.*).
Pecten qualicosta (*Et.*).
Echinobrissus scutatus (*Lam.*).

The *Phasianella*, *Sowerbya*, *Tancredia*, *Lima*, and *Pecten* are the most noteworthy fossils in this list, as being very characteristic of these beds, and yet recalling the facies of more ancient oolites.

The series which follows and concludes, in an ascending order, the more calcareous portion of the Corallian beds in this district is one of extreme importance, no less by the abundance of its fossils than by the lithological characteristics which approximate it most nearly to that class of rock which might fairly be called "Coral Rag." On account of the abundance of *Trigonia clavellata*, we have called these the "*Trigonia*-beds" of Weymouth. Although they present no very constant lithological characters throughout the range, there is no difficulty in identifying the equivalent bed, especially as it is almost everywhere overlain by at least some recognizable thickness of more argillaceous beds. In descending order, we may describe the section exposed on the coast near Weymouth as follows:—

Section of Trigonia-*beds near Weymouth.*

	ft.	in.
1. Rubbly gritty limestone, formed of a mass of shells, chiefly *Trigonia clavellata* and *Gervillia aviculoides*, but with many others, in several beds with hummocky irregular surfaces and marly partings, becoming less fossiliferous below	9	0
2. Strong limestone band with a few *Trigoniæ* only...	1	6
3. Harsh suboolitic grits, showing, on weathering, ramose projections in moderate relief. *Myacites* numerous. A *Nerinæa*-bed about 7 ft. down.	12	0
4. Numerous irregular, blue-weathering, rather impure limestones in hummocky masses, full of shell-structure	6	0
	28	6

The following fossils have been found by us in the *Trigonia*-beds of Weymouth or Osmington.

Fossils from the Weymouth Trigonia-*beds.*

Ammonites cordatus (*Sow.*).
——, sp. (*cf.* eupalus, *D'Orb.*).
Belemnites (narrow form).
Chemnitzia heddingtonensis (*Sow.*).
——, sp. (*cf.* rupellensis, *D'Orb.*).
Nerinæa Goodhallii (*Sow.*).
—— fasciata ? (*Voltz.*).
—— Desvoidyi (*D'Orb.*).
Cerithium muricatum (*Sow.*).
Alaria Deshayesea (*Buv.*).
—— seminuda (*Héb. & Desl.*).
Natica corallina (*Damon*).
—— clytia (*D'Orb.*).
Nerita minuta (*Sow.*).
Littorina pulcherrima (*Dollf.*).
Turritella jurassica (*Qu.*).

Cylindrites elongata (*Ph.*).
Pleurotomaria Münsteri (*Röm.*).
—— reticulata (*Sow.*).
Dentalium cinctum (*Goldf.*).
Pholadomya decemcostata (*Röm.*).
—— paucicosta (*Röm.*), var.
Myacites jurassi (*Brongn.*).
Arcomya, sp.
Ceromya excentrica (*Ag.*).
Astarte ovata (*Sow.*).
—— extensa (*Ph.*).
—— polymorpha (*Cont.*).
Cypricardia glabra (*Bl. & H.*).
Opis Phillipsi (*Mor.*).
—— corallina (*Damon*).
Unicardium sulcatum (*Leck.*).
Lucina aliena (*Ph.*).
Isodonta Deshayesea (*Buv.*).
Sowerbya triangularis (*Ph.*).
Cardium cyreniforme (*Buv.*).
Protocardium isocardioides (*Bl. & H.*).
Trigonia clavellata (*Sow.*).
—— Meriani (*Ag.*).
—— monilifera (*Ag.*).
Nucula nuda (*Ph.*).
Cucullæa corallina (*Damon*).
Mytilus pectinatus (*Sow.*).
Modiola subæquiplicata (*Gldf.*).
Pinna granulata (*Sow.*).
Avicula Struckmanni (*De Lor.*).
—— pteropernoides (*Bl. & H.*).
Perna quadrata (*Ph.*).
Gervillia aviculoides (*Sow.*).
Lima elliptica (*Whiteaves*).
—— rigida (*Sow.*).
Plicatula fistulosa (*M. & L.*).
—— semiarmata (*Et.*).
Pecten fibrosus (*Sow.*), var.
—— qualicosta (*Et.*).
—— virdunensis (*Buv.*)*.
—— intertextus (*Röm.*).
Hinnites velatus (*Goldf.*).
Ostrea solitaria (*Sow.*).
—— deltoidea (*Sow.*).
—— duriuscula (*Ph.*).
Exogyra nana (*Sow.*).
Astrogonium, sp.
Cidaris florigemma (*Ph.*) [rare].
Hemicidaris intermedia (*Flem.*)
Pseudodiadema versipora (*Ph.*).
Echinobrissus scutatus (*Lam.*).
Thamnastræa arachnoides (*E. & H.*).
—— concinna (*Ph.*)
Thecosmilia annularis (*Flem.*).

The appearance of these various divisions, when we encounter them in an inland section, is so different from that on the coast, and such sections are so rare, that we are induced to give an account of such a one as is met with in the Rodwell cutting of the Weymouth and Portland Railway. We here find the following series :—

Section of Corallian beds in Rodwell cutting.

		ft.	in.
	1. Blue clay		
"*Trigonia*-beds".	2. Hard blue impure limestone in 6 courses, with numerous casts of *Trigoniæ, Pleurotomariæ*, &c....	12	0
	3. Rubbly limestones with marly partings (8 in.) very slightly oolitic	7	0
	4. Oolite marl, full of fossils, particularly *Myacites*. This might almost be termed a fine-grained pisolite	4	0
	5. Grey rubbly limestone, scarcely oolitic	1	6
	6. Stiff marl, very oolitic towards the base, with a hardened ferruginous bed in the centre	4	9
	7. Hard ferruginous oolite	4	0
"Osmington-Oolite" series.	8. Marl with flaggy calcareous grit..........................	3	0
	9. Strong semi-oolitic flagstone with calcareous markings	1	0
	10. Blue clay with oolite grains at the base	3	8
	11. Solid, shelly and oolitic light-coloured limestone, with *Echinobrissus scutatus*	3	8
	12. Light-coloured marl, becoming oolitic below	2	0
	13. Rough shaly oolite in 2 blocks	4	0
"Bencliff Grits."	14. Marls	6	0
	15. Fine-grained calcareous grit	2	0

* Allied to *P. lens*.

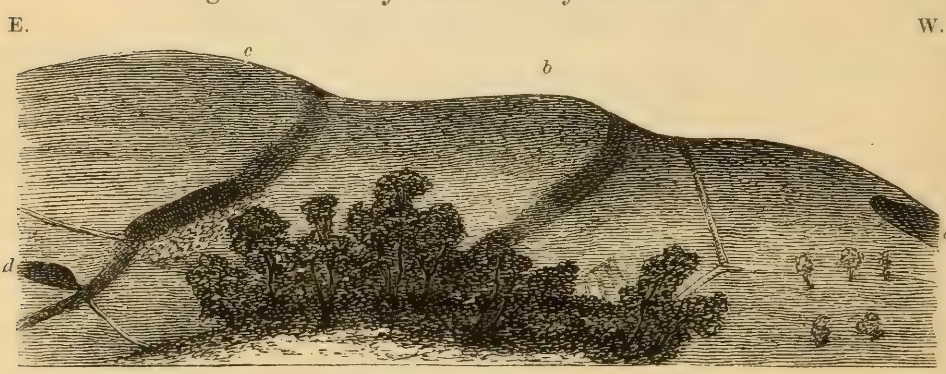
And about 22 ft. below this occur the great doggers previously noticed on the coast.

Nearly the whole of this section shows oolitic conditions, though the beds are very various in character, illustrating what has been very forcibly impressed upon us, that these Corallian beds cannot be trusted to be constant any further than we can see them. The upper portion, as on the coast, is the most fossiliferous. Passing on in the same direction to Wyke, we find the whole series here indicated massed into one suboolitic, false-bedded, rubbly limestone, indicating, perhaps, a source of the calcareous material situated to the west; but of this section we need not give details.

The beds corresponding to these *Trigonia*-beds at Osmington are a perfect mine of wealth to collectors; and the matrix being peculiar, the locality of hand specimens is easily identified. The upper part of the limestones here becomes a large-grained purple oolite, the marly partings becoming a soft oolitic rock from which the fossils are extracted in good preservation. Blocks may be obtained covered with double valves of *Trigonia clavellata* with the ligament uninjured; and hence is said to have come the beautiful coral *Comoseris irradians*, figured by Edwards and Haime, as well as other corals, which, however, are by no means common.

From this locality the same beds may be traced at various points along their outcrop, always characterized by their extremely fossiliferous nature, being, indeed, largely composed of shells, and showing very little oolitic structure. In a quarry in this stone at Broadwey, Mr. Damon has recorded the occurrence of *Ceromya excentrica* (Ag.), a fossil of importance in some localities.

Fig. 1.—*View of Linton Hill from the North.*



a. Oolite Quarry. *b.* *Trigonia*-beds. *c.* Sandsfoot Grits. *d.* Iron Sands.

The development of these and the overlying beds near Abbotsbury is admirably seen in the picturesque elevation called Linton Hill (fig. 1). Its gently sloping sides are scored obliquely by two cliff-like escarpments passing over it from S.S.W. to N.N.E. These are due to the succession of hard beds which have a rather less slope to the east than the surface of the ground; they crop out in succession in a long longitudinal valley to the south, where the large tabular doggers are seen, and spread out in broad patches on the northern slope.

On the western slope of the hill, opposite St. Catherine's Chapel, is situated the quarry (*a*) already noticed (p. 265) as representing the Osmington Oolite; and the first of the abrupt escarpments going east is composed of the series representing the *Trigonia*-beds (*b*); while the next escarpment presents us with higher beds, which will be described in the sequel.

On the broken edge of the first escarpment the following beds may be traced, in descending order:—

	ft.
1. Thin flaggy limestones with abundant fossils	5
2. *Trigonia*-grit with *Myacites*	2
3. Strong shelly limestone.	
4. White marl with *Trigonia*.	
5. Thin shelly limestone.	
6. Marl.	
7. Flaggy white Oolite	1
8. Whitish marl.	—
The total being about	30

In the space between the base of this and and the Oolite quarry are some thin flaggy sandstones. Possibly Nos. 7 and 8 should belong to the series below. These beds are most nearly paralleled by those at Weymouth, but they chiefly illustrate the great variableness of the formation.

The fossils collected from the upper part of these beds are interesting and peculiar. Several of the species enumerated from the *Trigonia*-beds of Weymouth and Osmington occur here, and we note the following in addition:—

Ammonites plicatilis (*Sow.*).
Ceromya inflata (*Ag.*).
Anatina, sp. (*cf.* undulata, *Sow*).
Myacites decurtatus (*Phil.*).
Goniomya v-scripta (*Sow.*).
Mytilus jurensis (*Röm.*).
Pygaster umbrella (*Ag.*).
Acrosalenia decorata (*Haime*).

Although the whole of the Corallian deposits have a distinct character in the Weymouth area which can scarcely be paralleled elsewhere, yet the most remarkably distinct are those which succeed the beds already described. Immediately overlying the shelly limestones of the *Trigonia*-beds, and without any gradual change, a considerable thickness of clay is seen, reaching to as much as 40 ft. at Sandsfoot Castle, somewhat less at Wyke, where about 12 ft. are seen, and making a comparatively slight show at Linton Hill and Osmington. This clay, at Sandsfoot, is extremely calcareous, and contains two indurated bands which may be described as a mixture of lime, sand, and clay with a moderate proportion of ferrous carbonate, disseminated pyrites, and carbonaceous matter. These two bands are highly charged with fossils, often of a large size. In the intervening clay the fossils are, on the contrary, dwarfed, as may be especially seen in a large colony of deltoid oysters, which are extremely small. The other fossils are *Astarte supracorallina* (D'Orb), *Corbula Deshayesea* (Buv.), *Nucula Menkei* (Röm.), and small *Arcæ* and *Trigoniæ*. In the harder portions a more numerous collection may be made, including, in addition to those just mentioned:—

Ammonites plicatilis (*Sow.*).	Pholadomya æqualis (*Sow.*).
Turbo? exiguus (*Röm.*).	—— hemicardia (*Ag.*).
Littorina pulcherrima (*Dollf.*).	Avicula pteropernoides (*Bl. & H.*).
Cerithium septemplicatum (*Röm.*).	Perna mytiloides (*Lam.*).
Pleurotomaria reticulata (*Sow.*).	Pinna pesolina (*Cont.*).
Cardium delibatum (*De Lor.*).	Pecten lens (*Sow.*).
Trigonia clavellata (*Sow.*).	—— vimineus (*Sow.*).
Goniomya marginata (*Ag.*).	—— midas (*D'Orb.*).
Cucullæa corallina (*Damon*).	Hinnites velatus (*Goldf.*).
—— superba (*Cont.*).	Ostrea deltoidea (*Sow.*).
Thracia depressa (*Sow.*).	Cidaris Smithii (*Wr.*).

In these beds, which have the same character as the great pelolithic formation of which the Corallian beds themselves are, as it were, an exceptional development, we have no physical causes to produce a special fauna; and therefore we may regard them as giving us a fair index of the lapse of time. The aspect, however, of this fauna, is markedly Kimmeridgian, only a few of the fossils being usually found in Corallian beds. Any one finding this clay inland without the association of the other rocks, and noting the commonest of the fossils, would doubtless call it Kimmeridge Clay; indeed Prof. Sedgwick, in his description of this very section at Weymouth, boldly calls it so. It serves to show how very much of a Kimmeridgian aspect the upper portions of these exhibit, as the lower ones do of an Oxfordian. We may quote this clay as the "Sandsfoot Clay."

On this clay lies a series of remarkable sands and grits of a ferruginous colour, which are extremely well developed at Sandsfoot and on Linton Hill, but cannot be matched elsewhere in England for extent and thickness, and which are extremely fossiliferous. These have been well described in their lithological characters by previous authors; but, for the completion of our account, we may be excused the repetition. They may be well seen along the shore beneath and on either side of Sandsfoot Castle. Our section commences below what one of us has called the "Kimmeridge passage-beds," and ends above the Sandsfoot clay.

Section of the Sandsfoot-Castle beds, in descending order:—

	ft.	in.
1. Thin band of ironstone	1	0
2. Blue marly clay, badly stratified, unfossiliferous	15	0
3. Glauconitic ferruginous grit, hardest at the top, with an open structure, and having impressions of shells	6	0
4. Brown and grey spongy calc-grit of hackly fracture, with numerous interlacing stem-like bars, and hollow tubes of clay. *Myacites* in the natural position	2	2
5. Blue clay, with a layer of large, almost continuous ironstone doggers passing downwards into the next, and thus becoming more sandy	7	6
6. Uniform yellow sand, becoming very ferruginous-looking and compact below; becoming also irregular and concretionary. The lower part is distinct in some parts as a purplish ironstone with shales. Very fossiliferous 12ft. to	18	0

It is to this lowest set of beds, which we may call the "Sandsfoot Grits," that the chief interest attaches; and they require more particular notice. A few feet from the top of the sand we find a bed with *Pinna pesolina* in the position of life. Below this a dark green rock comes on. Grit is certainly a chief component of all these rocks; but they are so coloured by iron in various combinations and states of oxidation, as to seem much richer in that metal than they really are. The middle and lower portions are most calcareous, and are specially remarkable for the strange interlacing fucoid or sponge-growths, which are not only met with here and there as in the lower grits, but make up a large part of the rocks, and, weathering out in a purplish tint upon a greenish ground, give a very curious aspect to the surface. What we see here, indeed, is not drifted material brought from a distance to be deposited along with its organic remains, but the actual spot on which colonies of fucoids and sponges luxuriated, and on which they left their remains, their most constant Molluscan companion being the great *Lima pectiniformis*.

The beds thus described are very variable in character and thickness; and the limits between two beds can scarcely be traced for more than a few yards. We have found in them the following fossils:—

Ammonites achilles (*D'Orb.*).
Belemnites nitidus (*Dollf.*).
Pleurotomaria Münsteri (*Röm.*).
Littorina pulcherrima (*Dollf.*).
Astarte ovata (*Sow.*).
—— supracorallina (*D'Orb.*).
—— polymorpha (*Cont.*).
Pholadomya hemicardia (*Ag.*).
Pleuromya tellina (*Ag.*).
Gresslya peregrina (*Ph.*).
Thracia depressa (*Sow.*).
Goniomya literata (*Sow.*).
Cardium delibatum (*De Lor.*).
Lucina substriata (*Röm.*).
Trigonia muricata (*Goldf.*).
Pinna pesolina (*Cont.*).
Pecten midas (*D'Orb.*).
Pecten distriatus (*Leym.*).
Lima pectiniformis (*Sow.*).
—— rigida (*Sow.*).
Hinnites velatus (*Goldf.*).
Avicula ædilignensis (*Blake*).
Plicatula, sp.
Exogyra nana (*Sow.*).
Ostrea deltoidea (*Sow.*).
—— solitaria (*Sow.*).
—— duriuscula (*Ph.*).
Serpula tetragona (*Sow.*).
—— sulcata (*Sow.*).
Discina Humphriesiana (*Sow.*).
Lingula ovalis (*Sow.*).
Cidaris florigemma (*Ph.*).
—— Smithii (*Wr.*).
Echinobrissus scutatus (*Lam.*).

The rocks which we are now describing make a very marked feature on Linton Hill, where they score the hillside with a ruddy sloping cliff, to the east of that which is composed of the *Trigonia*-beds (see fig. 1, *c*). The characters are here very similar to those at Sandsfoot, the lower and more ferruginous beds being alone exposed. We see the same variegated concretions and branching organisms, and meet with the same fossils, though more sparingly. They are also exhibited in considerable thickness in the Fleet, their maximum lying perhaps rather south and west.

In the neighbourhood of Osmington and in the western part of Ringstead Bay, this series is also well developed, the divisions being nearly the same as at Sandsfoot, though the beds are, as a whole, more argillaceous. Thus on this side of Weymouth Bay the "Sandsfoot Grits" are largely mixed with clayey matter, and therefore make less show on the cliff. Yet it is quite possible to identify them both west of Osmington and in Ringstead Bay itself. The following may be deemed an average development of this upper series between the cliffs west of Osmington and its final disappearance in the dip in Ringstead Bay:—

	ft.	in.
Kimmeridge Clay.		
a. Bed charged with *Exogyra nana* and many other fossils......	0	8
b. Blue clays of variable thickness, having usually a large quantity of *Rhynchonella inconstans* towards the middle, with many *Serpulæ* and fossils of a decidedly Kimmeridgian character .... say	4	0
Upper Corallian.		
1. An Upper Coral Rag, chiefly made up of *Thamnastræa concinna* and *Thecosmilia*, with an assemblage of highly characteristic fossils, *Pecten vimineus*, *Lima rigida*, *L. pectiniformis*, spines of *Cid. florigemma* &c., in a hard marly grit	0	8
2. Thin clay, with *Serpula*	0	4
3. Bands of hard yellow ferruginous clay .... capping	1	4
4. A waxy unfossiliferous clay, with occasional ferruginous corals	9	0
5. Red grit (top of the Sandsfoot grits), with *Pecten midas*, *Goniomya v-scripta*, *Ammonites decipiens*	5	0
6. Ferruginous sandy shale, being a continuation downwards of no. 5	14	0
7. Sands and shales, with two strong bands of *Ostrea deltoidea*, based upon an intermittent band of shelly ferruginous stone, full of small *Ostreæ* and *Cardia*. *Bel. nitidus* common...	7	0
8. Unfossiliferous shales (the Sandsfoot Clay)	18	0
	55	4

The beds vary much both in character and thickness within short distances. Thus No. 1 is not always to be made out west of Osmington, but is well seen in Ringstead Bay. In the analogous position at Sandsfoot there is a slight indication of this bed; but nowhere else in the Weymouth district is there such a satisfactory exhibition of Coral Rag as on this horizon in Ringstead Bay—a fact which seems to have escaped the notice of Waagen. Besides the fossils above mentioned, *Astarte ovata* (peculiar form), *Opis corallina*, and a very large *Modiola* are characteristic; there is also an abundance of *deltoid* oysters both above and below. The Ammonite accompanying this group is a modification of the form figured by D'Orbigny as *A. cymodoce*, described as a Corallian species.

A very similar form occurs in the *Rhynchonella*-bed, which we, in common with Waagen, consider to be the true base of the Kimmeridge Clay in this locality. This circumstance would indicate that no very great lapse of time intervened between the two groups. The continuity of deposit is practically unshaken, the character only is changed. But here on this horizon the Corallian fauna apparently made its last stand before succumbing finally to the new conditions. The above-mentioned Ammonite, which is doubtless itself a modification of the old plicatiloid forms, would be deemed Kimmeridgian if found in middle or northern England. In the Weymouth district, however, the Ammonites for the most part seem to occur on horizons lower than we should expect, judging from the rest of the fauna, and perhaps on the whole incline to French rather than to English types *.

The Abbotsbury Ironstone.—It has long been known that vast deposits of hydrated ferric oxide associated with silica occur at Abbotsbury; but their geological position has not been made clear, nor their fossil contents enumerated. The deposit is a very local one, and is contained in a synclinal trough on which the village stands. It is very well exposed in two sections to the north of the main street. The first is in the roadway leading over the hill to Gorwell, which is cut into the natural rock; and the dip to the south being greater than the slope of the road, we meet with the highest beds below, and continually rise into lower ones. It is not, therefore, easy to estimate the total thickness. It is a tolerably uniform deposit as seen in this road, the weathering having obliterated most of the minor features. In the second section, that in Red Lane (a very appropriate name), the beds are less changed, and we may recognize the following variations in them:—

Section of Ironstone, Red Lane, Abbotsbury.

	ft.	in.
1. Loose ferruginous sand ... 2. Granular iron-ore, with grains about the size of a millet-seed, and with streaks of ferric hydrate in various directions. Fossils abundant, especially Brachiopoda, as *Rhynchonella corallina* and *Waldheimia lampas* ...	20	0
3. Coarse ferruginous suboolitic grits in hard cherty bands with numerous *Ammonites decipiens* ...	2	6
4. Yellow weathering sand without fossils ...	2	0
5. Dark green earthy suboolitic rock highly charged with ferrous oxide ...	1	0
6. Dark ferruginous sandstones with intercalating variable hard beds, with fossils in the form of casts, including *Exogyra virgula* ...	10	0
	35	6

We are unable in this section to trace the connexion of the beds either upwards or downwards; but we can see that there is no room for any thing above them to dip beneath the Kimmeridge Clay. That these, or at least their equivalents, overlie the Sandsfoot Grits is satisfactorily proved on Linton Hill (see fig. 1), where the cliff formed by the latter is distinctly seen to be continued beneath a small mound, in which is an excavation showing the characters of the ironstone. The clays and sandy beds which intervene between the yellow sands at Sandsfoot and the true Kimmeridge Clay are not seen here; and the Abbotsbury Ironstone may be, as far as stratigraphy is concerned, on their horizon. But this must be better judged of by their fossils.

In the ironstone we have found the following:—

* When we first inspected this Osmington section, the sliding forward of the superincumbent clay had so advanced the upper beds as completely to obscure the reading. The very wet winter of 1876–7 seems to have cleared much of this away. One of us, on visiting the locality in March 1877, had the good fortune to find the Ringstead-Bay Section especially clear. The statement, therefore, that there is no Coral Rag whatever in the Weymouth district must be modified.

Ichthyosaurus (tooth).
Ammonites decipiens (*Sow.*).
—— hector (*D'Orb.*).
Belemnites nitidus (*Dollf.*)
Chemnitzia pseudolimbata (*Bl. & H.*).
—— delia (*D'Orb.*).
—— ferruginea (*Bl. & H.*).
Pleurotomaria reticulata (*Sow.*), var.
Alaria, sp.
Pterocera, sp.
Natica eudora (*D'Orb.*).
Modiola subæquiplicata (*Goldf.*).
Arca sublata (*D'Orb.*).
Trigonia monilifera (*Ag.*), var.
Pleuromya Voltzii (*Ag.*).
—— tellina (*Ag.*).
Pleuromya donacina (*Ag.*).
Cardium delibatum (*De Lor.*).
Inoceramus, sp.
Pinna pesolina (*Cont.*).
Pecten midas (*D'Orb.*).
Rhynchonella corallina (*Leym.*).
—— inconstans (*Sow.*).
Terebratula subsella (*Leym.*).
Waldheimia lampas (*Sow.*).
—— dorsetensis (*Dav.*).
Echinobrissus scutatus (*Lam.*).
Glyphæa ferruginea (*Bl. & H.*).
Serpula Royeri (*De Lor.*).
—— gordialis (*Goldf.*).
Wood.

Some of the fossils are so badly preserved that we are unable to identify them with certainty; and among these are species of *Pterocera*, which are of great interest as possibly indicating a deposit similar to those known as "Pterocerian" on the Continent, but not elsewhere found in England. The other great feature of the fauna is the presence of Brachiopoda, which we have nowhere else met with in the Corallian beds of this district; and from the association of *Rhynchonella corallina* with *R. inconstans* we may infer that we are really dealing with beds at least on the horizon of the passage-beds to the Kimmeridge Clay; and the other fossils lead to the same conclusion. Combining this with the stratigraphical evidence, we may arrive at a pretty correct estimate of the age of this Abbotsbury Ironstone.

The remarkable structure of this rock requires more than a passing notice. It has undergone much chemical change since its deposition; and this has caused the decortication and destruction of the more tender fossils. Except where seen unweathered, as in some of the lower beds, it has not usually much coherence; so that when dried and pressed the particles readily separate; and we find it to be made up of three principal constituents:—

1. Quartz grit, rounded and subangular, and variable in size.

2. Coffee-coloured granules with a smooth surface, for the most part circular and flattened, but occasionally oval, about the size of a large pin's head, with fragments of the exterior scattered about like broken egg-shells.

3. A buff-coloured investment, much poorer in iron than the granules, which adheres to the quartz grains, and sometimes forms a cement to the whole mass; it contains a considerable amount of ferrous carbonate.

The presence of so much silica in the form of quartz is said to detract from the commercial value of the ore; but the small amount of phosphoric acid found in the granules may possibly compensate for this.

The granules, when broken, are seen to consist of a brown exterior shell, which is largely but not wholly composed of ferric hydrate, and of an interior filled with a buff-coloured powder much poorer in iron. There has been a centrifugal movement in the iron here, such as is known to occur in many peroxidized iron-ores; but this is perhaps a comparatively recent action. The granule may perhaps be called "an oolitic grain of the hydrous oxide;" but even the outer skin is not pure oxide; and after treatment with acid there remains a residue presenting a sphere-on-sphere structure, hollow within, and composed of a uniform subcrystalline material, the greater part being silica.

An analysis of the mass of the ore is given in Damon's account. A sample of the granules has yielded the following:—

Moisture	1·21
Constitutional water	11·29
Ferric oxide	73·57
Alumina and soluble silica	4·17
Lime	1·60
Magnesia	1·41
Insoluble in HCl	5·53
Organic matter, carbonic acid, and loss	1·22
Phosphoric acid	trace
	100·00

It would lead us too far from our subject to inquire the causes of the changes that have brought the rock into this state, and what was its original condition, which must have been very different from what it now is; but these points must be determined by chemical rather than by geological considerations.

Such are the Corallian rocks of the Weymouth district. They have been separated after the Yorkshire type by authors; but though the series of changes have been remotely similar, we shall see that this affords no reason for the subdivisions being contemporaneous; and we have therefore abstained from the use of the old Yorkshire names. There is nothing specially "coralline" in the series as connected with Corals; and the term "Coral Rag," which is an essentially lithological name, is here especially inappropriate; for such a rock occurs only in one limited locality in the whole district.

II. The North-Dorset District.

A considerable and important mass of Corallian rocks is developed in this district; but beyond their mapping by the Geological Survey, and a paragraph by Mr. Mansel Pleydell in the 'Geological Magazine,' no illustration of them has yet been given. Yet the district has features which are not met with elsewhere. In general the rocks strike north and south; but they have a prolongation along their southern boundary far to the west of their general range. In our description we shall find it best to commence at Sturminster, where the railway-cutting affords a magnificent section, which to a large extent serves as a key to the whole district, the other developments being best understood by their relation to the rocks here exposed.

This cutting (fig. 2) crosses the escarpment at right angles at about 25 feet above the level of the river Stour, which runs over Oxford Clay; and as the beds dip at about 4° E., higher beds are met with in that direction till cut off by the denudation of the country where the railway leaves the cutting.

The following beds are here exposed in descending order:—

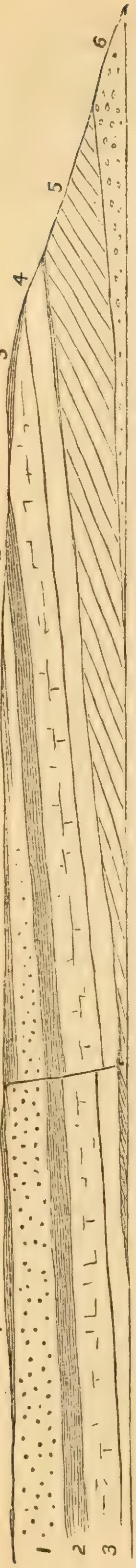


Fig. 2.—*Section in the Railway-cutting, Sturminster.* (Length about 240 yards.)

	ft.	in.
1. Foxy sands, much mixed with soil at the bridge ...	14	0
2. Marl and clay ...	8	6
3. Upper calcareous series ...	15	6
4. Rubbly (*Florigemma*) limestone ...	9	0
5. False-bedded series ...	18	0
6. Oolite, Marl, &c. ...	12	0

Section in Sturminster Railway-cutting.

	ft.	in.
No. 1. Yellow argillaceous sands, much mixed with soil	14	0
No. 2. Blue marl and clay, with numerous small oysters	8	6
No. 3. Calcareous sandstone, graduating downwards into rubbly limestone bands with marly partings, containing *Ammonites plicatilis, Perna mytiloides, Myacites securiformis, Astarte polymorpha*	8	9
No. 3*a*. Light-blue marl, with light rubbly limestone concretions at the top	4	6
No. 3*b*. Rough limestone, shelly and hardened towards the upper part, and having a thin bed of blue clay below. This contains a few oolitic grains of all sizes up to that of a pea. *Trigonia clavellata, Echinobrissus scutatus, Astarte aliena, Lucina*, sp., *Exogyra nana*	2	3
No. 4. Rubbly limestone, discoloured except near the base, where it is white and soft for 2 feet, with a hardened band of 1 foot below. The fossils in this bed, though very numerous, are much rolled and rubbed, most, if not all, having been brought from a distance, or subjected to currents in the neighbourhood. The most abundant is *Cidaris florigemma*; and there are besides *Alaria Deshayesea, Pleurotomaria reticulata, Chemnitzia heddingtonensis, Nerinæa*, sp., *Natica dejanira, Phasianella Buvignieri, Littorina muricata, Cerithium muricatum, Sowerbya triangularis, Opis corallina, Perna mytiloides, Lima subantiquata, L. elliptica, Unicardium*, sp., *Modiola*, sp., *Exogyra nana, Ostrea gregarea*. Thickness	9	0
No. 5. False-bedded shell limestone, of varying hardness, and often quite soft, made up almost entirely of fragments of shells, very few being of recognizable completeness; oolitic grains are also numerous. The false-bedding is very regular, dipping east at an angle of 16°, so that in the space of the cutting more than 60 feet are seen as measured perpendicular to the successive beds. As, however, they are traced to the east, they are found to be gradually becoming conformable to the beds above; the two uppermost beds, one of which is more compact, are distinctly wedge-shaped, decreasing in the direction of the false dip, which here has the same inclination as the true dip of the overlying bed, from 4 feet to almost nothing. The surface of this set of beds is waterworn and irregular, with the overlying rubbly beds in pockets. *Phasianella*, sp., *Cerithium muricatum, Lima elliptica, Pseudodiadema radiatum*. Thickness as a whole	15–18	0
No. 6. Black and white rubbly marl, the whiter portions in hard bands, the light upper, and dark central parts very fossiliferous; but all the fossils are small, and appear to have been transported. *Littorina muricata, Turbo funiculatus, Cerithium muricatum, C. inornatum, Ceritella*, sp., *Orthostoma*, sp., *Quenstedtia lævigata, Cypricardia glabra, Lima elliptica, Pecten strictus, Exogyra nana, Echinobrissus scutatus, Acrosalenia decorata, Hemicidaris intermedia*. Thickness	8	0
No. 6*a*. Loose pisolite of large flattened concretions ...	1	0
No. 6*b*. Oolitic marl with large grains, 3 feet seen.		

No sign of any sandy or grit beds can here be discovered below this.

Before drawing attention to the peculiarities of these strata and their relation to others, it will be well to complete the section of the Corallian beds in this immediate neighbourhood, as we are enabled to do by various minor exposures. The first is seen on the surface of a path on the south of the river leading down to a water-mill. After having here traced the beds down to the loose pisolite (No. 6 *a*), we find about 12 feet of rubbly creamy oolite underlying it, easily distinguished from the oolite above. This doubtless takes the place of No. 6 *b*; and beneath it immediately comes stiff blue clay, below which no surface indications are seen; and the only representative of any thing like grit that we could hear of was met with in the bottom of wells. The "Lower Calcareous Grit," as marked on the map, must therefore here be very feeble indeed.

Not far from this spot, on the highroad-side, are some other exposures, serving to show the variable nature of No. 5, as in one place it is only 10 feet thick, and a little further to the west thins out altogether, and the lower marls, here crowded with *Echinobrissus scutatus*, are in contact with the rubbly beds, which are more argillaceous.

On the roadside to the east of the bridge are seen rough, shelly, thin-bedded limestones, dipping east at about 5°, which represent the base of No. 3; and these are followed in the direction of the dip, as seen in a quarry, by more creamy shelly limestones, with abundance of *Natica*, *Nerinæa*, &c., which have a thickness of at least 12 feet, and represent therefore a larger development of calcareous matter in this part of the section than is seen in the railway-cutting. Above these, in the Hole road, we meet again with the clays and sands of the railway-section; but above them we find ferruginous fossiliferous sands and concretions, which form a rock mass at the top, and are succeeded by broken Kimmeridge Clay. The fossils of these beds are *Ammonites plicatilis* (?), *Belemnites nitidus*, *Pleuromya tellina*, *Pinna pesolina*, *Pecten midas*, *Avicula ædilignensis*, *Ostrea deltoidea*, *Serpula runcinata*. This completes the series; and we may anticipate so far as to say that the characters here exhibited are, with minor exceptions, fairly typical of the whole region of North Dorset.

We first remark here the feeble development of the grits and sands at the base, which usually form so marked a feature. They are hardly to be discovered at all at Sturminster; and to the south of the town, along the westerly range, we have but very slight indications of occasional grits. As we pass north, however, they become of slightly more importance, and at Cucklington form part of a somewhat steep escarpment. In the neighbourhood of Marnhull and Stower Provost also grit beds of some thickness occur; and at the eastern entrance to the Gillingham tunnel a good section appears, which, as it is the only one in this district, we give in descending order.

Section of Lower Corallian Beds in Gillingham Cutting.

	ft.	in.
1. Brown, oolitic, gritty limestone, with *Pecten lens* and *Echinobrissus scutatus*	6	0
2. Blue marl	2	0
3. Ferruginous, oolitic, gritty limestone	0	6
4. Blue marl, with numerous small oysters	3	0
5. Purple rubbly calcareous grit, with fossils. *Pecten articulatus*? ...	8	0
6. Blue marl, with large spheroidal doggers, with *Ostrea dilatata*, *Serpula tricarinata*, &c.	12	0
7. Blue-black calcareous grit in two or more solid blocks, with *Myacites* in a natural position and covered by interlacing ramose bodies, *Echinobrissus scutatus*, &c.	2	0
8. Dark blue sandy marl, containing at various levels immense spheroidal doggers of calcareous grit, and sometimes thin layers of alternating sand and clay. *Myacites decurtatus*, *Ostrea solitaria*	18	0

The stratigraphy, lithology, and fossils, all prove to us where we are in the series here, and show how very little calcareous grit is to be found among the more argillaceous base of this district. While the top bed is here oolitic, and therefore belonging probably to some portion of the Sturminster section, the lowest bed shows every sign of continuing downwards into the Oxford Clay, in which, indeed, there are hard bands, as seen at the western opening of the tunnel *; so that we see all that is to be seen. We are not, in this district, too far from the Weymouth area to prevent our comparing these grits with the Nothe Grits, which, it will be remembered, were thinning out and almost disappearing to the north.

This fundamental divergence from the general type of Corallian beds, viz. the absence of a considerable base of calcareous grit, seems to have affected the subsequent deposits; for argillaceous conditions made themselves largely felt during the formation of the lower oolitic beds. Thus, after the production of the overlying clay, we find in this district, not a new series of grits, as the Bencliff Grits in the Weymouth area, but a set of oolite marls and pisolites, which in places, indeed, become entirely oolitic. Indeed the second remarkable feature of the North-Dorset district is the enormous amount of calcareous matter it contains, which, when impure, is in almost every case mixed with clay and not with sand. This would indicate a remoteness from the source of detritus, and a proximity to some coral reef, or other organic formation, which has been in this case situated to the west. We may remember that in the Weymouth area the calcareous beds become thicker in that direction.

It is by this idea that we must interpret the succeeding marls and pisolites (No. 6). The state of these beds and their rough though small fossils seem to indicate that they are the result of irregular currents bringing material that had been rolled about for some time in a calcareous ooze, the origin probably of the pisolite, and gives us an idea that these North-Dorset beds are

* The colouring of the Survey Map is hereabouts not quite correct,

exceptionally conglomeratic. This portion of the series may be traced along the lower part of the Corallian range to the south by its pisolitic beds, though the exposures are meagre in the extreme. Near a farm called Canning's Court, it is associated with a shell-heap, consisting almost entirely of *Myacites decurtatus* and *Natica corallina.* To the north of Sturminster these beds are well developed at Hinton St. Mary's, where they show the same sequence. They are known to be at the base at Marnhull; and the pisolite spreads out on the surface at Stower Provost, the village square being entirely upon it, presenting a very interesting appearance. Passing still northwards, we catch a glimpse of these again at the top of Gillingham Cutting, though they are not easily recognized on the surface. An interesting section, however, is seen in a quarry at Cucklington, which is valuable, as showing a certain amount of persistence of the character of the beds to the extreme north. It is as follows:—

Section at Cucklington.

	ft.	in.
1. Rubbly large-grained oolite. *Ammonites plicatilis, Pecten fibrosus. Myacites decurtatus, Echinobrissus scutatus*	1	0
2. Pisolite, in a large-grained oolitic matrix. *Pecten fibrosus, E. scutatus,* and fragments of small corals within some of the concretions	1	8
3. Dark rubbly oolite, and oolitic marl, with scattered pea-stones. *A. plicatilis, Turbo,* sp., *Lima rigida, E. scutatus,* sponge	2	4
4. Black and brown clay	0	8
5. Solid block of blue-hearted brashy oolite, gritty and broken	6	0
	11	8

The fauna of this series, as seen here and at Sturminster, is hard to interpret. Some of the species, which occur in beds of Rag at a much higher level, are doubtless due to physical conditions; but the *Pecten* points to a low position, not higher, and perhaps lower than the "Osmington Oolites." Among the Echinoderms the form quoted is very abundant; and we remark the total absence (as we might expect) of *Cidaris florigemma.*

The false-bedded limestones that succeed these are of extreme importance in this district. They are doubtless due to the irregularity of the sea-bottom, either by the scooping out or non-deposition here and there of the oolitic marls below; and their angle of false dip is therefore not constant, and may be sometimes unobservable; but it is always towards to the east, indicating clearly the westerly source of the deposits. They are, however, a more than usually local deposit; for they thin out, as has been noticed, a little S.W. of Sturminster, and are never encountered again, to our knowledge, in that direction. Neither do they appear much to the north of Stower Provost; but they are magnificently developed in the neighbourhood of Marnhull and Todbere, where they are largely worked for lime and building-stone. The section seen in a fine quarry at Todbere, which contains this and higher beds, is as follows:—

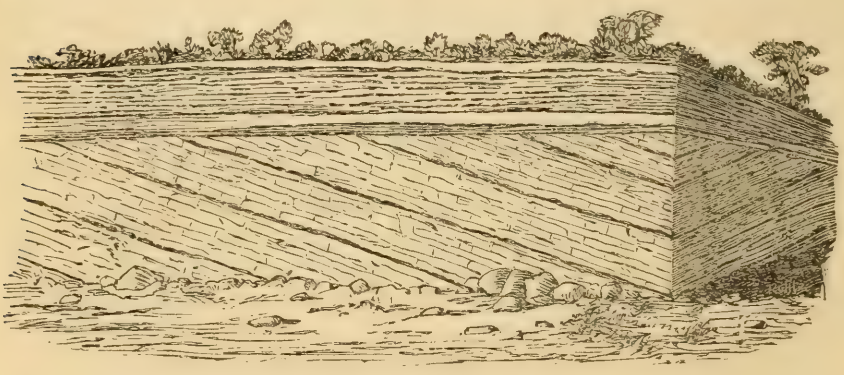
Section of Oolites and Limestones at Todbere.

	ft.	in.
1. Loose, soft yellow oolite marl, and rubbly thin-bedded oolite limestone, with numerous fossils. *Natica*, sp., *Chemnitzia heddingtonensis*, *Ostrea solitaria*, *Echinobrissus scutatus*	3	0
2. Oolitic and shelly limestone, with soft marly partings, breaking into thin layers, fossiliferous. *Echinobrissus scutatus*, *Ammonites plicatilis*	7	0
3. Solid block of blue limestone, composed of comminuted shells, with scattered oolitic grains. It is locally called "rag-stone," and is used for road-mending on account of its hardness; but it is a beautiful building-stone, and has been extracted as such. The fossils all obliterated	4	0
4. Rubbly clay parting of insignificant thickness here, but increasing to 1 foot in a quarry a little to the west, where it is full of small broken fossils.		
5. Solid creamy fine-grained oolitic limestone, false-bedded, very hard, and blue in the unweathered portions, weathering light yellow. Joints filled with calcite. The best is used for building; the rest for lime. No distinguishable fossils	12	0
6. Not seen here, but reported to be hard blue marl with small stones. Some of it, seen by the road-side, was very pisolitic, and contained many oysters. *Exogyra nana*	17	0

The last of these beds makes clear our stratigraphical horizon; and in the absence of fossils, the lithology of bed No. 5 may prove its identity with the false-bedded series of Sturminster. The higher beds will be referred to again.

A similar section to the above is seen in enormous worked-out quarries a little to the west, where the false-bedded series and the superincumbent flaggy oolites and marls form a delightful picture to the geological eye, which we have attempted to pourtray (fig. 3).

Fig. 3.—*View of Section of False-bedded Oolites near Marnhull.*



Further to the west, again, the false-bedded limestones are still more largely exposed in a quarry with a 14-feet face, now in work, where they are extremely uniform and smooth, in beds from 1 foot to 2 feet in thickness, without apparent dip in any direction. They are beautiful building-stones, having a fine grain, and being free from fossils, except a single bed near the top, which contains *Trigonia clavellata*, *Chemitzia heddingtonensis*, *Nerinæa fasciata*, *Pleuromya tellina*, and *Echinobrissus scutatus*. As no false-bedding is here seen, their identity might be considered doubtful; but their aspect and the stratigraphical connexion with the last-described quarries leave no doubt on the subject, especially as they are overlain close by by similar flaggy oolites, which contain *Trigonia Meriani*.

In spite, therefore, of their very local nature and their comparative paucity of fauna, these false-bedded limestones are of great importance economically, and play the same part here that the Coralline Oolite does in Yorkshire, with which they may possibly agree in age, though more probably they are a little older. We may compare them also in time perhaps with the Osmington Oolites.

The next set of beds in the ascending order at Sturminster is a very curious one. As it planes off the edges of the beds below and lies on their uneven surface, we may conclude that some time elapsed between the deposition of the two. The rubbly character of these rocks and the abundance of *Cidaris florigemma* and of other fossils would lead us to consider these beds the equivalent of the Coral Rag of other districts, and, indeed, to have been deposited at the same time that the coral reefs were in growth further to the west and north, and to have been derived from them, although it must be acknowledged that the list of fossils includes some which are usually only found in older deposits than the Coral Rag proper.

We are not able to trace this division in its typical form to any distance. In the section at Todbere above described it is doubtless represented by the massive limestone No. 3, though *Cidaris florigemma* has not been found in it; but it must be of an extremely patchy character, as, even at Marnhull it cannot be recognized, and *Cidaris florigemma* is not to be found in the quarries at present exposed to the south of Sturminster, or, indeed, elsewhere in this district.

There are not *usually* any limestones overlying the "Coral Rag;" and if the rubbly limestones of Sturminster represent this, then the succeeding upper calcareous series are a rather exceptional development. In the Marnhull quarries the upper beds, in the form of flaggy oolites, as represented in figure 3, overlying the false-bedded series, undoutedly represent them; but beyond this neighbourhood the type is too much altered to enable us to trace them.

It has been seen that we have been unable to identify the beds above the pisolites at any distance from Sturminster; but if the false-bedded series and the rubbly and upper limestones are so local, what has taken their place?

With regard to the district south of Sturminster, the few openings all expose limestones whose approximate age can only be determined by their fossils. At Mappowder is a quarry in rubbly shell-limestone, in which the fossils consist of abundance of *Trigonia clavellata*, also *Chemnitzia heddingtonensis*, *Modiola varians*, *Lucina aliena*, and, most astonishing, *Rhynchonella Thurmanni*, a fossil unknown elsewhere at so high a horizon. A more fossiliferous quarry may be seen at Glanvilles Wootton, composed of hard blue finely oolitic ragstone, containing shell-layers, and graduating into pure shell-limestone. The fossils here are *Trigonia clavellata* (abundant), *Astarte polymorpha, Lucina aliena, Modiola varians, Mytilus pectinatus, Perna mytiloides, Pholadomya æqualis, Pecten qualicosta, Ostrea gregaria* (abundant), *Exogyra nana, Chemnitzia heddingtonensis,* and *Nerita minuta.* The mixed character of this fauna shows that where the conditions remained constant no satisfactory divisions can be made out, but that the whole must be taken as equivalent to the period which elsewhere developed the false-bedded series to the upper limestone inclusive.

With regard to the north beyond Gillingham, the Sturminster section seems to be little guide above the pisolites ; for though there is here a considerable amount of limestone, which from its nearly horizontal lie covers much of the country, it cannot be identified either with the false-bedded or the rubbly series. We have here probably a distinct area of deposition, in which again calcareous conditions largely prevailed, though not developing beds of the same character in points of detail as those at Sturminster. The openings made for the extraction of roadstone in this district are very shallow, and they exhibit rocks of the same character for some distance across the strike.

The lower portion, which is probably not much above the pisolites of Cucklington, may be illustrated by a quarry at Langham.

Section at Langham.

	ft.	in.
1. Rubbly grit, with *Ammonites cordatus, Belemnites abbreviatus, Perna quadrata*	1	0
2. White oolitic marl with abundance of *Natica clio*	2	0
3. Hard gritty limestone, used for roadstone, broken and irregular at the top, with *Ammonites*, sp. (*Schilli*), *Phasianella striata, Chemnitzia heddingtonensis, Trigonia,* clavellate sp., *Gervillia aviculoides, Perna quadrata, Modiola*	3	0

The Cephalopoda here are quite strange to the district, but elsewhere belong generally to low horizons. The characteristic fossils are the *Natica*, *Gervillia*, and *Perna* ; these are in great abundance, and together point to a time certainly previous to the *Trigonia*-beds of Weymouth or the rubbly limestone of Sturminster.

The upper portion of the Corallian beds in this part of the country may be studied in similar openings further to the east, on the west side of the river Stour, near Preston. We here see some 12 feet of sandy oolites weathering in flaggy beds, but with a tendency to run, as it were, into large doggers. The character of the stone is not unlike that of the fine-grained Osmington oolites. It is remarkable as containing a vast number of short fragments of narrow algæ, evidently floated from a distance. The brown marks made by these on the white stone render it very conspicuous. With this exception the stone is not very fossiliferous, but contains a clavellate *Trigonia*, *Perna quadrata*, *Gervillia aviculoides, Chemnitzia*, sp., *Echinobrissus scutatus*, and *Exogyra nana.* These fossils link the rocks containing them to the series just described to the west. These rocks, however, are overlain by still more noteworthy ones, consisting of what may almost be called shell-beds, so numerous are the fossils. Where these are small the matrix is still a sandy oolite ;

but where they are large the calcareous matter renders it more compact. Among these shell-masses are here and there masses of *coral*, the only ones found *in situ* in this district. The commonest is a species of *Stylina*, in masses about six inches in diameter; and there are also portions of *Thamnastræa*. The shells are *Cerithium muricatum*, *C. Pellati* (De Lor.), *Acteonina miliola*, *Nerita minuta*, *Natica clio*, *Astarte polymorpha*, *Gastrochæna carinata*, *Trigonia* (clavellate), *Tancredia planata*, *Pecten qualicosta*, *P. lens*, and probably many more. Although this can scarcely be called a "coral rag," it is the nearest approach to it that we have yet seen; but the character of the fauna leads us to the belief that it is probably older than the Coral Rag of the period of *Cidaris florigemma*, though possibly not far removed in age from the *Trigonia*-beds of Weymouth. The uppermost beds throughout this neighbourhood are similar shell-beds, with the fossils included in the above two lists, with the addition of *Ammonites plicatilis* and *Cucullæa corallina*, associated, where the group is cut off by a fault to the north, with thick beds of blue calcareous grit.

Such are the calcareous beds of this district. Of the overlying sands and grits, the glimpses are few and far between. We have found no exposures of them between the oolites and the Kimmeridge Clay, except at the spot mentioned and from Gillingham northwards. Their intermediate position and their fossils at Sturminster mark them plainly as comparable with the Sandsfoot series, proving that towards the end of the period, if not before, there was some community between the two areas. A representative of these sands and clays to the north of Gillingham is generally seen as a comparatively thin covering of ferruginous semi-earthy material merging gradually into the quaternary soil, and lying on the waterworn edges and in the cracks of the sandy oolites and shell-beds, showing a distinct interval of time between them, and incidentally proving the early age of the former. In some places, however, this material is itself a *remanié* deposit, having fragments of rolled oolitic ironstone interspersed in layers in the clay. The contained fossils are *Phasianella Coquandi*, *Belemnites nitidus*, *Exogyra nana*.

Comparing this district generally with the Weymouth area, we find similarities and differences. They are similar by the great variety of calcareous beds intervening between the sandy series above and below, by the reduction of corals to a minimum and the substitution of rubbly beds, also by the presence of false-bedded limestones. They differ by the former containing a much smaller development of arenaceous material, by the abundance of pisolite, and by the general massiveness of the middle beds.

III. The North-Wiltshire, Berkshire, and Oxfordshire Range.

The area of Corallian rocks on which we now enter, though continuous by some part of the series from one end to the other, is so long and narrow, and presents so many minor areas that have distinctive characters, that we cannot treat it as a whole as we have done the two former districts, but must divide it into sections geologically connected. Among these are included:—the classic grounds in which Mr. Smith, and others before him, have worked, and where first the name "Coral Rag" was applied; others, which have been admirably illustrated by Mr. Wm. Lonsdale, in the 'Transactions' of this Society, 2nd series, vol. iii. pt. 2; others again, on which the officers of the Geological Survey have written*; and others that have come under the study of the geologists of Oxford, among whom must be particularly mentioned Mr. Whiteaves, who gave a list of all the fossils found by him in these rocks †, and Prof. Phillips ‡, who added various particulars and comparisons. By all these we have profited, especially by Mr. Lonsdale's work; but our studies in the field have thrown much further light even on this area than we had previously been able to obtain.

Our separate sections commence with,

1. The Westbury District.

The chief interest of the Corallian beds in this neighbourhood undoubtedly centres in the iron-ore, which, at the time of our visit, was being energetically worked. The large excavations on either side of the railway-station afford excellent sections for study. The deposit appears to be of very limited extent, occupying a narrow strip of ground running nearly north and south; although its actual boundaries have not been traced, it is stated to terminate in both these directions at a very short distance from the extreme workings, which are not more than half a mile apart. To the west it crops out; and to the east it dips beneath the Kimmeridge Clay. How far it may extend beneath the surface in that direction is not known. A well sunk about halfway between the town and the railway-station, after passing through about 50 feet of Kimmeridge Clay, showed that the ore had diminished to a thickness of 2 feet. When last seen it is under the influence of a local rise; but its general dip is from 3° to 4° to the east. A fresh-cut surface in a working north of the railway gave the following:—

Section of the Westbury Ironstone.

	ft.	in.
Baring:—		
Soil and top clay	3	0
Sand and marl in pockets (quaternary?)	0	6
Stiff unstratified clay (redeposited Kimmeridge)	5	0
Mixture of ferruginous sandy clay and iron oolite	1	0
	9	6
Ore:—		
1. Dark earthy friable stone, rather oolitic: contains a band of hard blue shelly rock	2	0
2. Dark green blocks of earthy and oolitic stone §, in layers from 6 in. to 9 in. thick, with much ferric hydrate along the joints and lines of bedding	7	0
3. Band of oxidized stone	0	3
4. Dark oolitic stone to floor of working	4	0
	13	3

* Explan. of Sheets 13 & 34. † Ann. Nat. Hist. 1861, ser. 3, vol. viii. p. 142.

‡ Geology of Oxford.

§ In the Jermyn street Museum are specimens of these ores with analysis attached, showing 42 per cent. of iron in the brown portions and 37¾ in the green.

No. 1 here contains enormous quantities of *Ostrea deltoidea*. In different parts of the workings there are several blue shelly bands, which contain most of the fossils, especially Ammonites, which are very numerous. These shelly bands being of inferior quality as ore, are rejected, and masses of the deltoid oysters are thrown out in heaps.

Nos. 2, 3, 4. The ore varies from 11–14 feet in thickness, being generally thickest towards the west. It may be termed an oolitic ironstone more or less mixed up with black argillaceous ore. It is almost free from grit, and exists partly as ferrous carbonate and partly as hydrated peroxide; but the condition of oxidation varies according to the amount of clay which happens to be over the beds. In the oolitic portions of the stone oxidation has progressed to a greater extent than in the black earthy portions, which are almost in the condition of clay ironstone. The chief difference between this and the granules of Abbotsbury consists in the greater abundance of phosphoric acid.

The fossils that we noted in the ironstone beds, though probably not by any means their whole fauna, were:—

Ammonites Berryeri (*Les.*).
—— decipiens (*Sow.*),
—— pseudocordatus (*Bl. & H.*).
Cardium delibatum (*De Lor.*).
Pholadomya hemicardia (*Ag.*).
Perna quadrata (*Sow.*).
Pecten lens (*Sow.*).
—— midas (*D'Orb.*).
—— distriatus (*Leym.*).
Ostrea deltoidea (*Sow.*).
Serpula.

This list, scanty though it be, serves conclusively to prove the late and essentially Kimmeridgian date of the rock from which the fossils are derived. The Sandsfoot grits are also essentially Kimmeridgian; and this is linked to them very markedly by these fossils, especially by *Pecten distriatus*; but as the Ammonites point to a still later period, we are almost driven to correlate them with the oolitic ore of Abbotsbury.

The iron ore of Westbury is underlain by (5) dark green ferruginous sand, becoming lighter and softer towards the base, but with much argillaceous matter throughout, said to be destitute of fossils, and having a thickness of from 4 to 7 feet. The descending section was continued in a well-sinking, particulars of which were kindly furnished us by the manager, as follows:—

	ft.
6. Oolitic limestone, compact where unexposed, weathering rubbly ...	28
7. Stiff marl	12
8. Loose sands, containing four or five beds of rocks about 1 ft. thick each	50

The well left off in dark hard rock, from which the water flowed abundantly.

The only one of these beds that is exposed in the neighbourhood is the rubbly oolite, whose fossils are in a rubbed and broken state, the only recognizable ones being *Pecten qualicosta*, *Echinobrissus scu-*

tatus, spines of *Cidaris* (not *florigemma*), and small fragments of corals. This, then, does not appear to be of the age of the true Coral Rag characterized by the last-mentioned urchin, but is perhaps older; the underlying beds, however, agree in description with those of the nearest point of possible comparison, Calne, in which No. 7 would well represent the oolite clay or marl, and No. 8 the Lower Calcareous Grit, which thus appears in somewhat of its usual thickness and importance.

2. Steeple Ashton.

The succession of the beds in this renowned locality has been indicated by Lonsdale in the paper already referred to; and he seems to have had superior opportunities to those which are now available. We were exceedingly anxious to ascertain the true stratigraphical position of the celebrated coral-bearing beds, about which our information was, after all, but scanty; but so little opportunity does the neighbourhood afford for their study that we cannot persuade ourselves that we have arrived at our conclusions on thoroughly satisfactory grounds.

Lonsdale describes the Upper Calcareous Grit as occurring here, and consisting of an upper 10 feet of sand and a lower 10 feet of ferruginous clay. Of this there is no present exposure; but the high ground round the village church is highly charged with red oxide of iron; and pits are said to have been dug here for ore.

The same author divides his "coral rag" into (α) freestone, (β) rubbly oolite, (γ) irregular beds of *Polyparia*, and states that the two latter occur near Steeple Ashton, placing the coral-beds *below* the rubbly oolite. This would be contrary to our usual experience elsewhere; and though the position of the beds must, unfortunately be settled entirely by surface indications, as there are no illustrative sections, we think that these prove that the coral-bearing beds lie *above* the rubbly oolite.

The numerous corals that have been obtained from this locality appear to have been all collected from the surface of the ploughed fields, we might almost say field, so very local is the area where they are found; and we could not hear of any excavation having been made in which they had been seen *in situ*. The field from which they chiefly come is situated on the north side of a road that turns off to the S.E. from the high road between Steeple Ashton and Bratton; and the area of their occurrence seems to be a narrow band running E. and W. This field, whose every stone is still a coral, though the best have long since been removed, slopes on one side to the S.E.; and at the bottom of the slope, which is rather rapid, is an old pit now filled up, but with numerous fragments of rubbly oolite about. The coral-bed is here in such a position that to bring it below the oolite would require an amount of dip for which we have no evidence at all, as the corals occupy the whole of the higher surface of the field, where, indeed, they seem to be growing above the oolites, as is usually the case. They are also coloured

red, which may most probably be due to their having been covered by the ferruginous clays.

Tracing the coral-beds to the S.W. no more can be seen of them; but when we reach East Ashton in that direction, and run a traverse from a pit of rubbly oolite, seen near that village, to the outcrop of the Kimmeridge clay, we find abundant surface indications between the two at "Broad Mead," not, indeed, of a coral reef, but of a shell-bank, in which one, at least, of the corals, *Thecosmilia annularis*, occurs, the matrix of the shells being a red-coated calcareous grit, recalling much of the appearance of the corals themselves. This we consider the continuation of the coral reef under a changed aspect. Such a phenomenon we might expect, and find too, repeatedly, elsewhere. The fossils obtained from this field by a local geologist include:—

Ammonites plicatilis (*Sow.*).	Perna mytiloides (*Lam.*).
Natica corallina (*Dam.*).	Lima elliptica (*Whit.*).
Trigonia clavellata (*Sow.*), var.	Pecten intertextus (*Röm.*).

Cidaris florigemma does not appear to occur here; and it is absent from the whole neighbourhood south of Seend. The other fossils indicate a rather early date for this reef—though, if two other fossils, *Rhynchonella corallina* and *Terebratula subsella*, are rightly determined, later beds must be present here also.

The rubbly oolite, of which more than 12 feet are seen in a lime-pit on the high road leading south from the village, is a succession of marly pisolites and harder beds of similar but more compact material. The fossils are all worn, and covered with a coating of calcareous matter. They include *Chemnitzia heddingtonensis*, *Opis Phillipsi*, *Pecten qualicosta*, a clavellate *Trigonia*, *Ostrea gregaria*, and *Exogyra nana*. The false-bedding of these rocks is very remarkable: the false dip of the lower 8 feet is to the north-east, at an angle of 12°. These are planed off, and a series of thinner false beds cover them, which dip in a direction at right angles to the first at an angle of 4°. The lower beds of calcareous grit may be seen in the road-sides to the west of East Ashton, but present no points of interest.

These two districts, Westbury and Steeple Ashton, though interesting, each for their only particular products, show a very meagre development of Corallian beds as a whole; but their area is separated from the main range by a narrow band, in which only the lower beds occur, as is seen at Seend. Here a fine section, well described by Lonsdale, has long been exposed, where the furnaces for the Neocomian iron-ore stand. It is entirely in the Lower Calcareous Grit, of which 25 feet are seen, and more is indicated in the neighbourhood. This part of the series is here exceptionally fossiliferous, the greater number of fossils coming from a shell-band near the top; but *Ammonites cordatus* and *Gervillia aviculoides* characterize the lower portion. Our list from the shell-band is:—

Nautilus hexagonus (*Sow.*).
Pleurotomaria Münsteri (*Röm.*).
Turbo Meriani (*Goldf.*).
Cerithium muricatum (*Sow.*), var.
Trigonia, sp. (cf. Bronnii, *Ag.*).
Opis Phillipsi (*Mor.*).
Astarte depressa (*Goldf.*).
Lucina circumcisa (*Zit. & G.*).
Arca æmula (*Ph.*).
Sowerbya triangularis (*Ph.*).
Modiola subæquiplicata (*Goldf.*).
Avicula ovalis (*Ph.*).
—— inæquivalvis (*Sow.*).
Lima elliptica (*Whit.*).
Pecten lens (*Sow.*).
—— subtextorius (*Goldf.*).
—— fibrosus (*Sow.*).
Exogyra nana (*Ph.*).

A very remarkable list, if rightly determined, showing, as it does, several forms unknown elsewhere, the whole pointing to the upper part of the Oxfordian portion of the series.

3. The Calne District.

For some miles north of this section at Seend the Corallian series is chiefly represented by beds on the same horizon; but at Westbrook we enter upon the area in which the formation was first studied, and where the names originally applied are indeed extremely appropriate, but which must be considered in reality exceptional with reference to the whole of England, in being generally deficient in the numerous deposits which intervene between the early arenaceous series and the Coral Rag with *Cidaris florigemma*. So great is the interval thus represented, as indicated to us by the great masses of oolite in the regions already described to the south, and the still more important ones developed in the north, that we are inclined to say of a bed of Coral Rag resting on Lower Calcareous Grit that it may be of any age, especially if it be not covered by any upper arenaceous or ferruginous series. Learning, indeed, from other localities, the enormous lapse of time between the formation of the Lower Calcareous Grit, indicated by its ordinary fossils, and the Kimmeridge clay, we must look upon any small coral growth that rests upon the former as representing but a very small portion of it, the date depending on the occurrence of the physical conditions to which such growths are subject. We cannot speak of *the* Coral Rag; for *a* Coral Rag may be of very various ages. Thus, at Westbrook, we have a fine coral reef, the first in our journey northwards that we have been able to examine *in situ*. Layer upon layer of large masses of *Thamnastræa concinna* and *Isastræa explanata*, bored by the characteristic *Lithodomus inclusus*, and changed not seldom into crystalline limestone, in which the organic structure is no longer visible, here spreads over the surface, resting immediately upon a bed of sand, which is itself not far removed in elevation from the Oxford clay. The spaces between the coral growths are filled with a rubbly brash, made up of comminuted materials, and sometimes with clay charged with fragments of shells. These intercoralline accumulations obtain the mastery here and there; corals disappear, and we have great rubbly beds of shelly clay and limestone brash forming the whole reef. This is what we might expect, and have often to infer; but it may here be seen and proved. In the intercoralline beds the chief recognizable fossils, which are in infinite numbers, are *Ostrea gregaria*, *Lima densepunctata*, *L. pectiniformis*; and amidst the coral growth we find *Littorina muricata*, *Opis Phillipsi*, *Gastrochæna recondita*, *Pecten lens*, *P. subtextorius*, *Exogyra nana*, *Cidaris Smithii*, *Pseudodiadema versipora*. This reef, the absence of *Cidaris florigemma* from which is a most noteworthy circumstance, is the only representative on this side of Calne of all the beds elsewhere seen above the Lower Calcareous Grit; and in spite of the agreement of its coral fauna with that associated with *Cidaris florigemma*, its molluscs and echinoderms point, in our opinion, to an early age, not far removed from that of the calcareous grit on which it rests. We regard this therefore as an interesting example of an earlier-formed reef than usual, such as we find, though not commonly, in Yorkshire and elsewhere.

In approaching Calne we come to the locality of the chief section given by Lonsdale, which has been of great use to us, and which we are able to confirm, though it seems to us that there is still something to be said about this neighbourhood.

The sandy beds at the base, like those forming a modern sandbank, such as was here formed towards the close of the Oxfordian period, thicken rapidly and as rapidly die away, so that in Bowood Park and to the north they occupy square miles of country, but six miles from Calne they have become so thin as to be only recognizable as a single bed.

The characters of these beds where best developed in this district may be studied in the railway-cutting, in a quarry near Conygre Farm, and in another near the Bremhill and Studley road; from these combined we obtain the following

Section of the Lower Calcareous Grit near Calne, in descending order.

	ft.	in.
1. Rubbly calcareous grit with numerous shell-fragments; among them *Ceromya minima*, *Pecten fibrosus*, *Ostrea solitaria* .... This is still more rubbly in the Conygre Quarry.	2	0
2. Rock of similar structure, but more arenaceous, and running into beds	1	3
3. Loose sand	2	0
4. Solid block of calcareous grit	1	0
5. Loose sand	7	0

The above description and thicknesses are derived from the section in the railway-cutting; but in the Conygre Quarry they are more irregular and of smaller total thickness (about 9 ft.). The hardened bands are irregular in their position; and the whole deposit, though not exactly false-bedded, was evidently formed in disturbed or moving waters.

	ft.	in.
6. Solid block of blue-hearted calcareous grit of very compact structure, sometimes in two bands, and showing branched fucoid forms on weathering	3	0
7. Loose sand of a dark colour, and apparently graduating in the railway-cutting into true Oxford Clay; but in the Bremhill-road Quarry showing more beds of grit, which are very variable, and with scarcely any fossils	9	0

The whole thickness thus described amounts to little more than 25 feet, which would not appear to be so much as it attains in the direction of the outcrop, but is nearly the whole where seen, the rubbly nature of the upper beds pointing to a change in character coming on above. The form thus exposed is not unlike the general development throughout this range. The fossils of these quarries come chiefly from the upper beds, Nos. 2 and 4, *Gervillia aviculoides* being left almost alone in No. 7. They are:—

Ammonites cordatus (*Sow.*).	Pecten lens (*Sow.*).
—— perarmatus (*Sow.*), var.	Ostrea gregaria (*Sow.*).
Cerithium muricatum (*Sow.*), var.	—— dilatata (*Sow.*).
Gervillia aviculoides (*Sow.*).	Exogyra nana (*Ph.*).
Pholadomya concinna (*Ag.*).	Serpula tricarinata (*Sow.*).
Pecten fibrosus (*Sow.*).	

which is very much what we might expect, though not a very rich list. The nature of the Lower Calcareous Grit, as it runs on to the north, will be seen in the sections we shall give subsequently with reference to the higher beds.

Overlying the sand and grit in the neighbourhood is an untested thickness of marly clay, as stated by Lonsdale; but very little can be seen of it. In a well close by the great quarries, near the Union Workhouse, after passing through 20 feet of blue oolitic rock, 10 feet of this was sunk into; it consists of light hard marl with indurated lumps surrounding ill-preserved shells such as *Natica*, *Alaria*, and *Lima*. It may also be seen underlying Coral Rag, on the west of Fisher's Brook, a stream running parallel to and west of the Wootton-Bassett road. This marl alone represents the great intervening deposits of other localities, and is quite an exceptional development at that period, though not absolutely unique. It recalls the marls and marly pisolites which constitute so much of the Corallian beds of the North-Dorset district.

The most interesting portion of the Corallian beds, however, in this neighbourhood is the uppermost. Proved by stratigraphy and by fossil contents to be of the same age, there is a marvellous variety of rocks whose lithological characters have scarcely any thing in common. First there is the true Coral Rag, formed of great masses of *Thamnastræa*, with intervening brash; this may be traced up to the Kimmeridge Clay, all round the stream that runs down from Quemerford, where it presents its usual well-known characters and fossils, and of which we need say no more. Traced towards the town we see beds of large-grained oolite becoming mixed with it, sometimes above and sometimes below the Rag, but always, like it, containing *Cidaris florigemma*; and thus we are led on to the second form, which is seen in the great freestone quarries at the Union.

These exhibit a face of 25 feet, made up of beds about 1 foot to 2 feet in thickness, of more or less perfectly false-bedded oolite, the dip of the false-bedding being towards the N.E. In some parts the oolitic structure is little marked, the layers are more consolidated, and split into blocks with ease. It is on the surface of such blocks that the majority of the fossils are found. The Hemicidarids and other urchins, for which the locality is celebrated, lie in great profusion on the surface of some of the lower beds, where they are protected by the intervening brash. The circumstances of the deposition of these rocks are not unlike those which formed the false-bedded series of the North-Dorset district; but the fossils point to a later age—namely, that these Calne oolites are contemporaneous and alternate with the true Coral Rag with *Cidaris florigemma*, which they contain in abundance, associated with a tolerably rich fauna, in which the absence of Corals and the abundance of Gasteropods may be noted, viz.:—

Phasianella Buvignieri (*D'Orb.*).
Chemnitzia corallina (*D'Orb.*).
Littorina pulcherrima (*Dollf.*).
Turbo funiculatus (*Ph.*).
Cerithium limæforme (*Röm.*).
—— Humbertinum (*Buv.*).
—— muricatum (*Sow.*).
Trochotoma tornata (*Ph.*).
Mytilus pectinatus (*Sow.*).
—— angulatus (*Y. & B.*) (small).
Lima rigida (*Sow.*).
Lima subantiquata (*Röm.*).
Pecten lens (*Sow.*).
—— qualicosta (*Et.*).
—— strictus (*Münst.*).
Avicula pteropernoides (*Bl. & H.*).
Perna mytiloides (*Lam.*).
Cidaris florigemma (*Ph.*).
Acrosalenia decorata (*Haime*).
Hemicidaris intermedia (*Flem.*).
Stomechinus gyratus (*Ag.*).

We seem to see in these false-bedded oolites of Calne the physical conditions of the false-bedded series of North Dorset, which, beyond that area, may be traced as far as Westbury, and even to Steeple Ashton; but the fauna is richer and very different. This is no doubt due, in part, to the closer proximity of a reef. The form of deposit seen in the great quarries is probably exceedingly limited; for in the direction of the false dip we immediately come to the before-mentioned well, where its thickness is much less, and the upper beds are becoming quite rubbly; and amongst them are found the great corals of the period, which are also scattered over the fields. In this latter form the Coral Rag overlies the clay near Fisher's Brook.

A third form of the deposits of this age is the exceedingly interesting one at Hillmarton. On the south-west side of the small stream that descends from the Chalk is a plateau, into which two openings have been made for the extraction of road-stone. In the deepest of these, which has more the appearance of a clay-pit than of a quarry, are seen a series of dark-blue bands of clay, separated by beds of limestone of the same colour (fig. 4). These limestones are not even-surfaced, but irregular above and below: the deepest appear to be the thickest and most crystalline, and are often perceptibly formed of Thamnastræan and Thecosmilian corals; the upper bands are thinner, lighter-coloured, and more earthy, becoming near the surface almost like chalk.

These upper bands are so uniform in substance, and so evidently altered from their original state, that we must consider the lower crystalline and coralline bands the normal form; and it seems

Fig. 4.—*Section of Coral-beds, Hillmarton.*

a. Coral and altered Limestone. *b.* Clay.

most probable that they are all organic growths on the spot, rather than transported matter. How far they were coralline would be difficult to say. The clays contain some Foraminifera of very unusual character and other Microzoa; and the limestones are very fossiliferous; so that at the time of the formation of the beds this spot was teeming with life, among which the Echinodermata were abundantly represented, and the stony Algæ appear not to have been wanting. Our list from these quarries, to which the fossils collected and recorded by the Survey as from Hillmarton may probably be added, is:—

Littorina muricata (*Sow.*).
Chemnitzia heddingtonensis (*Sow.*).
Alaria, sp. (*cf.* tenuistria, *Buv.*).
Lithodomus inclusus (*Ph.*).
Pholadomya decemcostata (*Röm.*).
Lucina aliena (*Ph.*).
Astarte ovata (*Sow.*).
—— subdepressa (*Bl. & H.*).
Cypricardia glabra (*Bl. & H.*).
Mytilus ungulatus (*Y. & B.*).
Perna mytiloides (*Lam.*).
Lima elliptica (*Whit.*).
—— pectiniformis (*Sow.*).
—— densepunctata (*Röm.*).
—— rigida (*Sow.*).
Plicatula, sp.
Hinnites velatus (*Goldf.*).
Pecten qualicosta (*Et.*).
—— vimineus (*Sow.*).
Exogyra bruntrutana (*Th.*).
Ostrea gregaria (*Sow.*).
Terebratula insignis (*Schl.*).
—— margarita (*Opp.*).
Thecidea ornata (*Moore*).
Cidaris florigemma (*Ph.*).
—— Smithii (*Wr.*).
Pseudodiadema versipora (*Ph.*).
Parendea bullata (*Et.*).
Corallina, sp.

Most of these are the true characteristic species of the "*C.-florigemma* Rag" where best developed.

Rocks of the same epoch, but more closely coinciding in character with the freestones at Calne, occur not far from here, at Goatacre, whence a considerable portion of the building-stone of the neighbourhood is obtained. It is here more highly false-bedded, dipping 16° to 20° towards the south, and is much mixed with layers of clay, which attain as much as a foot in thickness, and indicate the relation of this quarry to those at Hillmarton. The limestone is not properly oolitic, but contains here and there small unrounded grains; it has been much subject to infiltration since its deposition, which has taken away all the substance of the fossils, leaving only empty spaces as casts. These lie throughout the mass of the stone, and are abundant, including *Phasianella striata*, *Chemnitzia heddingtonensis*, *Cerithium muricatum*, *C. limæforme*, *Littorina muricata*, *Alaria*, sp., *Lucina Moreana*, *Lima rigida*, *Cidaris florigemma*, and *Rhabdophyllia.* This, then, is a fourth form in which these upper rocks appear. This is continued for some distance along the strike, and may be seen again under a very slightly different form near Preston, where the beds are very irregular, and blue and moist from the presence of clay beneath, and have a considerable amount of pisolite. Here *Echinobrissus scutatus* is fine and abundant, and *Nerinæa fasciata* and *Unicardium sulcatum* are added. The depth of each of these quarries is about 12 feet.

Continuing in the same direction, we find at Lyneham Hillocks, and all along the narrow band that stretches towards Wootton Bassett, the Coral Rag alone representing the series above the sands. It is here in its normal form, with layers of Thamnastræan coral-growths, and drifted *Thecosmiliæ*, with associated bands of brash, rubble, and clay. Splendid sections of these reefs may be seen at various points along this line of road, and many of the usual fossils noted; but though exceedingly interesting to see, they present no special feature calling for remark.

At Calne, as before stated, the rocks on the horizon just described are the highest below the Kimmeridge Clay; but towards Hillmarton and for some distance further, indications of supracoralline beds very similar to those that lie in the cracks and uneven surfaces of the older Corallian rocks in North Dorset make their appearance. These ruddy, ferruginous, sandy clays are mapped by the strong colour they give to the soil, and can seldom be seen *in situ*. An opportunity, however, is afforded in the above-mentioned limestone-quarry at Preston. Here about 2 feet of rotten ferruginous rock is seen overlying the limestone, having, towards the base, nodules and fragments of a biplicated Ammonite, Belemnites, and a large oyster, similar to one that is found in an analogous position in Yorkshire. We know not how far this deposit may once have extended, and have been removed or covered by the Kimmeridge Clay; its perpetual reappearance in the same character, independent of the underlying beds, leads to our regarding it as a widespread indication of coming change, being the first introduction, if we except the intercoralline clays of Hillmarton, of the argillaceous conditions that were to succeed.

As a further illustration of the development of the Corallian beds in this district, we think that two sections visible near the escarpment, where the whole series is so thin as to have representatives of each portion in a single quarry-face, may not be uninteresting. In the neighbourhood of Clack the country presents a beautiful natural plateau, in which the surface is composed of not much more than a single bed over a considerable area. This plateau is upheld, and its declivities are formed, by Oxford Clay, the Corallian beds being merely on the surface. We meet here with the following section, showing the whole series in 9 feet.

Section of Corallian beds at "Green's Cleeve."

	ft.	in.
1. Coral-bed of *Thamnastræa*, *Thecosmilia*, &c., seen at a few yards distance, at a slightly higher level, and resting on		
2. Pisolite and rubbly oolite, in broken pieces, with *Lima elliptica* and *Avicula ovalis*	3	0
3. Large-grained oolite marl		6
4. Rubbly oolite, with *Cerithium muricatum*, with *Lima elliptica*, *Avicula ovalis*, *Lucina*, sp.	1	10
5. Clay, with innumerable shell-fragments and oolitic grains, *Hemicidaris*-spines	0	8
6. Yellow sand, with loose alternating layers of clay, and much intermixed and irregularly laid	3	0

The luxuriance of oak-trees a few feet below show that the Oxford Clay is not far off, and that we are, indeed, seeing the feather-edge of a formation. The occurrence of *Avicula ovalis*, so characteristic of the lower beds, indicates that these rubbly oolites are more to be associated with the sands below than with the coral-growth above.

The thickening of the series on the dip, in the direction of the fuller development at Goatacre, may be seen in another neighbouring quarry, of which the section is here given.

Section in Catcombe Quarry.

	ft.	in.
1. A mass of drifted corals and oolites, much mixed up with clay	4	0
Though the corals are numerous, their state and position indicate that they have not lived on the spot where we now see them, but have been drifted, though not, perhaps, from far. Associated with them are *Littorina muricata*, *Cucullæa elongata*, *Lima rudis*, and *Cidaris florigemma*.		
2. White, large-grained oolites, marly and loose, pisolitic at the top, and browner and less earthy towards the bottom	9	0
This bed probably corresponds to Nos. 2–4 of the last section, and contains *Cerithium muricatum*, *Littorina muricata*, *Opis Phillipsi*, *Sowerbya triangularis*, *Tancredia*, sp., *Myacites securiformis*, *Pecten fibrosus*, *P. qualicosta*, *Echinobrissus scutatus*, and *Serpula sulcata*.		
3. Sand, with argillaceous layers towards the top, with irregular bands of shelly limestone, 8 or 10 inches thick towards the base	6	0
For these the quarry is chiefly worked as wall- and building-stone. They are highly crystalline; and the fossils are beautiful pseudomorphs in calcite, the chief being *Natica clytia*; *Rhynchonella Thurmanni* also occurs.		

This quarry is also valuable in another respect—viz. that though we see here the whole section, the marls of Calne, which lie between the Coral Rag and Lower Calcareous Grit, are absent; and though the physical and petrological connexion is indicated by the mixture of the marl with oolite in the pit at Green's Cleeve, yet here their place is entirely taken by oolites, which we may thus compare to the "Coralline Oolite" of Yorkshire, or the false-bedded series of the south. We begin, too, to learn how characteristic *Naticæ* are, in this district, of the lowest fossiliferous beds.

4. Wootton Bassett to Highworth.

The rubbly Coral Rag which we saw occupying the whole Corallian area at Lyneham Hillocks, towards Wootton Bassett, continues to dominate in the neighbourhood of and beyond that town to the west, so that for some considerable extent of country hereabouts the name would be appropriate for all that is seen between the Oxford and Kimmeridge Clays. Its thickness at Wootton Bassett is about 25 feet; and it is in the form of a brash and rubbly coarse-grained oolite in which *Cidaris florigemma* is abundant. At Banner's Ash, a locality quoted by Smith, it is in the form of a true reef, with massive Thamnastræan corals in full development, and with an abundant fauna, including *Nerita Guerrei*, and excluding *Phasianella striata*, which is elsewhere so common. Traces of the existence of some gritty beds below may be noted in brooks and similar exposures; but they make no show upon the surface.

The maximum development hereabouts seems to take place in the neighbourhood of Purton, where the change of strike from N.E. to more nearly E. occurs. The minor exposures are numerous; and whether of much thickness or not, the Corallian rocks are of considerable surface-importance. The chief exhibition of them is seen in a fine old quarry about $\frac{3}{4}$ of a mile east of the village.

Section at Purton.

	ft.	in.
1. Rubbly coral bed, showing several lenticular masses of Thamnastræan corals, of only limited extent, from a few inches to 1 foot in thickness, the remainder made up of broken pieces and *Thecosmiliæ*, as if washed about on the spot. It contains the usual coral-bed fossils. Thickness...	7	6
2. Blue-hearted strong limestones in courses, forming flags, not oolitic, but formed of shell-fragments; the division between the layers often consists of more shelly and less compact limestone-rubble. The stone is used for building and paving, and is not at all false-bedded. The fossils are all broken; but among them may be recognized *Littorina muricata, Perna mytiloides, Pecten vimineus, Lima rudis, Lima rigida, Avicula ovalis, Cidaris florigemma*, and abundance of small oysters. Thickness	10	0

The upper of these beds is instructive, as showing how Thamnastræan and Thecosmilian reefs amalgamate and inosculate; but the main interest attaches to the lower. We have here, indeed, a series of limestones containing *Cidaris florigemma*, undoubtedly underlying the Rag, and not alternating with it, as the similar though false-bedded ones appear to do at Calne. The association of *Avicula ovalis* points to an earlier age, and would induce us to compare these shelly limestones to the series below the Rag, as its position here indicates, and to note that in this district, at least, the Urchin appeared before its usual time, of which we have confirmation elsewhere, and that the lower beds are beginning again to assume importance under a different aspect. We are, in fact, now entering upon the confines of a region which extends, as will be seen, to Marcham, and perhaps even to Oxford, where the more normal state of things no longer obtains. The thickness of the limestones is seen to be not inconsiderable, and has probably been the cause of the wide extension of Corallian rocks in the neighbourhood. But little more of them, however, is to be seen, for they everywhere support a luxuriant coral growth, probably the largest reef of the age in England. Every stone is Madreporarian, and the roads are all mended with magnificent specimens of *Thamnastræa* and *Isastræa*.

As we approach Highworth, however, the Coral Rag becomes diminished in importance by the development of lower beds at its expense, and is at the same time thrown back from the escarpment to form the surface of the dip-slope of the country near Sevenhampton. Hereabouts small shallow openings, in which not more than 5 feet are seen, seem to bespeak its thinness, and to show, by their position above the brooks that are cut down to the Oxford Clay, that it is developed where the lower beds have also thinned on the dip, the whole of the Corallian beds in the region between Sevenhampton and Watchfield being not more than 30 feet thick. It presents no features of importance as distinguishing it from the similar beds to the west, except some admixture of clay. It is seen to rest sometimes on a semi-oolitic stone, full of calcite, and sometimes on clay, and is also overlain hereabouts in the direction of the dip, which is southerly in the main, by a considerable mass of reddish sands, which at Shrivenham village are of importance; but of their precise nature and thickness we have found no opportunity of judging.

Our interest here becomes transferred to the beds below the Rag, which are finely developed in the quarries about Highworth, one of which, the most important, has already been described, first, by Mr. Lonsdale, and, secondly, in the Geological Survey's brief memoir. In these descriptions the measurements and characters of the beds do not differ more than in the quarry itself; but the interpretations given to them are totally at variance with each other. Mr. Lonsdale considers the quarry to represent the whole formation, and states that here the *Upper* Calcareous Grit can be seen to the greatest advantage; while in the Survey map it is all coloured *Lower* Calcareous Grit, and is said in the memoir to be the "finest section" of these beds. We think the truth lies in the happy mean, and that we see here a fine development of beds, mostly lying above the Lower Calcareous Grit proper, and representing in time the interval between it and the Coral Rag. To prove this point, if for no other reason, we think it advisable to give yet a third description of the quarry, which, indeed, from its extreme interest, we should be sorry to omit.

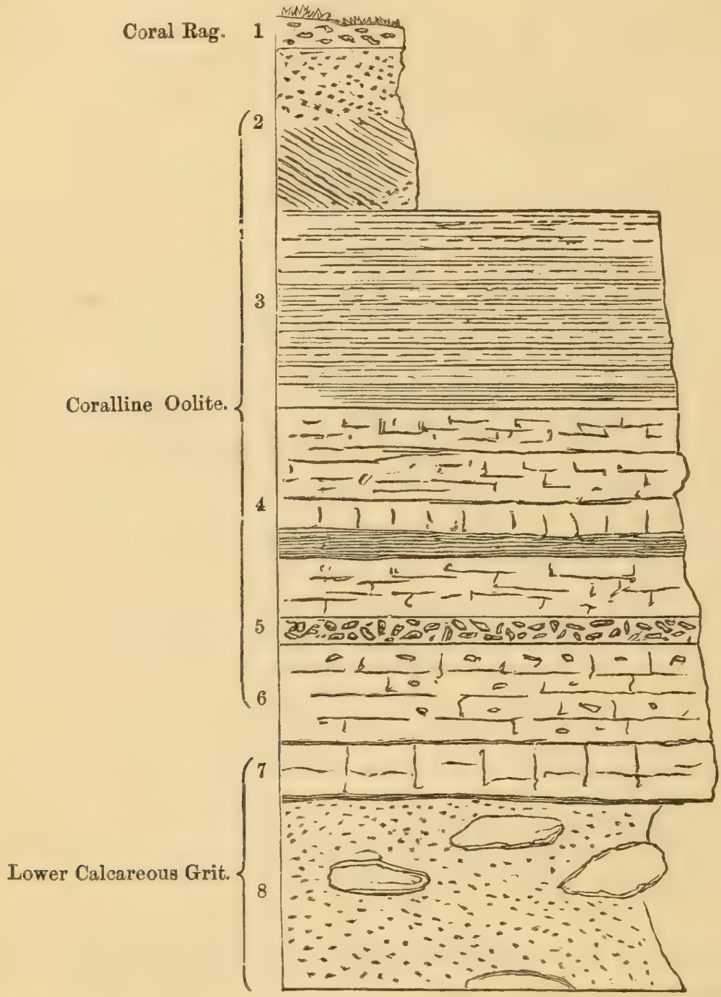
The lower part of this quarry is worked for stone, and the upper for brick; and the working faces do not coincide; so that our section is a double one combined, the upper portion having apparently been overlooked by the Survey.

Section at Highworth South Quarry (fig. 5).

	ft.	in.
1. Rubbly limestone, with prostrate *Thecosmiliæ* and *Cidaris florigemma*, an irregular bed of varying thickness	1	0
2. Laminated current-deposited yellow sands, with large white oolitic grains. These oolite grains in various parts form nearly the whole mass of the stone, which then becomes a false-bedded flaggy oolite, with large grains, having a very peculiar appearance. The surface is covered with fragments of oysters and Pectens, but none large enough to name specifically	5	0
3. Even-bedded sands, becoming dark and argillaceous below, and used for bricks. [No. 1 of the Survey section.]	6	0
4. Rubbly large-grained oolitic beds, divided irregularly by layers of soft sandy or fossiliferous oolite, the lower parts the hardest. [Nos. 2–4.]	6	6
5. Ferruginous, rubbly, and somewhat sandy limestones, mostly made up of prostrate and drifted corals. [No. 5.]	0	8
6. Shelly limestone, with oolitic grains. [Part of No. 6.]	3	0
7. Hard calcareous sandstone, becoming a blue-hearted grit, of variable thickness. Average	1	9
8. Soft white sand, with calcareous doggers, and often false-bedded	6	0

With regard to the interpretation of this section, we may be sure that Lonsdale would never have called Nos. 2 and 3 Upper Calcareous Grit, though they are sandy, if he had seen No. 1, and traced it on the line of dip till it enlarges to a true coral-bed, as near Watchfield. It is, indeed, a rubbly and possibly disturbed deposit, but proves at least the higher position of the beds from which it has been derived. Mr. Hull, the Geological Surveyor, on the other hand, confining the term Coral Rag to the Upper Coralline formations, classes all the beds below as Lower Calcareous Grit. To this horizon the lowest bed in this section would be universally referred; but the beds between, from No. 2 to No. 7, though underlying the Rag, may correspond in character, fossil contents, and time to the rocks which elsewhere occupy the interval. The calcareous portion of them is referred by Lonsdale to the true Coral Rag; and the intervening beds, corresponding to the marls of Calne, are represented by him as absent, an interpretation which, though in our opinion erroneous, proves that he saw the difference between these beds and the Lower Calcareous Grit.

Fig. 5.—*Section of Highworth South Quarry.*



The bed No. 7 lithologically agrees better with the beds below than with those above, though closely amalgamated with No. 6; and we would include it with the Lower Calcareous Grit, from which No. 6 forms a kind of passage to the beds above. The drifted Coral-bed, No. 5, is a feature which we have not yet met with on this horizon, but which may be paralleled in Yorkshire. It is not, however, a reef, but derived from one in the neighbourhood, the locality of which, if still existing, has not yet been discovered. It contains also *Ammonites plicatilis*, *Littorina muricata*, *Opis Phillipsi*, *Unicardium plenum*, and fragments of *Trichites* bored by *Lithodomus*. The *Littorina* seems to be the constant companion of coral, whenever formed about this epoch. The Ammonite, however, clearly distinguishes this bed from the Lower Calcareous Grit, in which that species is seldom, if ever, found; and the other fossils have the same tendency. The series No. 4, which Lonsdale divides into seven, and the Survey into three, but which may really be divided according to fancy, in different parts of the quarry, is the most important portion of the section, as it contains a fine suite of fossils which serve to determine the age. They are very abundant, the most characteristic being *Lima rigida.*

Fossils from Coralline Oolite, Highworth.

Ammonites plicatilis (*Sow.*).
—— perarmatus (*Sow.*).
—— cordatus (*Sow.*).
—— goliathus (*D'Orb.*).
Belemnites Owenii (*Pratt*).
Pleurotomaria Münsteri (*Röm.*)
Trochus dædalus (*D'Orb.*).
Cerithium muricatum (*Sow.*), var.
Littorina muricata (*Sow.*).
Phasianella striata (*Sow.*).
Chemnitzia heddingtonensis (*Sow.*).
Opis Phillipsi (*Mor.*).
Sowerbya triangularis (*Ph.*).
Lithodomus inclusus (*Ph.*).
Quenstedtia lævigata (*Ph.*).
Tancredia curtansata (*Ph.*).
Cucullæa corallina (*Dam.*).
Myacites decurtatus (*Ph.*), var.
Pholadomya decemcostata (*Röm.*).
Unicardium depressum (*Ph.*).
Mytilus pectinatus (*Sow.*).
Gervillia aviculoides (*Sow.*).
Lima rigida (*Sow.*).
—— læviuscula (*Sow.*).
—— elliptica (*Whit.*).
—— subantiquata (*Röm.*).
Pecten fibrosus (*Sow.*).
—— lens (*Sow.*).
Avicula ovalis (*Ph.*).
Plicatula, sp.
Anomia suprajurensis (*Buv.*).
Ostrea, sp. (*cf.* dilatata, *Sow.*).
—— solitaria (*Sow.*).
Exogyra nana (*Ph.*).
Echinobrissus scutatus (*Lam.*).
Serpula tricarinata (*Sow.*).
Cidaris Smithii, test and spine.

The association of *Ammonites perarmatus* (of the particular form here found) with *A. cordatus* and *A. plicatilis* (in the bed below) is indicative of the vast mass of limestones which in Yorkshire overlie the Lower Calcareous Grit proper, though belonging to the period of the latter far more than to the zone of *Cidaris florigemma*; and in the Weymouth district a similar form of *A. perarmatus* occurs in the Osmington Oolites. The *Avicula ovalis* is a low form, except in this district (as at Purton); and the rest, so far as they mark any particular horizon in the series, are certainly characteristic of beds above the Lower Calcareous Grit, such as, where well developed, are called Coralline Oolite, to which age we refer these beds, carrying along with them all the deposits Nos. 2–6. The sandy and curiously false-bedded mass above, is a development we have not yet met with just below the Coral Rag; but we are here entering a district of which this Highworth section is more typical.

The series so well exhibited here is exposed also in other openings near the town, none of which are so full and satisfactory, but which serve to demonstrate the variability in thickness and character of the whole. The nearest approach to conformity with the above section is seen to the north of the town, about on the line of dip, where the most important beds are thickened and the corals are scattered over a depth of 5 feet, a state of things which points to the same conclusion as the thinning-out of the beds to the south—viz. that the sediment came from the north, and the dip of the overlying Rag is due chiefly to the shape of its supporting rocks. There is a considerable descent over sands and grits below any thing seen in the quarries before the springs indicate the Oxford Clay, the Survey estimate being 80 feet.

As we depart on either side from this line we find the beds much diminished, especially on the west, where the great sandbank and its supported limestones take their origin. We see just the beginning of it, as it were, in an opening near the turnpike, on the western road, like the little miniature formation at Green's Cleeve, near Clack.

Section at Highworth Turnpike.

	ft.	in.
1. Blue, fissile, large-grained, rough but not oolitic limestone, with *Ammonites plicatilis* and *Echinobrissus scutatus*................ .... 8 in. to	1	0
2. Soft brash, with shell-fragments, and a 4-inch rubbly limestone, with *A. plicatilis* near the top...	1	2
3. Coral-bed, with all the corals (*Thecosmiliæ*) lying down flat, with *Littorina muricata, Lima elliptica, Pecten fibrosus, Exogyra nana*, and *Echinobrissus scutatus*	1	0
4. Light-coloured limestone, weathering brashy, containing *Ammonites cordatus, Sowerbya triangularis, Pecten fibrosus, Ostrea solitaria*, and a great number of casts of *Cyprina tancrediformis*, 1 ft. to	1	6
5. Calcareous sandstone		3
6. Sand and sandstone	3	3

The occurrence of the Coral-bed here enables us to correlate this section with that of the south quarry, and to see, as pointed out, the greatly diminished thickness of the beds, while they maintain an almost exact correspondence.

A similar section in a quarry on the east side of the town proves the falling-off to be less in that direction.

Section in the East Quarry, Highworth.

	ft.	in.
1. Brown clay, slightly laminated	2	6
2. Brashy oolite..	1	8
3. Grey shelly limestone, slightly oolitic, in two courses, parted by brash	2	8
4. Hard limestone, with ball-concretions and *Thecosmiliæ*	2	4

The Coral-bed is here scarcely discernible; it is probably at the top of No. 4, in which case the correlation is clear. Bed No. 3 is as fossiliferous as the corresponding one in the south quarry (4 of the type section), and adds the following fossils to the list (their tendency being certainly to assign it to the age we have indicated) viz.:—

Trigonia Meriani (*Ag.*).
Modiola cancellata (*Röm.*).
Avicula expansa ? (*Ph.*).
Hinnites velatus (*Goldf.*).
Trichites Plotii (*Lhwyd.*).

The thinning of the lower beds in this direction is proved by the Coral Rag coming back again to the same position with reference to the general strike, as is seen in all the quarries on the road to Faringdon.

5. Faringdon to Oxford.

We here enter upon the region studied by Whiteaves and Phillips, and upon a distinct sheet of the Geological Survey; but as our object is to give somewhat more detail than they have done, we still have something to do.

Of the Corallian rocks in the neighbourhood of Faringdon we are able to give a tolerably complete section, which will serve more or less as a type and standard of comparison for the rest of this district. We may first see the passage downwards of the Kimmeridge Clay in a clay-pit a little to the south-east of the town, where we have the following section:—

Section in Faringdon Clay-pit.

	ft.	in.
1. Solid pale grey unstratified Kimmeridge Clay	6	0
Gradual passage into a reddish-brown porous earth	0	9
2. Chocolate-coloured ferruginous earth, with black stains from dissolved fossils, and lumps of calcareous clay, ironstone, and fragments of *Ostrea deltoidea* and *Serpula* towards the base	1	2
3. Coral Rag, with the surface and fissures iron-stained	3	4

This shows us the fragment of ferruginous beds which here and there appear to have escaped removal by denudation before the formation of the Kimmeridge Clay, as we have seen near Preston and in North Dorset, and spreading over the surface at Shrivenham. They remind us, by the association of *Serpula tricarinata* with large fragments of *Lima pectiniformis*, by the presence of numerous *Pinnæ*, and by the occurrence of a peculiar Ammonite (*A. decipiens*), of the great development of this class of rock at Sandsfoot Castle. The surface of the Rag, as usual when thus overlain, is uneven, with the red earth in the interstices, showing a kind of unconformity. The continuation downwards may be studied in the Workhouse quarry.

Section in the Workhouse Quarry, Faringdon.

	ft.	in.
1. Ragstone, quarried for lime-burning	6	0
Red clay parting, and broken Rag	0	4
2. Road-stone...	4	4
3. Building-stone	3	0
4. Rather loose sands, with water at the bottom.		

The top bed is the ordinary Coral Rag of the neighbourhood, as seen in the last section, rather divided by clays.

The road-stones may be divided as follows:—

	ft.	in.
a. The top block is a hard calcitic limestone, with *Thecosmilia* in the upper part. The central and lower portions are semicrystalline pisolite. The fossils are small; and we may consider the bed to belong to the group of coral shell-beds, which sometimes underlie the Rag	0	6
b. Oolite of variable hardness, and rather shelly towards the middle, with hard crystalline nodules, and an Urchin-bed of *Pygaster umbrella* and *Echinobrissus scutatus*, &c.	2	0
c. The principal shell-bed. A fawn-coloured limestone, gritty, and only moderately oolitic, with abundance of large shells—*Trigonia Meriani*, *T. perlata*, *Hinnites velatus*, *Astarte ovata*, *Pecten fibrosus*, *P. lens*	1	1
d. A dirty-yellowish limestone, partially oolitic, with curious flattened lumps of marl of smooth surface	0	8

The building-stones (3) are coarse, ironstained, sandy oolites, blue-hearted towards the base. They contain much wood, and some large fossils, including *Pecten lens*, *Perna mytiloides*, and *Gervillia aviculoides*. Below this are loose sandy beds, becoming sufficiently argillaceous to hold up the water. The continuation downwards cannot be anywhere satisfactorily traced on the surface, the section in the Lechdale road, alluded to in the Survey memoir, being no longer visible; but the following well-section exhibits completely the lithology of the lower beds, which, if all are to be reckoned as belonging to the Lower Calcareous Grit, have here an enormous development:—

Section of Bore-well at Fairthorne and Phillips's Brewery, Faringdon.

	ft.	in.
Coralline oolite (the same as in the lower part of the Workhouse quarry)	6	6
Sandy clay, with much carbon, and curious white nodules (?). The lower portion of this bed holds up the water in the Workhouse quarry, and at the bridge over the railway....................................	4	0
Coralline (?) and shelly limestone, hard and subcrystalline, with loose marly stuff at base	10	6
Water of shallow wells.		
Grey sandy clay	9	6
Similar, but less coherent	9	0
Similar...	11	6
Line of subcalcareous nodules..............................	2	6
Dense grey clay	2	0
Grey sandy clay..	8	0
Impure grey oolite, and hard grey calcareous grit ...	6	0
Water.		
Loose grey quartz sand, extremely fine in grain, with a few plates of mica	5	0
Grey sandy clay	13	0
Grey clayey sand	5	0
Water, 53° F., constant.		
Grey clayey sand	4	0
Grey sand, rather more argillaceous	5	0
Grey argillaceous indurated grit, of fine grain	13	0
	114	6

The chief interest in the Corallian beds here centres in those that are seen in the Workhouse quarry, which are obviously on the same horizon as in that at Highworth, and the variations of which are exposed in the several quarries to the eastwards. The shell-bed of this quarry we may fairly compare to the similar bed at Highworth in the same stratigraphical position, especially as we notice that this conchiferous feature is continued to the east. At Faringdon, however, we notice a difference both above and below. Above, we here have the oolites immediately beneath the Rag; there we have sands and clays, which appear to be wanting here; and these two are the alternate types developed on different areas, as will be seen by our future illustrative sections. Below, we have here a bed with curious clay balls, representing, we may suppose, a kind of pisolite; and there we have a Coral-bed. Beneath these in all the quarries is a kind of passage-bed to the Lower Calcareous Grit.

In a quarry about a mile to the east of Faringdon we have a section representing the arenaceous type of the upper beds, showing how quickly we lose the excessively calcareous type. There are here seen:—

		ft.	in.
1. Calcareo-arenaceous, partly false-bedded flags, with lenticular masses of calcareous sand, which produce the false-bedding, containing *Cidaris florigemma*, *Pecten fibrosus*, and *Lima elliptica*	4 ft. to	6	0
2. Alternations of sands and clays in thin layers in the lower part, black from carbonaceous matter	about	10	0
3. Solid blue calcareous grit, with large flattened oolitic grains, rendering it almost an oolite. *Gervillia aviculoides*, *Pecten lens*, *Littorina muricata* (base of quarry).			

The whole mass here looks so like calcareous grit that we require the guidance of the fossils to point out that the upper bed must be closely underlying the Rag, and that the base bed corresponds to the shelly beds of Faringdon. An additional feature of interest here is the black carbonaceous band, similar to that which appears in the Brewery section below the shell-bed, indicating probably the proximity of land.

Another section in the neighbourhood, a little further east, and south of the high road, whence the stones are obtained to mend the road, should be given as confirmatory of the above interpretation. We have here:—

		ft.	in.
1. Red earth.			
2. False-bedded fissile oolitic flags	1 ft. to	3	0
3. Black and brown laminated sandy clays	3 in. to	1	0
4. Shelly beds, with flattened nodules near the base		3	6
5. Soft sands, becoming in places blue-hearted grit		5	0

The succession of beds with the flaggy oolites at the top is here too like that at Highworth to allow of much doubt; and the fossils of the shelly bed, *Ammonites plicatilis*, *Cerithium muricatum*, *Pecten lens*, *P. qualicosta*, *Gervillia aviculoides*, *Lima laviuscula*, assist in the correlation. The passage-bed *below* the shell-zone is not here well marked, though probably represented by the extreme top of No. 5, in which *Ammonites varicostatus* is not rare.

As we pass onwards to the east, we come to an important quarry in which these lower beds are again well represented, though the arenaceous type of the upper ones is still in the ascendant. This is the quarry near the Lamb Inn, about six miles from Faringdon, described by the Geological Surveyor as being the only indication of Upper Calcareous Grit in the neighbourhood. We will add the names assigned to the various portions to our own description.

Section at the Quarry near the Lamb Inn.

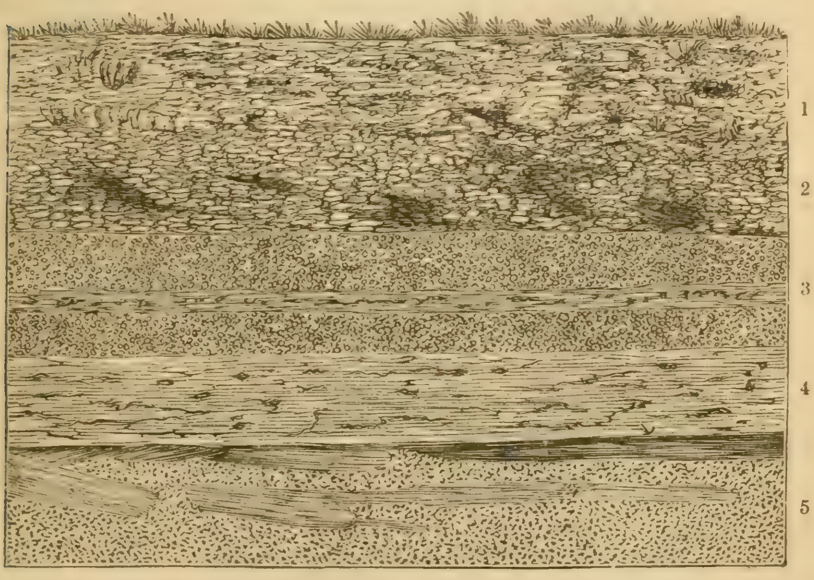
	ft.	in.
1. Deep-red sandy loam, of varying thickness, unconformable to the lower beds, resting in some places on No. 2, and in others on No. 3	3	0
2. Flaggy oolitic sandy limestones, resting on sand with small shelly calcareous fragments and Lydian stones	1	3
3. Siliceous sands (1 ft. 6 in.) graduating into brick-earth clays, unconformable to the bed below, which is half cut through in places, and exposes an eroded surface. [Upper Calcareous Grit of Survey.]	7	6
4. Blue-hearted shelly limestone, partially oolitic, with brashy partings. The top is deeply eroded in places, forming pockets. *Ammonites plicatilis, Belemnites abbreviatus, Opis Phillipsi, Trigonia perlata, T. Meriani* (abundant), *Perna mytiloides, Gervillia aviculoides, Trichites*, sp., *Modiola cancellata, Pecten lens, P. qualicosta, P. fibrosus, P. demissus, Hinnites velatus, Echinobrissus scutatus.* [Coral Rag, *a.*]	3	6
5. Blue pisolite, becoming more shelly below, with fossils similar to those of the bed above and *Lima rigida.* ["Coral Rag, *b.*"] ...	3	6
6. Blue-hearted intensely hard calcareous grit, graduating downwards into the next. [Lower Calcareous Grit.] ......1 ft. 4 in. to	2	0
7. Yellow and white sand (base not seen)	7	0

The fine fossiliferous bed here seen, which from the abundance of that shell we may call the *Trigonia*-bed, gives us at once our datum-line in its obvious identity with the shelly beds at Faringdon and Highworth; and thus we see the pisolite below taking the place of the nodule-bed of the former and the Coral-bed of the latter locality—not, be it noted, of the Coral Rag proper of this district, with which it has no relation; and the passage-bed below is here again slightly marked.

We learn also something here from the upper beds. One cannot fail to be struck with the remarkable erosion of the top of the calcareous bed, No. 4. Though it may be partially due to subsequent chemical action on the spot, it is certainly also due to an interval of time between the two deposits. This fact and the graduating upwards of the sands and clays into the red ferruginous earth in some parts of the quarry doubtless induced the Surveyor to map the former as Upper Calcareous Grit, though the lower portion by no means coincides with its character elsewhere; and the isolated position of the patch, so far from the dip margin of the formation, is apt to attract attention. Having seen the red earth overlain by Kimmeridge Clay at Faringdon, and capping other beds in the neighbourhood, we have no doubt that the red soil here is the representative of the Upper Calcareous Grit; but the sands and clays below, being overlain by oolitic rock, which never occurs in the Upper Calcareous Grit, and to which the red earth is unconformable, and being in the position of similar beds at Highworth and elsewhere, we take to be a continued representation of the arenaceous form of the infra-coralline beds, the erosion being an interesting indication of the wide separation in time of the oolite shell-beds and the Coral Rag. These conclusions are confirmed by sections at Marcham.

All the openings hereabouts are in somewhat the same horizon, and carry on the sequence of the various divisions, till in the neighbourhood of the last-named village the calcareous type of the infra-coralline beds sets in, and we have Rag supported on beds of broken oolite and oolitic brash. A very good example of this is seen in a limepit near "Noah's Ark," a representation of which we give without further description (fig. 6).

Fig. 6.—*Section at Noah's-Ark Limepit, Marcham.*
(Total thickness, 10 ft. 6 in.)



1. Coral Rag. 2. Broken Oolite. 3. Oolite and Brash.
4. Shell Limestone. 5. Lower Calcareous Grit.

Elsewhere in the neighbourhood these brashy and oolitic beds beneath the Rag are thicker; but we need only give one illustrative section, that in "Marcham field," whence doubtless, for many a decade, the fossils have come which have been quoted from this locality, and which every writer mentions. There are, however, two quarries; and it is the most southerly to which the following description applies:—

Section in Marcham Field, South Quarry.

	ft.	in.
1. Thin-splitting, rough-bedded blue limestone with *Thecosmilia* ...	2	6
2. Rubbly Coral Rag in small pieces; *Thecosmilia, Cidaris florigemma*	2	6
3. Soft irregular thin-bedded limestone amalgamating with the Coral Rag above; *Gervillia aviculoides* .... 3 in. to	0	8
4. Oolite and oolitic brash, variable; *Ammonites plicatilis*	1	8
5. *Trigonia*-bed, composed of large specimens of *Trigonia perlata*, particularly towards the base; contains *Pleurotomaria reticulata, Quenstedtia lævigata, Perna mytiloides, Lucina Moreana, Opis Phillipsi, Lithodomus inclusus, Gervillia aviculoides*, &c.	1	0
6. Loose yellow sands, sometimes false-laminated, with thin layers of clay and abundance of *Ostrea gregaria* and *Exogyra nana* at the top, and flat calcareous balls and Lydian stones towards the base.. 1 ft. to	2	0
7. Solid blue false-bedded calcareous grit, having the top full of *Natica marchamensis*; contains also *Chemnitzia abbreviata* and *Cerithium muricatum*, var. .... 8 in. to	1	0
8. Loose sand, holds up water.		

This magnificent quarry gives us the whole sequence, and is a splendid illustration of the Rag supported on a calcareous basis There is no difficulty in correlating it with our other sections; and its fossil contents give it an interest of its own, the *Trigonia*-bed being, like the corresponding beds elsewhere, the chief repository of them.

Very close to this quarry, but nearer to the Abingdon road, is another, into which the lower beds may be traced one by one; but above the *Trigonia*-bed we have the shelly sand of the Lamb-Inn Quarry again, and the same erosion, though not so marked, with a bed of rolled oolitic fragments; but we see no Coral Rag. This quarry is mapped as being in Lower Calcareous Grit.

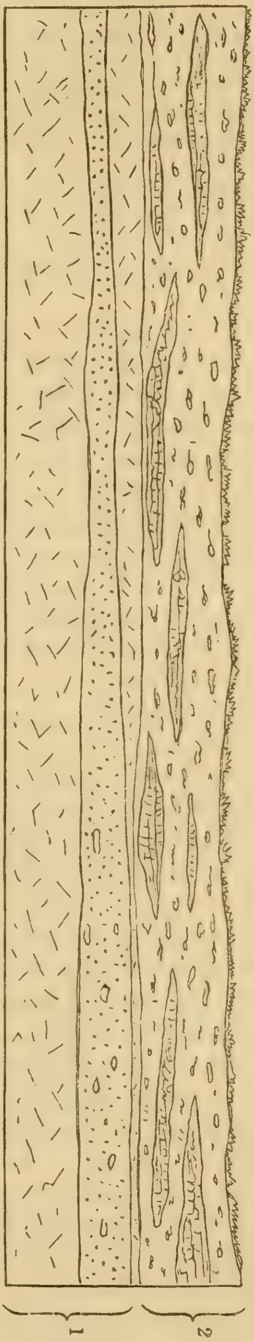
Now we notice that in these quarries we have two types of rock overlying the shell-beds: in some places there are rubbly oolites, and in others sands. In the former we generally see the Rag resting on the top; but in the latter the Rag is mostly driven out; so that these sandy areas are to a certain extent alternative with those with Rag developments, and may, perhaps, have been so in their original deposition.

In the quarry of which the last section is given we are introduced to a new point of interest, which to some extent continues to attract attention, in the openings between this and Oxford, namely a fossiliferous or *Natica*-bed in the Lower Calcareous Grit.

In passing north from Marcham, we find that the beds which have just occupied so much of our attention disappear, and the Coral Rag rests directly, as at Westbrook, on the Grit. The exposures in this range are few, and mostly show the sands and grits at the base with their characteristic *Ammonites perarmatus*, presenting no special points of interest; but at Bradley farm and at the cross road to Cumnor very instructive sections are seen.

In the first of these quarries (fig. 7) we have at the top about six feet of magnificent Rag, the massive portions growing in lenticular masses with bases not horizontal, and the intermediate spaces filled to a large extent with *Thecosmiliæ.* The reef-corals here are in a more perfect state of preservation than in any locality we know of, and leave little to be desired. Beneath the Rag is the uppermost bed of the Lower Calcareous Grit, a very remarkable rock, composed of very sharp fawn-coloured sand in a calcareous matrix, and containing nodules surrounding *Ammonites cordatus*, or enclosing a nest of shells in which *Cylindrites Luidii* is abundant. It also contains *Natica clytia*, *Gervillia aviculoides*, *Ostrea solitaria*, and *Serpula tricarinata*, and is the uppermost fossiliferous zone of this portion of the series. It is irregular in the same quarry, and is possibly only a modification of the sands below, as, where it thins out and is only to be traced just beneath the Coral Rag, the sand contains similar nodules here and there. The whole is underlain by a strong bed of Calcareous Grit, five feet in thickness, with *Natica marchamensis*, *Cylindrites Luidii*, and *Chemnitzia abbreviata*, which corresponds to the *Natica*-bed at Marcham. These beds probably represent a later period than the ordinary Lower Calcareous Grit, approaching that of the Coralline Oolite.

In the quarry at the Cumnor cross road we have an equally remarkable development of the Coral Rag, but with nothing like the above-described beds underlying it.



1. Lower Calcareous Grit. 2. Coral Rag.

Fig. 7.—*Section near Bradley Farm.*

Section at the Cross Road to Cumnor.

	ft.	in.
1. Coralline brash in discontinuous beds, the fossils mostly broken, with *Cidaris florigemma*, *C. Smithii*	5	0
2. Solid blue crystalline limestone, with irregular branching cavities, with *Cidaris florigemma*	2	0
3. Soft brash in loose calcareous paste, full of broken fossils and occasional *Thamnastrææ*, *Littorina muricata*, *Lima rigida*, *Pecten vimineus*, *Exogyra nana*, *Cidaris florigemma*, *C. Smithii*, *Hemicidaris*, sp. Towards the base it becomes more compact, and is made up of prostrate *Thecosmiliæ* and occasional *Thamnastrææ*	4	6
4. Indurated limestone similar to above, the base a shell-bed with *Littorina muricata*, a clavellate *Trigonia*, *Pecten vimineus*, *Cidaris Smithii*	2	0
5. Soft bluish sand, in which no fossils or doggers are seen	2	0

There are three noticeable points about this quarry:—1st, the rubble overlying the representative of the Rag, a feature not before noticed, but introducing us to a similar peculiarity at Headington, to be presently described; 2nd, the massiveness of the crystalline Rag limestone, and its similarity to a bed of Calcareous Grit, by which we might be misled but for the characteristic urchin; it is probably a highly altered coral-growth; 3rd, the coral shell-bed below, which we must plainly associate with the Rag rather than with the shell-beds of Faringdon &c. The whole series presents here a greater thickness than we have elsewhere seen on this horizon throughout the range.

6. North-east of Oxford.

Here we have the last development of Corallian rocks before their disappearance for many miles. Their character has already been made known by Prof. Phillips and the Geological Survey, both of whom have described the quarries at Headington.

In the base of these quarries, as also in others, such as those near the windmill on the Shotover road, we find the sands of the Lower Calcareous Grit, with sometimes strong bands of stone, as in the Littlemore railway-cutting, or large doggers with *Ammonites varicostatus* and other fossils. We have not met with the *Natica*-bed of Marcham in these quarries; but the uppermost part of the sands shows indications of that remarkable band at Bradley farm in which *Ammonites cordatus* occurs in nodules of sharp calcareous sand.

That same fossil occurs here also in a similar matrix. There is also at the top of the grit about eight inches of a pebbly bed, with rolled oolite and quartz crystals, and containing *Ostrea solitaria*, *Avicula expansa*, *Lima læviuscula*, and *Natica clytia*. This probably indicates some lapse of time during which deposits which are here wanting were laid down elsewhere in the district.

The continuation downwards of the Lower Calcareous Grit may be observed in the road leading north from these quarries; on the slope of the hill a considerable amount of loose yellow sand is seen, with occasional hard bands with *Ammonites perarmatus.*

Overlying the Lower Calcareous Grit there are several different types of rock in this neighbourhood. In the great Headington quarries we have no less than three series of beds, as indicated in the following section :—

Section of Headington Quarries.

	ft.	in.
1. False-bedded comminuted shell-limestone, seen better in the quarries at Shotover at a higher level .... here	16	0
2. Irregular Coral Rag with *Thecosmiliæ*, passing into and alternating with the beds above 10-17		0
3. Semi-oolitic shell-bed with *Cidaris florigemma*........................	7	0
4. Pebbly bed and layers of nodules with *Ammonites cordatus*	0	8
5. Sands of the Lower Calcareous Grit.		

The shell-bed, No. 3, is a very interesting one from its abundance of fossils, among which we notice *Ammonites plicatilis*, *Phasianella striata*, *Natica clytia*, *Astarte ovata*, *Gervillia aviculoides*, *Perna mytiloides*, *Corbicella lævis*, *Myoconcha Sæmanni*, *Lima læviuscula*, *Pecten lens*, and *P. vimineus*, as well as *Cidaris florigemma.* It is the presence of this last fossil that makes us associate this with the Coral Rag, as a bed not seen before except near Cumnor, rather than consider it the equivalent of the shell-beds at Faringdon. The *Phasianella striata* gives the same indication, though it occurs also at Highworth. It is a feature more common in Yorkshire than in the south of England to have such a shell-bed associated with the Rag. In one of the quarries this bed contains a mass of corals; and in another place it is separated by a layer of sand from the overlying Rag. The stone is mostly composed of broken shells and impure limestone, but occasionally shows oolitic structure.

The Coral Rag, No. 2, is almost entirely composed of *Thecosmiliæ*, very few *Thamnastrææ* being observed. It is very irregular, and cannot be traced far continuously. It appears to be false-bedded, probably from growing on a false-bedded basis; sometimes it is quite soft, like loose calc tuff; at others it hardens into lenticular masses of solid rock with fewer corals—a very typical Thecosmilian Rag. We noted *Pleurotomaria reticulata*, *Pecten vimineus*, *Lima elliptica*, and *Ostrea solitaria*, besides the inevitable urchin.

This Rag becomes in parts undistingnishable from the false-bedded limestone, No. 1, which is finally substituted for and overlies it. This is seen in one of the quarries on the south of the general quarry; so that the relation of the two rocks is undoubted. This soft limestone, however, is better seen in a quarry higher up the hill, where it is quarried beneath the Kimmeridge Clay, which, as noticed by Phillips, lies on an eroded surface. The limestone is composed of comminuted fragments of shells—a very unfavourable condition for holding any recognizable fossils; but it appears to contain the spines of *Cidaris florigemma.* About 10 feet are seen in one quarry, and 10 feet more in a lower one; but there are reported to be 30 feet altgether. The lower portion is more compact and crystalline than the upper, and contains a bed of Coral Rag in a state of crystallized limestone.

We have seen rubbly oolites overlying the representative of the Rag near Cumnor; but the great thickness here of beds of a calcareous nature above the actual coral growth is a very unusual phenomenon.

Prof. Phillips has noticed the patchy character of the calcareous beds on the surface, and refers it partly to denudation; but certainly, if we may judge from their changing character, they were never very continuous.

The Headington type is continued onto the opposite hills to the north, as may be seen in a quarry on the road to Stanton St. John, the Rag and shelly beds inosculating; but on crossing a fault, as drawn in the Survey map (quarter-sheet 45, S.E.), and reaching the last-named village, a new type has set in.

Close to the symbol $\searrow^{4°}$ is a very remarkable quarry. Here about 24 feet are seen, composed of alternate layers of hard doggery bands and marl. Towards the base the hard bands are closer together, thicker, and more crystalline, the lowest being a hard blue compact limestone 1 foot in thickness, with fragments of shells. The lower marly beds are more like a small calcareous brash than true marl, which becomes, however, more abundant towards the top. We see here something of the Hillmarton type of Rag; but the argillaceous matter is by no means so abundant, nor is it so connected with Coral; for what is remarkable in the fauna here is, that all corals seem to be absent or very scarce, nor are there any Pectens to be seen. It is, however, a complete nest of Echinoderms, the chief being *Cidaris florigemma*, *Pseudodiadema versipora*, *Echinobrissus scutatus*, and *Dysaster* (?). The accompanying fossils are *Ammonites plicatilis*, *Chemnitzia heddingtonensis*, *Gervillia aviculoides*, *Lima rigida*, *L. elliptica*, and *Exogyra nana*.

We see here the spot where the corals did *not* grow, as at Headington we saw where they did. Here we have the débris of the ground-up, variably hardened reef, along with the Echinoderms that lived in the neighbourhood; and we thus have a natural termination of the Coral Rag in this direction.

The *Cidaris-florigemma* beds are here immediately underlain by thin flaggy calcareous grits, rather ferruginous and full of shells, which are quarried for road-metal. They have much resemblance to beds in a similar position with reference to the Lower Calcareous Grit in Yorkshire, but are a type of rock not much seen in Oxfordshire; so that even these lower beds vary.

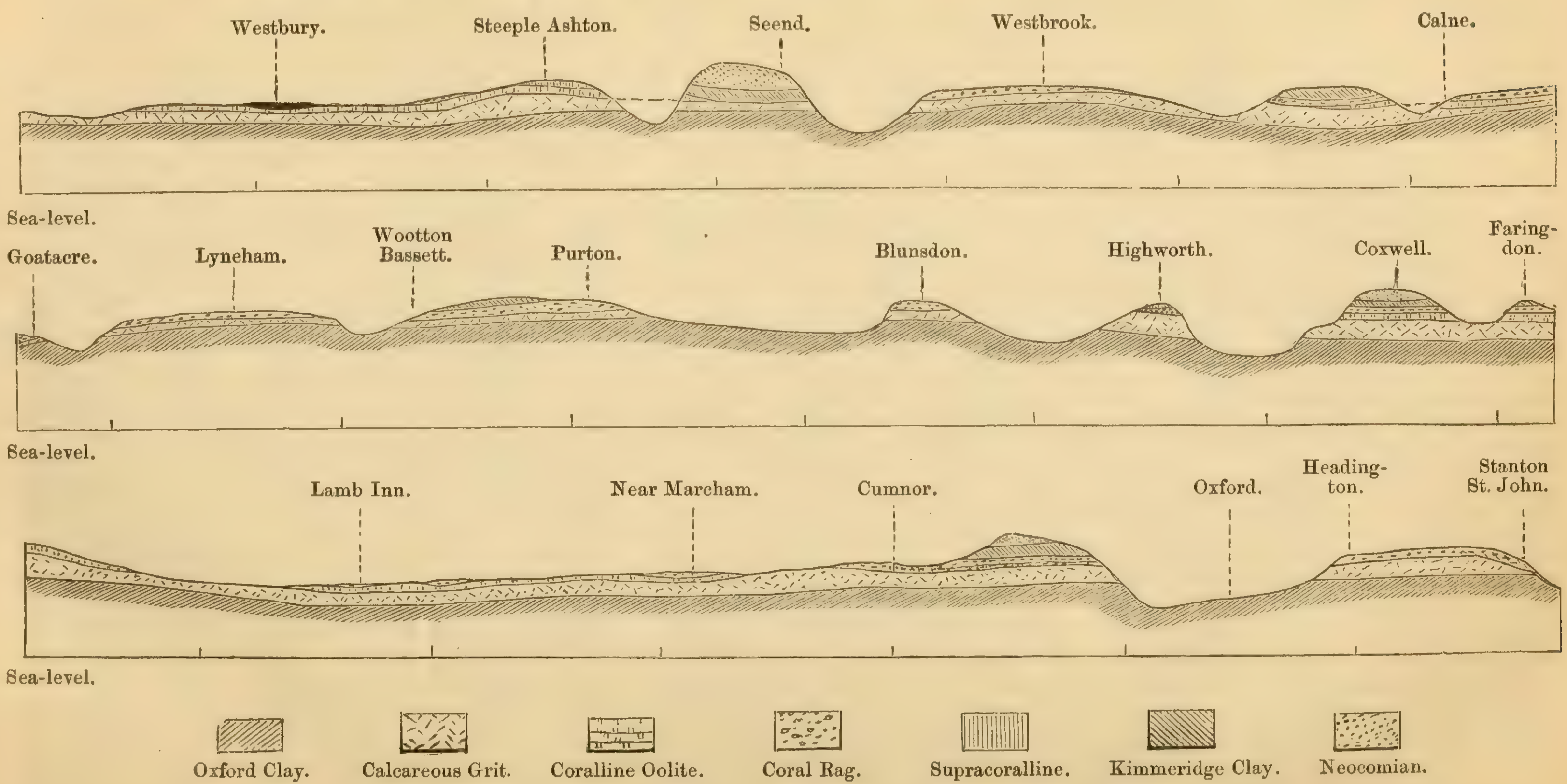
On the south of Headington a somewhat similar type of rock may be seen overlying the Lower Calcareous Grit in the Littlemore cutting; but, unfortunately, it appears to be very unfossiliferous. About 14 feet of alternate clays and limestones are here seen, the upper limestones decayed as at Hillmarton, and some of the clays having a considerable thickness. The only fossils noted being *Exogyra nana* and *Astarte*, sp. (cf. *ovata*), we are left in some doubt as to what these beds represent; but at least we learn that the Rag of Headington is lost ere this.

If we go to the east we see it disappear also; but its place is taken by the false-bedded limestones that were seen overlying it at Shotover; for it is beds of this series that we think are to be seen in the great quarries at Wheatley. The amount of stone that is or has been excavated here is something extraordinary, but scarcely less so than the rarity of recognizable fossils; just as in the stone at Shotover, they are all ground down and obliterated. Nevertheless *Ammonites plicatilis*, *Belemnites abbreviatus*, *Exogyra nana* and *Cidaris florigemma* have here been noted, and reptile bones have been known to occur. These beds, measured perpendicularly to their apparent dip, have a thickness of 70 feet in one quarry alone; and as the dip, wherever observed, is easterly, or partially so, we should have to allow some considerable additional amount if measured in this way. The exceedingly local nature, however, of this vast accumulation leads us to the conclusion that we are here viewing false dip, such as may be seen in the corresponding beds at Headington. We are here, then, presented with the deposits which were formed on the extreme edge, not only of the coral reef, whose thickness would not account for so much false dip (which amounts in the most easterly quarry to 12°, and is even marked at 18° at another spot on the map), but probably of the Lower Calcareous Grit sandbank also—a conclusion which is supported by the fact of its apparent sudden termination eastwards, and the immediate succession of Kimmeridge (?) Clay. Nevertheless, considering it coeval with the Shotover limestones, it is of supracoralline age. The character of the stone here is variable; but it contains good facing-stones. There are blue-hearted limestones, grey oolites, loose oolitic grit, and rubbly oolite, with clay partings towards the base.

These Wheatley quarries are a kind of expiring effort on the part of the Corallian formation; for, magnificent as they are, all signs of them, or of any other part of the formation, suddenly disappear on the north-east of a line between Stanton St. John and Holton. Professor Phillips has noticed, in his 'Geology of Oxford,' that the Lower Calcareous Grit forms what we may call an isolated sandbank at Studley, whence he has named some fossils; but of the vast spread of this rock, marked in the Survey map between Holton and Brill, not a trace can be seen. No sand-pits or quarries are to be heard of; and the whole soil indicates a stiff clay beneath. Indeed the Corallian formation has died out, not gradually, but suddenly, and the normal pelolithic formation reigns supreme.

In this range from Westbury to Wheatley the most remarkable feature is the variety exhibited by this essentially variable set of beds, a good idea of which can scarcely be obtained by the aid of words, even though more details should be given. We therefore present a generalized section (fig. 8) along a line following the range, with beds at a moderate distance on either side projected on it; so that it must be considered diagrammatic, and the thickness only approximate.

Fig. 8.—*Diagram Section from Westbury to Wheatley, showing the Corallian rocks.* (Horizontal scale, 4 miles to 1 inch. Vertical scale, 24 times the horizontal, or 880 feet to 1 inch. The line of section is not straight.)



As we indicated at the commencement, it is not our object in this paper to correlate the various deposits described with what may be their representative portions of the argillaceous series; but, for the sake of indicating the possibility of such a correlation, we may record the fact that at Ampthill, the place after which Mr. Seeley has called the middle division of the clay, we have found in the débris of the railway-cutting a well-marked spine of that most characteristic Corallian fossil *Cidaris florigemma*, associated with *Ammonites plicatilis*, *Ostrea gregaria*, and *Serpula intestinalis*.

We do not propose either to enter into a complete discussion of the "Elsworth Rock" of the same geologist, although we think that it belongs to some portion of the time during which, elsewhere, Corallian rocks were being formed, and should probably be referred to a position analogous to that of the Lower Calcareous Grit. Thus much appears likely from the character of the fossils in the rich collection in the Woodwardian Museum, among which we may note the following—*Ammonites vertebralis*, *A. goliathus*, *A. convolutus*, *A. perarmatus*, *Pleurotomaria Münsteri*, *Astarte ovata*, *Cucullæa clathrata*, *Lima elliptica*, *Avicula ovalis*, *Millericrinus echinatus*, and many others pointing to a lower horizon. As we are promised a description of the whole by their discoverer, and the mass of rock is so isolated amidst the clays as to render its correlation greatly dependent on them, we must pass over any further discussion.

The same may be said of the Red Rock of St. Ives, which immediately overlies the fossiliferous Oxford Clay. This slightly exposed band has yielded several fossils, of which the following have been recognized—*Ammonites cordatus*, *Pleurotomaria Münsteri*, *Pecten lens*, *P. subtextorius*, *P. fibrosus*, *Ostrea gregaria*, *Waldheimia Hudlestoni*, *Pseudodiadema versipora*, *Collyrites bicordatus*, and (!) *Cidaris florigemma*.

These seem to indicate that it belongs to some part of the age of the Lower Calcareous Grit, or even higher.

IV. The Cambridge Reef.

The well-known though very inaccessible exposure of Corallian beds at Upware, between Cambridge and Ely, demands a more careful description. It has been partially, but not very fully described by Mr. Bonney in his 'Geology of Cambridgeshire,' in which he correlates it with the lowest portion of the Corallian region, on account of its containing *Cidaris florigemma*—a reason which would make *us* assign it to nearly the highest. It has always been called Coral Rag, except by Mr. Seeley, who denominates it "Upware Limestone"*, and places it in the series above the clay equivalent of the Coral Rag. After a comparison of it with the Coral Rag of other areas, its age and nature are left in no doubt whatever.

The position of the Corallian beds is well known; they form the basis on which lie the phosphatic nodules and Neocomian sands.

There are two distinct openings in which the rocks may be well

* Index to the Fossil Remains of Aves, Ornithosauria, and Reptilia. 1869.

studied. The best-known is the one at the south, not far from the Inn called "Five miles from anywhere." Here the extremity of a low plateau is cut into by a shallow quarry, in which the beds dip N. by W., at an angle of about 4°, so as to expose on the whole about 20 feet. Generally described, it is entirely a creamy white but rather irregular limestone, in parts crystalline. It contains, however, several layers of considerable size, composed of *Thamnastræa arachnoides*, *Rhabdophyllia*, &c. Between the more crystalline portions are some more earthy parts, containing abundance of shells, some complete, but others almost rolled into oolitic granules. The fossils in some beds have entirely perished, leaving, however, external casts, with loose internal casts inside. The corals and other fossils, of which a list is given below, prove this to be the true Coral Rag as we have restricted the term. It is not so rubbly as many of the Rags are, but compares well in some portions with that which occurs in Yorkshire, at North Grimston. It has, however, in some cases a peculiar creaminess about it that is hard to match elsewhere. It has *very* occasional admixtures of clay, but as a rule may be considered exceptionally pure. The irregularity of the bedding is an indication of its reef-like character, to which, and not entirely to denudation, its termination may be due.

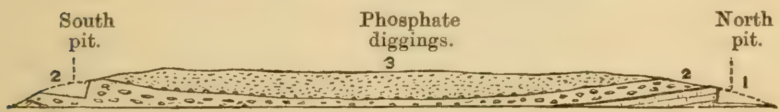
The fossils obtained by ourselves at this pit are as follows:—

Emarginula Goldfussi (*Röm.*).
Littorina muricata (*Sow.*).
Turbo princeps (*Goldf.*).
Chemnitzia heddingtonensis (*Sow.*).
Neritopsis Guerrei (*Héb. & Desl.*) and operculum.
Cerithium muricatum (*Sow.*).
Pholadomya decemcostata (*Röm.*).
Astarte aytonensis (*Mor. & Lyc.*).
Trigonia Meriani (*Ag.*).
Lithodomus inclusus (*Ph.*).
Opis virdunensis (*Buv.*).
—— lunulata (*Buv.*).
—— corallina (*Dam.*).
——, sp. (*cf.* paradoxa, *Buv.*).
—— Phillipsi (*Mor.*), var.
Cypricardia glabra (*Bl. & H.*).
Arca quadrisulcata (*Sow.*).
Arca pectinata (*Ph.*).
—— contracta (*Ph.*)
Isoarca texata (*Qu.*).
—— multistriata (*Et.*)
Gervillia aviculoides (*Sow.*).
Lima rigida (*Sow.*).
Pecten vimineus (*Sow.*).
Anomia suprajurensis (*Buv.*).
Ostrea solitaria (*Sow.*).
Exogyra nana (*Sow.*).
Rhynchonella, small species.
Crustacean.
Cidaris florigemma (*Ph.*).
Pentacrinus.
Thamnastræa arachnoides (*Park.*).
Isastræa explanata (*Goldf.*).
Montlivaltia dispar (*Ph.*).
Rhabdophyllia Phillipsi (*Edw.*).

This remarkable fauna, with its *Rhynchonella*, Crustaceans, and various peculiar molluscan species, shows how much our lists depend upon the conditions of deposit of the beds, though we should naturally expect somewhat of an exceptional fauna in a reef so far separated from all others as this appears to be.

The second exposure of Corallian beds in this neighbourhood is at the northern end of the same low plateau. On entering this quarry we see at once we have to do with a very different type of rock. Here the creamy and coral-bearing limestones are not to be seen; but their place is taken by coralline oolite with large grains in well-marked beds, separated by soft oolitic brash, which is also of some thickness on the top, the total seen being about 12 ft. The fauna here too is much more scanty, and of a different character, the most abundant fossils being the Echinoderms *Echinobrissus scutatus* and *Holectypus depressus*, which are pretty numerous. The other fossils noted were *Littorina muricata* (var.), *Gervillia aviculoides*, and *Opis Phillipsi*. This, then, is not to be confounded with the former quarry, but viewed as an example of what we have seen, and shall see to occur often—an oolite underlying the Rag. The beds here dip to the south, or in an opposite direction to those of the Rag-pit; so that there is a synclinal, in which are found the Neocomian sands. The presumed section of this reef is therefore as in fig. 9.

Fig. 9.—*Presumed Section near Upware, Cambridgeshire.*
(Length of Section about 1 mile.)



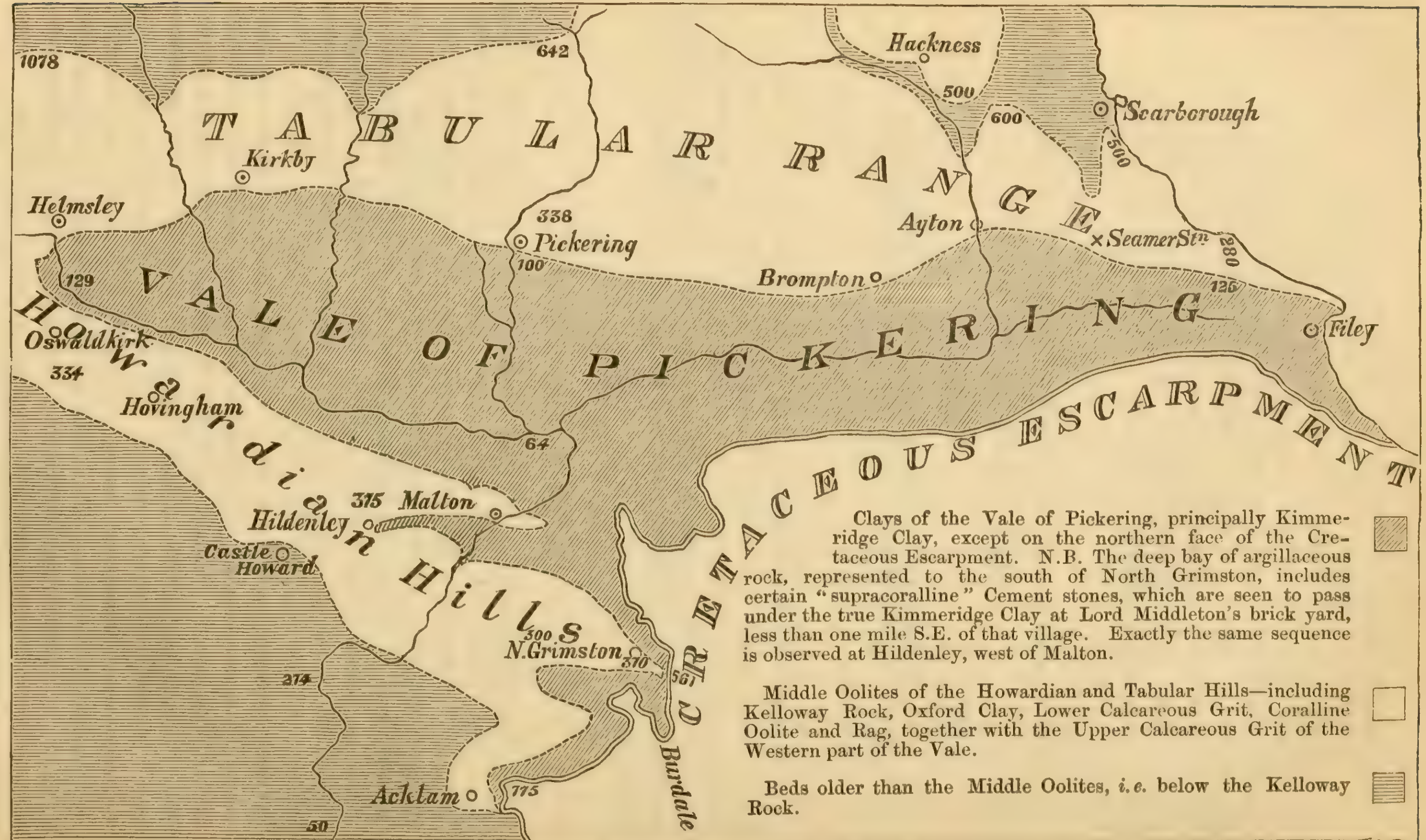
1. Coralline Oolite. 2. Coral Rag. 3. Neocomian.

It is much to be regretted that more exposures are not to be found here, as we have no indication of the Lower Calcareous Grit, which probably exists. The plateau, however, is surrounded by fen; and it is, so to speak, quite a chance in the irregular pre-fen denudation that has given us what we have, as it is possibly only a fragment of a larger mass.

V. The Yorkshire Basin.

The Corallian beds of this area are completely cut off from all the previously described ones by a long belt of country, extending through the counties of Norfolk and Lincoln, where no such beds are developed, but where the Kimmeridge gradually passes into the Oxford Clay. The most southerly portion of the Yorkshire Corallian area, under Acklam Wold, is distant 130 miles in a direction N. by W. from the coral reef at Upware. The stratigraphical features which in East Yorkshire characterize the whole of the Jurassic deposits are seen in these beds, which, from whatever cause, are grouped, like the rocks below them, in a basin round the vale of Pickering. They have a development of great thickness and variety, unequalled even by the thickest and most varied portion of the Weymouth district. We do not forget that in this area the original subdivisions were made out by Phillips, and that his identifications and figures of the fossils are amongst the most important parts of our knowledge of the beds in England. Notwithstanding this, the information conveyed, even by his last edition, is very meagre, and leaves much to be desired; nor do we know where else to look for any additional details, except an occasional refer-

Fig. 10.—*Sketch Map of the Country surrounding the Vale of Pickering.*



ence by Dr. Wright, Dr. Lycett, or other writers in the monographs of the Palæontographical Society.

One of us has recently, in a communication to the Geologists' Association, endeavoured to a certain extent to supply the want as regards the lower beds; but the upper portion is now no better known by publication than after the year 1829. It would scarcely be right, however, to omit the mention of Young and Bird, who supplied some interesting details, especially about Grimston and Langton Wold, and who showed themselves careful observers, though unfortunately they mixed the various oolites together.

The absence also of the published maps and sections of this district by the Geological Survey will render more description and stratigraphical details necessary on our part.

Even in this one region there are considerable differences of development in its several portions, and it is only by an extended study that we can hope to arrive at the true history of the deposition of the beds. It will therefore be most convenient to subdivide the Yorkshire Corallian area into districts where the development is fairly similar, and note the gradual change from one into the other.

For the sake of convenience, we arrange our description under the four following heads:—

1. The Scarborough District.
2. The Pickering District.
3. The Hambleton District.
4. The Howardian District.

Although we class all these together under the head of the Yorkshire Basin, in magnitude and importance they are scarcely less than the whole of each of the other of our subdivisions.

1. The Scarborough District.

In this we may include the area between Filey and Brompton on the south and Scarborough and Hackness on the north (see Map, fig. 10). In the eastern portion of this area, excepting the outlier of Scarborough Castle Hill, the beds have a general dip rather to the west of south; but at Ayton the strike changes, and the dip becomes one to the S.E. From the sea-coast as far as Brompton the newest beds, as a rule, occupy the lowest and most southerly portion of the district, and, with one trifling exception, the lowest beds occupy the highest ground in the direction of the outcrop.

As one of us has so lately published a detailed description of the sections to be seen at Filey and Scarborough *, we here need only include what is necessary for reference to the other parts. Having measured these beds independently of each other, and yet agreeing in our description, we submit the section with some confidence, only premising that, as the beds vary in thickness within short distances, some latitude may be allowed on this score.

* Proceedings of the Geologists' Association, vol. iv. p. 353 *et seq.*

Section at Filey, in descending order, according to the grouping adopted in the Paper already referred to.

A. The Upper Calcareous Series.

	ft.	in.
1. Broken thin-bedded oolites (Coralline Oolite), containing a few fossils—*Cerithium limæforme, Actæonina, Echinobrissus scutatus, Holectypus,* &c. .... about	5	0
2. Coarse gritty limestones, with large oolitic granules, divided by and occasionally thinning off into yellow calcareous grits. These in their upper part gradually shade off into the oolite above, and are, in short, a sort of passage-beds between these oolites and the grit of Filey Brigg	8	0

The fossils of A. 2 are tolerably numerous. We have been able to determine the following:—

c. Ammonites cordatus, *Sow.*
c. —— goliathus, *D'Orb.*
—— plicatilis, *Sow.*
—— perarmatus, *Sow.*, var.
Chemnitzia heddingtonensis, *Sow.*
Nerinæa, sp.
Littorina muricata, *Sow.*, var.
Pleurotomaria Münsteri, *Röm.*
v. c. Exogyra nana, *Sow.*
v. c. Pecten fibrosus, *Sow.*
—— vimineus, *Sow.*
Lima, sp.
Lima elliptica, *Whiteaves.*
c. Gervillia aviculoides, *Sow.* (very large).
c. Trigonia (clavellate sp.).
v. c. Lucina Beanii, *Lyc.*
v. c. ——, sp. (*cf.* lirata, *Phil.*).
Astarte, sp.
Sowerbya triangularis, *Phil.*
Pholadomya decemcostata, *Röm.*
Myacites jurassi, *Brongn.*
Gresslya peregrina, *Phil.*
Goniomya literata, *Sow.*

	ft.	in.
B. Massive yellow calcareous grits, poor in lime; in some situations laminated towards the base; contain a very large variety of *Ostrea bullata*, Sow., with occasional specimens of *Avicula ovalis* and *Perna quadrata*—Filey-Brigg Calc-Grit	10	0

C. The Lower Calcareous Series.

	ft.	in.
1. Thin alternations of hard blue gritty limestones, and softer yellow calc-grits. About 4 feet from the top occurs a rough oolitic limestone in two beds, with *Chemnitzia heddingtonensis* and some other fossils. The lower portions are sandy, but contain stray specimens of *Rhynchonella Thurmanni* and some of the commoner forms of the Lower Calcareous Grit	15	0
2. Suboolitic gritty limestones and calc-grits, full of dichotomizing forms, are highly fossiliferous, especially as regards Brachiopoda, a circumstance which distinguishes them at once from the limestones above the Filey-Brigg Calc-Grit	11	0

The following are the fossils of C. 2 which we have been able to determine:—

Belemnites hastatus, *Blainv.*
Nautilus hexagonus, *Sow.*
Ammonites cordatus, *Sow.*
—— goliathus, *D' Orb.*
—— perarmatus, *Sow.*, var.
v. c. Exogyra nana, *Sow.*
Ostrea solitaria, *Sow.*
——, sp. (*cf.* flabelloides, *Lam.*).
—— (gigantic form).
Gryphæa dilatata, *Sow.*
Pecten fibrosus, *Sow.*
c. Gervillia aviculoides, *Sow.*
Trigonia, sp.
Isocardia tenera, *Sow.* (tumida, *Ph.*).
Pleuromya, sp.
Terebratula fileyensis, *Walk.*
Waldheimia Hudlestoni, *Walk.*
r. —— bucculenta, *Sow.*
v. c. Rhynchonella Thurmanni, *Voltz.*
Pseudodiadema versipora, *Phil.* (small).
Acrosalenia decorata, *Haime* (small).
Echinobrissus scutatus, *Lam.*
Astropecten ? (plates).
Millericrinus echinatus, *Goldf.*
Serpula tricarinata, *Sow.*

The beds underlying those above detailed belong to the Lower Calcareous Grit proper, which may be deemed to terminate upwards with the remarkable series of "ball-beds" so characteristic of Filey and of the coast section generally.

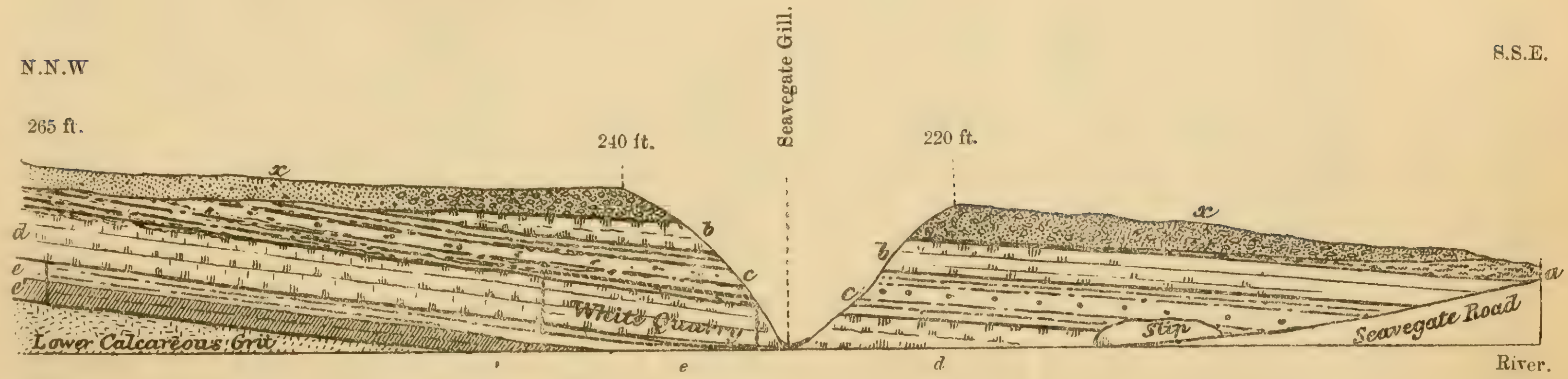
D. The Lower Calcareous Grit proper.	ft.	in.
1. Soft calcareous sands, with huge doggers, in three or four layers, often containing nests of fossils. The fauna of these beds, though scantier, includes some of the fossils of those immediately above (C. 2). *Rhynchonella Thurmanni* is still tolerably abundant. We noted also, besides some of the usual forms, *Trigonia triquetra?* Von Seeb., *Pecten*, sp. (cf. *vimineus*,) *Pinna lanceolata*, *Ostrea solitaria*, *Collyrites bicordatus*—principally towards the base	12–15	0
2. The above group is based upon a hard gritty blue rock, divided into two beds, which is sometimes rather cherty, and may be distinguished, both on the scar and in the cliff to the westwards, by its mural outline, which is brought into relief owing to the soft nature of the overlying "ball-bed" sands—fossils chalcedonized*	6	8
3. The rest of the Lower Calcareous Grit proper consists of hard blue siliceous limestones and lines of doggers alternating with softer grits. In many cases the fossils are chalcedonized. Amongst the most noteworthy are *Belemnites hastatus*, *Ammonites perarmatus* (rounded, thick-whorled form, with very prominent spikes), *A. cordatus*, *Gryphæa dilatata*, *Pecten fibrosus*, *Perna quadrata*, *Rhynchonella Thurmanni*, and *Astropecten rectus*. The total thickness down to the Oxford Clay is about	40	0

The lower part of the Filey section, as far as the top of the "ball-beds," which gives an horizon readily recognized both on the coast and in the interior, is easily correlated with the Lower Calcareous Grit proper, of which the ball-beds may be viewed as the top. But the various beds which overlie the ball-bed on the Filey promontory can only be satisfactorily correlated after a comparison with the interior, on which subject we must refer to our subsequent remarks. It may be as well to notice here, however, that, as the several formations are traced along the cliff in a direction W.N.W. towards Newbiggin Wyke, the Filey-Brigg calc-grit (B) and the whole of the Upper Limestones (A), crop out and disappear close to Filey Spa. The Lower Calcareous series (C), on the contrary, maintains its thickness and general character; and its upper beds (C. 1) are becoming so calcareous and oolitic that they, together probably with a portion of the lower part (C. 2), have formerly been extracted for lime. The remnants about the old lime-kilns conclusively prove that the fauna is that of the series *below* the Filey-Brigg calc-grit—*Gervillia aviculoides*, *Rhynchonella Thurmanni*, and *Acrosalenia decorata* being amongst the most conspicuous fossils. The lithology is equally clear, as also the position of these lime-

* We are informed by Mr. Fox Strangways that this mural band beneath the ball-beds is very persistent, and, like them, may be traced into the interior, where it often forms the cap of the escarpment salients. This bed also forms a prominent feature in the section of Scarborough Castle Hill just under the ball-beds.

Fig. 11.—*Section at the Mouth of Forge Valley.*

(Datum line 115 feet above sea-level. Length of Section 800 yards.)



* White Quarry.
x. Pebble-gravel and sand, an old beach ?
a. Coral Rag.
b. Coralline Oolite of Seamer.
c. Intermediate series.
d. Coralline Oolite of Scarborough Castle.
e. Upper portion ; and
e'. Lower portion of the basement or passage-beds.

stones with reference to the ball-beds, which they immediately overlie. This suboolitic phase of the Lower Calcareous series in a northerly direction is important, as it tends to exhibit a link between the oolite of the Lower Limestones presently to be described and the somewhat abnormal development of its presumed equivalents at Filey; and, as will be seen in the sequel, it gives a means of more accurately correlating the overlying grit (Filey-Brigg calcareous grit).

In Oliver's Mount only the lower beds of the Lower Calcareous Grit occur. These are quarried for building-stone, and contain but few fossils. *Avicula braamburiensis*, Phil., *Modiola bipartita*, Sow., *Trigonia Bronnii*, Ag., and *Rhynchonella lacunosa*, Schlot., are quoted from here.

We must now follow the Corallian series into the interior; and, by way of introduction to its development in the inland portion of our eastern or Scarborough district, we submit a section at the mouth of Forge Valley (fig. 11). The gorge of the Derwent, which passes completely through the Tabular Chain, debouches into the vale at the village of Ayton. In so doing it cuts across the several formations as they dip to the south; and as the dip is more rapid than the surface-slope, we continue to meet with higher beds in that direction. The section is as follows, the thicknesses ascribed to the beds being perhaps somewhat in excess:—

	ft.	in.
A. Upper Limestones.		
a. Coral Rag (Seavegate)	14	0
b. Coralline oolite of Seamer (Seavegate)	25	0
B. "Intermediate Series" (*c* of fig.) (above the White Quarry)	34	0
C. Lower Limestones.		
d. Coralline oolite of Scarborough Castle (White Quarry)	33	0
e. Upper portion of the basement or passage-beds (White Quarry and Greengate) } *e′.* Lower portion—ferruginous (Greengate) }	30	0
Total thickness of beds between the top of the Lower Calcareous Grit proper and the top of the Coral Rag	136	0

The above section has been constructed with the view of showing the sequence of the Corallian Limestones; and it may be deemed a good introduction to the study of their development in Yorkshire, being far more complete than any thing seen on the coast. The lowest group of all (*e′*) is a thick-bedded ferrugineo-calcareous grit, quarried for building towards the N.N.W. end of the section at Greengate. It contains *Lima læviuscula* (peculiar coarsely-ribbed form), *Gervillia aviculoides* (very large), *Pecten fibrosus*, *Rhynchonella Thurmanni*, *Millericrinus echinatus*, &c. The upper portion (*e*) of the passage-beds of the Lower Limestones is thinner-bedded, being generally an impure splintery limestone, with occasionally oolitic structure. This upper portion has irregular shell-beds; and one may be noted at the foot of the White Quarry, containing numerous *Myacites*, along with three very characteristic fossils, viz. *Cylindrites elongatus*, *Gervillia aviculoides*, and *Rhynchonella Thurmanni*.

The oolite of the Lower Limestone (*d*) is fully seen in the "White Quarry," where, exclusive of the impure limestones assigned to the preceding group, it has a thickness of about 33 feet, measured to a projecting sheet of impure broken-shell limestone, which forms the base of the "Intermediate Series." It is rather unfossiliferous here, as is the case with the oolites of the Lower Limestones. A few large *Gervilliæ* and a stray *Cylindrites* were noted; and there are also undeterminable specimens of *Nerinæa*.

The "Intermediate Series" (B, *c*) of our section is rather an arbitrary group, and one difficult to define. We take as its base the lowest sheet of gritty shelly limestone which projects above the softer white oolite in the "White Quarry." This lowest portion is, in places, a blue-hearted stone with impure brashy partings of considerable thickness, and is petrologically distinct from the beds below. The lower middle portion, which may be seen by dint of scrambling up the steep slope above the quarry, is softer and more gritty; whilst the upper portion is more oolitic, being frequently conspicuous for quantities of large *Chemnitzia*, as may be seen in the cutting in the Seavegate-road, where the lowest beds visible belong to this group. Here about 10–12 feet of buff hackly impure oolite and other limestone is exposed. In assigning a thickness of 34 feet to the "Intermediate Series," we consider it to terminate with the highest bed beneath the oolite that we recognize as identified with the base of Seamer Quarry (presently to be described). This estimate is, perhaps, somewhat in excess.

The whole series, however, is so highly calcareous, and so frequently oolitic, that the upper line especially is hard to trace; and it may be asked why these beds should be separated from the limestones above and below. The reason is, that here, and especially in the lower middle portion, certain gritty appearances occur. On this horizon, therefore, we must look for the representatives of the vast mass of grit which further westward is seen to separate the two limestone series. This grit will be referred to subsequently as the Middle Calcareous Grit; and where that distinction can be well drawn, the calcareous equivalents of our "Intermediate Series" will usually be referred to the Upper and Lower Limestones respectively.

The Upper Oolite (*b*), or Coralline Oolite of Seamer. These beds may be seen in a small quarry close to the top of Seavegate, on the road from Ayton to Hackness (just above *d* in the word "road"). *Astarte Duboisiana* and a few *Rhabdophylliæ* may be noted. This is seen to underlie the regular *Thamnastræa*-Rag (*a*) of the district.

The Coral Rag (*a*) has a thickness of 14–15 feet in the above quarry, but appears to thin out, or to have been denuded off on the rise. As the gravel (*x*) slips over the side of the hill, its presence or absence is more or less a matter of conjecture; but coral doggers may be noted on both sides of Seavegate Gill. In the direction of the dip the Rag maintains its full thickness through the village of East Ayton, where it is quarried down to the level of the river.

We have thus a total thickness of about 130 feet, made up of limestones of varying degrees of purity with but little intervening grit, a sequence not to be met with perhaps in an equal space in any other locality. If we are to find the representative of the "Filey-Brigg Calcareous Grit" here, it must be in some portion of the Intermediate Series, whose equivalents both to the east and west contain a greater amount of arenaceous matter.

The next step is to trace the development of the several portions of the series here indicated, as they occur elsewhere in the Scarborough district.

The Lower Limestones.—To the east of the Derwent Gorge the basement beds on their outcrop are so markedly ferruginous as to be easily traced; and this is a fortunate circumstance, as they constitute a reliable datum line. Following the outcrop towards Scarborough, we find them as flaggy ferruginous limestones, used for walling, and much made up of broken shells—the Hackness type. On Irton Moor, where they crop out, we noted *Ammonites Williamsoni* and *Avicula expansa.*

It is just possible that towards the base of the Lower Oolite there may be, in places, a slight development of a Lower Coral Rag, such as we shall see to be the case at Hackness in a similar position. These indications should be sought in the high plateau east of the line of section, where the beds crop out in succession. The fields hereabouts contain *Spongia floriceps,* and curious lumps, such as may frequently be noted in fields having corals underneath. The characteristic fossils of this horizon, towards the base of the Lower Oolite, such as *Cylindrites elongatus*, *Gervillia aviculoides,* and *Rhynchonella Thurmanni*, may be noted in a small quarry of greyish limestone. This is probably the outcrop of the beds towards the base of the "White Quarry" (fig. 11). Further eastwards there are no very definite indications whereby we can judge the character and value of the Lower Oolite.

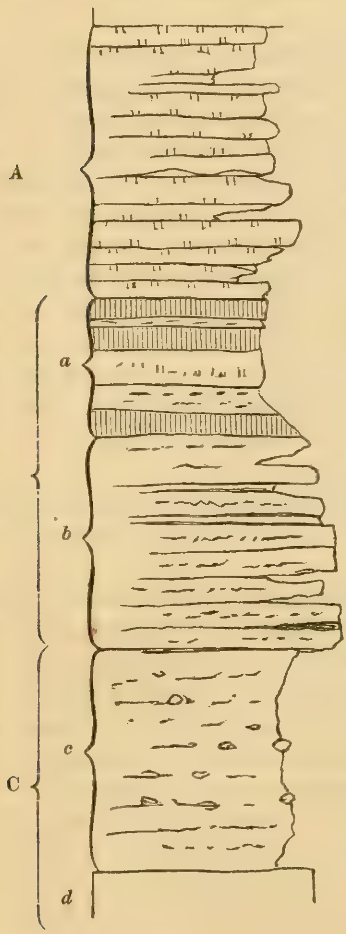
The section on Scarborough Castle Hill (fig. 12), though imperfect towards the top, is, however, an exception, as it exhibits the Lower Limestones very well indeed.

The close correspondence between this section and that of Forge Valley is remarkable, the thickness and general development of the several subdivisions being well maintained. Commencing our comparison bove the ball-beds, we have (B. *b*, 17 feet) the "red beds," evidently the equivalents of *e'* of the Forge-Valley section. Their ferruginous character is still maintained at Scarborough; but the petrology is more that of the Hackness type. The next series (B. *a*, 11 feet) corresponds to *e* of the Forge-Valley section, and contains the characteristic fauna of this horizon. But it happens here at Scarborough to be unusually rich, containing some very shelly beds, from which the following are amongst the species which have been determined:—

c. Cylindrites elongatus, *Phil.*
v. c. Gervillia aviculoides, *Sow.*
Avicula ovalis, *Phil.*
Astarte Duboisiana, *D'Orb.*
Trigonia (clavellate form).
c. Sowerbya triangularis, *Phil.*
Gresslya peregrina, *Phil.*
Myacites recurvus, *Phil.*
—— jurassi, *Brongn.*
r. Rhynchonella Thurmanni, *Schlot.*
Waldheimia Hudlestoni, *Walk.*
c. Echinobrissus scutatus, *Lam.*
——, sp.
Millericrinus echinatus, *Phil.*
Rhabdophyllia (fragments).
c. Spongia floriceps, *Phil.*
c. Manon, sp.

The above groups (B. *a* and *b*), having a thickness of 28 feet, constitute the *Passage-beds* of Mr. Fox Strangways, and will subsequently be referred to under that title. It follows, therefore, that the oolite of Scarborough Castle Hill (A of fig. 12) is no other

Fig. 12.—*Section of the Upper Part of Scarborough Castle Hill.*



A. Oolite of the Lower Limestones, locally known as Coralline Oolite, 24 ft.
B. *a*. Gritty and variable Limestones with shell beds, 17 ft.
b. Flaggy, ferruginous Limestones, very gritty; the "red beds," 11 ft.
C. *c*. Ball-beds, 18 ft. } Lower Calcareous Grit proper.
d. Angular cherty bed. }

than the lower oolite (*d*) of the Forge-Valley section; and this conclusion is fully warranted by the few fossils it contains.

To the west of the Derwent Gorge the Lower Limestones may be seen spread out over the surface of the hills, and in quarries in the gorges of Yetmandale and Beedale. The basement-beds are generally very thick-bedded and highly ferruginous, as near the Farm-House in Beedale, where we note a variety of *Lima gibbosa* found on the same horizon at Scarborough. At a higher level, in oolitic roadstone quarries, occurs the obese *Ammonites goliathus*; and the main mass of the lower coralline oolites is well exposed in fine quarries about a mile north of Wykeham, though there are few fossils beyond the characteristic *Gervillia aviculoides*. As we pass a little to the south of Sawdon, towards the boundary of the district, we find very characteristic exposures, not only of the oolites but of the calcareous flags beneath them. These are so ferruginous as strongly to recall the "red beds," weathering into red as they do in the fields, though they are white in the roadways. Several of these beds are much made up of comminuted shells, and are fossiliferous, yielding *Ammonites cordatus, Cylindrites elongatus* (abundant), *Dentalium entaloides, Nerinæa*, sp. (long and narrow), *Exogyra nana, Pecten fibrosus, P. lens, Perna quadrata, Gervillia aviculoides, Sowerbya triangularis, Rhynchonella Thurmanni.*

The Intermediate Series.—Where the beds above the Lower Calc-Grit are almost entirely calcareous, and the change from the Lower to the Upper Oolite is made through beds so similar that the line of demarcation is arbitrary, we can expect to distinguish them only in a complete section, which nowhere else can be so satisfactorily made out as in the Forge Valley. But as we pass westwards and approach an area in which this part of the Corallian Series has a different development, we meet with signs of the change; for in Sawdon Lane, overlying the shivery Lower Oolite, according to the dip observed, we see indications of a mass of yellow sandy and purplish blue grit, in places semioolitic; and overlying this, again, we seem to see the upper portion of the intermediate series at the base of a roadstone quarry, about half a mile N.N.E. of the village of Brompton, where we have the following section, in descending order:—

	ft.	in.
1. Fossiliferous oolites, showing false-bedding. *Chemnitzia heddingtonensis, Trigonia* (clavellate and costate), *Astarte Duboisiana* (common)	4	6
2. Pale buff grits and oolites mixed. *Phasianella striata, Pleurotomaria*, sp., *Exogyra nana, Avicula ovalis, Gervillia aviculoides, Sowerbya triangularis, Lucina*, sp.; also wood, and curious, vertical, root-like markings	6	6
3. Coarse-grained gritty oolite, with large fossils. *Belemnites abbreviatus, Ammonites perarmatus, Chemnitzia heddingtonensis* (very large) ...	4	0
	15	0

Here bed No. 3, by its large Chemnitzias, reminds us of one of the upper beds of the same series in Forge Valley.

The Upper Limestones.—These have long been known at Seamer &c. under the name of Coralline Oolite; they are well developed all along this range, and have numerous exposures on the hill-sides sloping south. A detailed description of the most accessible and best-known quarry will give an idea of their character.

Section of the Crossgates Quarry, Seamer.

		ft.	in.
Coral Rag.	Soil, broken rock, and boulders of *Thamnastræa concinna* (round-heads)	2	0
Oolites and Corals.	Oolite in a buff pasty matrix, with a bed of *Rhabdophyllia* at the base	3	0
	Oolite in a buff pasty matrix, with a shell-bed at the base. *Nerinæa visurgis*, *Trigonia* (costate sp.), *Lucina*, sp., *Astarte Duboisiana*, spines of *Cidaris Smithii*, and a few delicate fingers of *Rhabdophyllia*	2	8
	Thin clay parting	0	1
	Shelly bed, partially oolitic. *Ammonites plicatilis*, *Nerinæa*, *Lucina*, *Astarte Duboisiana*, many *Rhabdophylliæ* and stray fragments of *Thamnastræa*. "Snake-bed"	1	4
	Indurated, cemented, large-sized pisolite, with an occasional coral. The "top hard."	1	0
The Coral shell-bed.	The Coral shell-bed. A pale grey oolite, rather pasty; shells and corals very sparry. Fragments of *Thecosmilia*, often prostrate, and principally in the upper portion; *Rhabdophyllia*; a few lenticular masses of *Thamnastræa* towards the base; *Pecten fibrosus*, *Lima rigida*, *L. densepunctata*, *L. pectiniformis*, *Perna rugosa*, *Trichites*, *Arca pectinata*, spines of *Cidaris Smithii*, very large; megalomorphic fauna. There is much comminuted shell in this bed. "The Bottom Hard."	2	0
Oolites.	Rubbly pisolite, full of small *Exogyræ*	0	2
	Oolitic series, poor in shells, with an occasional brashy parting; excellent lime	6	6
	Rubbly pisolite, full of small *Exogyræ*; contains *Echinobrissus scutatus*, *Phasianella striata*, &c.; a constant parting	0	6
	Fine-grained oolites, making excellent lime; some of the upper portions of the beds are rather lumpy, owing to casts of *Phasianella striata*, and to nodules which may represent sponges. There is one moderately shelly bed. *Exogyra nana*, *Pecten fibrosus*, *Gervillia aviculoides*, *Trigonia*, *Lucina*, &c., to base of quarry	6	0
		25	3

Below this the beds are said to be fair limestones, but rather gritty.

To any one acquainted with the formation, it need hardly be said that the above measurements vary in different parts of the quarry. The Coral shell-bed, for instance, varies from one to four feet, and encroaches upon the subjacent oolites.

A remarkable feature in this quarry is the development of about eight feet, or, if we include the Coral shell-bed, of about ten feet or more of an intermediate group, which may fairly be said to form a sort of passage between what we have usually termed the Coralline oolite and the Coral Rag. In most instances round the Vale of Pickering, Coral Rag rests directly upon Coralline oolite, or, as in the western part of the vale, merely with the intervention of two or three feet of a Coral shell-bed. In these cases, where the line of demarcation is very sharp, there has probably been a certain amount of submarine denudation before the surface was prepared for the coral-growth; and it may be that in this district we are enabled to inspect a class of beds which in other areas have been removed. The fauna, too, is of a somewhat intermediate character; but the abundance of the spines of *Cidaris Smithii* serves to connect it with the overlying Rag.

Of the identity of the beds here exhibited with those of the upper series of limestones in Forge Valley we have no doubt; and the fragmentary oolite at the top of the Filey section is possibly on the same horizon, whilst the oolite on Scarborough Castle Hill belongs, as we have seen, to the Lower Limestones. Towards the west we have traced this oolite as far as Brompton still retaining similar characters.

The rubbly beds containing corals, to which alone we apply the name of Coral Rag, taking the term in a petrological sense, are in this, as in other districts, very distinct from the beds below. They also present some features which are peculiar as compared with similar beds elsewhere. The exposures are very numerous all along the edge of the vale, and, from the abundance of fossils, very attractive.

At the Crossgates quarry we just catch a glimpse of the Coral Rag, its most easterly exposure, though it has been proved beneath the superficial accumulations at the Cayton Waterworks still further to the eastward. On the other side of the road a ten- or twelve-foot face used to be worked for roadstone, the dip of about 3° S.S.W. bringing the upper beds into lower positions in a southerly direction. Even in Crossgates quarry itself "Roundheads," *i. e.* boulders of *Thamnastræa concinna*, were found on the top of the Coralline oolite; but they became scarcer in the direction of the outcrop.

The position of the coral-bearing beds may be seen at various points near Ayton. About a mile to the east of the village, on the Scarborough road, we have, to a certain extent, a repetition of the Seamer (Crossgates) quarry, viz. the Coralline oolite, showing about eight feet on the north side, surmounted by a bed of oolite brash, and then by true Coral Rag, which is in force on the south side of the road.

The character of the Rag in a quarry at the base of Yetmandale should also be noticed. The greater part of it consists of Rag rubble, broken up and deposited in beds about two feet in thickness, with softer partings, becoming more crystalline and solid towards the top, and graduating into or surmounted by two feet of fissile shelly oolite. In another part of the same pit the whole thickness is irregularly filled with thick-bedded crystalline coral. There are two things to notice here:—(1) the irregularity of the coral growth; (2) the surmounting of the Rag by oolite. With regard to the first, Mr. Leckenby appears to consider that the patches of coral reef, the crystallized remains of which form the Rag, are detached and not continuous. It would necessitate an accurate survey of the whole ground to say how far this view is correct, or whether, on the other hand, there is not something like a belt of Coral Rag on the dip for some considerable distance on both sides of the village of Ayton. There certainly is great irregularity of development as seen in this and other Rag-quarries, where the coral itself is parted by masses of a peculiar chalky rock, the calcareous débris of powdered coral, which contains the bulk of the fossils. With regard to the second point, we may notice that in Irton Lane the same phenomena occur in an equally indubitable manner, where the appearances are such as would lead us to suppose that 14 feet of Coralline oolite, with numerous *Nerinææ*, observed on the dip-side of a strong coral reef, were deposited at the same level as the reef, or even partly above it. Leaving this matter, however, as unproved, the undoubted overlying of the oolite on the Rag seems to indicate that in some parts of this district other, later reefs may have been formed, which have now disappeared or are only to be found in the more westerly portion of the vale. Certainly there are peculiar features in the fauna of this Rag. *Cidaris florigemma*, that highly characteristic urchin, is never, to our knowledge, found in these beds, its place being taken by *Cidaris Smithii*. We must also notice the extreme abundance of *Phasianella striata*, elsewhere not abundant in the Rag, but in the oolite below. It is remarkable also that the prevailing coral is *Thamnastræa concinna*, to the exclusion of almost any other form except *Rhabdophyllia*.

These beds may be traced as far as Brompton, where they have a similar character, and continue to yield a large and interesting suite of fossils.

There is nothing to be seen along this range which could represent any higher beds, such as the Upper Calcareous Grit, the great thickness of well-stratified sand between Ruston and Wykeham being apparently a superficial deposit. That the Upper Calcareous Grit is not entirely absent in the district, is manifest from the curious fragment yet remaining on Silpho Heights; its presence there may be taken to indicate that it once had a greater extent in the district of which we are now treating.

Fossils of the Seamer-Ayton-Brompton Rag.

Some of the more characteristic fossils of these Rag-beds, including both the hard and the soft parts, and also certain brashy partings are :—

Natica arguta, *Phil.* (? clio, *D'Orb.*).
c. Cerithium inornatum, *Buvig.*
—— limæforme, *Röm.*
—— Humbertinum, *Buv.*
c. Nerinæa fusiformis, *D'Orb.*
—— fasciata, *Voltz.*
c. Littorina muricata, *Sow.*
Turbo funiculatus, *Phil.*
—— corallensis, *Buvig.*
Trochus aytonensis, *B. & H.*
Delphinula muricata, *Buvig.* (Strickl. Coll.).
c. Phasianella striata, *Sow.*
c. Trochotoma tornata, *Phil.* (*cf.* T. discoidea, *Buvig.*).
Bulla Beaugrandi, *De Lor.*
Ostrea duriuscula, *Phil.*
c. Exogyra nana, *Sow.*
c. Ostrea gregaria, *Sow.*
Anomia, smooth species.
Pecten vimineus, *Sow.*
—— lens, *Sow.*
Hinnites velatus, *Goldf.*
c. Lima fragilis, *Röm.*
—— rudis, *Sow.*
—— rigida, *Sow.* (small).
Perna mytiloides, *Lam.*
c. Arca quadrisulcata, *Sow.*
—— pectinata, *Phil.*
Cucullæa elongata, *Phil.*
? Astarte aytonensis, *Lyc.*
Myoconcha texta, *Buvig.*
c. Modiola inclusa, *Phil.* } borers.
—— Lycetti, *Whit.* }
Terebratula insignis, *Schub.* (juv.).
c. Pseudodiadema versipora, *Phil.*
Cidaris Smithii, *Wright.*
Hemicidaris intermedia, *Flem.*
Rhabdophyllia Edwardsi, *M'Coy.*
Thamnastræa concinna, *Phil.*

The Hackness Outlier.—Having given a general description of what may be deemed the average development of the Corallian beds in the Seamer-Ayton-Brompton subdivision of the Scarborough district, there remains one remarkable locality which belongs to this district, though separated by denudation, and isolated on a lofty plateau. This is the Hackness outlier, where, within a space of a few hundred acres, may be seen a complete epitome of the whole Corallian system, resting upon Oxford Clay, which itself may be traced down into the Kelloway Rock.

Omitting stratigraphical details, the following is a summary of the beds which rest upon the Lower Calcareous Grit on Silpho Heights, in descending order, with approximate thicknesses:—

		ft.	in.
	1. Upper Calcareous Grit, partly *in situ*, and partly occurring as a fragmentary wash covering the fields to the north of Loffeyhead Heights.		
Upper Limestones.	2. Upper or true Coral Rag—a crystalline limestone made up of roundheads of *Thamnastræa concinna*	12	0
Upper Limestones.	3. The Bell-heads Limestone, or equivalent of the Coralline oolite, made up of large oolitic granules in a dense greyish paste, and containing towards the centre a strong band of *Thecosmilia*-rag full of fossils	18	0
	4. Thin bands of gritty limestones and sandy beds—Middle Calcareous Grit.		
Lower Limestones.	5. The Lower Oolitic Series. Small-grained oolites towards the centre of the mass with flaggy limestones towards the top and thick-bedded fossiliferous limestones towards the base—the rock of the lime-quarries of Silpho and Suffield	18	0
Lower Limestones.	6. Lower Coral Rag: a brown ferruginous coral limestone, with brashy partings and interspaces, having a peculiar set of fossils	8	0
Lower Limestones.	7. Basement- or passage-beds: a series of impure, gritty, and rather flaggy limestones, in some cases made up of comminuted shelly matter, and generally very ferruginous; quarried for walling and road-mending	24	0

No. 1. The Upper Calcareous Grit is limited to a small space, chiefly between Loffeyhead Heights and Silpho. It presents the usual characters so well recognized at Pickering and elsewhere to the westwards; but this is the only locality where we know of its preservation in the eastern area. From its existence here as a fragmentary outlier, we may perhaps infer that it covered the Ayton Rag in the same way as it does that of the region to the west of Pickering. Owing to partial denudation and weathering on an exposed plateau 600 ft. above the level of the sea, the more indestructible Coral Rag is thrust through it in knobs and hillocks, and might seem at first sight to overlie it; but a careful examination of the ground on Loffeyhead Heights, where a complete sequence may be traced, failed to indicate its infraposition. The Coral Rag may there be seen distinctly reposing on the Bell-heads oolite, though the latter is at a much greater elevation than one would expect without calling in the aid of a fault, or sharp roll of the beds; and on the Bell-head itself the fields exhibit the Upper Calcareous Grit in such a position as renders it impossible for it to be underlying the Rag. A mass of this Upper Calcareous Grit, apparently bedded, was found to contain the

characteristic fossils—*Ammonites biplex*, *Pecten midas*, *Avicula ovalis*, var. *obliqua*, two species of *Lucina*, *Thracia*, *Pleuromya*, &c.

No. 2. The Upper Coral Rag. There can be no doubt that this is the true Coral Rag of Ayton &c. Only the harder portions, the coral mineralized *in situ*, are visible; and these contain few fossils other than *Lithodomi*; an exposure of the intercoralline brash would doubtless exhibit the usual fauna, already indicated. The thickness is merely estimated.

No. 3. The Upper Coralline oolite. This, too, is confined to a limited area, and may best be studied in the Bell-heads quarry, where we note the following section:—

	ft.	in.
a. Rubbly limestone fragments with occasional coral doggers in a reddish soil; abundance of *Phasianella striata*	1	0
b. Large-grained oolites in a bluish grey calcareous paste. *P. striata*, *Chemnitzia*, *Astarte Duboisiana*, *A. ovata*, &c.	7	0
c. Strong band of *Thecosmilia*-rag—a kind of Coral shell-bed, showing a handsome arabesque of fossils. Spines of *Cidaris Smithii*, in great abundance, quantities of *Exogyra nana*, *Ostrea gregaria*, *Nerinæa*, sp., *Cerithium inornatum*, *Littorina muricata*, *Cylindrites Lhuidii*, *Arca quadrisulcata*, *A. pectinata*	2	9
d. Thick-bedded large-grained oolites, similar in character to those above, but rather softer; beds visible	6	3
	17	0

The general accordance of this section with what we have already seen at Seamer leaves us no room to doubt that here we have the representative of what is usually known as the Coralline oolite of that locality. The band of *Thecosmilia*-rag in the oolite with so many of the same fossils, the presence of *Phasianella striata* and *Astarte Duboisiana* in considerable numbers in the upper portion of the oolite, all point in the same direction, and go to prove the identity of this formation, making due allowance for variation, with that which immediately underlies the great stretch of Coral Rag between Seamer and Brompton.

No. 4. The lower portions of the Bell-heads limestone pass, we presume, into the gritty limestones called by Mr. Fox Strangways the Middle Calcareous Grits. We have seen no good exposure of these beds at the base of the upper oolite on Loffeyhead Heights, unless certain gritty layers represent them; but further back towards Silpho they are more spread out and occupy a considerable extent of ground.

Nos. 5, 6, and 7. The great group of the Lower Limestones has been far more extensively preserved on the Hackness outlier, as these rocks may be seen on both sides of the many-fingered ravine, which divides the heights of Silpho, comprising the limited region just mentioned, from those of Suffield. It has probably in most places, including the Lower Coral Rag and passage-beds, a total thickness of not less than 50 ft. Taking the Suffield district in this case as our principal guide, we subjoin the following rough outline of their development.

No. 5. The Lower Oolitic Series.

Section in Suffield Lime-quarry.

	ft.	in.
a. Thin-bedded shelly limestones, in which the forms are partially obliterated. *Cerithium muricatum* (rare), *Exogyra nana*, *Ostrea gregaria*, *Pecten fibrosus*, *Trigonia*, sp. (rare), *Echinobrissus*, sp. (cf. *clunicularis*), *E. scutatus*; fauna micromorphic	4	0
b. Small-grained oolites with few fossils, forming the mass of the limestone	10	0
c. Fossiliferous suboolitic limestones, with *Ammonites cordatus*, *Avicula inæquivalvis* (? *expansa*), *Gervillia aviculoides*, *Perna quadrata*; fauna megalomorphic. To floor of quarry, below which there may be some 6 or 8 feet before reaching the next series	3	6
	17	6

The oolites of the Lower Limestones, whose acquaintance we first made in the "White Quarry" of the Forge-valley section (fig. 11), here maintain their usual poverty; and this feature, together with a smallness of the granule and a general gritty feel, may serve to distinguish them. In the corresponding quarry at Silpho the occurrence, though rare, of *Rhynchonella Thurmanni* further serves to connect their fauna with that of the Lower Calcareous Grit.

No. 6. Not the least interesting feature of the Hackness outlier is a well-developed Lower Coral Rag, of which there are indications, as we shall see subsequently, in other extensions of the Lower Limestones, but nowhere so well developed as here.

Section of Suffield "Sandstone" Quarry.

	ft.	in.
a. Soil and broken Rag	0	6
b. Crystalline gritty coral-doggers in a brownish brash containing abundance of a small *Waldheimia*, with *Spongia floriceps* and many other fossils	3	0
c. Massive coralline block with shell-tablets. *Cidaris Smithii* (spines and test), *Trichites*, &c.	1	9
d. Flaggy shelly bed with a few corals imbedded in a brown gritty limestone	2	0
e. Ferruginous brashy parting, with seams of ferric hydrate	1	0
	8	3

These rest upon flaggy ferruginous limestones largely made up of broken shelly matter.

The fossils of the Rag, chiefly occurring in *b*, are numerous and interesting. There are some peculiar forms of *Ostrea*. The list includes *Ostrea*, sp., *O. gregaria*, *O. solitaria*, *Exogyra nana*, *Gryphæa chamæformis* ?, *Pecten fibrosus*, *P. articulatus* (dwarf), *Hinnites velatus*, *Lima rudis*, *Lima*, sp., *Trichites*, *Cypricardia* (small), *Astarte rhomboidalis* (small), *Waldheimia Hudlestoni*, *Cidaris Smithii*, *Spongia floriceps*, *Serpula tricarinata*. The corals present more variety than might be found in an equal amount of the Upper (true) Coral Rag of the district. We found *Isastræa explanata*, *Thamnastræa concinna*, *Thecosmilia annularis*, and *Rhabdophyllia Phillipsi*, with the inevitable *Modiola inclusa*.

The occurrence of a Lower Coral Rag, which is by no means confined to this quarry, but underlies the oolites of the Lower Limestones everywhere on the Hackness plateau, as may well be seen at the Suffield limekiln, is a somewhat exceptional feature. Still there are indications in several places throughout the Scarborough district of something of the kind, though not on an equal scale. The horizon of the Lower Coral Rag is situated towards the top of the gritty limestones, which succeed the ball-beds of the Lower Calcareous Grit. In the outcrops of the Lower Limestones this horizon may be looked for wherever *Spongia floriceps* and brown rubbly masses occur upon the surface. The chief features in the fauna are the great variety of *Ostreæ*, and the stunted character of the Mollusca &c. generally. The spines of *Cidaris* are less than half the size of those usually found in the true Rag; we observe also curious micromorphs of species which afterwards become characteristic of the Coral Rag, such as *Pecten articulatus*, *Astarte rhomboidalis*, &c. The peculiarities above noted, together with the great abundance of *Spongia floriceps* and *Waldheimia Hudlestoni*, may be deemed indicative of this group. It is remarkable that at Scarborough and Filey, though nothing in the way of corals beyond a few fragments of *Rhabdophyllia* have been discovered, these two fossils occur together on the corresponding horizon. At the first-named locality we have noticed the *Waldheimia*, though rarely, in the top shell-bed of B *a* (fig. 12); at the second it is very plentiful along a line about 7 feet above the ball-beds. This is a further corroboration of our view that the oolite of Scarborough Castle belongs to the Lower Limestones, whose representatives at Filey must be sought for below the Filey-Brigg Calcareous Grit. It will appear subsequently that there is a line of intermittent coral growth, possibly more than one, towards the base of the Lower Limestones, and also towards the base of the Upper Limestones in the Pickering district. At Highworth, too, in the south of England, we have a luxuriant coral growth surmounted by shell-beds belonging to the Coralline oolite, whilst proof is given of the true Coral Rag occurring at a higher level; so that there is nothing unprecedented in England in the phenomenon of a Lower Coral Rag.

No. 7. The Basement-, or Passage-beds, which lie betwixt the Lower Coral Rag and the Lower Calcareous Grit proper, are flaggy ferruginous limestones, much quarried for road- and walling-stones. Their thickness in some places is probably not much less than 24 feet. Although portions of these beds are a mass of broken shells, the recognizable forms are few, and consist of species common to most parts of the Lower Calcareous Grit. *Ostrea solitaria*, *Exogyra nana*, *Gryphæa dilatata*, *Lima*, sp. (small), *Gervillia aviculoides*, *Pleuromya*, and *Gresslya* were noted. The irony character of these lower passage-beds is well marked, but not so decided as in Scarborough Castle Hill, Forge valley, and Beedale. It may be deemed a characteristic feature of the basement limestones of the Corallian series in the Scarborough division of the Yorkshire basin.

2. The Pickering district.

The separation between this and the district first described is most simply made by the assistance of stratigraphical features, which, though not quite accurately coinciding with a change of type in the rocks, coincide sufficiently for the purpose. In going westwards from Brompton we find the Corallian beds thrust up by an anticlinal curve having its axis apparently a little to the west of Ebberston*. The general dip of the beds is still southerly; but this slight dome makes them fall away both to the east and to the west, causing the Lower Calcareous Grit to form the base of the hills, and even bringing up the Oxford Clay to the surface near Allerston. These beds are brought against the Kimmeridge Clay of the vale by a great fault running nearly east and west. The upper limestones are quite thrown out; and, as we have noticed, the beds below are already putting on the Pickering type. The openings in the Lower Calcareous Grit are abundant; and the country is eminently a sandy one. With the fall of the anticlinal we enter on our Pickering district, which extends for us as far as the neighbourhood of Helmsley (see Map, fig. 10).

Throughout this range, as in the Scarborough district, the highest beds occupy the lowest positions, and must be sought, for the most part, at the edge of the vale.

In the gorge of Newtondale, at the outlet of which lies the town of Pickering, we obtain a complete section of all the Corallian beds in this district; and as the upper and most interesting portion is magnificently displayed in the numerous quarries near the town, we shall commence with a description of the formation as here seen, with which we may afterwards more clearly compare the development in other portions of the area.

The general Corallian section on the meridian of Pickering, as proved in the deep gorge of Newtondale, is nearly as follows:—

	ft.
Supra-coralline beds	20
Upper Limestones	50
Trigonia-beds and Middle Calc-Grit	45
{ Lower Limestones	60
{ including Basement- or passage-beds	30
Lower Calc-Grit	—
	205

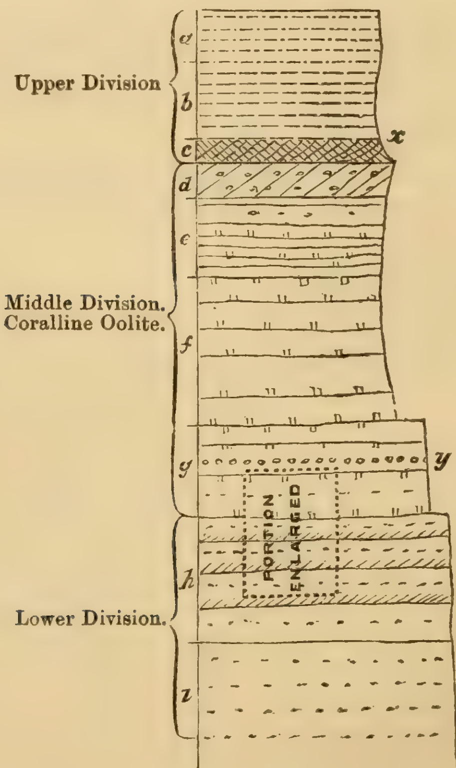
The Lower Calcareous Grit can hardly be less than 100 feet thick. Towards the top occurs the usual ball-bed series. Doggers of gritty limestone in soft yellow calcareous sand, much as at Filey Brigg, are succeeded by hard tables of similar rock. This series of impure limestones has a thickness of about 30 feet. The commencement of the calcareous series is well seen at the base of the S.E. angle of Blansby-Park woods, close to the railway, where it is by no means fossiliferous—rather a contrast to this horizon in some localities. The character of its upper portions and also of the oolites of the Lower Limestones is not well revealed at this spot, though the beds may be more clearly seen just on the other side of the river in Little-Park

* A determination due to Mr. Fox Strangways.

wood, where they are cut through by the road. Here the oolites are rather crystalline limestones towards the base, but become creamy, close-grained, and thin-splitting further up, becoming, however, once more crystalline and gritty as they change gradually through true calcareous grits into yellow sandstones, the limestones having a shell-bed towards the top. The yellow grits in their upper parts alternate with hard blue rock and shelly beds, the equivalents of the *Trigonia*-beds of the Pickering quarries lying about 2 miles to the south-west. Ascending the S.E. angle of Blansby-Park woods, the Upper Limestones are partially revealed through the thick matting of undergrowth; and, finally, the plateau at the top is found to be held by an argillaceous form of Coral Rag. The thicknesses in this very complete section are pretty nearly those already given, but the supra-coralline beds are absent.

These latter, however, together with the Upper Limestones, and that portion of the Middle Calcareous Grits which contain the *Trigonia*-beds are extensively quarried at Pickering. The following section (fig. 13) is the result of a careful average of the quarries on both sides of the valley as far as the workmen's cottages near the third quarry on the west side. North of this the Coral Rag, which is barely recognizable in the quarries nearest the town, begins to make a better figure.

Fig. 13.—*Generalized Section at Pickering.* (Scale 32 ft. to 1 inch.)



For details of the beds see table, p. 335.

x. Bed of *Ostrea bullata.* *y.* Line of Pisolite.

Generalized Section—Pickering.

Upper Division (supra-coralline).—Grits, Shales, &c.

	ft.	in.
a. An Upper Calcareous Grit with abundance of tuberous and ramifying forms and many fossils in bad preservation	7	0
b. Sandy and marly shales resting upon a thin bed full of *Ostreæ*	10	0
c. Bed of argillo-calcareous stone, locally termed "Throstler," wanting in places, or represented by a flaggy parting of a few inches	3	0
	20	0

Middle Division.—Upper Limestones.

	ft.	in.
d. Top-stone—a grey ferruginous limestone, generally false-bedded, thicker on the west than on the east side	5	0
e. Impure earthy limestones, known as "black posts," poor in fossils, but containing *Belemnites abbreviatus*, and towards the base *Ammonites varicostatus*	10	0
f. Chemnitzia-limestones, compact and suboolitic. Shell-beds, at intervals full of *Chemnitziæ* and *Nerinææ*; *Astarte ovata* and other bivalves less numerous	20	0
g. Variable limestones and pisolites, with shell-beds and nests of *Thamnastræa arachnoides* in the lower part; indications of Calc-Grit towards the base. Roadstones, walling, &c.	13	0
	48	0

Lower Division.—Shell-beds and Grits (Middle Calc-Grit in part).

	ft.	in.
h. The upper part of this division contains the principal *Trigonia*-beds, full of fossils, alternating with Calc-Grits. *Ammonites plicatilis* abundant. Building-stones, walling	17	0
i. Calc-Grits begin to predominate, base not seen. *Nautilus hexagonus*, *Ammonites-cordatus* group numerous, &c.	11	0
	28	0

Subjoined is a detailed description of the general section.

i. The upper portion of this division shades into the next one, *h*; its lower portion is obviously incomplete, as the Middle Calc-Grits are not bottomed in any of the Pickering quarries. There are very few fossils in it beyond those noted in the section, which occur of large size towards the top.

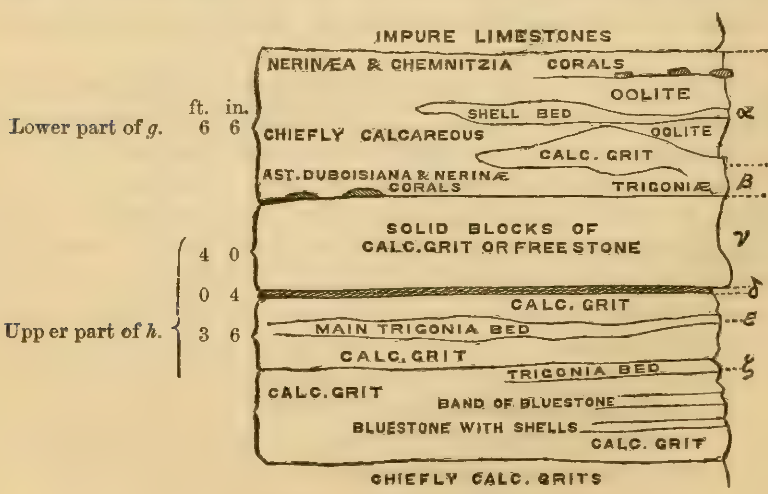
h. 17 feet.—This is the most interesting and richly fossiliferous of all the groups in the section. It is the horizon whence most of the fossils marked "Pickering" are derived, and is remarkable for three beds charged with *Trigonia perlata* in great profusion, but always in detached valves (ε, ζ in fig. 14). Petrologically the group consists of light porous calc-grits and of hard blue beds, locally termed "flint," these latter sometimes passing into shell-beds, which occasionally thin out to a mere string, and then develop into pockets full of the most magnificent valves of *Trigonia*. The middle bed is perhaps the best. By far the commonest fossils, besides *T. perlata*, are *Gervillia aviculoides*, *Nerinæa visurgis* (usually small), *Chemnitzia heddingtonensis, Lucina Beanii, Cucullæa corallina*. Besides the principal *Trigonia*-beds there is a very peculiar "small shell-bed" only to be found on the east side, its position on the west side being occupied by a few inches of a soft and rather argillaceous stone (δ of fig. 14), immediately underlying the top block of workable freestone or true calc-grit. On the east side, this bed, where well developed, is about 1 foot thick, and in some places is a perfect mass of shells with hardly any matrix at all. The species are for the most part the same as those in the regular *Trigonia*-beds, but are smaller and in better condition. The fossils we have obtained from these beds are:—

Fossils of the Trigonia-*beds*, *Pickering.*

r. Belemnites subhastatus, *Mont.*
Ammonites cordatus, *Sow.* (excavatus, *Sow.*).
—— vertebralis, *Sow.*
v.c. —— plicatilis, *Sow.*
v.c. Chemnitzia heddingtonensis, *Sow.*
v.c. Cerithium muricatum, *Sow.*
r. Littorina muricata, *Sow.*
c. Nerinæa visurgis, *Röm.*
——, species (imbricated).
v.c. Exogyra nana, *Sow.*
Ostrea solitaria, *Sow.*, var.
Anomia radiata, *Phil.*
Plicatula, sp.
Pecten fibrosus, *Sow.*
—— qualicosta? *Et.*
r. Hinnites (small form).
Lima elliptica, *Whiteaves.*
r. Avicula ovalis, *Phil.* (peculiar form).
c. Gervillia aviculoides, *Sow.*
c. Cucullæa corallina, *Damon.*
Limopsis corallensis, *Buv.*
v.c. Trigonia perlata, *Ag.* (many vars.).
r. —— Meriani, *Ag.*
Cardium cyreniforme, *Buvig.*
v.c. Lucina Beanii, *Lyc.* }
v.c. —— aliena, *Phil.* }
—— oculus, *Bl. & H.*
Corbicella, sp.
Cyprina corallina, *D'Orb.*
Cypricardia glabra, *Bl. & H.*
Opis Philipsi, *Morr.*
c. Sowerbya triangularis, *Phil.*
v.r. Rhynchonella lacunosa, *Schlot.*
r. Echinobrissus scutatus, *Lam.*
r. Cidaris Smithii, *Wright* (spine).
r. Rhabdophyllia Phillipsi, *M.-Edw.* (fragment).

The division between this group and the next is drawn above the uppermost continuous block of Calc-Grit, which in some places is four feet thick, but splits up and changes rapidly. The latter is represented by γ in fig. 14.

Fig. 14.—*Enlarged Portion of Section at Pickering, Fig.* 13.



g, 13 feet. Fig. 14 is a portion of the general section, enlarged for the purpose of exhibiting the peculiarities noticed about the junction of these two groups. It represents the appearances on the west rather than on the east side. We have already referred to it as showing the mode of occurrence of the *Trigonia*-beds, and the argillaceous representative of the "small shell-bed." Although both the groups (*h* and *g*) may be deemed passage-beds, their petrology linking them with the calcareous grits, whilst their palæontology draws them towards the oolites, yet in *g* we very soon lose all traces of grit (an important physical difference) and obtain, along with corals, some change in the fauna; hence we consider the Coralline oolite of Pickering to commence at the base of this series. The beds classed in group *g* are variable and impure limestones, mostly used for road-metal. At its base is the thin and very variable bed β of the enlarged section (fig. 14) which also forms in an irregular way the top *Trigonia*-bed; it is most generally a discoloured oolite, chiefly characterized by a quantity of *Nerinæa visurgis* (large) and *Astarte Duboisiana*, and contains also *Perna mytiloides* and *Pecten fibrosus*. Above this, and sometimes perhaps included in the base of it, is the great block locally called "Wilf," which comprises the whole of α (fig. 14). It is sometimes divisible into as many as three minor blocks, and is a complete mixture of every thing; corals may be noted both at the bottom and at the top, and possibly also in some parts of the central mass. Isolated groups of *Thamnastræa arachnoides* appear to have grown upon the top of the last bed of calc-grit; then came a shell-drift with *Trigonia*-valves, *Astarte Duboisiana* &c., then mixtures of calc-grit, and oolite, another string of shells, then some more decided oolite, with very fine *Nerinæa visurgis*, mixed with some more *Thamnastræa arachnoides*. Some parts contain so much coral as to present the appearance of a Coral Rag, but without the fauna of the true Rag.

Returning now to the general section, the block above this contains impure, and often blue-centred limestones; but is most remarkable for a band of pisolite, which may readily be proved in all the quarries. This pisolite contains the same *Nerinæa* and *Astarte* as below; and *Trigonia perlata*, along with some of the other fossils of the *Trigonia*-beds, continues to be met with sparingly. Immediately above the pisolite is an extremely compact limestone, in texture almost like china-stone, with a few very small, round, oolitic granules. It is curiously marked by the sparry shells of small *Cerithia* (*C. inornatum*?) and of *Nerinææ*, so thoroughly sealed into the rock as to afford no hope of extraction or of specification. Fine-grained rocks are often associated with small shells, and coarse-grained rocks with large ones. In this case the mechanically-derived sediment, which is by no means inconsiderable, is of the finest texture. In the next block we have the succeeding group prefigured, *Chemnitzia heddingtonensis* beginning to prevail in the upper part: here also are many examples of *Phasianella striata*, often of immense size. In the quarries further north in the direction of the outcrop, the character of these fine suboolitic limestones undergoes considerable modification, as, indeed, do all the groups if traced for any distance.

f, average 20 feet.—These beds form the backbone of the "Coralline Oolite" of Pickering, where, in one of the quarries on the west side, they have a thickness of 22 feet. *Chemnitzia heddingtonensis* and *Nerinæa* are tolerably abundant throughout, but especially so in a block towards the top of the series, which is evidently an old shell-bed. The sparry sections of *Chemnitzia*, in the white limestone or oolite, produce an appearance known to the workmen as "rabbit-eye;" and these beds mark the termination for a while of the more fossiliferous limestones. This series at Pickering may be viewed on the whole as a mixture of creamy limestones full of oolitic grains with true oolites. On account of the great difficulty in extracting the fossils, the fauna cannot be determined with the same ease as that of the *Trigonia*-beds. There are multitudes of shells in layers, but in such a compact matrix as to defy extraction. *Astarte ovata* and *Lucina aliena* are amongst the most plentiful of the bivalves; and *Trigoniæ* very like *T. perlata* occur sparingly.

e, 10 feet.—The "black posts" are dirty-looking limestones of somewhat variable thickness and not in the least oolitic, but rather carbonaceous. Portions are quite slaty and of no use to the lime-burners. The lower parts are of better quality: here the bedding is so uneven that the workmen call one of the bottom blocks "hilly and holey." It is from just below this that the Ammonite which most resembles *A. varicostatus* is said to come; but there are no sections of fossils on the surface of the stone, and the contrast afforded by this group to the fossiliferous and sparkling limestones below is most complete. This subdivision, of which there is not a trace in any part of the Scarborough district, has great importance in the Pickering district. It certainly prefigures the "throstler;" for in the neighbourhood of Kirkby Moorside there are indications that "black posts," rag, and "throstler" all more or less replace each other or commingle. The base of the subdivision "hilly and holey," is the cave-line throughout the district, as we shall see at Kirkdale (page 346).

d, 5 feet.—In the first quarry on the west side the top course of limestone, resting on 8 feet of the earthy limestone (*e*), has a thickness of 5 feet 6 inches, and contains layers of stone having a false dip of nearly 15° in a westerly direction; yet the upper surface is quite level, as though it had been planed away subsequently. Here the rock is full of vertical fissures filled with clay and other matters from above. In the second quarry on the west side these beds have a thickness of eight feet, but the false-bedding is inclined at a lower angle. It is rather remarkable that the slaty limestones (*e*) shrink correspondingly to the increase of these beds. At the principal quarry on the east side the face, exposed during the summer of 1875, exhibited only 2 feet 6 inches belonging to this group. It is there called the "iron post," and is a hard, blue-speckled, compact limestone, full of small, whitish, nodular bodies. Generally speaking, it may be described as a grey ferruginous limestone. Numbers of small shells, such as *Ostrea*, *Nerinœa*, and, possibly, *Littorina muricata* and *Pecten intertextus*, mixed with flatted sphericles, seem compressed into a grey and somewhat sparry matrix of considerable density. On account of the abundance of iron and alumina in its composition, it is much prized for smelting-purposes. Although this bed occupies the position of the Coral Rag, no flints, recognizable spines of *Cidaris florigemma*, or other well-known indications of that class of rock occur. If, however, we trace it backwards on the rise, we find it passing into, and inosculating with, a *Rhabdophyllia*-Rag in the fourth quarry on the west side; so that its relations are undoubted.

c, 4 feet.—By the incoming of beds which gradually prepare us for the true Kimmeridge Clay, we have an unmistakable intimation that, within the area at present under description, Corallian limestones are not be found above this horizon. On the planed-down surface of the false-bedded series last-named reposes that very curious bed locally known as the "throstler." It is a kind of sandy argillaceous limestone, of peculiar texture, with few, if any, recognizable fossils, but having numerous copper-coloured specks which probably represent fragments of shells now replaced by iron-oxide. In the first quarry on the west side there is just a little hummock of it interposed as a lenticular mass between *b* and *d*. In the second quarry on that side a 6-inch layer of dirty flaggy limestone probably represents it; while in a quarry at the back of the main ones it is about 2 feet thick, is undulated by 4 inches of laminated soft sandstones, and appears to contain remains of Polyzoa. On the east side it is fully 4 feet thick.

a and *b*, 17 feet.—These complete the series of rocks intervening between the Upper Limestones and the true Kimmeridge Clay, which may be seen capping the hills above one of the quarries on the west side. They are there, however, less favourably exposed than on the east, whence our descriptions and thicknesses in the generalized section are taken. The upper, or "red rock," is the most remarkable. It is a true calcareous grit, and maintains its characters throughout this district and even on the Hackness outlier already described. Indeed these characters are so marked that there is no mistaking the rock when once seen. In exposed portions it is almost devoid of lime, and is full of "pinhole" structure, with soft parts adhering to the harder cores; but it differs from the Lower Calcareous Grit in being exceedingly sharp and gritty, as if every particle were angular and stood out by itself. It is highly charged with tuberous and dichotomizing forms, which, in their enormous proportions, almost exceed those of the Lower Calcareous Grit. The fossils are abundant and varied; but most of them being in casts, their identification is not entirely satisfactory. Attention should be drawn to the remarkable layer of *Ostrea bullata* at the base of the sands.

Fossils of the Upper Calcareous Grit, Pickering.

r.	Belemnites nitidus, *Dollf.*		Modiola cancellata, *Röm.* (dwarf).
c.	Ammonites, sp. (cf. Achilles, *D'Orb.*).		Trigonia Voltzii, *Ag.*
c.	—— "biplex."		Protocardium, small sp.
	—— alternans, *Von Buch.*	v.c.	Lucina aspera, *Buvig.*
	Chemnitzia, sp.		—— substriata, *Röm.*
	Patella mosensis, *Buvig.*		? Corbicella.
	Exogyra nana, *Sow.*		Goniomya literata, *Sow.*
c.	Ostrea bullata, *Sow.* (Oyster-bed above "throstler").		—— v-scripta, *Sow.*
	Avicula ovalis, *Phil.*, *var.* obliqua.	c.	Pleuromya tellina, *Ag.*
	Perna mytiloides, *Lam.*	c.	—— Voltzii, *Ag.*
c.	Pecten midas, *D'Orb.*		Myacites &c. (numerous).
	—— demissus, *Phil.*		Thracia, sp. (cf. depressa, *Sow.*).
			Discina elevata, *Blake.*

The section at Pickering is so complete, so accessible, and so easy to trace, that we may be pardoned for having dwelt upon it at considerable length. The divisions adopted might, perhaps, in some instances, be considered slightly arbitrary; but there are, without doubt, three principal divisions or groups, corresponding to (1) *The upper part of the Middle Calcareous Grit,* here in unusual force, (2) *The Upper Limestones, i. e.* the Coralline oolite and the equivalents of the Coral Rag, and (3) *The Upper Calcareous Grit.* Of these the former two are blended by passage-beds, whilst the latter is sharply separated from the middle member. The absence, as far as we know, of *Ammonites perarmatus,* even from the lowest quarries, proves that we are dealing with a different fauna from that of the Lower Calcareous Grit, as does also the absence of *Rhynchonella Thurmanni*, so characteristic of that horizon and of certain portions of the Lower Limestones; so that, if we did not know it on stratigraphical grounds, we might suspect that the "freestones" of Pickering could scarcely belong to the Lower Calcareous Grit proper. Still the abundance of cordate Ammonites in the lowest accessible portions shows that we have not yet done with the Oxfordian fauna.

Throughout the whole series, from the *Trigonia*-beds well into the Coralline oolite, Ammonites generally referable to *A. plicatilis* are obtained; these sometimes attain enormous dimensions. We would draw attention again to the abundance of corals in the base of group *g*, unassociated with the Rag-urchins, which, with the Myacidæ and Anatinidæ seem, throughout the section, to be wanting.

The principal limestones, group *f*, from their usually compact nature, with only an occasional mixture of oolite, seem to have been the result of finely ground coral-mud, which has produced these calcareous pastes with oolitic grains, in some cases so closely cementing the shells and other organic fragments as to form rocks with a fracture almost like flint. The physical history of such beds, whether compact or oolitic, seems to have been this:—The coral is being perpetually ground down to the finest powder, which is held suspended in the sea like ordinary sediment; but as it falls towards the bottom, it encounters an acid stratum of water, due to the quantity of carbonic acid generated by the decomposition of organic matter and the respiration of animals. This slightly attacks the calcareous sediment and forms the usual soluble bicarbonate, which is again precipitated as calcic carbonate amongst the interspaces of the slowly settling mud, thus cementing the whole into a mass of most compact rock, and gluing up all the shells.

We now proceed to trace the several subdivisions seen in the section at Pickering and the gorge of Newtondale behind it, as they are modified at various localities to the east and west within the district.

The Lower Calcareous Grit.—This and the overlying limestones are the only members of the series that, to our knowledge, pass across to the Scarborough district. It presents no points of great interest, though stratigraphically it is of importance. The moorland streams that, cutting down to the Oxford Clay, force their way southwards through the overlying strata to join the Derwent, have their steep flanks formed by the sandy beds of this division; and not seldom we meet with dry sandy gashes, presumably due to a kind of subterranean denudation, the streams, instead of keeping upon the surface, sinking through the porous rock to come out as springs. The uppermost beds almost invariably have large cannon-ball doggers in them, to which those at Filey bear about the same relation that a 68-pound shot does to a 13-inch shell. These doggers are not very fossiliferous, but occasionally contain *Ammonites perarmatus*, *Perna quadrata*, *Pecten fibrosus*, and *Rhynchonella Thurmanni*. The most accessible spot where the Lower Calcareous Grit may be studied is in the neighbourhood of Allerston, on the Pickering and Scarborough road, where at the mouth of Givendale several quarries, some showing a face of from 40 to 50 feet, are worked for free-stone.

The Lower Limestones and Middle Grit.—We take these together because the sections illustrative of one often elucidate the other. Coming from the east, we first see these limestones graduating through the passage-beds into the Lower Calcareous Grit, itself traceable down to the Oxford Clay, at the mouth of Oxdale near Allerston, in a large quarry about the 400-foot contour (dip about S.W.). The oolites of the Lower Limestones have a face of about 30 feet. A noteworthy feature is a line of intermittent corals (*Thamnastræa*) of large size quite in the oolite, and tuberous masses of silicified oolite towards the base. These peculiarities are also well observed in the next-described quarries on the hill east of Thornton. These are excavated wholly in these limestones at different levels. In one of these quarries we have the following section :—

Section in the Further Quarry East of Thornton Dale.

	feet.
1. Fine-grained oolites, measured down to a line of intermittent coral (*Thamnastræa*), partly silicified	14
2. Oolitic limestone of similar character	11
3. Stronger-bedded oolitic limestone, with tuberous and spherical masses of silicified oolite	3
	28

These coral masses are of excessive interest, as being on an horizon not far removed from that of the Lower Coral Rag of Hackness. The silicification of the oolite seems also an important feature in the Lower Limestones here, as we shall see further west. The limestones, as usual, are not very fossiliferous; but we noted the following—*Pleurotomaria Münsteri*, *Chemnitzia heddingtonensis* (rare), *Cylindrites elongatus*, *Anomia radiata*, *Avicula ovalis*, *Lima fragilis*, *Pecten fibrosus*, *Gervillia aviculoides*, *Trigonia* (clavellate species), *Lucina Beanii*, *Echinobrissus scutatus*. In an adjoining quarry about 35 feet of oolites are seen, of which 17 feet lie above those last measured. Towards the base there are abundance of *Gervillia*; and towards the top, of *Nerinæa*. The several beds have red clay partings and contain also *Exogyra nana*, *Perna quadrata*, and plates of *Astrogonium*.

These quarries are close to an escarpment overlooking a deeply excavated glen which runs far up into the hills to the northward; here the Lower Limestones may be traced down into the Lower Calcareous Grit, which occupies the slopes of the glen, and also much of the surface of the high ground where the limestones have cropped out; but far away to the north the limestones come in again. This glen debouches into the vale at the beautifully situated village of Thornton; and on the opposite side is another large quarry in the Lower Limestone showing a face of nearly 40 feet of rock, mostly soft, white, small-grained oolite of a somewhat sandy nature. Upwards these oolites may be traced, in a northerly direction, on the road towards Highfields, well into the Middle Calcareous Grit. In an opening for road-stone we observed the following section:—

		ft.	in.
Middle Calcareous Grit.	Soil and shattered stone	5	0
	Flaggy calcareous sandstone	4	0
	Hard blue rock, slightly oolitic, with *Ammonites plicatilis*	1	6
	Flaggy calcareous sandstone, with some oolite	5	0
	Hard blue rock	1	2
	Flaggy sandstone, with *Avicula expansa*	0	6
Top of Lower Limestones.	Principal shell-bed, an impure suboolitic limestone	1	3
	Flaggy parting	0	3
	Lower shell-bed (base of quarry)	1	6
		20	2

These shell-beds appear to mark the top of the Lower Limestones in this district, and form a notable horizon likewise on the other side of Pickering. The shells are fine, and not different from those of the Coralline oolite proper, except as regards the greater abundance of *Gervillia*. The following were noted—*Belemnites abbreviatus*, *Chemnitzia heddingtonensis*, *Perna quadrata*, *Avicula pteropernoides*, *Pecten lens*, *P. fibrosus*, *Anomia radiata*, *Trigonia* (clavellate sp.), *Lucina Beanii* (*aliena* ?).

To the west of Pickering the Lower Limestones spread out over a great area and become of considerable importance, capping the hills for many miles. They are evidently very thick on the meridian of the Seven, where, including the flaggy beds at the top and the bottom, they are fully, if not more than, 100 feet in thickness. Their general development is best studied at the village of Cropton, on the road to Rosedale. This village is situated upon the angle of a plateau, some 400 or 500 feet above the sea-level. One of the containing sides is flanked by the deeply excavated Seven gorge, whilst the other faces the northern moorlands. The road from Rosedale Abbey ascends this escarpment facing the north, and crosses successively the Oxford Clay and the Lower Calcareous Grit. The upper portion of the latter is marked by a great development of the ball-beds. Immediately succeeding these, on the edge of the plateau at the north end of the village, is a thick series of the "basement-beds" of the Lower Limestones, here remarkable for enormous specimens of *Gervillia*. These basement- or lower passage-beds are less ferruginous than in the Scarborough district, but in other respects not materially different from the beds already described at Hackness and Forge Valley. Upon these rest the oolites of the Lower Limestones, which are well exposed in the large quarry on the S.W. side of the village. As in the great quarry of these oolites near Thornton Dale, there is a face of nearly 40 feet of small-grained suboolitic limestone in very large blocks. The general resemblance of the rocks to some of the less fossiliferous portions of the oolite of the Upper Limestones (Coralline Oolite) might cause even an experienced palæontologist to doubt the true position of these beds without the aid of stratigraphical evidence, here fortunately of a most unmistakable character. Still the prevalence of *Gervillia*, abundant in one of the lower blocks, rather than of *Chemnitzia*, is a point of difference which may always be relied upon; doubtless a closer inspection would reveal additional points. The other fossils noted were *Pecten subfibrosus*, *Avicula lævis*, *Trichites*, *Lucina Beanii**. The beds have an inclination of 4° to the south.

It is not possible in this quarry to trace the oolites of the Lower Limestones upwards into the shelly series which, in this district, marks the close of the Lower Limestones; but an important step in this direction is obtained at a quarry between Cropton and Cawthorne.

Section at Whitethorn Quarry.

	ft.	in.
a. Impure flaggy limestones of a purplish colour, having, towards the base, a bed full of Ammonites. *A. perarmatus* (type form) plentiful, *A. cordatus* (*excavatus*) frequent, *A. goliathus* frequent, *A. plicatilis* less common	12	0
b. White oolite with *Cylindrites* to base of quarry. (These are the uppermost beds of the Lower oolite)....................	10	0
	22	0

We here obtain a glimpse of a series intermediate between the

* One of the workmen declared that during a period of forty years he had never seen an Ammonite in this quarry.

top of the oolites of the Lower Limestones and the base of the Middle Calcareous Grit*.

It is probable that the shelly limestones and coarse fossiliferous oolites which overlie the mass of the Lower Oolite and underlie the Middle Calcareous Grit of this locality, are the true home of the original *A. perarmatus* of Sowerby. This fossil was first described from the "pisolite of Malton;" but it certainly never occurs in the ordinary Coralline oolite of that locality. The abundance of *A. perarmatus* in beds lying at the top of the Lower Oolite would induce us to refer the whole group palæontologically to the Lower Calcareous Grit.

If we trace these beds along the sides of the Seven valley towards Sinnington, we see them in great force flanking the hillside, and resting upon passage-beds of coarse gritty limestones, with *Pecten fibrosus*, *Gervillia aviculoides*, and *Lucina Beanii*, which form the bed of the river below Coptonbanks wood, and themselves rest on the "ball-beds," as seen at the mill. Further south still, we see an old river-cliff in which the top of this mass of Lower Limestones is exposed, capped by a shell-bed which here, as elsewhere, seems the upper limit, and may be probably on the horizon of the fossiliferous beds of Whitethorn quarry.

At the entrance to Sinnington gorge a magnificent section is exposed, which will be more fully described in reference to higher beds. At the base of this section 5 ft. of beds (F, fig. 15) represent the shelly cap of the Lower Limestones. It is a coarse hackly oolite with many pisolitic grains, and contains *Ammonites cordatus*, *Chemnitzia heddingtonensis* (fine), *Exogyra nana*, *Anomia*, sp., *Pecten fibrosus*, *Gervillia aviculoides*, *Lucina Beanii* (v. c.), *Opis Phillipsi*, *Myacites*, sp., *Trigonia perlata*. Above this lies the representative of the Middle Grit (E, fig. 15), about 34 ft. in thickness, less arenaceous than in Newtondale (Pickering), but with a fine development of *Trigonia*-beds towards the top.

Between the valley of the Seven and Kirkdale the best sections are obtained in the valleys of Hutton Beck and of the Dove †. On or about this meridian the Lower Limestones seem to attain their maximum, which, inclusive of the basement- or passage-beds, is not much less than 150 feet. The base of the Lower Limestones is here becoming cherty, and there are great accumulations of oolitic flint. West of Kirkdale this peculiarity increases greatly, and extends downwards to the ball-bed series at the top of the Lower Calcareous Grit proper. The Middle Calcareous Grit is well exposed in the bed and on the flanks of the Kirkdale stream about opposite the church. This is one of the best places for studying the junction with the Lower Limestones. Its upper portion, containing the equivalent of

* This proceeds upon the assumption that the oolite (*b*) of this quarry is really the upper part of the oolite of the Cropton great lime-quarry; should that not be the case, the arguments founded on such a supposition, of course, fall to the ground.

† One of us had the good fortune lately to accompany Mr. Fox Strangways, the Government Geological Surveyor, through these most interesting valleys, and thus to profit by his great experience.

the *Trigonia*-beds of Pickering, occupies the channel of the stream at the ford on the old road between Kirkby Moorside and Helmsley.

Passing still to the west, we find these Lower Limestones of great importance between the gorges of Hodge beck and Riccal dale. Some of these quarries present us with examples of the silicification of the whole of the beds composing them. Sections of the oolitic grains show the concentric structure; and they are coloured brown or black by the presence of carbon, as in ordinary flint, with a trace probably of iron. They are imbedded in a white matrix, which is almost pure silex, while every crack, exposed surface, or fossil is covered with the same substance in the form of beekite. These features are well seen in quarries behind Skiplam wood and Oxclose wood.

The Middle Calcareous Grit here varies as much as it is seen to do towards the east, being a yellow sandstone in the region immediately north of Marston, but in the sides of Riccal dale so compact and calcareous as to be with difficulty distinguished in small openings from the limestones above and below, except by its being non-oolitic. We thus see throughout this range that this Middle Grit appears in the form of isolated sandbanks, its maxima being near Pickering and Kirkby Moorside, its minima near Thornton and Riccal dale.

The Upper Limestones and Upper Calcareous Grit.—As we enter the Pickering district from the east, along the edge of the vale, we first meet with the Upper Limestones in a small quarry just west of Thornton, where the beds are dipping S.W., as we should expect; but a little further on we see a very good section at the end of a dry gash called Howl dale, about halfway to Pickering, where the dip is southerly and moderate.

Quarry west of Hagg House, in the Upper Limestone.

Corresponding in Pickering Section.		ft.	in.
a.	1. Upper Calcareous Grit, very fossiliferous ...	6	0
b.	2. Argillaceous marly layers	2	0
d.	3. Dense ferruginous limestone in irregular lumps	0	6
	4. Oolite—few fossils	6	6
e.	5. Dense and sometimes earthy limestones, with some oolitic granules—few fossils	12	0
f.	6. *Chemnitzia*-limestones to base of quarry.		
		27	0

With the exception of the oolite (4), all these beds have their counterparts in the great Pickering section, though in very different degrees and conditions of development. Excepting the fragment on the Hackness outlier, this is the last place to the eastward where the Upper Calcareous Grit is noted. It is also the most easterly point in Yorkshire where there is any trace of the *Florigemma*-rag, the richest and most interesting of all the subdivisions of the Corallian Limestones. Here this is feebly represented by no. 3, which contains a mass of fossils glued together in a dense ferruginous limestone with hard cores, indicative of its coral origin. The following, in very bad condition, were noted—*Natica*, *Nerinæa*, *Chemnitzia*, *Phasianella striata*, *Lima pectiniformis*, *Perna mytiloides*, *Arca quadrisulcata*, *Exogyra nana*, *Cidaris florigemma* (spines).

This quarry affords additional proof of the correctness of our identification of the false-bedded rocks, *d*, of Pickering with the Coral Rag, which is here found occupying the same position, with beneath it some oolite (No. 4) of peculiar character, not seen in the type section. The argillaceous portion of the Upper Calcareous Grit is here seen to be much thinner.

Our next illustrative section of these rocks is at Sinnington, about $3\frac{1}{2}$ miles west of Pickering, on the side of the Seven valley to which we have already referred.

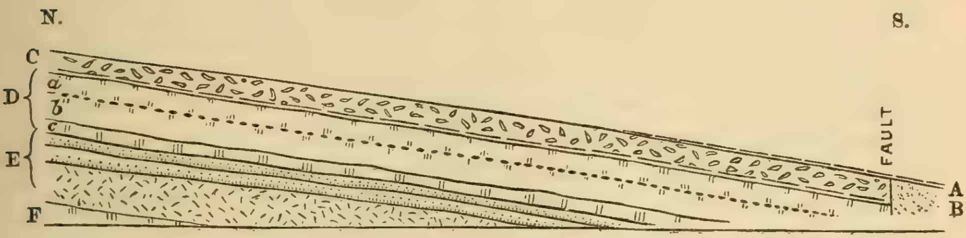
Seven-valley Section, near Sinnington.

On the east side of the valley, just behind the village, there is a very extensive quarried surface, laying bare the structure of the Corallian Series from the Upper Calcareous Grit to the very base of the Middle Calcareous Grit, including, of course, the *Trigonia*-beds. A fault at the south end has thrown the Upper Calcareous Grit against the Coral Rag and Coralline oolite, bringing all three classes of rock into juxtaposition at a point where they can be easily examined (see fig. 15).

The two lower groups of this section, representing the Middle Grit and the shelly cap (F) of the Lower Limestones, we have already referred to; the remainder serves to confirm the Pickering section, with which all its beds agree, with the exception of a fine development of Coral Rag. As all the other groups of that section are in their places except group *d*, or the top stone, it is evident, as previously pointed out, that this peculiar false-bedded series represents at Pickering, in position, if in no other way, the true *Florigemma*-Rag. The persistence of group *e*, or the "black posts" (D. *a* of this section), seen here as well as at Pickering and near Hagg House, and of which there is not a trace in the Scarborough district, is also remarkable. The base-bed of this group, called by the workmen at Pickering "hilly and holey," is the "cave line" throughout this district.

On this line occurs the celebrated Kirkdale Cave, in a quarry by the side of the old road between Kirkby Moorside and Helmsley, just above the ford across Hodge beck. It is well known that most of the rivers hereabouts "swallow," *i. e.* run underground at certain points, as their predecessors seem to have done at a higher level, of which this cave now presents an example. The explanation is that such beds present a hummocky surface of hard impure limestone difficult of solution, with interspaces filled in by a soft limestone brash, which is readily disintegrated both chemically and mechanically by the action of running water. The origin of the peculiar rock called "black posts," as also of "throstler," though in some way

Fig. 15.—*Section in the Gorge of the Seven, showing Upper Calcareous Grit faulted against Corallian Limestones.* (Length 230 yards; dip about 5°.)



Details of the Sinnington Section.

		ft.	in.	ft.	in.
	A. Soil, rainwash, and clay at the fault...			4	0
	B. Upper Calcareous Grit, consisting of (1) "red beds" (*a* of the Pickering section), (2) a band of hard blue rock, and (3) shaly sands, base not seen .... about			18	0
Upper Limestones, Middle Division of Pickering.	C. 1. Coral Rag, with plenty of *Cidaris florigemma* in the lower block, at the fault	13	0		
	2. *Rhabdophyllia*-bed. The upper part is very full of small branches. This is the equivalent of the Coral shell-beds of other places	2	3		
	D. Coralline Oolite.				
	a. Comparatively unfossiliferous lime stone, the lower portion impure and dirty (*e* of the Pickering section)................................	11	0		
	b. *Chemnitzia*-limestones. The great shell-bed at the top is charged with *Chemnitzia heddingtonensis*, *Nerinæa* sp., *Astarte ovata*, *Lucina Beanii*, &c. Noted also *Ech. scutatus* (*f* and part of *g* of Pickering section)	17	9		
	c. Impure bluish limestones, with a line of scattered pisolite (remainder of *g* of Pickering section)	6	0		
				50	0
	E. *Trigonia*-beds and Middle Grit (*h* and *i* of Pickering section plus the remainder of the Middle Calcareous Grit)........			34	0
	F. Top of the Lower Limestone series ...			5	0
				111	0

connected with coral, is not quite clear, the fossil evidence having been more or less melted up by some powerful action.

Remarkable instances may be noted on both sides of the valley of the Dove of the connexion of this class of bed with Coral Rag, there well developed; and in the neighbourhood of Kirkby Moorside there are evidences of the "black posts," Coral Rag, and "throstler," more or less inosculating with or replacing each other.

Towards the edge of the vale the Upper Calcareous Grit continues to be of considerable importance: the town of Kirkby Moorside is built upon a slope consisting mainly of this rock; and the Kirkdale cutting discloses about 16 feet without reaching the base. Towards the top of this cutting are red sandy clays with calcareous disks and nodules. Ammonites, some in a tilted position, were found at the base of this, along with the valves of *Ostrea bullata*, exactly the form so common above the "throstler" at Pickering. The remainder of the cutting was seen to consist of hard blue rock, and of buff-coloured calc-grits full of dichotomizing forms. Several Ammonites of considerable size were found during the progress of the railway. They may perhaps be referred to the following species:—

Ammonites Berryeri, *Leseur.*
,, Achilles, *D'Orb.* (pl. 207. fig. 1).
,, decipiens, *Sow.*

These forms have a strong Lower Kimmeridge aspect, and are not unlike some of those from the Westbury ironstone, which occupies a somewhat analogous position. The "throstler" has a great development in certain situations beneath the Upper Calcareous Grit, as is well seen in the bed of Hutton beck: the Upper Calcareous Grit at this latter place has itself a thickness of not less than 30 feet, and may be traced right up into the Kimmeridge Clay, which comes on conformably, and even with a certain degree of gradation, as the highest bed of the Upper Calcareous Grit is darker-coloured, fucoidal, and more argillaceous. It is crammed with a Belemnite very near to *B. nitidus*, Dollfus, and contains little nests of *Serpula tetragona*, and numerous *Pholadomyæ.*

Behind the village of Nawton the development of these upper beds is very similar to what we have seen elsewhere. Some fine quarries occur, showing the central portions of the Coralline oolite, here exceptionally hard and crystalline, but with abundance of fossils, especially Gastropods, and in parts carbonaceous. The village of Nawton is built, like Kirkby Moorside, on Upper Calcareous Grit, which may be seen on both sides of the road. It has scarcely the peculiar character here that it has at Pickering, but is more like an ordinary Grit.

Towards the mouth of Riccal dale, about 1 mile E.N.E. of Helmsley, we obtain a fine view of the Corallian development in this district in a magnificent quarried face of 54 ft., having 4 ft. of Upper Calcareous Grit, 14 ft. of Coral Rag, and the remainder Coralline oolite on the Pickering type, *Phasianella striata* being the most characteristic fossil.

Thus between Pickering and Helmsley there is considerable identity of type in the Corallian beds, with certain gradual changes, which become more marked towards the west. Throughout, the dips are southerly. Helmsley, however, which lies in a well-marked synclinal, is the turning-point in the inner rim of the long elliptical belt of Corallian strata. An imaginary line passing north-west through this town may roughly divide the Pickering district from that of Hambleton.

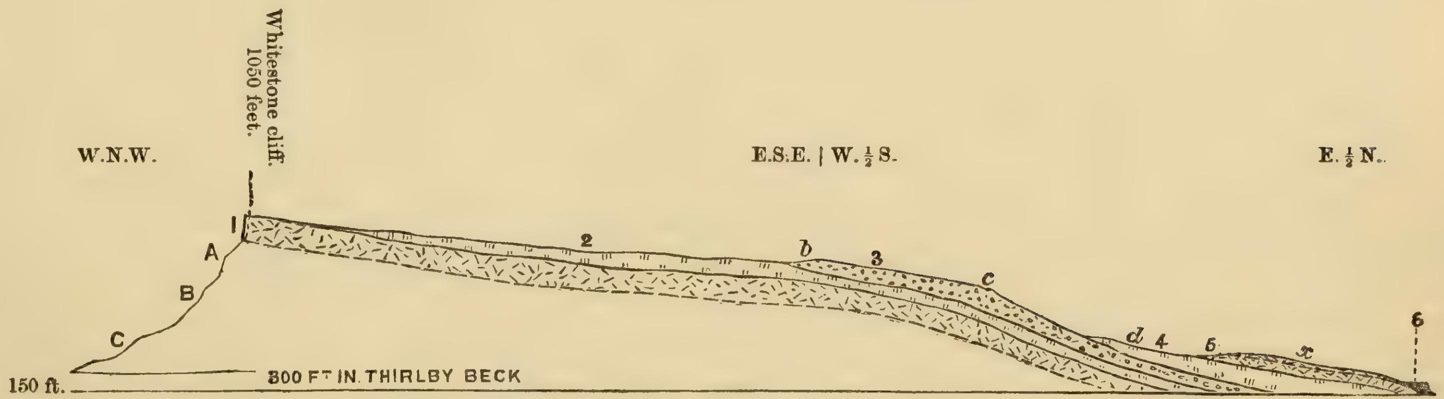
3. The Hambleton District.

The area included under this title extends considerably to the westward of the district included in the sketch map fig. 10 (p. 316), and, though not exactly typical for Yorkshire, sums up and includes almost all the beds known to occur on a large scale in the county. We commence with the wide circle sweeping round the north-western and western escarpments of the Hambleton Hills by Arden Moor and Black Hambleton, one of the highest points in the district, then by Whitestonecliff and Roulston Scar, till the beds gradually drop to the east by Byland, Wass, and Ampleforth. The natural continuation here would be sought in the Howardian Hills; but a great valley, the result of erosion acting upon a line of complicated dislocation, completely severs these latter. Through this valley, by Coxwold and Gilling, the railway from Thirsk to Malton passes easily from the vale of Thirsk to the more secluded vale of Pickering. The Corallian beds on the south of this erosion constitute our fourth division, viz. the Howardian District.

Returning to the northern side, within the semicircle thus marked out we have higher beds continually developed as we approach the interior curve, which girdles the bay of Kimmeridge Clay, whose western extremity just reaches the meridian of Helmsley. In the annexed figure a general section is given of the whole series from the Hambleton escarpment to the vale of Pickering, immediately east of Rye House (below Helmsley), where the railway cuts a few feet of Kimmeridge Clay, which is there covered by a superficial wash of moderate thickness.

No. 1 in this section is the Lower Calcareous Grit proper, speaking in a petrological sense; it forms the parapet, as it were, of the western escarpment between Roulston Scar and Whitestonecliff, where it has a thickness of about 120 feet. In this exposure the lower portion is seen to consist of a peculiar ferruginous sandstone, which seems to be developed at the expense of the Oxford Clay, here very thin, and no doubt corresponds to an earlier period than the one with which we are now dealing. There are about 20 feet of this peculiar ironstone at the base; and the rest of the beds are alternations of hard and soft grits, with large doggers, fucoid (?) growths, and small nests of fossils; but in general both cliff and moor are so beaten by the winds and storms of ages, that little remains of an organic nature on the exposed portions of these rocks,

Fig. 16.—*Section through the Hambleton Massive, from the vale of Thirsk to the vale of Pickering.*
(Length about 8 miles. Base-line 150 feet above sea-level.)



A. Lower Oxfordian.
B. Lower Oolites.
C. Lias.
b. Public quarry on Wass Moor.
c. Waterloo-Plantation gravel-pit.
d. Sproxton lime-quarry.
x. Superficial beds and outliers of Kimmeridge Clay.

1. Lower Calcareous Grit.
2. Hambleton Oolite.
3. Middle Calcareous Grit.
4. Coralline Oolite and Coral Rag.
5. Upper Calcareous Grit.
6. Kimmeridge Clay.

though certain peculiar forms, externally not unlike sponges, roughen the surface, as on Scarborough Castle Hill. To the north these same rocks spread out over Arden Moor as hungry grits and sands, every particle of lime having been dissolved away; and the whole series may be seen in the northern escarpment, in the bed of the road from Hambleton to Yarm, having the same characters as at Roulston Scar. Passing inwards by Byland and Wass, we meet them in a better state of preservation. In Wass Bank about 80 feet may be seen resting on the Oxford Clay. Towards the base we have a rough sandstone with cherty bands and fucoidal (?) stems; higher up some of the beds are semioolitic, though still calcareous grits. The fauna is scanty; we noted *Pecten fibrosus, Perna quadrata, Avicula ovalis,* and *Myacites recurva.* These rocks retain a similar character wherever we catch glimpses of them throughout the long escarpment facing the Gilling erosion; they gradually sink to lower levels by Ampleforth, where *Amm. goliathus, Rhynchonella Thurmanni*, and the characteristic *Aviculæ* may be found. Further east they form part of the low ground at the base of Oswaldkirk Bank. (See also fig. 17.)

No. 2 is a remarkable series of flaggy oolites, to which we propose to assign the name of "Hambleton Oolites." They correspond in position to part at least of the Lower Limestones of Newtondale, Cropton, &c., and are perhaps continuous with that belt of rock. Their development may be well studied in the Hambleton moors, where they are quarried for lime, and where we have had opportunities of proving their position. The group is well seen in Cold-Kirkby quarry, and in several other quarries on the moor, about the line of section, between the escarpment and Duncombe Park. South of the line of section it begins to lose much of its importance as a distinct body of limestone, and has not been traced by us as a separate formation in the Howardian Hills. North of the line of section the Hambleton Oolite appears to increase in thickness; and in the extreme north-west of the Oxfordian area, where the escarpment is curving round from west to north, it comes to the edge of the cliff as at Kepwick, where nearly 50 feet of thick, massive, and by no means flaggy limestones are quarried for agricultural purposes. Eastward from this point it may be traced, always on high ground, as capping the picturesque and isolated plateau-summits above the village of Hawnby, where the scale and character of the scenery are of a thoroughly Jurassic type. The rock is usually a meagre, gritty, suboolitic limestone, with a tendency in places, especially on Hambleton moor, to become an oolite flagstone, the quarries being marked on the 6-inch map as "Slate Quarries." Where the oolitic structure is developed the granules are very small. Fossils are far from numerous, a marked contrast to the true Coralline oolite and Coral Rag. The best localities are Cold Kirkby, where some beds are a congeries of small shells, and Hawnby, where *Aviculæ* and other shells are tolerably abundant. The beds at Kepwick are remarkably poor, considering the amount of rock which is being excavated. The small list our limited time has enabled us to put together is—*Belemnites*, *Ammonites cordatus, Nerinæa*, *Avicula ovalis*, *Avicula expansa*, *Avicula lævis*, *Pecten lens*, *Lima elliptica*, *Lucina*, *Rhynchonella Thurmanni*, *Echinobrissus scutatus* (abundant), *Holectypus oblongus*, *Astropecten* (fragments).

Although these limestones are probably continuous along the strike with the Lower Limestones of the Tabular Hills, it is certain that in this area they thin to the south and south-east. We have seen that at Kepwick, in the face of the western escarpment, they are about 50 feet thick; but on the summits of the moors the thickness in the several localties can only be inferred. None of the numerous quarries, allowing for the dip, require that they should be more than from 20 to 30 feet; and towards the south the oolitic character of the stone seems to be becoming more uncertain. For instance, in Shaw's-Gate quarry, at the back of Roulston Scar, the following section is seen:—

	ft.	in.
Soil and broken stuff		
Flaggy, fine-grained, sandy oolite	0	9
Flaggy calc-grit, with pinhole structure in the lower part	2	4
Sandy suboolitic limestone, generally in three blocks	5	2
Half grit, half limestone	3	9
	12	0

Echinobrissus scutatus and a small Belemnite were the only fossils here noted. It is where we find it overlain by the next series of beds that we begin to have proof of its thinning out, as will presently be shown.

No. 3. This series, which may be identified as the Middle Grit, nowhere reaches the western escarpment, but is spread out over the moors, and may be seen on the dip. If we trace the oolites (No. 2) from the Dialstone quarry (Cold Kirkby), where about 15 feet are exposed, in an easterly direction along the road called High Street, we find limestone quarries with a stone very similar to that at the Dialstone as far as a point rather over two miles from the inn. Here the country rises from 822 feet to 857 feet in about a quarter of a mile; the thickness of this rise of about 35 feet is entirely occupied by reddish sands, henceforth keeping the surface of the moor, which rises to within the 875-feet contour. The oolites may thus be distinctly traced to a position below these sands; and the outcrop of these sands, as they are traced backwards in a south-westerly direction, is seen to encroach upon the area occupied by the Hambleton oolite until the latter is covered up altogether, as is the case on the top of Wass Bank. On descending this we should expect to find the oolites again; but they can scarcely be made out at all, though there seems to be a line of quarries where calcareous matter has been dug out at intervals, and a narrow band of such oolite may be seen. The semioolitic calc-grit of Wass Bank is at too low a level to represent them. Upon Wass Moor the Middle Grits generally consist of loose sands of a reddish colour, occasionally consolidated into stone. Their present physical condition is due to the powerful action of the organic acids generated by the gradual decay of the peat. These dissolve out the calcareous matter and tend to run it into doggers and calcitic layers, whilst the iron, being oxidized, invests the sands with a coating of ferric hydrate, which resists more effectually the action of the solvents. From beds in such a condition it is almost hopeless to expect to obtain fossils.

Reverting now to the line of section, we may trace these sands on their dip to the eastwards, where the country begins to fall towards the vale of Pickering. A fair section may be seen in the "gravel-pit" (*c*, fig. 16), where *Pecten fibrosus* was the solitary fossil noted. This leads us on to the instructive gorge-section of Howl beck, a ravine cut by the moorland drainage on its way to the deep valley of the Rye in Duncombe Park. The upper part of this gash in the hillside consists wholly of the loose foxy sands, not less than 60 feet thick; but on descending the dry bed of the stream which should run at the bottom, we obtain, at about the 400-feet contour, the following section:—

	ft.	in.
Sandy suboolitic limestone	13	0
Cherty calc-grit	6	0
Splintery limestone	2	6

Here, then, after losing sight of the Hambleton Oolite, we find it laid bare in the bottom of a deep gully, where its thickness and relation to the beds above and below are ascertained with far greater accuracy than in any of the quarries on the moors; as usual, hardly a fossil is to be noted. On descending the gully still further, the Lower Calcareous Grit proper is also seen to be cut through to the very base, exhibiting about 80 feet of beds, to a point where the water springs out, not far from the course of the river Rye. The Hambleton Oolite, or limestone of the Lower Calcareous Grit, crosses the river just below Sproxton-Mill bridge, near the 200-feet contour. This gives a dip of about 1 in 30, equal to 2° nearly, in a direction E. by N. from its section in the ravine of Bridge Howl. Judging from a cursory survey of its occurrence in the bed of the river, it appears to be still diminishing in this direction. On the other side of the river it may also be seen in the neighbourhood of Rievaulx Abbey. On the road from Helmsley, descending the hill, is a quarry of this limestone, with *Ammonites plicatilis, Millericrinus echinatus,* and abundance of *Echinobrissus scutatus.*

If we take the maximum development of the three subdivisions of the Lower Calcareous Grit in this region, we obtain something like the following:—

	ft.
1. Lower Calcareous Grit proper, Whitestonecliff	120
2. Hambleton Oolite, Kepwick	50
3. Middle, or Wass-Moor Grit	60
	230

No. 4. This division consists of the Coralline oolite and Coral Rag, the former of which is especially well developed, along the line

of section in Sproxton quarry (*d* of fig. 16). Its actual relation to No. 3, or the Wass-Moor Grit, may be seen in ascending the hill from the river Rye in Duncombe Park, near the footbridge, where the sandy beds are seen to lie underneath it. In Sproxton quarry we have:—

	ft.	in.
a. Coral Rag	4	0
b. Coral shell-bed..	1	6
c. Coralline oolite, compact and occasionally suboolitic limestones ...	26	0
	31	6

a. A few feet of true Coral Rag is here to be found capping the true Coralline oolite; it has the usual fossils, of which we noted *Lima pectiniformis*, *Pecten vimineus*, *Cidaris florigemma*, &c.

b. This is one of the shell-beds occasionally to be found at the base of the Coral Rag, which forms a conspicuous feature in some of the quarries throughout the Tabular range, but is a rare phenomenon, as far as our experience goes, in the neighbourhood of Malton and Langton Wold. This particular one contains corals, abundance of the spines of *Cidaris florigemma*, *Lithodomus inclusus*, *Lucina*, sp., together with *Nerinæa* and *Chemnitzia*. These, on weathering out, form a handsome entablature in arabesque.

c. Numerous long univalves occur in the upper layers: the whole forms a series of thick-bedded limestones, which are very different in appearance from those of the Hambleton Oolite. The base of the limestones is not seen.

The floor of the quarry shows a dip to the eastward of 4° or 5°; perhaps this may be due in part to the rapid thinning-out of the Middle Grit beneath.

Descending the hill still further, the Coral Rag keeps the surface for some distance. Its general character hereabouts must be inferred from quarries in or near to Duncombe Park. In the Park there is a quarry, on the 325-feet contour, which presents coralline layers and boulders, with the peculiar chalk-like limestone so characteristic of this subdivision, and which usually contains the fossils. *Chemnitzia*, *Littorina muricata*, *Perna mytiloides*, *Astarte rhomboidalis*, *Pecten vimineus*, and *Cidaris florigemma* were noted.

In the quarry on the York road just out of Helmsley, a little above the 200-feet contour, about 20 feet of Rag beds are seen putting on a somewhat different lithological type. The stone is in strong blocks, and is a hard cherty (?) limestone with many flints, both in sheets and in tuberous masses; it is very rarely coralline. The beds are not so full of fossils as in the more typical Rag; but a considerable number of species may be noted, such as *Belemnites abbreviatus*, *Chemnitzia* (short variety of *heddingtonensis*?), *Natica clio*, *Nerinæa fasciata*, *Phasianella striata*, *Pecten vimineus*, *Trigonia* (large clavellate form), *Lucina aspera*, Buvig., *Terebratula insignis*, *Cidaris florigemma* (spines). Dip of quarry N.N.E. moderate.

This peculiar phase of the Rag is rather local; for on following the steep southern bank of the Rye in an easterly direction below

Helmsley we find it gradually assuming a more coralline form. The exposures referred to consist of about 15 feet of dense creamy limestone, with a few corals and some of the usual fossils, resting on 7 feet of Rag with flints. Below this is a coral shell-bed with *Thamnastræa*, much *Thecosmilia*, *Rhabdophyllia*, *Hinnites velatus*, *Lima rigida*, *Lucina*, &c. This last is seen to rest on oolite a few feet above the level of the river. Such conditions of the Coral Rag have some relation to the type already noted at Kirkby Moorside, where there is so much "throstler" and "black posts" associated with the ordinary form of Coral Rag. Here, however, the impurities are siliceous and the fossils well preserved.

No. 5. The Upper Calcareous Grit. In the above quarry on the York road 3 or 4 feet of this rock may be noted, there rather flaggy and argillaceous. It is merely the base of the formation; for we can trace it along the road as yellow sandstone and hard blue rock from the level of 210 feet to 280 feet, which, allowing for probable dip, would indicate a thickness of perhaps 30 feet. This, from indications in other portions of the district, we consider to be the general thickness of the formation in the western part of the vale as it gradually passes under the Kimmeridge Clay on the dip-slope.

In the line of section (fig. 16), the Upper Calcareous Grit comes on a little west of the village of Sproxton: it may there be seen on its outcrop, forming a light soil favourable to the cultivation of roots. Near the village, however, the highest part of which just reaches the 350-feet contour, the country is covered up by a superficial deposit (*x* of fig. 16) of considerable thickness. This is principally a mixture of sand and Rag pebbles; and further east, where this is not present, there are patches of blue clay, most probably shallow outliers of Kimmeridge Clay. But the Upper Calcareous Grit is again seen *in situ* on the west side of the alluvial flat in which the river flows opposite Rye House. The same class of rock is again seen on the east side, forming the little precipice on which Rye House is built. It is extremely red and cherty near the surface; this passes steadily under the Kimmeridge Clay, as previously stated.

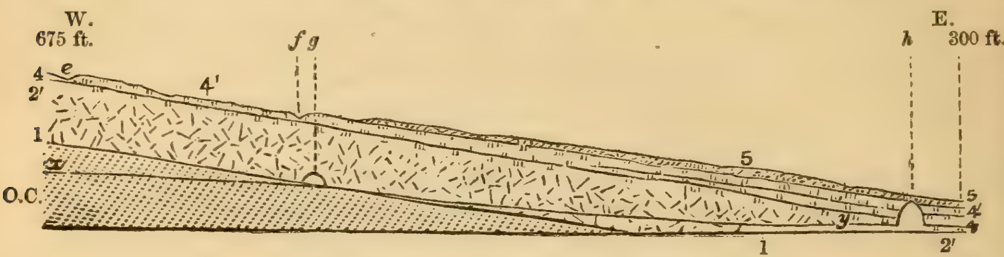
One of the chief points of interest in the Hambleton District is to trace the gradual change from the types of the Tabular Range (which includes the Pickering and Scarborough Districts) to those which prevail in the Howardian Hills, and to note more especially what becomes of the great deposit of the Lower Limestones, and of that Middle Grit which divides them from what is usually known as the Coralline oolite*. Natural causes fortunately have provided us with a section of the Hambleton massive in the escarpment which bounds the Gilling-Coxwold erosion on the north, at the same time that it forms an abrupt termination to the chain. The portion of the escarpment between Ampleforth Beacon and Oswaldkirk is perhaps the most instructive.

In order to connect this section with the main Hambleton one

* This will serve to explain the amount of stratigraphy introduced into this portion of the paper.

(fig. 16), attention to the following points will be necessary. The two are approximately parallel; the distance between them about $1\frac{3}{4}$ mile. Their eastern terminations correspond; but Ampleforth-Beacon quarry (*e* of fig. 17) is due south of a point 300 yards to the

Fig. 17.—*Section from Ampleforth Beacon to Oswaldkirk* (about 2 miles).



Base-line 225 feet above sea-level.

1. Lower Calcareous Grit.
2'. Passage beds.
4. Coralline Oolite.
4'. Coral Rag.
5. Upper Calcareous Grit.
O. C. Oxford Clay.
e. Limestone quarry at Ampleforth Beacon.
f. Quarry above Oswaldkirk Hagg.
g. Quarry below Oswaldkirk Hagg.
h. Quarry in Oswaldkirk village.
x–y. Ampleforth College to St. Oswald's Church.

west of Sproxton quarry (*d* of fig. 16). This fixes the relation of the two sections. As regards elevation, the Coralline Oolite has risen from *d* of fig. 16, 450 feet, to *e* of fig. 17, 675 feet. This is the greatest elevation attained by it in any part of Yorkshire. It will be observed that this escarpment runs nearly in the same direction as the dip. The beds fall over towards the north, however, especially on the reverse slope.

The line from *x* to *y* represents the level of the road between Oswaldkirk and Ampleforth projected upon the section, *x* being the position of Ampleforth College. Starting from this point, the road to within a short distance of quarry *g* passes over Oxford Clay, but east of this point enters the Lower Calcareous Grit, all the beds descending with a considerable dip to the eastwards. There are several quarries in the Lower Calcareous Grit at various points in the escarpment between the two villages. The stone is very unfossiliferous, and presents few features of interest; but we have altogether failed to detect the Hambleton Oolite, or Lower Limestone, as a distinct formation.

In a district where both faults and landslips tend to obscure and mislead, it may be dangerous to calculate thicknesses from heights taken upon an escarpment; but there seems good reason to suppose that the Lower Calcareous Grit is at least 100 feet thick in that portion of the escarpment between *e* and *f*. It is succeeded by impure gritty oolites and speckled grits, which exhibit few traces of fossils in this locality. These constitute throughout this district the passage-beds: they are well seen under the great elm tree on Oswaldkirk bank, where they appear as buff calc-grits with straw-coloured ova, and are blue-centred in layers: there is a gradual increase of calcareous matter upwards. Fauna scanty—a stray *Chemnitzia*, *Avicula ovalis*, *Opis Phillipsi*, all small. Probable thickness from 15 to 20 feet.

Above these the Corallian Limestones are well developed. The lowest bed, at the great elm tree, is a very white limestone with sparry shells, mostly *Chemnitzia*. Commencing from the eastwards we have a fine exposure in Oswaldkirk quarry, *h* of fig. 17.

	ft.
5. Upper Calcareous Grit	8
4′. Coral Rag	22
4. *Chemnitzia*-limestones (Coralline oolite)	24
	54

The thickness of the Coralline oolite (4) in Oswaldkirk is from 25 to 30 feet. The difference between this class of rock and the overlying Rag is not so marked within the range of this section. The beds are mostly thick blocks of creamy limestones, with a few buff-coloured ova, very much resembling in their lithological aspect some of the intercoralline beds of the Rag; but the absence of *Cidaris florigemma* and of recognizable corals constitutes a difference which becomes more marked as we descend. *Chemnitzia heddingtonensis*, *Nerinœa*, *Astarte ovata* are the most usual fossils. The lower beds yield *Ammonites plicatilis*. Following this subdivision on the rise, we find it on the top of the hill at quarry *f* with only 6 feet of Rag over it.

Section at Quarry f, *on the top of Oswaldkirk Hagg.*

	ft.	in.	ft.	in.
5. Irregular patches of Upper Calcareous Grit, associated with a ferruginous clay filling hollows.				
4′. Coral Rag (see *posteà*, page 358)			6	0
4. *Chemnitzia*-limestones, the equivalents of the Coralline oolite, as follows:—				
α. Creamy limestones with a few univalves, alternating with brownish hackly oolite and brash	6	0		
β. The principal shell-beds: *Chemnitzia heddingtonensis* of all sizes in great profusion; *Nerinœa, Astarte ovata, Exogyra nana* plentiful; *Lucina oculus, Littorina muricata, Cerithium muricatum* less plentiful	6	0		
γ. White creamy limestones with buff-coloured granules: few shells	9	0	21	0
			27	0

This depth of 21 feet probably represents the full thickness of the equivalent of the Coralline oolite, which has its last exposure in Ampleforth-Beacon quarry. Westwards of that quarry it crops out, or else thins out to a feather-edge; we are not certain which is the real fact.

Section at Ampleforth-Beacon Quarry (east end).

	ft	in.
5′ & 5. Red clay, with boulders and fragments of Upper Calcareous Grit filling up gaps and fissures in the limestone ...... nothing to	10	0
4′. Coral Rag—principally *Thamnastræa*; the upper portions are much chalcedonized; *Cidaris florigemma*, *Exogyra nana*, but few shells nothing to	4	0
4. *Chemnitzia*-limestones, the equivalents of the Coralline oolite, about	18	0

Here the upper portion of the equivalents of the Coralline oolite has much resemblance to the intercoralline portions of the Rag, as we have previously noticed with regard to the quarry at Oswaldkirk. Lower down *Chemnitzia* and *Nerinæa* become more numerous; and about 12 feet below the base of the Rag there is a splendid mass of shells occurring in the creamy limestone with buff granules, so characteristic of the Coralline oolite of this district. We noted:—

Belemnites abbreviatus, *Mill.*
v.c. Chemnitzia heddingtonensis, Sow.
c. Nerinæa fasciata?, *Voltz.*
Cerithium muricatum, *Sow.*
r. Littorina muricata, *Sow.*
Cylindrites, sp. (small).
v.c. Exogyra nana, *Sow.*
Lima elliptica, *Whit.*
Perna mytiloides, *Lam.*
v.c. Lucina Beanii, *Lyc.* (?aliena *Phil.*).
c. —— oculus, *Bl. & H.*
c. Astarte ovata, *Smith* (large, both valves).
Opis Phillipsi, *Morr.*
Pseudodiadema versipora, *Phil.*
Phasianella striata in the bottom bed.

The character of the fauna and the richness of the beds at once shows the difference between this limestone and the Hambleton oolite. It is the true Coralline oolite, on which the true *Cidaris-florigemma* Rag reposes, constant in the main to its development even here on the edge of the moors, but apparently thinning out on the rise from what we have seen it at Sproxton, $1\frac{3}{4}$ mile north, and at Oswaldkirk, $1\frac{7}{8}$ mile east.

The Coral Rag (4′) attains its maximum thickness in this line of section towards the east end of Oswaldkirk village, where there is a face of probably not less than 22 feet. In the Birch-House quarry (just beyond the east end of the section) it forms a bold precipice, weathering in large, swelling, rounded masses, which exhibit much *Thamnastræa* and *Thecosmilia*, with profusion of spines of *Cidaris florigemma*, plenty of *Ostrea nana*, *Pecten vimineus*, &c. Throughout the village, wherever there is an exposure, we note the usual intercoralline beds, which tend to swell out the Rag. In the softer portions of such beds *Terebratula insignis*, Schub., is not unfrequent. In some places the upper surface is so extremely uneven as to suggest the idea of unconformability with the succeeding formation; but this is no doubt due to the fissuring and shifting of a more recent date, as we find the hollows filled in with Upper Calcareous Grit in a tumbled and fragmentary condition, showing that it too was deposited and consolidated before such fissures were formed.

Tracing the Coral Rag on the rise, it forms the steepest part of the hill for some distance westward of Oswaldkirk village, and begins to constitute the surface of the plateau about quarry *f*, though the hollows in it are filled up by Upper Calcareous Grit and the before-mentioned red clay. At quarry *f* it is only 6 feet thick. Whether this diminution is due to denudation of the upper surface or to thinning on the rise is not certain; but, as the Coralline Oolite clearly thins on the rise, this subdivision may also be affected. In the easterly continuation of this escarpment, outside the section, the Rag at the Nunnington cutting is only 8 feet thick. On the whole we are inclined to conclude that the attenuation is due to thinning, and that at Oswaldkirk we perceive the middle of a partially lenticular mass of Rag thinning towards the east and the west. In quarry *f* an old weathered surface exhibits a fine arabesque of *Thecosmilia* in an upright position, with very large specimens of *Chemnitzia*. *Exogyra nana*, *Pecten vimineus*, *Lima læviuscula*, *Lima pectiniformis*, and *Cidaris florigemma* (spines) are plentiful. *Thamnastræa arachnoides* and *Stylina tubulifera* noted.

Finally, there are traces of the Rag at the east end of Ampleforth-Beacon quarry; but it is probably no longer continuous.

The Upper Calcareous Grit (5) of this district assumes considerable importance, being fully 30 feet thick on Oswaldkirk Bank top: it extends over the escarpment with a N.N.E. slope till it insensibly passes under the Kimmeridge Clay of the vale of Pickering. Indications of its presence may be noted between Ampleforth-Beacon quarry and quarry *f*; but a field or two east of the latter it has entire possession of the surface of the plateau, and holds it also between Oswaldkirk and Nunnington cutting, the escarpment no longer sinking materially in this direction. Between the latter points, eastward of the section fig. 17, there are several instructive exposures.

In the Nunnington cutting we have the following. The dip at the bridge is about 5° N. ½ E.

	ft.	in.
Surface accumulations and ferruginous gritty brash forming the top of the Upper Calcareous Grit	7	0
Upper Calcareous Grit in solid blocks	25	0
Coral Rag. Block coralline and sparry limestones, with *Thecosmilia* and *Thamnastræa*: many fossils	8	0
Coral shell-bed. A peculiar white oolite, exhibiting in some places reliefs marked by an occasional coral, spines of *Cid. florigemma*, and more rarely of *Hemicidaris*, *Natica clio*, *Nerinæa*, *Chemnitzia* (short var. of *heddingtonensis*?), and numerous *Exogyra nana*; the upper part is the most fossiliferous	3	6
Unfossiliferous shivery oolites		

In a limestone quarry a few yards to the west of the cutting there is already some difference.

	ft.	in.
Upper Calcareous Grit (base only seen)	4	0
Coral Rag, extremely fossiliferous	7	0
Coral shell-bed. An oolite, with occasional spine of *Cid. florigemma*	2	6
Coralline Oolite.		
Bed of oolite limestone	2	6
Suboolitic shelly bed, with *Gervillia aviculoides*, *Cerithium muricatum*, *Trigonia* (clavellate sp.), &c.	1	6
Shivery oolites, having the character of thick-bedded limestones, containing occasional specimens of *Ammonites plicatilis*, but not very rich in shells.		

The Nunnington railway-cutting affords the thickest section of the Upper Calcareous Grit to be found in Yorkshire. It is usually a porous fine-grained stone, in parts almost devoid of lime. The beds are thick, and rather blue-centred. Although there has not been time to weather out the true structure, we have indications of huge doggers in the upper beds, and of the tuberous and branching forms so common at Pickering. It lies with perfect regularity upon the smooth even surface of the Coral Rag. Ammonites were frequently met with, especially in the upper beds, during the excavation of the line; we have not had the good fortune to meet with any of the large ones, and are thus unable to say how far they correspond with those of the Kirkdale cutting (see page 348). Small interior whorls, such as would be called "*biplex*," were common, and may also now be picked up on the fields. It does not appear that the formation is rich in the smaller Mollusca in this neighbourhood, as the following small list will show. *Belemnites* (phragmocones of *B. abbreviatus* or of *B. nitidus*), *Ammonites*, sp. (cf. *Thurmanni*, Cont.), a very involute form, *A. biplex* (small interior whorls), *A. alternans*, Von Buch (*A. serratus*, Sow.), *Pecten midas*, D'Orb., *Modiola cancellata*, Röm. This last shell is not unlike the *Modiola pulchra* of Phillips (figured as a Kelloway fossil, pl. v. fig. 26). In Yorkshire it is usually indicative of a high position in the Corallian series, being found in the Hildenley limestone. We have already recorded it from the great shell-beds of Highworth, and of the Lamb-and-Flag in the Wilts-Berkshire area.

The Coral Rag of the Oswaldkirk district, especially about Nunnington, is rendered very interesting by the quantity of *Thecosmilia* which it contains, and also by the profusion of spines of *Cidaris florigemma*. The varieties of Coral are perhaps more considerable than is generally the case in Yorkshire, as we frequently meet with *Montlivaltia dispar* and *Stylina tubulifera*, besides the more common reef-building forms: in these respects it differs much from the *Cidaris-Smithii* Rag of Seamer-Brompton, chiefly remarkable for *Thamnastræa concinna* and *Rhabdophyllia*.

The principal fossils noted are:—

Natica clio, *D'Orb.*
Chemnitzia (short form of heddingtonensis, *Sow.*).
Nerinæa fasciata, *Voltz.*
Littorina muricata, *Sow.*
Ostrea gregaria, *Sow.*
—— Moreana, *Buvig.*
Exogyra nana, *Sow.*
Pecten vimineus, *Sow.*
Lima pectiniformis, *Sow.*
Modiola inclusa, *Phil.*
Cidaris florigemma, *Phil.*
Hemicidaris intermedia, *Flem.*
Stomechinus gyratus, *Ag.*
Glyptic hieroglyphicus, *Ag.*

The Corallian district just described is prolonged for about 2 miles further eastward in the singular Cauklass promontory, which may be said to run out into a sea of Kimmeridge Clay at the Point of Ness, a name significant of the physical features, which are the result of the sudden termination of the various Corallian limestones and Upper Calcareous Grit. There are some exceptional characters to be noted in the quarries of this district, where a complete section of every thing from the Lower Calcareous Grit of Cauklass Bank, through the passage-beds into the Coralline oolite, and thence through the Coral Rag into the Upper Calcareous Grit, may be obtained. The features of the Oswaldkirk escarpment are to a certain extent repeated, and the reverse or dip slope, facing the north, is soon covered over by Upper Calcareous Grit. At the quarry near Cauklass End there is a small univalve-bed in a compact limestone, similar to one at Pickering, and perhaps on about the same horizon. We have determined the following species :—

Cerithium inornatum, *Buvig.*
—— limæforme, *Röm.*
—— muricatum, *Sow.*
Cerithium, sp. (*cf.* virdunense, *Buvig.*, xxvii. 13).
Phasianella striata, *Sow.* (juv.).
Rissoa ? sp.

The upper portion of this quarry contains a remarkable shell-bed, whose true position in the series is not easily fixed, though it would seem to be somewhere on the boundary line between the Coralline oolite and Coral Rag. *Chemnitzia*, *Nerinæa*, and *Astarte ovata* are the prevailing shells; here was found the fine clavellate *Trigonia* recently figured and described by Dr. Lycett as *Trigonia Hudlestoni*.

4. District of the Howardian Hills.

The fourth district into which we have divided the Yorkshire Corallian area includes the inner portion of the range of hills which bounds the vale of Pickering on the south-west (see Map, fig. 10, p. 316). This range, consisting wholly of Jurassic rocks, is completely buried beneath the still loftier Chalk Wolds a few miles east of the Derwent valley, which divides the Howardian range into two very unequal parts. The stratigraphy of the district is much more complicated than that of the far more massive Tabular range, already described in the three preceding sections, and is therefore of little assistance to us in judging of the sequence of the various rocks. The following arrangement is therefore based principally on palæontological, and sometimes on petrological data; and no attempt at a connected topography is made.

We should naturally expect that the highest beds throughout this range would be found along the northern edge of the hills, as they are generally along the southern edge of the Tabular range; but this is by no means the case either east or west of the Derwent. The beds crop out sometimes to the south and sometimes to the north.

1. West of the Derwent. *Lower Calcareous Grit and Passage-beds.*—We shall first describe the development of the Corallian rocks on the west of the Derwent, and, beginning at the base, take our first illustrative section from the Park quarry, Castle Howard. There is a steady dip in this quarry about N.N.E., which is the normal dip of the beds in the Howardian Hills, judging from the *general* outcrop. Here we may trace the beds down to the Oxford Clay. The Park quarry shows a face of some 12 feet of a light, porous, and thoroughly typical calc-grit. Its fossil contents too are equally typical; it is remarkable for large *Aptychi*, and for the phrag-

mocones of immense Belemnites, besides abundance of coniferous wood. The fossils known to us are:—

c. Belemnites abbreviatus, *Mill.* (phragmocones).
c. Ammonites cordatus, *Sow.*
—— vertebralis, *Sow.*
c. —— perarmatus, *Sow.*
c. Gryphæa, or Ostrea (large) dilatata?, *Sow.*
Exogyra (Ostrea) nana, *Sow.* ? young of dilatata.
c. Pecten fibrosus, *Sow.*
c. Modiola bipartita, *Sow.*
v.c. Rhynchonella Thurmanni, *Voltz.*
Collyrites bicordatus, *Leske* (small variety).
c. Holectypus depressus, *Lam.*

The Mill-Hill quarry on the east side of the Park presents us with a similar fauna; but there is more of the hard blue rock mingled with the freestones. The tolerable abundance of *Amm. perarmatus* in both these quarries at Castle Howard indicates that they are low down in the Lower Calcareous Grit, the basal portions of which are thus illustrated.

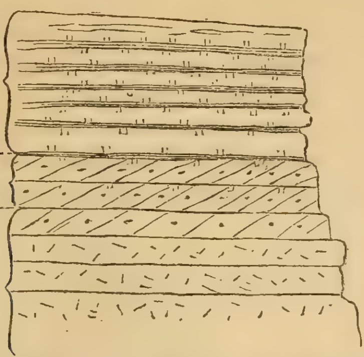
Higher portions, according to our judgment, of the same series may be seen some 4 miles to the N.W. of this in Hovingham Park, where the beds are cropping out to the north. Here the following section may be seen:—

	ft.	in.
1. Soil, shattered rock, and coral doggers	9	0
2. Fine white oolite (Coralline oolite)	10	0
3. Shale, sometimes merely a clay streak	0	9
4. Impure yellowish limestones spotted with oolitic granules, the bottom bed almost a calc-grit	10	6
5. Blue shale	0	9
6. Peculiar argillaceous calc-grit, with three clay bands—base not seen, say	12	0
	43	0

These beds are unfortunately very devoid of fossils; but we may judge them to represent the upper part of the Lower Calcareous Grit as it is changing into the Coralline Oolite: the impure speckled limestone has much of the lithological character we noted in the Passage-beds at Oswaldkirk and Cauklass Bank, on the opposite side of the erosion which divides the Hambleton from the Howardian Hills. It also resembles a fossiliferous rock which we consider to occupy the same geological position at Appleton. The upper portion is here so broken that we cannot tell what succeeds; but the presence of coral doggers in the top shows that the Rag is not far up the hill; perhaps, however, it would be unsafe to judge the representative of the Coralline oolite from this small exposure, as Hovingham quarry, only half a mile off, gives us 25 feet of this class of rock. The clays and shales are here an interesting feature, which, to a certain extent, is peculiar to this area.

The next section offered for consideration is more interesting, viz. that at Appleton, a village about halfway between Hovingham and Malton, where there is apparently a slight upthrow of the strata, so that a low horizon is obtained. The annexed general scheme of the Corallian beds (fig. 18) is drawn up from observations made in the "old-sandstone" quarry west of the village, in the church quarry, and in a quarry east of the village.

Fig. 18.—*General Section of Corallian beds near Appleton.*



A. Alternations of hard oolitic limestone and brash.
B. Passage-beds, fossiliferous, 4–7 feet.
C. Lower Calcareous Grit, upper beds.

C. These are the highest beds of the Lower Calcareous Grit; about 14 feet are quarried. The actual thickness of the formation here is uncertain; but water is obtained at a moderate depth, and there are springs on the escarpment facing the north. The beds visible consist of alternations of soft buff and hard blue rock, which are fairly fossiliferous, especially on approaching the next group. These are the "freestone" and "flint" of the workmen. The "flint," or hard blue, occurs in beds, and sometimes in doggers. The top bed included in this series is pretty full of *Rhynchonella Thurmanni*; it sometimes presents the speckled appearance of the next group. The Ammonites &c. lie mostly towards the upper part; the following are noted—*Nautilus hexagonus, Ammonites cordatus* (*excavatus*), *A. goliathus*, *A. plicatilis*? (*A. perarmatus* is less common), *Gryphæa dilatata*, *Glyphea rostrata*, teeth of *Pliosaurus* and *Lamna*?, wood. Some of the Brachiopoda quoted in the next series are also met with.

B. Sandy speckled limestones of considerable hardness, varying from buff to blue, and constituting a stone difficult to describe but easily recognized. These are beds intermediate between the Lower Calcareous Grit and the oolites, and represent, to a certain extent, the passage-beds of the Tabular range. They are somewhat irregularly developed, and vary in the different quarries. The fauna is much the same as the top bed of calc-grit, but richer both in individuals and species. In addition to some of the Ammonites already quoted, the following may be deemed characteristic:—

Pecten fibrosus, *Sow.*
Avicula ovalis, *Phil.*
—— expansa, *Phil.*
Trigonia*, sp. n.
Waldheimia bucculenta, *Sow.*
Terebratula fileyensis, *Walk.*
Rhynchonella Thurmanni, *Voltz.*
Glyphea rostrata, *Phil.*
—— scabrosa, *Phil.*
Echinobrissus scutatus, *Lam.*
Millericrinus echinatus, *Goldf.*

* A new scaphoid form remotely related to *Trigonia recticosta*, Lyc., of the Inferior oolite; it occurs on the same horizon, associated with *Waldheimia Hudlestoni* and *Terebratula fileyensis*, in the neighbourhood of Snainton.

The association of Brachiopoda strongly reminds us of the fossiliferous group a few feet above the ball-beds at Filey; *Millericrinus echinatus*, essentially a lower passage-bed form, is also abundant in both. There is moreover a strong lithological resemblance in the peculiar speckled character of the stone. Altogether this is the best exposure obtained in the Howardian Hills of a fossiliferous phase of the junction-beds between the Lower Calcareous Grit and the oolites (Corallian Limestones). They differ much from the ordinary type of passage-beds (the flaggy ferruginous calc-grits) of the Tabular Hills.

A. Not much more than 2 feet of this series is observed in the church quarry; but 14 feet of it may be seen in the "old-sandstone" quarry west of the village. There the group consists of thinnish beds of hard white oolite, separated by alternations of yellowish brash, full of *Echinobrissus scutatus*, like so many eggs packed in sawdust. *Holectypus* is less frequent; *Ammonites cordatus* may be noted, and a stray *Chemnitzia* here and there; but it is easy to perceive from the barrenness of the old exposures that fossils are few. It really looks as if the oolite of the Lower Limestones had come on again, although we have failed to recognize it in the extreme south of the Hambleton District (see fig. 17). Very similar beds, noted for fine specimens of *Echinobrissus scutatus* and *Amm. plicatilis*, are seen at Swinton Grange, which is nearer to Malton, and on much higher ground.

If we again seek a section showing these passage-beds into the oolites above, such a junction may be observed, as at Appleton, in the Brows quarry, situated in the western suburb of Malton.

Section in the Brows Quarry, Malton.

		ft.	in.
A.	*a.* Buff-coloured, gritty, suboolitic limestones and brash	6	0
	b. Bed occasionally containing much fine-grained calc-grit	2	0
	c. Buff-coloured gritty limestones, with a very few straw-coloured granules, in thick beds with thin brashy partings......	12	0
C.	*d.* Calc-grits, *i. e.* freestones, alternating with blue stone: *Ammonites plicatilis* in the upper part, *Glyphea rostrata*, *Gryphæa dilalatata*, wood, &c.,—not very fossiliferous............	27	0
		47	0

The contrast between this exposure and that at Appleton shows how much is due, even on the same horizon, to the accidents of distribution. The Brachiopoda are entirely absent (to the best of our knowledge*) in *c* and the upper part of *d*. *c* in this section occupies the position of the very fossiliferous passage-beds of Appleton; but there is no very marked difference in any of the beds forming the group A of the quarry. The fossils noted are *Amm. plicatilis*

* These beds have not been worked for some time. The quarrymen speak of their containing large Ammonites.

(interior whorls), *A. cordatus*, *Pecten fibrosus*, *Avicula ovalis*, *Pleuromya*, sp., and *Echinobrissus scutatus*. Altogether group A of this quarry comprises groups A and B at Appleton, the thickness being the same, viz. about 20 feet. It has already been intimated that these limestones have very little in common with the ordinary Coralline oolite; how far they represent the oolite of the Lower Limestones remains to be proved. It is by no means impossible that the oolites of Broughton, Swinton, Amotherby, &c. immediately overlie, or take the place of the upper part of this group, as in their general character, and, to a certain extent, in their fossil contents, they are very different from the Coralline oolite of Old Malton. But this question, and also the possible presence of some equivalent of the Middle Calc-Grit, must be left open for the present, the indications being obscure and difficult to read. Such being the case in those portions of Yorkshire most readily accessible, it is not surprising that the great development of Middle Grits and Lower Limestones—a discovery first made by Mr. Fox Strangways—should have escaped general notice. A streak of brash or a gritty line in some of the quarries may perhaps be all the trace we have of any separation between the two limestones. Perhaps the nearest approach to any thing like the Middle Grits hereabouts is in the old quarry at Middle Cave, on the north-west side of Malton. Here we perceive a very gritty limestone, 10 feet thick, presenting the lithological features of a passage-bed stone, and separating two oolites. Towards the base of this series there is a shell-bed charged with fossils, generally of large size. The bed is noted for large specimens of *Trigonia Meriani*, *Pecten intertextus*, and *Pholadomyæ*; otherwise the fauna is much the same as that of the Pickering *Trigonia*-beds. In column 11 of the Table of Comparative Sections (Pl. XII.) we indicate what we have ventured to consider may be the geological position of these beds.

Coralline Oolite.—The succession of beds, going upwards, in this district is best followed on the east side of Malton, where the great quarries in the Coralline oolite have long been known, but not, so far as we know, described. The Pye pits quarry, close to the town, from which chiefly the great supplies of fossils have been obtained*, is no longer worked. The Thirsk railway traverses this old excavation, and discloses for the most part moderate dips to the E.S.E. This line crosses the southern bounding fault of the Coralline peninsula near the Lady's Spring, and, after passing through a considerable thickness of Coralline oolite, emerges into the dry valley (apparently an old river-course) which bisects the town of Malton.

To the east of the railway are the principal quarries now worked. The one on the flat summit of the hill, at the cross-roads, is just within the 125-feet contour.

* N.B. The locality "Malton" is quoted by dealers and others for all oolite and Rag fossils within a radius of 5 or 6 miles, including sometimes the Inferior Oolite of Whitwell.

Section at the Cross-roads Quarry, Peasy Hills.

			ft.	in.
Coral Rag.	*a.*	Soil. Brash, which is coralline, and contains spines of *Cidaris florigemma*	7	0
		N.B. The Coral Rag is best seen in the east corner of the quarry.		
Coralline oolite.	*b.*	White oolite, not very fossiliferous	13	0
	c.	Shelly oolites	9	0
		Compact fine-grained oolites	2	6
			31	6

a. There is not much Coral Rag developed here, but quite enough to prove its character. It may be traced along the surface the whole of the way to the Highfield-road quarry, and thence into Old Malton village.

b. A clean white oolite, with very little paste. The ova are of medium size, regular, distinct, and usually free from shell-fragments; not many shells are to be seen. These oolites have a fauna somewhat approaching that of the Rag; and this may partly serve to account for the very mixed character of the fossils which come from the Malton district in an undoubtedly oolite matrix. *Phasianella striata* is plentiful towards the bottom. In an adjoining quarry this group has yielded some remarkable coniferous fruits: see description in the Appendix of a new species of *Araucarites*.

c. These are the regular *Chemnitzia*-beds of the Coralline oolite, and, in this quarry at least, contain the bulk of the fossils. The uppermost bed is a regular "rabbit-eye," *i. e.* a mass of *Chemnitzia heddingtonensis* in transverse section—along with other shells. The principal shell-bed is thus at the top of the series, as seems frequently to be the case throughout the oolitic formations. This group is less oolitic than the overlying one; and the sedimentary impurities appear to be rather greater. The fossils most obvious on the weathered surfaces are *Chemnitzia heddingtonensis*, *Nerinæa*, *Astarte ovata*, *Lucina aliena*, Phil., *L. oculus*, Bl. & H.; the less frequent are *Amm. plicatilis*, *Cerithium muricatum*, *Phasianella striata*, *Pecten lens*, *Lima læviuscula* (type form), *Cucullæa* (small sp.), *Cyprina corallina*, &c.

The limestone beds below have been proved in the adjoining quarry to a depth of several feet, making a total thickness of 38 feet quarried for lime; many shells and teeth have at different times been obtained from these beds. There is a well in this lower quarry in which about 8 feet more of beds has been proved; these are stated to be "white and blue rock, all lime," making a total of 46 feet of limestone. This may bring us somewhere about the Middle-Cave beds, or even the top beds of the Brows quarry; but no inferences are of much value in such a district.

It will be perceived from the above statements that within the space of about 30 feet in the Cross-roads quarry we have three different classes of rock, with a marked change of character in each, showing an alteration in the nature of the sediment, which not unlikely means a cessation of deposit within the area, or even a partial submarine denudation before each fresh set of beds was deposited.

With the immense difference between the *Florigemma*-Rag and the underlying limestones (Coralline oolite) the most casual observer could not fail to be struck; but here there is a well-marked difference in the group we term the Coralline oolite, as may be seen in the very considerable change which is noted between *b* and *c*. The great *Chemnitzia*-beds, where developed, are usually found to terminate about 10 or 12 feet below the Coral Rag, the intermediate belt of limestone being less obviously fossiliferous. It is quite possible that in other quarries (the old Pye pits for instance) *b* may have been more fossiliferous, and may perhaps contain a partially "Rag fauna." If this be so, it will serve to explain the mixed character of the following list of fossils:—

Fossils from the Oolites of Malton and the neighbourhood. N.B. All specimens occurring in a Rag matrix only are excluded from this list.

Reptilia.
Pisces.
c. Belemnites abbreviatus, *Mill.*
—— hastatus, *Montf.*
——, sp.
†Ammonites varicostatus, *Buckl.*
c. —— plicatilis, *Sow.*
—— cordatus, *Sow.*
v.c. Chemnitzia heddingtonensis, *Sow.*
*Cerithium muricatum, *Sow.*
c. †Nerinæa fasciata, *Voltz* (Rœmeri, *Goldf.*)
—— visurgis ? or Goodhallii, *Sow.*
c. †Phasianella striata, *Sow.*
Pleurotomaria reticulata, *Sow.*
? *Cylindrites elongatus, *Phil.*
? Acteonina retusa, *Phil.*
Ostrea solitaria, *Phil.*
*Gryphæa dilatata, *Sow.*
Exogyra nana, *Sow.*
Anomia.
†Pecten vimineus, *Sow.*
—— lens, *Sow.*
—— demissus, *Sow.*
†—— intertextus, *Röm.* (cancellatus, *Bean*).
†—— inæquicostatus, *Phil.*
—— fibrosus, *Sow.*
c. Lima læviuscula, *Sow.*
—— rigida, *Sow.*
—— elliptica, *Whit.*
†—— pectiniformis, *Schlot.*
*Avicula ovalis, *Phil.*
*Gervillia aviculoides, *Sow.*
*Perna mytiloides, *Lam.*
——, sp. n. (York Museum).
Trichites Plotii, *Lhwyd.*
Mytilus pectinatus, *Sow.*
Mytilus jurensis, *Merian.*
Cucullæa corallina, *Damon.*
Trigonia Meriani, *Ag.*
—— perlata, *Ag.*
——, sp.
†Protocardium isocardioides, *Bl. & H.* (? lobatum, *Phil.*).
v.c. Lucina aliena, *Phil.*
—— oculus, *Bl. & H.*
—— ampliata, *Phil.*
Corbis Buvignieri, *Desh.*
—— decussata, *Buvig.*
—— lævis, *Sow.*
—— "uniformis, *Bean.*"
Tancredia curtansata, *Phil.*
Unicardium plenum, *Bl. & H.*
Cyprina corallina, *D'Orb.*
c. †Astarte ovata, *Smith.*
Opis Phillipsi, *Morr.*
*Sowerbya triangularis, *Phil.*
Quenstedtia lævigata, *Phil.*
Panopæa gigantea, *Buvig.*
Anatina or Solemya, sp.
*Pholadomya paucicosta, *Röm.*
Myacites decurtatus, *Phil.*
—— recurvus, *Phil.*
——, sp.
Goniomya literata, *Sow.*
Gresslya peregrina, *Phil.*
Pygurus pentagonalis, *Phil.*
—— Hausmanni, *K. & D.*
—— Phillipsii, *Wright.*
Pygaster umbrella, *Ag.*
*Echinobrissus scutatus, *Lam.*
*Holectypus depressus, *Lam.*
Carpolithes plenus.
—— conicus, *Lindl. & Hutt.*
Araucarites Hudlestoni, *Carr.*

* Species usually indicative of a low position.

† Species usually indicative of a high position, and occurring frequently in the Rag.

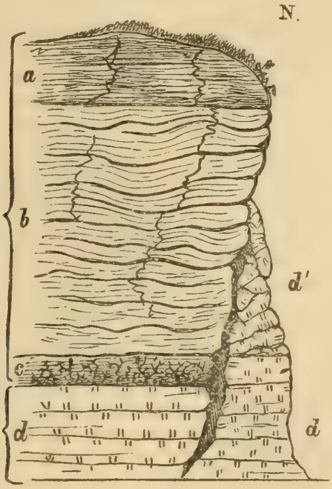
It is certainly a matter for regret that greater precision cannot be given in the way of localizing the above list; for if that were possible a great step in advance towards a proper classification of the Malton oolites might be made. Still it is certain that, although by no means exhaustive, the list does not contain any species which may not be found between the top of the passage-beds and the base of the Coral Rag, excluding both these subformations. The list is no doubt highly characteristic of an oolitic facies in the widest acceptation of that term. A comparison with the Coral Rag list of Langton-Grimston, subsequently given, will be found instructive.

The general character of the Coralline oolite of the Howardian district must be gathered from the above description of the Malton quarries. There are most extensive quarries in this class of rock between Malton and Appleton: they are not very obviously fossiliferous; but doubtless such fossils as they have from time to time yielded have gone to swell the Malton list. As we get further westward in this direction, beyond Appleton for instance, the Coralline oolite does not make such a display in the quarries, their upper portions being occupied by Coral Rag, and sometimes by an intermediate class of beds, already alluded to under the name of Coral shell-beds, where the branches of the *Thecosmilia* and the delicate fingers of *Rhabdophyllia* are mixed up in an oolite or limestone containing shells belonging to both facies. The presence of corals, and of spines of *Cidaris florigemma* induces us to include this group with the Rag of this district, presently to be described. Throughout the western portion of our Howardian district the Coralline oolite occupies a place far inferior in interest to the more fossiliferous Coral Rag, there so richly developed. It consists for the most part of thick beds of oolite of a most monotonous appearance, rarely relieved by a *Nerinæa* or a *Chemnitzia*. These beds of soft stone, however, are much quarried for lime; they have a thickness, where all seen, of from 25 to 30 feet. We have already alluded to a quarry in Hovingham village, where, at one end, about 25 feet of the most unfossiliferous oolite in Yorkshire may be seen. At the other end of the quarry a portion of this is faulted against the Coral Rag, and an excellent opportunity for observing the contrast between the two classes of rock is obtained.

Coral Rag.—The class of beds which overlie the Coralline oolite of Malton, and of the region to the westward, presents us in this area with considerable variety, being sometimes a mineralized coral reef, hard and impenetrable (as is the case with the lower beds of *b*, fig. 19), sometimes a dense creamy limestone with few but large oolitic granules, and sometimes, as at Hildenley, an almost homogeneous limestone, resembling hardened chalk.

In the district east of the Derwent, where there are some notable examples of the reef-like character just alluded to, we have also another phase of the Rag, of which the North-Grimston limestone may be accepted as the type. There, reposing upon crumbling pisolites with a decidedly Upper Corallian or Rag fauna, are thick beds of indurated calcareous mud, enclosing semi-crystallized masses of coral of various kinds, and also immense quantities of shells and shell-fragments, the whole forming a sparkling white limestone with a splintery fracture almost wholly devoid of oolite. This sort of rock often contains, as we

Fig. 19.—*Coralline Oolite faulted against Coral Rag—Hovingham Lime-quarry.*



a. Broken fissile Rag. 4–5 ft.

b. Hard coral limestones in massive undulating beds with rounded terminations. 14–15 ft.

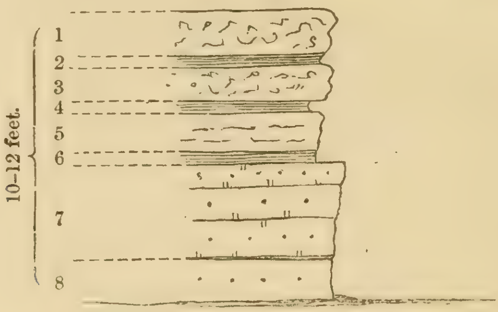
c. Coral shell-bed; not constant as such. The lower portion, which has the most shells, contains *Rhabdophyllia*; the upper *Thecosmilia*, enormous spines of *Cidaris florigemma*, *Exogyra nana*, *Astarte*, *Glypticus hieroglyphicus*, and broken shells. 2–3 ft.

d. Softish oolites, which on the downthrow side are seen in their true position beneath the Rag; portions of these are seen on the upthrow side in a shivery and ruinous condition.

have already seen at Helmsley, much flint. Commencing with the western extremity of our district, not far from Hovingham, we have some fine exposures of the reef-like variety, such as is represented in fig. 19, in quarries on Cawton Heights, and in the village below. In these places, where there is so much actual coral, without the layers of intercoralline mud, the fossils are not particularly numerous or easy to extract; but we may note of course *Pecten vimineus*, *Exogyra nana*, *Lima pectiniformis*, immense spines of *Cidaris florigemma*, a stray *Hemicidaris* or *Pseudodiadema hemisphæricum*, and in the intercoralline portion *Terebratula insignis*. There is, however, on Cawton Heights, one most fossiliferous exposure, which, from the mixed character of the fossils, has long provoked discussion as to its true position. This occurs at a place, near the top of the plateau, called Sike Gate (fig. 20). There is so much apparent faulting about here that it is dangerous to rely upon the evidence of adjacent quarries; but in a quarry 800 yards to the eastward, the surface of which is about the same elevation, are displayed about 25 feet of thick-bedded oolites, "soft rock," with one or two shaly partings towards the bottom.

Ammonites plicatilis is rather common in this quarry; and towards the top, although there is no regular Coral Rag, a few *Montlivaltiæ* are noticed. On the whole, therefore, the stratigraphical evidence is rather in favour of placing Sike-Gate quarry in the Rag subdivision; and the workmen themselves believe that "soft stone" lies underneath.

Fig. 20.—*Section of Sike-Gate Quarry on Cawton Heights.*



1 & 3. Broken Oolites.
5. A less fractured Oolite.
2, 4, 6. Brashy partings.
7. Strong blocks of bluish-grey limestone with yellowish ova.
8. A smaller bed with many Ammonites.

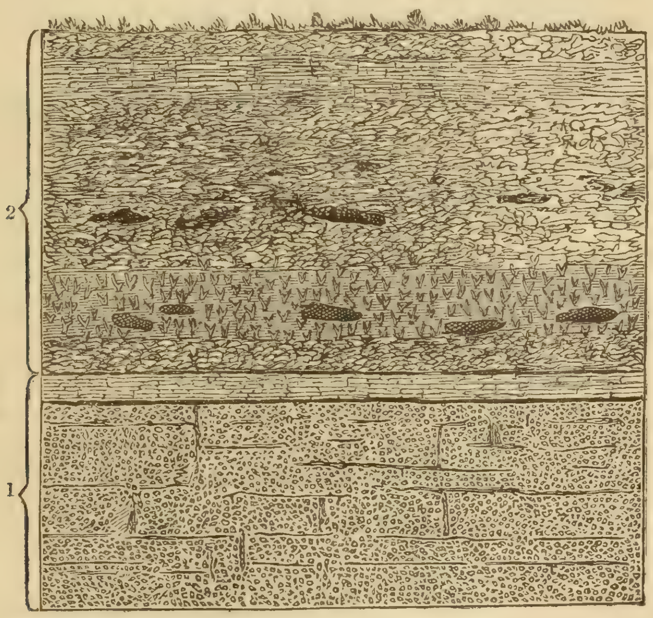
The upper portions, 1–6, constitute one subdivision, and are remarkable for the number of urchins. *Collyrites bicordatus* (large form, similar to the one at Hildenley and North Grimston) occurs. *Holectypus depressus* and *Echinobrissus scutatus* are very plentiful; spines of *Hemicidaris intermedia* not uncommon, and more rarely *Pseudodiadema hemisphæricum*. Spines of *Cidaris florigemma* were observed in stone piled up by the side of the kiln. In these beds also occur *Pholadomya æqualis*?, *Myacites recurva*, *Goniomya v-scripta*, and in the brash at the bottom, No. 6, occasional specimens of *Amm. plicatilis*. The lower hard band contains many univalves—*Natica clio* or *corallina*, *Littorina pulcherrima*, Dollf., and *Chemnitzia*, sp. *Lucina aspera*, Buvig., a shell generally indicative of a high position, is also very abundant; and in the lowest bed of all are many specimens of *Ammonites plicatilis*, and of *A. cordatus* and *A. vertebralis*, presenting singular varieties, of which we have figured one as *A. cawtonensis*. The rest of the fossils obtained from this quarry, but the exact position not noted, are:—

Belemnites abbreviatus, *Mill.*
Ammonites, sp. (*cf.* perarmatus) (remarkable form).
Purpuroidea nodulata, *Y. & B.*
Pleurotomaria reticulata, *Sow.*
Exogyra nana, *Sow.*
Gryphæa dilatata, *Sow.*
Pecten, sp.
—— vimineus, *Sow.*
Lima rigida, *Sow.*
Modiola subæquiplicata, *Goldf.*
Trigonia (narrow costate form).
Astarte ovata, *Smith.*
Protocardium isocardioides, *Bl. & H.*
Goniomya literata, *Sow.*
Terebratula insignis, *Schüb.*
Pygaster umbrella, *Ag.*
Clypeus or Pygurus, sp.

This happens to to have been one of those places where the accidents of distribution were favourable to the accumulation of shells. Although no corals have been found, the general facies is intercoralline, and presents some analogies with the Urchin-beds of Grimston presently to be described. Still it must be admitted that the abundance of Ammonites in the bottom beds, especially 8, is an exceptional feature in any portion of the Rag with which we are acquainted; but at the same time it is worthy of note that the cordate Ammonites quoted from here are of a very peculiar character, and that the one called *A. cawtonensis* has some features in common with *A. alternans*.

The character of the Rag of this portion of the district, west of Slingsby, however, is of the more massive and Coralline type; and the quarries often afford really fine pictures (see fig. 21), where the corals and shells and, above all, the spines of *Cidaris florigemma*, larger here than anywhere else, weather out in handsome arabesques. In the neighbourhood of Slingsby a change seems to be coming on; the division between the Rag and the Coralline oolite is for a while less pronounced.

Fig. 21.—*Section in the Rag Quarry at Slingsby, showing Corals* in situ.



1. Coralline Oölite. 2. Coral Rag.

Proceeding eastwards from Slingsby towards Malton, the Coralline oolite and yet lower beds occupy the country near the road, as previously noted, and there is very little development of the usual type of Rag to be seen hereabouts. Before crossing the Derwent to inspect the last group of Corallian rocks, enclosed between its tortuous valley and the Chalk escarpment, we should not omit to describe briefly the remarkable section at Hildenley, which is about halfway between Malton and Castle Howard.

In the quarry on Hildenley Heights there is a peculiar limestone with a marked Rag or Upper Corallian fauna, the only trace of coral now remaining being some remarkable cavities in the lower side of some of the beds, which represent places where branches of corals have been, and where they undoubtedly have grown. The stone is extremely fine in the grain, is said to contain about 95 per cent. of lime carbonate, and has the appearance of having been deposited as fine mud within a tranquil lagoon or bay. It rests upon oolite, and is supposed by Sir Charles Strickland to be flanked also by that class of rock. The stone, from its homogeneous character, is valuable for building, and especially for carving, with the exception of those beds which contain a small *Ostrea.* The valves of these are partly silicified, and the chisels of the workmen thereby spoilt. It is evident that there is a considerable amount of chalcedonic silica in these beds; and the action which this silica has undergone is not without its effects upon the fossils: indeed the variety of fossilization is remarkable. The fauna indicates a high position in the series; and some of the most characteristic fossils are those of the Upper Calcareous Grit of other places, as *Modiola cancellata,* Röm., and *Lucina aspera,* Buvig.

The following partial list will serve to show the character:—

Ammonites varicostatus, *Buckl.*	Gryphæa, large sp.
Natica grandis, *Münst.*	Exogyra nana, *Sow.*
—— clio, *D'Orb.*	Pygurus pentagonalis, *Phil.*
Lucina aspera, *Buvig.*	Collyrites bicordatus, *Leske* (large).
Protocardium isocardioides, *Bl. & H.*	Pseudodiadema hemisphæricum, *Ag.*
Arca pectinata, *Phil.*	Hemicidaris intermedia, *Flem.*
Modiola cancellata, *Röm.*	Cidaris florigemma, *Phil.*

The upper part of the quarry is just on the edge of the little plateau called Hildenley Heights. The beds dip to the S.E. about 4° or 5°, *i. e.* obliquely to the steepest side of the hill, which is about S. ½ W. In this way they fall to the 275-feet contour, behind the hall; and the next beds proved on the dip, at the base of the hill, are the argillo-calcareous beds, which undoubtedly represent the supracoralline series, but in a form having the greatest affinities with the "throstler" (see Pickering Section, p. 335). They are still more closely related, as we shall see subsequently, to the "cement-stone" of N. Grimston. These beds were proved in the garden; and the foundations of the hothouses are laid in them. A short distance due south of this, on the 200-feet contour, is the brickyard, which gives the best and most characteristic display of the base-beds of the Kimmeridge Clay of any inland section in Yorkshire with which we are acquainted. It furnished the following:—

v.c. Ammonites mutabilis, *Sow.*	Trigonia (clavellate sp.).
Alaria mosensis, *Buvig.*	Thracia depressa, *Sow.*
v.c. Ostrea deltoidea, *Sow.*	Myacites oblatus, *Sow.*
v.c. Exogyra nana, *Sow.*	Pholadomya, sp.
c. Avicula ædilignensis, *Blake.*	

In the peninsula of Old Malton, where we get a moderate development of the ordinary type of Coral Rag, as previously noted in describing the quarries on Peasy Hills, there is a renewal of the upper beds, which, in the district bordering the vale of Pickering, we had lost sight of since leaving Slingsby. This continuity of the Corallian beds on the inner rim skirting the vale is there broken, and we cross over a flat expanse of clay for a mile and a half to the Langton ridge on the other side of the Derwent.

2. East of the Derwent.—This is the second, and smaller, section of the Howardian district. It comprises the high land of Langton Wold, the southern ridge of which is continued eastwards in North-Grimston Hill, where the Howardians are buried beneath the chalk.

In this area the Lower Calcareous Grit presents somewhat similar beds to those seen at the Park Quarry, Castle Howard; these are well exposed in large quarries at Birdsall, containing the usual fossils.

Though possessing here no special points of interest, it is of considerable importance as a formation. It spreads out in the neighbourhood of Mount Ferrant, whose precipitous sides are due to its presence; and passing further south, it alone is left, of all the Corallian beds between the Oxford and Kimmeridge Clays, though not immediately thinning out. Indeed, over Acklam it is of considerable thickness, not less than 80 feet, and, whether as grit or sandstone, contains abundance of *Ammonites cordatus* or *vertebralis*. South, however, of this spot it falls off, and with a gradually diminished thickness we trace it beneath Hanging Grimston, till it finally dies away in the vale of Kirby Underdale, and the two clays unite. Thus we have it proved that the separation of the Yorkshire basin is not due to denudation, but to non-deposition.

The higher beds, for which we have to look in general to the northern portion, viz. the Langton Wolds, are displayed in numerous quarries throughout this area. The northern roots of the hills as they spring out of the vale of Pickering contain several quarries, mostly in softish oolite (Coralline oolite), with sometimes a moderate development of Rag at the top. The oolite, taking that at Settington railway-quarry as the type, cannot be exactly brought into relation with the oolites of Malton; but the fossils indicate a rather high position, though not so high as the Rag.

Belemnites abbreviatus, *Ammonites plicatilis*, or *Achilles*, and *A. cordatus*, all occur here. This is one of the higher positions where we find the more recognized forms of the *A.-cordatus* group; yet there is a variety of *A. vertebralis*, probably the same as that of Sike Gate, which occurs in the Urchin-beds of N. Grimston, which are certainly within the *Florigemma*-zone. *Nerinœa fasciata*, *Pecten inœquicostatus*, *P. intertextus*, *Astarte ovata*, *Pygurus Hausmanni* are some of the more noteworthy fossils. In the principal lime-quarry the coral beds above are not particularly rich; but the demarcation between the oolite and the Rag is well kept up throughout the cuttings between here and the North-Grimston station. This oolite has yielded, besides the usual fossils, such as *Nerinæa fasciata*, *Pecten fibrosus*, *Astarte ovata*, &c., a Belemnite which reminds us very much of *B. Owenii*, together with *Pecten qualicosta*, *Opis Phillipsi*, *Lucina aliena*, *Corbicella*, &c.

The main interest, however, of the Corallian beds in this portion of the Howardian Hills certainly centres in those of the age of the Coral Rag and subsequent to it. On the high ground of Langton Wold, of which North-Grimston Hill is merely a continuation (outlier), the Coral Rag may be said to culminate both as to variety and thickness of development, and also in the richness of its fossil contents. There is no such display of this class of rock elsewhere in England. The type along the northern side, where the Rag is seen to cap the Coralline oolite, is very much the same as has already been described, though with more variety perhaps in the fossils. On the southern slope of the Langton-Grimston ridge, another phase of the Upper Corallian obtains; and this is so well exemplified in the escarpment and quarries on North-Grimston Hill, that we propose to conclude with a detailed accouut of it.

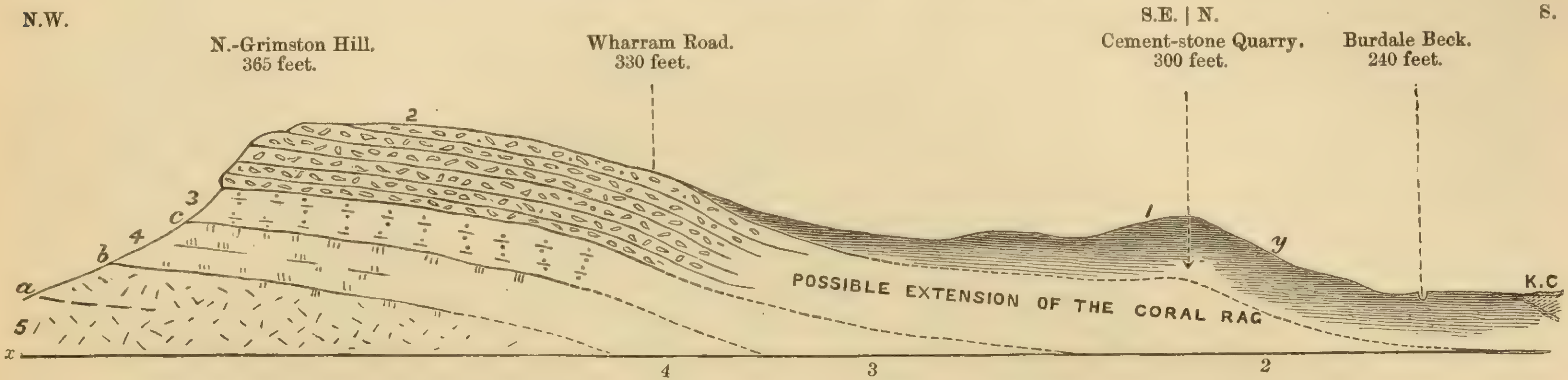
North Grimston.—At this village the Langton-Grimston ridge is cut through by a transverse valley, thus forming, in conjunction with the escarpment here facing the north, that remarkable salient, North-Grimston Hill. In this way, starting from the village itself, we may trace a continuous sequence from a low position in the Lower Calcareous Grit up into the Kimmeridge Clay of Burdale. Fig. 22 represents the section thus obtained, which is as follows:—

		ft.	in.	Elevation on escarpment. ft.
Supra-coralline.	1. Cement-stone, or "Lias," maximum proved (at quarry)	36	0	
Coral Rag.	2. Coral Rag, "North-Grimston limestone," about	40	0	365
	3. Marly Oolites, with an occasional coral band or hard limestone, the mamillated-Urchin series, say	25	0	325
Coralline oolite and passage-beds.	4. Drab-coloured marly oolites, becoming very earthy towards the base: full of *Echinobrissus scutatus*, the equivalent of the Coralline oolite of other districts, say ...	30	0	300
	4¹. Passage-beds (not specified in section; occur about *b*)	6	0	270
L.C.G.	5. Lower Calcareous Grit down to bed of beck	62	0	202
	Total thickness of beds in the escarpment	163	0	

The above section is drawn obliquely to the fullest dip of the Coral Rag; and the exaggeration of the vertical scale produces a certain amount of distortion; but the actual thicknesses have been estimated on the escarpment, and checked, when practicable, by measurements in the quarries.

5. *The Lower Calcareous Grit* possibly commences about the level of the beck (x) in Grimston village, or on a line of springs a few feet higher. Above this are occasional exposures of the ordinary

Fig. 22.—*Section from North-Grimston Hill to Burdale Beck.* (Distance 1100 yards. Scale 1 foot to 1 mile, except south of Burdale Beck. Datum line 200 feet above sea-level.)



K. C. Kimmeridge Clay of Lord Middleton's brickyard.
a. Bed of hard blue calc-grit, seen at the gateway where the bridle-road commences.
b. Bed of impure greyish limestone with straw-coloured granules. *A. plicatilis* noted.
c. Hard coralline band towards the base of the mamillated Urchin series.
1. Cement-stone or "Lias."
2. Coral Rag, "North-Grimston Limestone."
3. Mamillated Urchin series.
4. Drab-coloured marly oolites, with passage-beds at base.
5. Lower Calcareous Grit.

x. Level of beck at village.
y. Malton and Driffield Railway.

[Beds 1–4 probably thin off to a feather edge in a southerly direction.]

N.B. The line of section does not cut the great limestone quarries of North Grimston. These quarries are on both sides of the Wharram road, a short distance to the west of the line of section. The upper quarry, or that on the left hand, discloses about 40 ft. of hard flinty limestone Rag, dipping at an angle of 20° in a direction nearly due S. The same beds are repeated in the lower quarry, or that on the right hand; but there they are seen to repose on the Urchin series, which is very finely exposed in the S.W. corner of the quarry.

types of Lower Calcareous Grit, viz. alternations of hard blue, and soft buff, spongy beds, through a thickness of rather under 40 ft., allowing nothing for dip, which is not very marked in this part of the section; then occurs the hard blue grit at *a*, just where the bridle-road passing up the escarpment leaves the main highroad. At a higher level some more soft yellow calcareous grits of rather an earthy character occur, with occasional bands of hard stone; and rather more than 20 ft. above *a* are seen some grey sandy limestones (at *b*) which may be called passage-beds. We thus have 60 ft. as the thickness of the Lower Calcareous Grit of this locality, though it may very possibly extend below the water-line.

Above the Lower Calcareous Grit there is in the escarpment, including some 6 or 7 ft. of passage-beds, just about 100 ft. of Corallian limestones, which are divided, though with difficulty, between the Coralline oolite and Coral Rag.

4. *The Coralline Oolite.*—The true character of the lower half of this series is not very clear. It consists of harder and softer layers of brownish marly paste with oolitic granules, in this respect somewhat resembling the overlying series, which on palæontological grounds is included with the Rag: *Echinobrissus scutatus* is the prevailing fossil. There is a small opening towards the base of the escarpment under Grimston-Hill House, where the harder beds are extracted for road-stone. Few fossils other than *Ech. scutatus* were noted here; but the lower beds contain stray specimens of *Chemnitzia heddingtonensis.* Towards the middle of this quarry a well-preserved spine of *Cidaris florigemma* was noted. The latter fact is remarkable, as this urchin is very characteristic of the Rag; nevertheless a stray specimen has been noted as low as the *Trigonia*-beds of Sinnington; whilst in the south of England it is seen below the Rag at Purton, and possibly near Faringdon, but in these cases always sparingly. Its presence in this oolite is of more significance, as it seems to prepare the way for the next series, group 3, between which and this one the line drawn is more or less arbitrary. All that can be said is that a Rag-fauna gradually makes its appearance in the marly oolite, groups 4 and 3, and that in the upper group, 3, this has become most pronounced. We have ventured to draw the line just above a bed of hardish oolite containing numerous specimens of *Astarte ovata.*

3. *The Mamillated-Urchin series.*—The best place for studying the development of the Urchin-beds is at the west end of the lower quarry on the south side of the Wharram road, where the lime-kilns are built in some soft drab-coloured marly oolites, said to be very full of *Echinobrissus scutatus.* The latter probably represent the upper portion of group 4. But between these and the limestone No. 2 are some 20–25 feet of beds the representatives of group 3. They are seen to consist of flattened buff-coloured granules in a buff or drab-coloured marl; and sometimes the marl or paste is devoid, or nearly so, of any granules. They are divided occasionally by beds of hard compact limestone having partially the features of the Rag, and containing a few corals, many spines of *Cidaris florigemma,*

and small muricated univalves: one of these hard bands, towards the top of the series, has a thickness of 2 ft. 6 in., and exhibits a fine arabesque of shells such as are usually associated with a Rag-fauna. Throughout the series, and especially towards the upper part, a profusion of the spines of urchins may be noted, and the tests of many are from time to time discovered. *Pseudodiadema hemisphæricum* is especially abundant, and may be called the North-Grimston Urchin *par excellence*. *Cidaris Smithii*, *Cid. florigemma*, *Hemicidaris intermedia* also occur, the latter frequently. *Collyrites bicordatus* and *Pygaster umbrella* are also quoted from here; and *Echinobrissus scutatus*, which swarms in the lower beds, cannot fail to put in an appearance. The remains of the Mollusca in the softer beds are not usually in good condition. Cordate Ammonites, *Naticæ*, *Pleurotomariæ*, *Alariæ*, and one specimen of *Terebratula insignis* have to our knowledge been obtained from here.

In the escarpment also, about 20 ft. below the limestone No. 2, at the point marked *c*, there occurs in the midst of marly oolites a dense buff-coloured limestone with much spar. It contains corals, both *Thecosmilia* and *Rhabdophyllia*, along with *Pecten vimineus*, *Modiola inclusa*, and spines of *Pseudodiadema hemisphæricum*.

These beds then, although partly allied by their lithology to what we must call the Coralline oolite below them, have an undoubtedly Rag-fauna, and present us with what we must consider passage-beds between deposits elsewhere clearly separated. In other districts, indeed, are found a variety of intermediate deposits between the Coralline oolite with Chemnitzias (*Chemnitzia*-limestones), and the Coral Rag with *Cidaris florigemma*, such as the various shell-beds of Nunnington and elsewhere, or even the "black posts" of the Pickering district; but these do not so completely exhibit the double-faced character of the Urchin-beds. There is nothing unprecedented, as we have often pointed out, in the presence of corals below the regular Coral Rag; but for the abundance of Rag-Echinoderms, in an oolitic matrix, we must, in Yorkshire at least, come to the Howardian district only. At the remarkable quarry near Sike Gate, already described, we have somewhat similar conditions, as also in a portion of the limestone series at Coneysthorpe, which is faulted down into the midst of the Lower Calcareous Grit. At certain points, too, along the southern slope of Langton Wold, we meet with exposures proving the existence of similar beds. As the above indications all occur on the extreme southern edge of the area now occupied by Corallian limestones in the Howardian Hills, it leads to the possible conclusion that this great Urchin series is restricted to the southern margin of the formation as developed in Yorkshire. The great abundance of Echinoderms in groups 3 and 4 has evidently a kind of connexion with the argillaceous impurities of the limestone. Their profusion in the inter-Coralline clays of Hillmarton is equally remarkable. These same urchins, too, are very abundant in the fine-grained Hildenley limestone, the result of the finest calcareous mud. It is, perhaps, due to this abundance of Echinoderms that we meet with *Cidaris florigemma*, so to say, before its time.

2. *North-Grimston Limestone*, or *Coral Rag proper*.—About 40 feet of hard limestone is wrought in the two quarries on either side of the Wharram road. The stratigraphy of these beds is at first sight a little difficult to understand. The Rag beds are nearly level in the face of the escarpment and on the top of the plateau, whilst in the quarries the beds are inclined at an angle of 20° S., or S. by E. to N. by W. (See fig. 22.) This peculiarity is more or less noticeable along the whole of the southern slope of the Langton-Wold ridge, of which North-Grimston Hill is an extension. If they really are the same beds as those seen on the escarpment, their strong dip is due probably to the undermining action of water upon the softer beds below, whereby the harder beds are bent down, and in some cases almost snapped off from their horizontal continuations. The Rag of the escarpment, however, shows little or no flint, whereas the lower portions of the hard Rag of the quarries is full of it. How to account for the difference is one of the difficulties of this most puzzling section. The alternative possibility is that the whole group is a series of false-bedded accumulations.

In the quarries the hard Rag (2 of section, fig. 22) presents two phases. Without detailing the beds, the following is a description, taken principally from the upper quarry, in descending order:—

	ft.	in.
a. Buff-coloured limestones with yellowish markings; beds of white stone, seldom hard and crystalline like the series below. Indications of corals moderate: flints rare. Spines of *Cidaris florigemma* less plentiful. *C. Smithii* and *Hemicidaris intermedia* numerous. Beds less shelly than lower series, but contain a fair assemblage of some of the Rag-fossils, *Nerinæa*, *Littorina pulcherrima*, *Opis*, &c., along with *Pentacrinites* and *Apiocrinus* .... about	20	0
N.B. At Grimston Field, where the junction of this series with the cement-stone (1 of sect.) may be noted, a specimen of *Nautilus aganiticus*, Schlot., not hitherto found in the Corallian of England, was secured.		
b. Soft yellowish brash, with *Ammonites varicostatus*	0	4
c. White sparry and compact limestones in strong blocks, which become largely charged with flint, especially about 6 ft. above the base of the series. Beds full of fossils: fauna megalomorphic *	17	0
d. Urchin series (3 of section, fig. 22)		
	37	4

Some of the beds are very rich in shells; but these are frequently so glued into the general mass of the limestone as to be difficult of

* This division (*c*) is the chief fossil-bearing series of North Grimston. The lower portions are very siliceous; and there are great masses of flint both parallel with the bedding and lining the diagonal fissures, as well as masses which seem developed in the interior of the blocks. Some of the masses of flinty chalcedony seem to throw light upon the origin of flint and chert in limestone. There is an abundance of a small *Ostrea* (*Exogyra nana*?), the shells of which are more or less "beekised;" whilst in some of the beds the silicification appears in connexion with *Thecosmilia*. The original structure of the limestone is very well preserved in specimens of these flints: one which includes a section of *Pygaster* shows this very well, the peculiar markings of the limestone, so different from those of ordinary oolite, being faithfully transferred to the replacing substance. We have already seen how faithfully true oolitic structure is copied in the flints from the Lower Limestones of the Pickering district.

extraction. Nevertheless a fine body of fossils, without enumerating the teeth of Reptilia, have been proved here, and the list of Rag-fossils occurring in this district is pretty nearly a list of the fossils from this subdivision of the quarry. The lowest portion consists of alternations of hard and soft Rag having a thickness of about 6 ft.: this is moderately shelly, and contains numerous spines of *Cidaris florigemma.* Above these occurs the great shell-bed, about 3 ft. thick; it is a mass of the most splendid fossils, all of them the finest and largest of their kind. The small univalves so frequent in other parts of the Rag are not common here, the fauna being essentially megalomorphic. *Lima læviuscula* (var.) is the prevailing shell. The species of corals are those found elsewhere in Yorkshire; but *Thecosmilia* and *Rhabdophyllia* are most frequent.

Subjoined is a list of the fossils of the Rag, or Upper Corallian, of the Langton-Grimston district:—

Belemnites abbreviatus, *Mill.*
r. Nautilus aganiticus, *Schlot.*
Ammonites varicostatus, *Buckl.* (var. of A. plicatilis).
—— alternans, *Von Buch* (A. cordatus, var.?).
—— vertebralis, *Sow.* (same var. as at Sike Gate).
Purpuroidea nodulata, *Y. & B.*
Natica grandis, *Münst.* (? cincta, *Phil.*).
—— clio, *D'Orb.* (? arguta, *Phil.*).
c. Chemnitzia, var. of heddingtonensis, *Sow.*
r. —— pollux, *D'Orb.*
r. —— langtonensis, *Bl. & H.*
r. Nerinæa tornatella, *Buvig.*
v.c. —— fasciata, *Voltz.*
Littorina pulcherrima, *Dollf.*
c. —— muricata, *Sow.*
Nerita, sp.
Neritopsis Guerrei, *Héb. & Desl.*
——, sp.
Trochus, sp.
Turbo corallensis, *Buv.*
Pleurotomaria reticulata.
—— Moreana?, *Buvig.*
Trochotoma tornata, *Phil.* (T. discoidea, *Buvig.*).
Alaria, sp. (*cf.* tridactyla, *Buv.*).
v.c. Ostrea duriuscula, *Phil.*
v.c. Exogyra nana, *Sow.*
——, sp.
Ostrea gregaria, *Sow.*
c. Anomia radiata, *Phil.*
r. Plicatula, sp. (*cf.* fistulosa, *M. & L.*).
v.c. Pecten vimineus, *Sow.*
—— inæquicostatus, *Phil.*
—— intertextus, *Röm.*
Pecten lens, *Sow.*
c. Hinnites (very large).
v.c. Lima læviuscula, *Sow.* (N.-Grimston variety).
c. —— rigida, *Sow.*
v.c. —— { pectiniformis, *Schlot.* / rudis, *Sow.* }
——, sp. (*cf.* elliptica, *Whit.*).
—— subantiquata, *Röm.* (small).
r. Avicula ædilignensis, *Bl.*
c. Trichites Plotii, *Lhwyd.*
Mytilus ungulatus, *Y. & B.*
Modiola inclusa, *Phil.*
c. Arca quadrisulcata, *Sow.*
—— pectinata, *Phil.*
Cucullæa elongata, *Phil.*
r. Trigonia (costate sp.).
*Protocardium isocardioides, *Bl. & H.*
v.c. Astarte ovata, *Smith* (attaining a great size).
c. —— rhomboidalis, *Phil.*
Opis virdunensis, *Buvig.*
—— lunulata, *Röm.*
—— Phillipsi, *Morr.*, or corallina, *Damon.*
Panopæa gigantea, *Buvig.*
Homomya crassiuscula, *M. & L.*
Goniomya v-scripta, *Sow.*
Terebratula insignis, *Schüb.*
c. Cidaris florigemma, *Phil.*
c. —— Smithii, *Wright.*
c. Hemicidaris intermedia, *Flem.*
v.c. Pseudodiadema hemisphæricum, *Ag.*
Collyrites bicordatus, *Leske.*
c. Pygaster umbrella, *Ag.*
Echinobrissus scutatus, *Lamk.*
Pentacrinites, sp.
Apiocrinus, sp.

* This is probably the *Cardium lobatum* of Phillips. Also cf. *Cypricardia isocardina*, Buvig. x. 40.

The above list is by no means exhaustive; but it may be deemed fairly characteristic of the Rag horizon in this locality. Species here seem to have attained, as regards individual growth, their maximum development; and some forms such as *Astarte ovata* are nearly twice the size of those occurring in the oolites. It is quite possible that in this way species really occurring in the lower beds, having as it were outgrown themselves, are no longer recognized.

1. *The Cement-Stone.*—There is no section on North-Grimston Hill where this formation can be seen in actual superposition upon the Coral Rag. In the neighbourhood of the great quarries, south-west of the line of section, the slope of the hill and the dip of the beds are so rapid that a considerable portion of the cement-stone has fallen completely over, and may actually be seen in the railway-cutting with the dip apparently reversed. It will be necessary therefore to follow the line of section (fig. 22) in order to read the sequence.

From the northern edge of the escarpment the Coral Rag keeps the surface of this salient promontory as far as the Wharram road; and the section cuts that road at a point where the Rag ceases to appear on the lower side. Here, as indicated in the section, we find the Cement-stone *in situ*; and there is every indication that it forms the surface of the slope from this point in a south-easterly direction. It is quarried extensively at the point marked "300 feet," just above the railway (*y* of the section). There are 28 feet of beds exposed here, making, with 8 feet more proved by boring, a total of 36 feet without reaching the bottom. The dip in the upper part of the quarry is about 4° S.S.E.; but lower down, towards the railway, these dips increase rapidly, keeping pace apparently with the surface-slope. Fragments of a similar kind of stone are met with in Burdale beck, on the south bank of which is an old quarry in one of the harder beds, whence the stone used in building Wharram church is said to have been extracted. A short distance south of this is Lord Middleton's brickyard, unfortunately now no longer worked. This is unmistakable Kimmeridge Clay, with abundance of selenite, fragments of deltoid oysters, and the septaria characteristic of that formation *. The sequence is the same as at Hildenley. On the north side of the brickyard the "hard stone" was proved at a depth of 12 feet; but on the south side none was found at twice that depth, showing that the supra-coralline beds are getting deeper, or failing in a southerly direction. This "hard stone" is of very inferior quality to the cement stones of the principal quarry, and is probably higher in the series than any there proved; it contains more sand, and has some of the features of a calc-grit.

The lithological aspect of the Cement-stone, as shown in the principal quarry, and in numerous exposures in the valley between the Corallian ridge of Langton-Grimston and the Chalk escarpment, is quite that of a "lias;" that is to say, it consists of hard argillo-

* Stories are told of cartloads of septaria and many Ammonites having been taken away by the farmers.

calcareous bands, divided by softer subcalcareous shales. The shales burn to a whitish brick, but without any of the properties of a fire-brick. The hard stone yields a good hydraulic mortar, lately much used for the Scarborough aquarium. The formation is the probable equivalent of the entire upper series of Pickering; and the fauna has strong analogies with that of the Upper Calcareous Grit as there developed, especially in the great abundance of the same forms of *Lucina*. The Ammonites also fairly correspond, as far as it is safe to judge where the state of preservation is so indifferent. Subjoined is a list, the determinations to be received with a qualification.

Belemnites hastatus?, *Montf.*
—— *nitidus, *Dollf.* (B. explanatus, *Phil.*).
Ammonites biplex-varicostatus.
——, sp. (*cf.* alternans, *Von Buch*, serratus, *Sow.*).
Gryphæa subgibbosa, *Bl. & H.*
Pecten vimineus, *Sow.*
Pinna, sp.
Avicula, sp.
Lucina aspera, *Buvig.*, common.
——, sp.
Thracia depressa, *Phil.*
Pholadomya, sp. (*cf.* concentrica, *Röm.*).
Goniomya literata, *Sow.*

The conditions being different, the fauna of the Coral Rag has for the most part disappeared, whilst that of the regular Kimmeridge Clay has not yet fully set in. There can be very little doubt that such beds are the result of the grinding-down of masses of Corallian limestone, whose débris, largely mingled with the argillaceous mud now invading the sea, no longer coralligenous in this particular area, went to form banks of bastard limestones, which have probably only a limited range, forming a fringe, as it were, round reefs which have been wholly or partially destroyed during the interval marking the close of the Corallian conditions in the Oxford-Kimmeridge sea.

As a formation the supracoralline limestone has considerable extension in the valley at the foot of North-Grimston Wold; and further westward it is to be found in the low ground between Langton Wold and Birdsall. Near the latter village it may be seen faulted against the Lower Calcareous Grit at Rowmire Spring; and in this way the Lower Calcareous Grit is again brought in, now occupying its normal position, which in the Howardian Hills should be to the S.S.W. of the Corallian limestones.

Summary.

We will here recapitulate the results that our detailed study of the Corallian rocks in the above districts have produced, and would refer to our Table of Comparative Sections (Pl. XII.) for their illustration.

Weymouth district.—We have here three principal localities, the development in which is represented by our sections Nos. I., II., III. The most complete series is in the neighbourhood of Weymouth itself (section I.), where, in ascending order, we have the

* This is rather stouter than the usual Kimmeridge form, and is intermediate between the regular *B. nitidus* and *B. abbreviatus*.

series as follows:—First, sands and grits well developed everywhere, but especially at Nothe Point, where they are 30 feet in thickness, and characterized by abundance of *Perna quadrata* and *Pecten fibrosus*—the "Nothe grits." This portion is separated by thick masses of clay ("Nothe clays") from an upper grit (the "Bencliff grit"), in the base of which are huge doggers, by which its presence may be sometimes recognized, the whole forming together what would elsewhere be called Lower Calcareous Grit. This part may be equally recognized in Sections II. and III. The next series, consisting of oolites and marls, and including the remarkable "Osmington Oolite," is perfectly distinct in character from the overlying limestones. It may be seen by the sections to vary its character even within the district, at Weymouth being least marked, and at Abbotsbury, though very unfossiliferous, being largely composed of compact beds of oolite. The fossils are peculiar, but have a relation rather with the Lower Calcareous Grit than with the upper beds. These latter are the main limestones of the district, but in general show but little oolitic structure, Osmington affording an exception; they are usually rather rubbly or hummocky in character, and contain corals, but they do not constitute a "Coral Rag," and contain much sandy material. They are richly fossiliferous, and show a decided change of type, their relations being upwards. From the abundance of *Trigonia clavellata*, we have called them the "*Trigonia*-beds." *Cidaris florigemma* occurs in them but rarely, while it occurs more commonly in a higher horizon here; and the other fossils are not entirely those that are elsewhere associated with corals, but are partly found below them. Above the main limestones at Weymouth we have a great thickness (40 feet) of clay, which we call Sandsfoot Clay, overlain by ferruginous sands and grits of very remarkable character, both in lithology and fossils, having large spongeous growths, and containing *Cidaris florigemma*, *Lima pectiniformis*, *Lingula ovalis*, *Littorina muricata*, *Astarte supracorallina*, and many other fossils which are generally associated with corals, or rise to higher zones. All this is well represented, as far as can be seen, at Abbotsbury (Section III.), and somewhat inconspicuously and of less thickness at Osmington. In Ringstead Bay a remarkable Upper Coral Rag is developed above these grits and immediately below the Kimmeridge passage-beds. On a higher horizon, perhaps, than any of the Corallian rocks of the rest of the district comes the Abbotsbury ironstone, alike remarkable for its peculiar character and abundant Brachiopods, which are elsewhere almost absent from the Corallian beds. The great feature of this district is the limitation of any thing that can be called a coral reef to a very small area; while the changes that have taken place in the characters of the deposits, which are, on the whole, of great thickness, are exceptionally numerous.

North Dorset.—In this district we have considerable variety in the Corallian development. In the southern part of it (Section IV.) there is a very little Lower Calcareous Grit, its place being taken by a continuation downwards of oolites and marls with beds of pisolite. These are followed by a thick false-bedded series with few fossils, overlain by a rubbly bed with abundance of rolled spines of *Cidaris florigemma,* associated with other fossils which occur generally in lower beds than the Coral Rag proper. The succeeding beds here are more calcareous than usual, and might possibly be included with the limestones below as far as their fossils are concerned; but they are more gritty, and are followed by sands and marls, with few fossils, and a ferruginous band corresponding with the Sandsfoot grits or higher beds; but these beds are local to the neighbourhood of Sturminster. In the northern portion, the Lower Calcareous Grit assumes more importance; it forms extensive banks near Cucklington, and may be traced downwards into the Oxford Clay in Gillingham cutting. The succeeding beds are almost entirely limestones of impure character, the upper portion developing corals in some places, but not so many as to form a reef or become conspicuous as a Rag. If any overlying beds were here deposited, they have been washed off and their remains deposited on the denuded limestones. There is more limestone in this region, in proportion to the whole development, than in any other; but it is generally too impure to burn for lime. The limestones become pure enough towards the extreme south-west, near Mappowder, where there are several limekilns—as there are also in the neighbourhood of Marnhull, where the false-bedded series is burnt.

Wiltshire and Oxfordshire Range.—In this long belt are contained several types, the most constant member being the Lower Calcareous Grit, which consists of loose sands, sometimes of considerable thickness, with occasional irregular bands of hard blue grit or huge doggers. In the extreme south we have the interesting iron-ore of Westbury (Section V.) occupying an analogous position to that of Abbotsbury, viz. the extreme top of the series. It has a bed of glauconitic sand between it and the main limestones, which are of minor importance here. Marls still intervene, as in the districts to the south, between the limestone and the Lower Calcareous Grit.

The section at Steeple Ashton is not very different from this, except that the ironstone is unimportant, and a bank of corals is developed at the top of the limestones, though of very limited extent. In both these localities the total development is meagre; and a little to the north, at Seend, the whole is reduced to the Lower Calcareous Grit, containing a rather peculiar fauna, and overlain directly by the Kimmeridge Clay.

In the neighbourhood of Calne (Section VI.) is a considerable development of the Lower Calcareous Grit, which is fossiliferous at Conygre, supports a coral reef without *Cidaris florigemma* at Westbrook, and thins out to very small dimensions northwards by Catcombe. We have again a marly bed intervening between this and the limestones, which in this area are of several inosculating types—sometimes being a true Rag, full of corals, sometimes a set of false-bedded limestones, and sometimes marls with interbedded occasional limestone bands, as at Hillmarton. Very slight traces of any beds above these can here and there be noted, chiefly in the form of ferruginous marls. This nearly total absence of higher beds and the comparatively feeble development of any beds but those containing *Cidaris florigemma* above the Lower Calcareous Grit is the chief feature here.

At Highworth (Section VII.) we enter on a new phase, which continues nearly constant as far as Marcham, *i. e.* while the escarpment faces north. The peculiarity here is the development below the Rag with *Cidaris florigemma* of wonderfully fossiliferous limestones, in which such shells as *Trigonia Meriani*, *Lima rigida*, *Ammonites plicatilis* are abundant; they also contain corals in the lower part, and are capped, here and there, by false-bedded oolitic sandstones. These beds, which may fairly compare with the Coralline Oolite of Yorkshire, are continuous beneath the rag, which sometimes rests upon them directly and at others is separated by more arenaceous beds. The true ferruginous Upper Calcareous Grit succeeds the Rag in the direction of the dip, but in an easterly direction entirely disappears, so as to be quite absent at Oxford. These remarkable shell-beds disappear on approaching Oxford by Cumnor, at which latter place the Coral Rag, in a magnificent form, lies directly on the Lower Calcareous Grit. At Oxford itself, however, or rather at Headington (Section VIII.), another shell-bed appears, with abundance of *Cidaris florigemma* and other fossils usually associated with it in the Rag, proving it not to be the Highworth bed again, but a more recent one. Here the rag inosculates with, and is overlain by a thick mass of false-bedded comminuted shell-limestone, which assumes enormous proportions at Wheatley, the whole formation above the Lower Calcareous Grit varying between marls and limestones, and finally disappearing at this point.

It is in this range that the whole series is reduced to a minimum, the last remaining members being the Lower Calcareous Grit and the Coral Rag proper, and these in places being of no great thickness. It is here also that we meet with the greatest variety of type within the same area, which we have endeavoured to indicate in figure 8.

The Cambridge Reef.—The only members here recognized (Section IX.) are the Coral Rag, here with an abundant and special fauna, but with sufficient of the characteristic species to connect it indissolubly with the ordinary Rag with *Cidaris florigemma*, and the apparently underlying and less fossiliferous Oolite. The nature of the ground is not such as to enable us to learn more of the real thickness of these than is seen in the quarries, nor the nature of the underlying rock. The Elsworth rock we take to be an exceptional development of the Lower Calcareous Grit.

The Yorkshire Basin.—If we except the fine series at Weymouth, the Corallian rocks in this district present an incomparably finer development than in any other, and constitute not a mere string of rocks, but a veritable massive, whose area, circumference, and maximum thickness are severally almost equal to those of all the other areas put together. Although we have divided the basin, for the purpose of detailed description, into several parts, we may here consider it as a whole, the varying structures of different localities being well illustrated by our sections X.–XIV.

The Lower Calcareous Grit has a far more constant and regular development than the other formations, and, as a mass of solid rock, attains an importance not observed in the south. In the Howardian Hills (sections X., XI.) the thickness is about 60 feet, chiefly in layers of buff freestone and hard blue rock. In the western and northern hills (XII., XIII.) the thickness is increased to 100 feet, all solid rock. In the eastern districts the top part is marked by ball-beds.

In connexion with the Corallian limestones the chief feature of interest is the double group so well marked in the Tabular Hills. Along the coast, where the lower beds are so admirably displayed, this duplicate series is by no means obvious, and requires to be interpreted by the light of exposures in the interior. The section at Filey still remains somewhat problematical; but we have reason to presume that the two limestones are there continued in an altered and more arenaceous form, and that the Filey-Brigg Calc-Grit is the representative of the Middle Calcareous Grit, although elsewhere in the Scarborough district this subformation is but feebly developed. As Filey Brigg is the most easterly point of the Corallian area in Yorkshire, the character of the rocks seems to indicate a lessening of calcareous matter in that quarter; so that possibly the Corallian deposits may have had their original termination in a south-easterly direction, not very far from the existing coast. The limestones generally in the Tabular Hills may be said to have a lenticular development, attaining their maximum along an east-and-west line which, in the Scarborough district, is not very far from the roots of those hills. The non-appearance, therefore, of particular beds may be due, in some cases, to thinning out rather than to denudation. The limestones of Scarborough Castle Hill clearly belong to the lower group alone; and this section is therefore more imperfect than that at Filey.

The fauna of the Lower Limestones, inclusive of the passage-beds, has much in common with that of the Lower Calcareous Grit. This is especially marked in the eastern districts, where alone we have been able to procure much fossil evidence. The purer oolites are generally very poor; but towards their base occasional shell-beds produce a characteristic set of Brachiopoda, which, with a great abundance of *Gervillia* and, in certain lines, of *Cylindrites*, may be said to mark them. There are peculiar phases of the passage-beds, however, which are an exception to this poverty, such especially as that above the Ball-beds at Filey, and a very similar rock in an analogous position at Appleton. In such places Brachiopoda seem to be unusually abundant, especially *Rhynchonella Thurmanni*; and these are associated with a tolerably numerous set of Conchifera, along with *Millericrinus echinatus*, *Acrosalenia decorata*, and, at Appleton, with *Glyphea*, some of the same species occurring, though less plentifully, in the Lower Calcareous Grit itself. Cordate Ammonites, especially of the *Goliathus* type, are prominent fossils, *A. perarmatus* much less so; but *A. Williamsoni* is often found in the lower or ferruginous portion of the passage-beds in the neighbourhood of Scarborough. The presence of undoubted forms of *A. plicatilis* is by no means common. In the Hackness outlier there occurs a well-marked Lower Coral Rag included within the Lower Limestones, and containing the usual species of corals and dwarf forms of some of the associated shells, but without *Cidaris florigemma*. Amongst its characteristic fossils are *Spongia floriceps* and *Waldheimia Hudlestoni*. This Rag is very local; but its position may be traced at Scarborough and Filey; and to the west corals may be noted about the same horizon. The Scarborough type of passage-beds seems to be lost in the western portion of the Tabular Hills; and vast accumulations of cherty beds occupy their place, the tendency to silicification extending upwards even into the oolites. The maximum thickness of the Lower Limestones, all included, near Kirkby Moorside, is estimated by Mr. Fox Strangways at not far short of 150 feet. At Kepwick, on the western escarpment, the oolite of the Lower Limestones (Hambleton oolite) has a thickness of about 50 feet, and thence continues to thin out towards the south-east, disappearing altogether ere we reach the Gilling Coxwold Gap (section XIII.). The revival of this group, as a separate formation, in the Howardian Hills, is somewhat problematical; but the peculiar phase of passage-beds already noted is seen to be highly fossiliferous at Appleton, and there is a still stronger development, though without so many fossils, in the western suburb of Malton. There are certainly two very different groups of oolite in the neighbourhood of that town; but that which is presumably the lower of the two cannot at present be identified with any portion of the Lower Limestones of the western and northern hills.

The Middle Calcareous Grit is rather irregular and uncertain. It seems to break out in Filey Brigg, but otherwise to have only a feeble development east of Forge valley (section XIV.). West of that meridian it begins to make some show on the surface; and at Pickering attains probably its maximum development in the northern hills (section XIII.). Here it so much recalls some of the features of the Lower Calcareous Grit as to show how similar must have been the physical conditions which produced it. But the characteristic Brachiopoda of the lower formation are either absent or so rare as to escape notice. At Pickering the higher beds are charged with bands of gritty suboolitic limestone, again constituting a series of upper passage-beds, rich in *Trigoniæ*, which form a fitting introduction to the Coralline Oolite. This phase may be traced, wherever there is an exposure, westwards as far as Kirkdale, and perhaps in a modified degree to within a short distance of Helmsley. Along the line of the Hambleton section (section XII.) the presumed equivalent of the Middle Calcareous Grit presents a different appearance; its thickness may be as much as 60 feet; but where the Lower Limestones are thinning out so much, the true division between this and the Lower Calcareous Grit proper is not always clear. A mile or two further south of this line the two grits seem to coalesce, and we obtain the reverse of the Forge-valley section, where it is the two limestones which are on the point of uniting. No certain indications of the Middle Grit are to be seen in the Howardian Hills.

The Upper Limestones, which are not seen on the coast at all, except in an altered and fragmentary form, peeping from beneath the drift of Filey promontory, are throughout divisible into Coralline Oolite and overlying Rag; and they are, on the whole, much more fossiliferous than, and never contain the Brachiopoda of the Lower Limestones. The Coralline Oolite, underlying the Rag in the great crescent of rocks which sweeps round the western half of the vale from Pickering to Malton, is fossiliferous in certain beds, which are generally characterized by the great abundance of *Chemnitzia*. It has two petrological types, the oolitic and the pasty; and its rocks are for the most part mixtures of these in varying proportions; but the variation in the character of the Coralline Oolite is not sufficiently marked to be here recapitulated. The Coral Rag has several different types. In the Scarborough district the absence of *Cidaris florigemma* from the Rag, and the interesting group of small univalves which it contains, give it a peculiarity; but whether this is due to the nature of the coral, in this district confined almost exclusively to *Thamnastræa concinna* and *Rhabdophyllia*, or to deposition in a separate basin, is not clear. When we meet with the Rag in the next (or Pickering) district, it is seen to be crowded with the spines of the characteristic urchin. Besides the ordinary form, we have a solid and compact form at Helmsley, which is highly siliceous, as, indeed, are most of the Rags; a beautiful free limestone at Hildenley; a strange medley at Sike Gate, near Cawton, where the fossils are very peculiar; and a very distinct type on the east of the Derwent (section X.), where, including the entire limestone series, there is a thickness of 100 feet, some portion being intercoralline, and containing an extraordinary profusion of urchins, as well as a rich molluscan fauna, of such a character as to indicate the possibility of this Rag being of slightly later date than that of the Tabular Hills.

The development of the supracoralline beds is copious and tolerably regular. In an arenaceous form, as Upper Calcareous Grit, these beds attain their maximum thickness in the extreme western bay of the vale of Pickering, where they may be seen in several places to rest upon the indurated surface of the Coral Rag. Eastwards, however, a peculiar argillo-calcareous deposit, less constant as a formation, is observed to intervene between the Coral Rag and Upper Calcareous Grit, the base of which at Pickering itself is also very muddy. The Upper Calcareous Grit of Yorkshire possesses features which can seldom be mistaken, and contains a series of fossils at least partially Kimmeridgian. There may be room to doubt the evidence of "biplex" Ammonites; but such forms as *A. alternans* and *A. Berryeri* are more satisfactory. *A. varicostatus* still seems to be present. In the Howardian Hills no Upper Calcareous Grit comes to the surface; but the great deposits of Burdale, overlying the North-Grimston Rag, contain several of the fossils of the Upper Calcareous Grit of Pickering.

Conclusions.

The descriptions we have given of the actual development of Corallian rocks in England shows how inappropriate is the term "Coral Rag" as a designation for the whole, any thing that could be lithologically called by that name forming but a very small part of the series. "Coralline Oolite" is an equally inappropriate term when separated from the rock which it properly describes. As, however, the great interest which attaches to the series of rocks which is the subject of this memoir centres in the fact of their containing the last development of coral-reefs within the British area, which is now too cold for their formation, they may be appropriately known under the name that we have used, "Corallian." We see, too, that we have not been describing a set of rocks under this designation that are sharply marked off above and below, but rather the gradual changes that took place during a certain epoch in the earth's history, and the results to which they led. We have seen how the lower beds are still markedly Oxfordian in the character of their fauna, and how gradually the peculiar forms suited for connexion with coral growths were introduced, and how, before they had died out, Kimmeridgian forms became their companions, and ultimately supplanted them. The earth's history is not the disjunctive story of a dynasty, but the continuous one of a nation.

Although it is true that the series of changes above indicated were generally introduced by the deposit of calcareous sands which have become to a certain extent grits, that the succeeding deposits, whether connected with corals or not, are limestones, frequently oolitic, and that in those cases where we see the return to the pelagic conditions of the Kimmeridgian epoch it is marked by a deposit of calcareous grits, we see that it is erroneous, and in the case of Yorkshire impossible, to call these simply the Lower Calcareous Grit, Coralline Oolite, and Upper Calcareous Grit, as we should thereby correlate all the limestones together, and the same with the other portions.

In the extreme north and the extreme south the series of changes were much more complex, and the development at a maximum; yet the characters of the several series differ widely, and in the inland counties the development reaches its minimum, and really has many of the better-developed portions not represented at all.

These facts show that a correlation in time is impossible; for where the Coral Rag rests immediately on the Lower Calcareous Grit, the latter may represent in time the whole of the vast deposits elsewhere forming the basis of the Rag, or this latter may not have been elsewhere contemporaneous.

The character of the deposits, wherever we have studied them, has been that of lenticular masses of an elliptical shape, thinning out in all directions, but with diameters of very unequal length. In this way it happens that beds of the same character and position are not parts of a widespread whole, but are the results of similar causes acting in isolated areas, and at periods which may, indeed, coincide in point of order, but not necessarily in point of time. It is only in such a sense as this that we can attempt any thing like correlation, or arrange the whole series in a chronological sequence. It is undoubtedly to Yorkshire that we must go for our type with which to compare the rest, and thence take our general names.

The Corallian deposits, then, may be considered, when complete, to be represented by the following series, in ascending order:—

1. *The Lower Calcareous Grit.*—This may have begun earlier in some places than in others. If we judge by the thickness of the Oxford Clay below, we should suppose it to have begun very early in the Tabular Hills, but not very early at Weymouth. In the latter place it is represented by the Nothe grits; and in the other districts there is no difficulty in its recognition.

2. *The Lower Limestone or Hambleton Oolite.*—This mass, which is so intimately connected by its fauna with the Lower Calcareous Grit, may be represented elsewhere than in Yorkshire by some portion of the latter; but its place is nowhere recognizable in the south, unless it be, 1st, near Sturminster, in the oolites which underlie the pisolites, and, 2nd, at Weymouth in the Nothe clays.

3. *The Middle Calcareous Grit.*—This also is nearly peculiar to Yorkshire, unless, having placed the Nothe clays on the horizon of the Hambleton oolites, we take the Bencliff grits to represent this in the Weymouth area.

4. *The Coralline Oolite.*—This is the mass of limestone which is developed beneath the Rag, and with which it has been usually confounded. It is well marked in Yorkshire as a massive limestone; we take the oolite in Upware north pit to represent it in the nearest locality to Yorkshire. Its equivalent begins again to the west of Oxford, and reaches to beyond Highworth, at which place and at Faringdon are fine developments of what we would correlate with it. At Calne it appears as a marl, and at Steeple Ashton and Westbury under both forms, the marl being below. The marls and false-bedded series of the North-Dorset district appear to belong here. In the Weymouth area the Osmington oolites represent the lower portion, and the *Trigonia*-beds the upper portion.

5. *The Coral Rag.*—Though there is a lower Coral Rag at Hackness and at Highworth, there is no danger in using this in its strict lithological sense; for, with these exceptions, the development of Corals uniformly represents the same term in the series. They are usually, but not universally, associated with *Cidaris florigemma*, which makes the term "*Florigemma*-rag" or "zone" sometimes convenient, since by this fossil in the absence of corals the corresponding beds may be most easily recognized. We note that the Ayton-Brompton Rag does not contain it. At Grimston we have the Urchin-beds below, which must be included with this. At Upware this Rag is well marked. At Oxford we have, associated with the Coral growth, a rich underlying shell-bed, and the Wheat-

ley and Shotover limestones above it. It is thence continuous westward, putting on various forms when it approaches Calne, including the Calne and Goatacre freestones, and having underlying flags near Purton. We cannot be sure of the age of the Westbrook Rag, which contains no *Cidaris florigemma*. The true Rag is developed again at Steeple Ashton; at Westbury its place appears to be taken by glauconitic sand. As a true Coral Rag it does not appear in the North-Dorset district; but its position in the series is indicated by the rubbly beds, and possibly by the overlying calcareous sandstones at Sturminster, and by slight coral-growths north of Gillingham. In the Weymouth area the sequence is physically altogether different.

6. *The Supracoralline Beds.*—We may use this name for the uppermost portion of the series, in spite of the exceptional small reef in Ringstead Bay. Omitting this, we may describe them as consisting of calcareous grits and clays, and consider them as belonging to two separate divisions. First and lowest are the Sandsfoot clays and grits, which appear to represent beds deposited between the epoch of the Coral-Rag deposits and the ordinary Upper Calcareous Grit of most other localities, having in some respects a highly Kimmeridgian fauna, but also a great and marked community of forms with the Rag; second and highest, the Upper Calcareous Grit of Yorkshire, which is local even there. It is essentially a Kimmeridge formation. It is represented by more argillaceous beds in the Howardian Hills. It has representatives in the red ferruginous marls with oolitic fragments, and the sands which overlie the Rag from Faringdon westwards to near Goatacre. To this horizon we assign the Westbury ironstone and the red marls at the top of the series in the North-Dorset district. In the Weymouth area we must look for this horizon *above* the Sandsfoot grits, in the beds which intervene between them and the Kimmeridge passage-beds, possibly including the latter. Here, also, belongs the Ringstead reef, and certainly the Abbotsbury ironstone, which may be even of somewhat later order in the series. We cannot, therefore, correlate what might be called the Upper Calcareous Grit of Weymouth with that of Yorkshire, the former representing a lower portion of the series.

In this arrangement of the beds in series we are of course assisted by their palæontology; but, with the exception of *Cidaris florigemma*, we have scarcely ventured to use fossils as universally characteristic of different portions. It will be well, however, to name some which are generally of use for this purpose. *Ammonites perarmatus* may be taken as an indication of something below the Coralline Oolite; yet it or one undistinguishable from it has occurred in the representative of the Rag at Sike Gate. *Avicula ovalis* and *Millericrinus echinatus* indicate the same portion. *Gervillia aviculoides* in Yorkshire indicates a low horizon, but in the south of England generally a high one. *Rhynchonella Thurmanni* belongs to the two lowest series in Yorkshire, but does not occur there in the south.

We pass finally to a brief consideration of the physical causes concerned in the formation of these rocks. In the Yorkshire area we have a maximum of calcareous deposits; and here too we obtain the finest reefs. The higher latitude of this county did not outmatch the influence of favourable conditions for their growth through a considerable period of time. We note, however, that on the east coast of Scotland Mr. Judd has not recorded a single coral from beds of this period, though the conditions there do not appear to have been unfavourable; so that the northern limit is soon reached. The disposition of the Corallian beds round the vale of Pickering, and some peculiarities of their stratigraphy in relation to tremendous faults by which they are affected, render it difficult to indicate precisely the source of the deposits; most probably the sediment, at least, came from the north and west.

In the extreme south, though the warmth would encourage coral-growth, the great preponderance of argillaceous conditions must have choked them, these clay masses, as all the others, having come from land to the south and west.

In the North-Dorset district we have again abundance of calcareous matter, and the reefs were probably not far to the west; but here some other causes prevented their growing on the spot.

In the central range the huge sandbanks appear to have given support first to some shell-beds at different ages, and then to have been very favourable to coral-growth.

In every case, however, we have, in the very fact of the great *variety* manifest in the deposits, a proof that we are not dealing with pelagic conditions, but are under the influence of neighbouring lands or shallow water; and the beds we see are a faithful record, not of permanent conditions, but of continual changes, favourable or otherwise to the growth of coral.

But one great change has passed over the country since then: it has become too cold for corals at all; so that we here see for the last time the formation of a reef, the structure of which is laid bare before us; and very beautiful it is, especially where it has been undisturbed. The influence of these rocks is not unfelt even in the great clay deposits in the centre of England, where a middle division has been indicated, characterized, as we have seen, by some essentially Corallian fossils; and we doubt not that a careful examination of these clays would show a still closer connexion.

Descriptions and Notes on the Fossils.

Belemnites.

Between the stout *B. abbreviatus* of the lower beds and the much narrower *B. nitidus* of the uppermost, are some which form, perhaps, the passage between them, being of intermediate age as well as shape. We have not thought it desirable, however, to give them distinct names at present.

AMMONITES PERARMATUS, Sowerby.

The group of Ammonites passing under this name presents three well-marked forms, "varieties" or "species:"—1. The typical form as represented by Sowerby, with moderately inflated, rounded, and subevolute whorls, tubercles of good size, and joined by a swollen rib. This occurs in the upper part of the Lower Limestones of Yorkshire. 2. An inflated more involute form, with less conspicuous ribs or tubercles, most common in the Lower Calcareous Grit proper of Yorkshire; and, 3. A flatter form with the inner tubercles and ribs almost obsolete, and the outer tubercles much smaller and more numerous. Its chief home is in the Lower Calcareous Grit of Wiltshire and Oxfordshire; and it is the variety to the casts of which the name of *A. catena* was given by Sowerby. A fourth form has also been met with as a single specimen at Sike Gate, Yorkshire, which, as it occurs probably at a higher horizon than any of the others, may serve to show that links between the *perarmatus* group and the *A. longispinus* of Kimmeridgian age are not wanting in the Corallian limestones. The intermediate character of this fossil favours the above view.

AMMONITES PSEUDOCORDATUS, spec. nov. Pl. XIII. fig. 1.

Although *Ammonitus cordatus* characterizes the lower portion of tho Corallian series, yet in the Upper Calcareous Grit of Yorkshire we find Ammonites that are undistinguishable from it, and the type was continued (through the form next to be described) into the *A. alternans* of the Kimmeridge Clay. We need not, therefore, be surprised to find it influencing Ammonites of the plicatiloid group. The Ammonite we propose to call *A. pseudocordatus* has, indeed, the ribbing of *A. plicatilis*, but the involution and sharpness of front of *A. cordatus*; so that its general aspect reminds us of both groups. The following is its diagnosis:—

Last whorl $\frac{3}{8}$ the diameter; inner whorls half-covered; greatest thickness of outer whorl $\frac{2}{9}$ the diameter, situated towards the inner side of the whorl, whence to the front the slope is uniform, giving a semi-acute rounded front. Aperture sublanceolate. Ornaments 35 ribs on the last whorl, which nearly die out and give place to about 96 smaller ones, which pass over the front without alteration; diameter nearly 9 inches.

In the Ironstone of Westbury.

AMMONITES CAWTONENSIS, spec. nov. Pl. XIII. figs. 2, 2*a*.

This form, though belonging to the *cordatus* group, is so distinct as to make it worthy of a specific name. It leads us on from the older forms to the newer *A. alternans*.

Outer whorl $\frac{2}{5}$ the diameter; inner whorl half-covered; sides of the whorls between the ribs uniformly convex for $\frac{8}{9}$ of the breadth, when they become concave on each side of the keel; greatest thickness of the whorls between the ribs $\frac{1}{4}$ the diameter; aperture convexo-quadrate; ornaments, 20 nearly straight ribs rising from the inner edge, and running nearly radially to the middle of the whorl, where they rise each to a tubercle, whence run bifurcating ribs to 38 smaller tubercles, which stand out boldly from the front. Front crenated by largish teeth, connected with the side-tubercles by almost obscure, not very oblique riblets; diameter $2\frac{1}{3}$ inches. In the young state, which appears slightly more evolute, the ribs are undeveloped, and the whorls have only scattered tubercles. This differs principally from *A. vertebralis* and others (1) by being more evolute, (2) by being more uniformly convex, (3) by its tubercles being more marked, (4) by its straighter and thicker ribs, (5) by the more complete separation of the keel, (6) by the teeth on the keel being less oblique.

In the limestones referred to the age of the Coral Rag at Sike Gate, near Cawton, Yorkshire; also at Culham, Oxfordshire.

CHEMNITZIA LANGTONENSIS, spec. nov. Pl. XIII. fig. 3.

Although this is an incomplete and unique specimen, its ornaments are so distinct and remarkable that it can be confounded with no other *Chemnitzia*.

It also possesses a remarkable callosity on the inner lip, which ought perhaps to separate it from this genus.

Spiral angle 19°, angle of suture 130°. Total length $5\frac{1}{2}$ inches (estimated); last whorl 2 inches long, double the next whorl; whorls only moderately convex, least so in the upper part; suture not deep, but rather abrupt; ornaments irregular, undulating risings parallel to the length of the shell, numerous, and close together.

In the Coral Rag of Langton Wold, Yorkshire.

CHEMNITZIA PSEUDOLIMBATA, spec. nov. Pl. XIII. fig. 4.

Spiral angle 14°, angle of suture 115°. Total length $2\frac{3}{4}$ inches; last whorl $\frac{3}{4}$ inch, not quite twice the next; whorls moderately convex, sutures ill defined. Ornaments, numerous fine transverse curved ribs, the concavity towards the aperture.

The nearest ally to this seems to be *C. limbata*, Contejean; but the present species is not limbate, and the ornaments are not sigmoid.

In the Ironstone of Abbotsbury.

CHEMNITZIA FERRUGINEA, spec. nov. Pl. XIII. figs. 5, 5 *a*.

Spiral angle 26°; angle of suture 110°. Total length 1 inch; last whorl more than $\frac{1}{3}$ the length, twice the next; whorls moderately inflated, each with 11–12 transverse elevated ribs, curved towards the aperture at the top; the ribs and interspaces between them covered with fine longitudinal striæ; mouth rather oval, beautifully shown in the specimen communicated by J. F. Walker, Esq., F.G.S. &c. (fig. 5 *a*).

In the Ironstone of Abbotsbury. (Woodwardian collection.)

The Woodwardian specimen is eminently chemnitzioid; but Mr. Walker's is more inflated, and is like a *Scalaria*. The ornaments are the same in both. It is possible, however, they may be distinct.

Cerithium inornatum, Buvignier, Géol. de la Meuse, pl. xxvii. fig. 17.

Unornamented *Cerithia*, to which the above-quoted figure bears the closest resemblance, are not uncommon in the Rag-beds of Brompton and Ayton. A similar shell, however, from the *Trigonia*-beds of Pickering, shows, under a strong lens, excessively fine longitudinal striæ; and we are not sure whether this may not be the *Terebra melanoides* of Phillips, which otherwise we have not met with. A block of Rag from Ayton is figured (Pl. XIV. fig. 1), showing this and three other species.

Cerithium, sp. (cf. virdunense, Buvignier). Pl. XIV. fig. 2.

A small shell from a bed full of micromorphs at Cauklass End, in the vale of Pickering, agrees well in other respects with Buvignier's species, but that it is only one sixth the size. As, however, its identity may be doubtful, we give a figure. If considered distinct, it may be called *Cerithium gradatum.*

Nerinæa fusiformis, D'Orbigny. Pl. XIV. figs. 3, 3 *a*.

Notwithstanding that this species is well figured in D'Orbigny's Pal. Franç. Terr. Jurassiques, we give a figure of it, because it is so important and characteristic a shell in the Rag of the Scarborough district.

Natica marchamensis, spec. nov. Pl. XIV. fig. 4.

Naticœ, as a rule, present few characters; and one usually feels an *embarras de richesses* when names have to be invented for them. Two, however, we cannot match elsewhere; and they are marked with extreme characters in opposite directions.

N. marchamensis is uniformly convex, the convexities of each whorl almost joining, to make but one curve, the sutures being very feebly marked. Spiral angle 66°. Last whorl more than $\frac{3}{5}$ the whole.

In the *Natica*-bed of Marcham and the neighbourhood.

Natica felina, spec. nov. Pl. XIV. fig. 5.

This is as remarkable for the step-like character of its spire, the top of each whorl being perfectly horizontal, and separated angularly from the sides. It was ornamented with three dark-coloured longitudinal bands. Spiral angle, which is increased by the last whorl, 85°. Last whorl $\frac{3}{4}$ the whole.

In the Lower Calcareous Grit, Catcombe, Wiltshire.

Neritopsis. Pl. XIV. fig. 6.

Fossils like the one figured were for a long time a puzzle, and were commonly referred to some Cephalopod, like *Beloptera*, under the name of *Peltarion*, till they were discovered by M. Beaudouin (Bull. Soc. Géol. de France, vol. xxvi. 2nd series, p. 182) in their natural position as an operculum of a *Neritopsis*. This particular one is probably the operculum of *N. Guerrei*, the only species known in the rock.

In the Coral Rag of Upware, Cambridgeshire.

TROCHUS AYTONENSIS, spec. nov. Pl. XIV. fig. 1 *d*.

Spiral angle 60°. Each whorl ornamented with a nodular band at the base, and three rows of tubercles above; base smooth, imperforate. Length $1\frac{3}{4}$ line.

In general shape and ornaments this is near to *T. carinellaris* (Buv.); but there are more rows of tubercles in that species.

In the Rag of Ayton, associated in the figured block with *Littorina muricata*, *Cerithium inornatum*, and *Eucyclus Buvignieri*.

PATELLA MOSENSIS, Buvignier.

We have inserted this in the list of Upper Calcareous Grit forms in spite of the absence of any remains of a muscular impression, which has led M. Deshayes to reject similar fossils from the Mollusca. We could scarcely expect to find such impressions in the fossils, when they are so difficult to perceive even in the recent shells of several patelloid mollusca.

GASTROCHÆNA CARINATA, spec. nov. Pl. XV. fig. 5.

Height half the length; valves moderately inflated; umbones $\frac{1}{4}$ the length of the shell from the anterior end, small, approximate; posterior end obliquely truncated, having one minor keel running from the umbo nearly parallel to the hinge-line, and enclosing a curved area, and one larger, running from the umbo to the ventral margin; area behind this keel smooth; gape reaching the middle of the ventral margin. Length 4 lines.

This is nearly allied to *G. corallensis*, but differs in having the first keel less conspicuous, and in having no ornament between the keels.

Among the corals in the Rag of Westbrook, Wilts.

TANCREDIA DISPUTATA, spec. nov. Pl. XIV. fig. 7.

Height $\frac{2}{3}$ the length; valves not very convex, most so opposite the umbo; umbo nearly median, slightly posterior; ventral margin uniformly convex, curving rapidly anteriorly to meet the sloping dorsal edge; posterior end more convex on the surface, having a very slightly flattened space diverging from the umbo; posterior margin rounded. Length $1\frac{5}{12}$ inch.

This differs from the common *T. planata*, associated with it, by its greater comparative length and its more pointed anterior end. Its uniformity of outline gives it something of the appearance of a *Pleuromya*.

In the Osmington Oolite.

LUCINA ASPERA, Buvignier. Pl. XIV. fig. 8.

The shells recorded under this name may perhaps be rightly identified; but they are more rhomboidal, and the lines or layers of growth are not so strongly marked, while the interspaces are striated. To prevent confusion we figure one of our shells, which are exceedingly characteristic of the Upper Calcareous Grit of Yorkshire.

LUCINA BEANII.

The shell which has long borne this name in Yorkshire, we have little doubt is the same as the *L. globosa* of Buvignier.

LUCINA OCULUS, spec. nov. Pl. XIV. figs. 9, 9 *a*.

Height nearly equal the length, thickness of the two valves together $\frac{3}{4}$ the height, making the valves very convex, most so over the umbones, which are $\frac{2}{5}$ the length from the anterior end; umbones not projecting far beyond the dorsal edge. Lunule and escutcheon both well marked; the lunule widest and shortest; ornaments, fine regular concentric riblets.

This is nearly allied in shape and ornaments to *L. Moreana*, Buv.; but it is more inflated, and the characters on the hinge-line, which give it the appearance of a pair of spectacles, very clearly separate it.

In the Coralline Oolite of Nawton, Malton, &c.

UNICARDIUM PLENUM, spec. nov.

All the *Unicardia* found in Corallian beds have hitherto been named *U. depressum* (Phillips); but there are certainly two forms which may be easily distinguished. We do not figure the one we call *U. plenum*, as there is little to characterize it; but it is distinguished by its greater obesity, and the obvious inappropriateness for it of the term "depressed."

It is most often found in the Coralline Oolite of Malton.

ASTARTE DUBOISIANA, D'Orbigny. Pl. XV. fig. 3.

This form, which was not figured by D'Orbigny, is highly characteristic of some portions of the Coralline Oolite of Yorkshire, and is therefore figured for reference.

ASTARTE SUBDEPRESSA, spec. nov. Pl. XIV. fig. 10.

Shell suborbicular; height $\frac{9}{10}$ the length; valves much depressed, but very uniformly convex. Umbones slightly anterior, very inconspicuous; lunule almost linear; posterior dorsal margin nearly straight, anterior slightly concave. Ornaments, very regular fine ribs with equal spaces between them, almost uniformly over the whole surface.

Length 11 lines, which is about a medium size.

The general orbicularity, and the regularity and fineness of the ribs, distinguish this from other depressed Astartes, the nearest being one described by De Loriol as *A. boucardensis*.

In the Coral Rag of Wiltshire.

Astarte aytonensis, Lycett. Pl. XIV. fig. 11.

A very remarkable form in the Leckenby collection has long gone under the name given it by Bean; and a similar shell is described by Dr. Lycett from the Great Oolite. It is elongated and subquadrilateral; height $\frac{3}{7}$ the length; valves very depressed; umbones $\frac{2}{7}$ the length from the anterior end, not very prominent, subincurved; ventral margin undulating, drawn in opposite the umbo; posterior margin obliquely truncated; anterior margin gibbous; dorsal posterior margin straight, horizontal; anterior sigmoidal: ornaments, regular large ribs following the contour of the ventral margin.

Length $1\frac{1}{2}$ inch.

The specimen figured is from a suboolitic matrix at Ayton; and the species also occurs in the Coral Rag of Upware.

Cyprina tancrediformis, spec. nov. Pl. XV. figs. 1, 1*a*.

Shell subtrigonal; height from umbo $\frac{4}{5}$ the length; valves only moderately convex. Umbones prominent; posterior side flattened, and the end truncated; anterior ventral margin curving rapidly up to meet the anterior dorsal margin, producing the appearance of a beak, as in a *Tancredia*; dorsal margin running to an angle beneath the umbo; surface smooth, shining. Hinge fairly comparable to that of a *Cyprina*.

This has a very great resemblance to a *Tancredia*, but it has scarcely the hinge of that genus.

In the Lower Calcareous Grit (Nothe grits), Weymouth, and abundant as casts at Highworth.

Cypricardia glabra, spec. nov. Pl. XV. figs. 2, 2*a*.

Shell roundly triangular; height equal the length; valves inflated; umbones rather prominent, nearly median; surface smooth.

Length $\frac{2}{3}$ inch.

There is little to characterize this shell. It is more inflated than most of its congeners, and the posterior ridge is very feebly marked.

In the *Trigonia*-beds of Weymouth, and many other parts of the series both in the south and north of England. It is somewhat remarkable that so plentiful a shell should have escaped the notice of authors, though it is just possible that some of the figures by De Loriol may be intended for this species.

Protocardium isocardioides, spec. nov. Pl. XIV. fig. 12.

Shell inflated, umbones very prominent, incurved; radiating lines very fine and scarcely observable, confined, as usual, to the posterior side.

This is so strongly inflated that it has very much the aspect of an *Isocardia*, under which genus it has certainly been known in collections.

In the *Trigonia*-beds, Osmington and elsewhere.

The Yorkshire forms which we have cited by this name may very possibly represent the *Cardium lobatum* of Phillips, which is badly characterized, and undeterminable from the figure alone.

Arca lanthanon, spec. nov. Pl. XV. fig. 6.

Shell elongate, subquadrilateral; height less than $\frac{1}{2}$ the length; valves obliquely convex; umbones prominent, approximate, very oblique, at $\frac{1}{8}$ the length from the anterior end; ventral margin uniformly convex, dorsal margin straight, no area seen; posterior margin obliquely truncated; anterior end narrower, sharply convex, posterior portion very slightly flattened; lines of growth the only ornaments.

The generic position of this shell is doubtful; but its similarity to the next, which is undoubtedly an *Arca*, renders this reference probable.

In the Coral Rag, Slingsby, Yorkshire.

Arca anomala, spec. nov. Pl. XV. fig. 7.

Shell elongate, irregular; greatest height $\frac{3}{7}$ the length; valves fairly convex; umbones very oblique, nearly approximate, at $\frac{2}{7}$ the length from the anterior end; ventral margin irregular, convex posteriorly, concave beneath the umbones, and rapidly approaching the dorsal margin, posterior end much larger than the anterior, which is produced; a keel runs from the umbo backwards; ornaments, concentric ribs following the curvature of the ventral margin.

In this specimen the teeth of the subgenus *Macrodon* are seen.

In the Coral Rag, at Upware.

Mytilus varians, Römer. Pl. XV. fig. 8.

We figure this, as there may be some doubt if it be Römer's species. It is common in the North-Dorset district in the higher beds.

Modiola cancellata, Römer. Pl. XVI. fig. 5.

This finely ornamented species presents different appearances according to its preservation. The one figured is from the Upper Calcareous Grit of Nunnington, and is more like what Phillips figured as *M. pulchra* from the Kelloway Rock. It is not uncommon in the shell-limestones of Highworth, and in the Faringdon district.

Avicula pteropernoides, spec. nov. Pl. XVI. figs. 4 & 6.

The general axis of the shell makes an angle of 40° with the hinge-line. The hinge is $\frac{5}{8}$ the length along this line; umbones nearly terminal; the convexity of the shell gradually declines as it leaves the umbo, till it is nearly flat; the wing is flat and broad and joins the shell in a uniform curve. Length of hinge $1\frac{1}{2}$ inch. When the shell is young it is more uniformly convex and marked by lines of growth.

It has very much the aspect of a *Pteroperna*, but has not its characters, and its hinge is that of an *Avicula*. It is very singular that so remarkable a shell should never have been noticed before, as it is rather widely spread, viz.:—in the Upper Calcareous Grit, Weymouth; the *Trigonia*-beds, Weymouth and Abbotsbury; Coral Rag, Calne; Coralline Oolite, Faringdon, and also Thornton, in Yorkshire.

AVICULA STRUCKMANNI, De Loriol. Pl. XVI. fig. 3.

This is a near ally of the last.

The axis is a uniform elliptic curve, causing the ventral margin to sweep round like the blade of a scymitar. The wing is broad, and joins the shell by an impressed angle. This might be supposed to be a *Gervillia*; but there are no pits on the hinge-line, which, however, is rather solid, even for an *Avicula*.

In the *Trigonia*-beds, Weymouth.

AVICULA LÆVIS, spec. nov. Pl. XVI. fig. 2.

The axis of the shell makes an angle of nearly 90° with the hinge at first, but bends back slightly at a later stage; convexity slight except at the umbo, which rises uniformly from the surface; hinge-line very short, wing obsolete; surface of shell smooth.

In the Hambleton Oolite, Kepwick, and in the uppermost bed of Lower Calcareous Grit in the Oxfordshire district.

AVICULA OVALIS, Phil., var. OBLIQUA. Pl. XIV. fig. 13.

A small and very oblique variety of this well-known shell. It is remarkable for the beauty of its ornament and its general difference of appearance from the type. A specimen from Cumnor seems to possess a hinge of peculiar character. Occurs in tolerable abundance in the Upper Calcareous Grit of Pickering.

LIMA LÆVIUSCULA, Sowerby.

There are certainly three forms which as much deserve separation as the corresponding ribbed species; and they come from very different horizons:—(1) A roughly ribbed, somewhat orbicular shell, occurring towards the base of the Lower Limestones in Yorkshire; (2) Sowerby's typical form, in the Coralline Oolite generally throughout England; (3) a very smooth transverse shell, frequently attaining large dimensions, extremely characteristic of the Rag of Grimston.

PECTEN INTERTEXTUS, Römer. Pl. XV. fig. 9.

This has long been known in Yorkshire as *P. cancellatus* of Bean, but has never been figured from English specimens, as it strangely escaped the notice of Professor Phillips, though magnificent specimens of it, 6 in. in diameter, are preserved in the York Museum. In England it occurs in the Coralline Oolite of the Malton district, and of comparatively small size in the *Trigonia*-beds of Abbotsbury and Broadwey.

PECTEN QUALICOSTA, Étallon. Pl. XV. figs. 4, 4 *a*.

We for some time called this *P. varians*, Römer; but as it appears doubtful what that species really is, and as Étallon's name so admirably describes its characters, we have adopted it. The shell is very characteristic of the Osmington Oolites and beds on a similar horizon, but passes up into the false-bedded Limestones of Calne. Each rib (and they are not regular) is crossed by a number of scaly risings; and those in the left valve in this species obscure the ribs.

In the nearly allied form *P. strictus*, Münster, every 5th or 6th rib in the right valve is enlarged, and in the left the ribs predominate. They both occur together.

PLICATULÆ.

There are several species noted in the Corallian beds which have not yet been recognized; but they are not in sufficiently perfect preservation to warrant our naming them further than by comparing them to their nearest allies.

GRYPHÆA SUBGIBBOSA, spec. nov. Pl. XVI. fig. 7.

At first sight one might take this great *Gryphæa* as merely a variety of *G. dilatata*; but as it seems to be always confined to a particular horizon, and to present a constant feature in its shape, it becomes worthy of notice. It is gibbous on the posterior side, rising up into a shoulder, something like *G. gibbosa* of Leseur (see Dollfus, 'La Faune Kim. du Havre,' pl. xvii. fig. 5), but obviously differing from that species. Known to us only in the cement-stone of North Grimston, where it is very common.

GLYPHEA FERRUGINEA, spec. nov. Pl. XV. fig. 10.

This species is very closely allied to *G. rostrata*, Phil., which occurs on a much lower horizon; but differs from it in the general shape, the lower margin being more convex. Also the anterior lateral furrow runs right forward to meet the cervical furrow at an acute angle, instead of having a lobe from the gastric region intervening. These lateral furrows are also more deeply impressed and more parallel.

It occurs in the Ironstone of Abbotsbury.

In Pl. XVI. fig. 1, is represented a curious crustacean fragment from the Coral Rag of Upware, which has been prolific in organisms of this class. It presents the appearance of a carapace like that of small spider-crab; but its slight want of symmetry indicates rather a joint from one of the legs.

List of the Continental Fossils recognized as British for the first time, so far as may be gathered from Publications.

Name.	*Notes.*	*Localities.*
Nautilus aganiticus, *Schl.*		Coral Rag, Grimston Field.
Acteonina miliola, *D'Orb.*		Limestones, North Dorset.
Nerinæa fusiformis, *D'Orb.*	So named in some collections.	Rag of Brompton, &c.; shell-beds, Pickering.
—— Desvoidyi, *D'Orb.*		*Trigonia*-beds, Weymouth.
Cerithium inornatum, *Buvig.*	Referred to *Eulima lævigata*, Lyc. t. 31. fig. 3. Perhaps also the *Chemnitzia melanioides*, Phil.	Rag of Ayton, Brompton; shell-beds, Pickering.
—— Humbertinum, *Buvig.*		Rag, Ayton, Faringdon.

Name.	*Notes.*	*Localities.*
Cerithium, sp. (*cf.* virdunense, *Buvig.*).		Shell-bed, Cauklass.
—— Pellati, *De Lor.*		Limestones, North Dorset.
—— michaelense.		Rag, Sproxton.
Littorina Meriani (*Goldf.*).	Hitherto included with *L. muricata.*	Lower Calc-grit, Osmington.
Turritella jurassica (*Qu.*).		*Trigonia*-beds, Weymouth.
Turbo corallensis, *Buvig.*		Rag of Ayton and Calne.
Eucyclus Buvignieri, *D'Orb.*		Rag of Ayton.
Phasianella Buvignieri, *D'Orb.*		Osmington Oolite, and *Florigemma*-bed, Sturminster.
Bulla Beaugrandi, *De Lor.*		Rag, Ayton.
Chemnitzia abbreviata, *Röm.*		Shell-bed, Cumnor.
Natica grandis, *Röm.*	Probably *N. cincta*, Phil.	Rag, North Grimston.
Trochus dædalus, *D'Orb.*		Coralline Oolite, Highworth, &c.
Alaria Deshayesea, *Buvig.*		*Trigonia*-beds, Weymouth; *Florigemma*-bed, Sturminster; ? Urchin-beds, N. Grimston.
—— tridactyla, *Buvig.*		Rag of N. Grimston.
Patella Mosensis, *Buvig.*		Upper Calcareous Grit, Pickering.
Emarginula Goldfussii, *Röm.*		Rag of Upware.
Ceromya inflata, *Ag.*	Much resembles an *Opis.*	Middle Limestones, Weymouth district.
Opis lunulata, *Röm.*		Rag, Upware and North Grimston.
—— paradoxa, *Buvig.*		Rag, Upware.
—— virdunensis, *Buvig.*		Rag, Upware and North Grimston.
Astarte Duboisiana, *D'Orb.*	So named in some collections, but usually referred to *A. elegans*, Sow.	Coralline Oolite of the Tabular Hills.
—— polymorpha, *Contej.*		Middle Limestones &c., South of England.
—— depressa, *Goldf.*		Lower Calcareous Grit, Seend.
Lucina aspera, *Buvig.*		Supracoralline of Yorkshire.
—— circumcisa, *Z. & G.*		Lower Calcareous Grit, Seend.
—— Moreana, *Buvig.*		Rag, Wiltshire &c.
Cardium cyreniforme, *Buvig.*	So named in some collections.	Shell-beds, Pickering.
Myoconcha Sæmanni?, *Dollf.*		Shell-bed, Headington.
Isoarca grandis, *Et.*	? = *I. multistriata.*	} Rag, Upware.
—— texata, *Qu.*		} Rag, Upware.
Arca sublata, *D'Orb.*		Rag, Lyneham, &c.
Limopsis corallensis, *Buvig.*		Shell-bed, Pickering.
Modiola cancellata, *Röm.*	Perhaps referred to *M. pulchra*, Phil.	Upper Calcareous Grit, Nunnington; Shell-beds, Highworth &c.
—— varians, *Röm.*		Limestones, North Dorset.

Name.	*Notes.*	*Localities.*
Modiola subæquiplicata, *Goldf.*	The shell so identified seems to take the place of *M. bipartita*, Sow., of the Lower Calcareous Grit &c.	Main Limestones of the Weymouth district; Sike Gate.
Mytilus jurensis, *Merian.*		Main Limestones of the Weymouth district.
Avicula Struckmanni, *De Lor.*		
Lima subantiquata, *Röm.*	So named in some collections.	Osmington Oolite, &c.
—— fragilis, *Röm.*	A somewhat doubtful identification.	Rag of Ayton, &c.
Pecten qualicosta, *Et.*	Varieties of the *fibrosus*-group.	Osmington Oolite, &c.
—— striata, *Münst.*		Chiefly Oolite and Rag of the Malton district.
—— intertextus, *Röm.*	The *P. cancellatus* of Bean.	*Trigonia*-beds, Weymouth.
—— virdunensis, *Buvig.*		
—— subtextorius, *Goldf.*		Marcham and Westbrook.

Description *of a* new Species *of* Araucarites *from the* Coralline Oolite *of* Malton. By W. Carruthers, Esq., F.R.S., F.G.S.

Araucarites Hudlestoni, Carruthers, sp. nov.

Cone oblong-ovate, supported on a thick branch, which is clothed with leaves to the base of the cone. Scales numerous, supported on a thick axis. Scales small, wingless, with a well-marked lepidium or upper scale. Seed small, oval, borne at the base of the scale.

The two cones, found by Mr. Hudleston, are mature, and each scale, except those imperfectly developed at the apex and base of the cone, bears a seed. The cones are small, being $3\frac{3}{4}$ inches long by $2\frac{1}{2}$ inches broad. The scales also are small in proportion to the thickness of the axis. The axis must have been the first part of the organism to decay, as the matrix in which the cones were imbedded was yet unsolidified, and has been pressed into the cavities left by the decayed axes. The scales, however, persisted until the rock became indurated; and when this decay took place, the cavities were filled in with crystalline calcite, which now represents the external form of the scales and seeds, often with singular minuteness.

The fragment of branch which still adheres to one of the cones, exhibits the bases of the leaves, which were of considerable size and thickness, as is shown by the transverse section of the calcite cast.

The characters which I have described as found in the scales show that this *Araucaria* belonged to the *Colymbea* section of the genus, now represented by two species in South America, one in Australia, and a fourth in New Caledonia. The *Araucarites sphærocarpus*, from the Inferior Oolite of Bruton, and the *A. pippingfordensis*, from the Wealdens at Pippingford, belong to the same section of the genus.

EXPLANATION OF PLATES XII.–XVII.

Plate XII.

Table of Comparative Sections of the Coralline Rocks of England.

Plate XIII.

Fig. 1. *Ammonites pseudocordatus*, Bl. & H., Westbury ironstone, two fifths nat. size.

2, 2 *a*. *Ammonites cawtonensis*, Bl. & H., Coral Rag of Sike Gate, Cawton, Yorkshire, nat. size.

3. *Chemnitzia langtonensis*, Bl. & H., Coral Rag of Langton Wold, Yorkshire, nat. size.

4. *Chemnitzia pseudolimbata*, Bl. & H., Abbotsbury ironstone, nat. size.

5. *Chemnitzia ferruginea*, Bl. & H., Abbotsbury ironstone, nat. size. In the collection of J. F. Walker, Esq.

5 *a*. *Chemnitzia ferruginea*, Bl. & H., Abbotsbury ironstone, nat. size. In the Woodwardian Museum, Cambridge.

Plate XIV.

Fig. 1. Fragment of the Coral Rag of Ayton, showing, *a*. *Cerithium inornatum*, Buv.; *b*. *Eucyclus Buvignieri*, D'Orb.; *c*. *Littorina muricata*, Sow.; *d*. *Trochus aytonensis*, sp. n., nat. size.

1 *d*. *Trochus aytonensis*, Bl. & H., Coral Rag, Ayton, enlarged.

2. *Cerithium virdunense*, Buv., Small-shell bed, Cauklass End, Ness, Yorkshire, nat. size.

3. *Nerinæa fusiformis*, D'Orb.; 3*a*. Fragment showing the mouth: Coral Rag, Brompton, Yorkshire: nat. size.

4. *Natica marchamensis*, Bl. & H., Marcham, near Oxford, nat. size.

5. *Natica felina*, Bl. & H., Lower Calcareous Grit, Catcombe, Wiltshire, nat. size.

6. Operculum of a *Neritopsis*, Coral Rag, Upware, nat. size.

7. *Tancredia disputata*, Bl. & H., Osmington Oolite, nat. size.

8. *Lucina aspera*, Buv., Upper Calcareous Grit, Yorkshire, nat. size.

9, 9 *a*. *Lucina oculus*, Bl. & H., Coralline Oolite, Yorkshire, nat. size.

10, 10 *a*. *Astarte subdepressa*, Bl. & H., Coral Rag, Wiltshire, nat. size.

11. *Astarte aytonensis*, Lycett, Ayton, Yorkshire, nat. size.

12. *Protocardium isocardioides*, Bl. & H., *Trigonia*-beds, Osmington, nat. size.

13. *Avicula ovalis*, Phill., var. *obliqua*, Upper Calcareous Grit, Pickering, enlarged.

Plate XV.

Fig. 1, 1 *a*. *Cyprina tancrediformis*, Bl. & H., Nothe Grits, Weymouth, nat. size.

2. *Cypricardia glabra*, Bl. & H., *Trigonia*-beds, Osmington; 2 *a*. the interior of another valve, *Trigonia*-beds, Pickering: both nat. size.

3. *Astarte Duboisiana*, D'Orb., Coralline Oolite, Seamer, nat. size.

4, 4 *a*. *Pecten qualicosta*, Etall., right and left valves, Osmington Oolite, nat. size.

5, 5 *a*. *Gastrochæna carinata*, Bl. & H., North Dorset limestone, enlarged.

6. *Arca lanthanon*, Bl. & H., Coral Rag, Slingsby, Yorkshire, nat. size.

7. *Arca anomala*, Bl. & H., Coral Rag, Upware, nat. size.

8, 8 *a*. *Mytilus varians*, Röm., Coralline of North Dorset, nat. size.

9. *Pecten intertextus*, Röm., Coralline Oolite, Settrington, nat. size.

10. *Glyphea ferruginea*, Bl. & H., Abbotsbury ironstone; carapace, nat. size.

PLATE XVI.

Fig. 1. Fragment of unknown Crustacean, enlarged. Coral Rag, Upware.
2. *Avicula lævis*, Bl. & H., Hambleton Oolite, Kepwick, Yorkshire, nat. size.
3. *Avicula Struckmanni*, De Lor., *Trigonia*-beds, Osmington, nat. size.
4. *Avicula pteropernoides*, Bl. & H., Lower Limestones, Thornton, Yorkshire, nat. size.
5. *Modiola cancellata*, Röm., Upper Calcareous Grit, Nunnington, Yorkshire, nat. size.
6. *Avicula pteropernoides*, Bl. & H., *Trigonia*-beds, Abbotsbury, nat. size.
7. *Gryphæa subgibbosa*, Bl. & H., Cement Stone, North Grimston, Yorkshire, half nat. size.

PLATE XVII.

Cone of *Araucarites Hudlestoni*, Carruthers, from the Coralline Oolite of Malton, Yorkshire.

Fig. 1. Basal portion of the cone, nat. size.
2. Longitudinal section of the cone, nat. size.
3. Detached scales, in part broken, showing seeds, nat. size.

DISCUSSION.

Mr. ETHERIDGE spoke in high terms of the merits of the paper, with the opinions expressed in which he fully agreed. It required immense experience and careful study to correlate the various beds, which presented great palæontological and petrological differences.

Prof. SEELEY said that he studied the Coral Rag in 1860–1866, during which period he went all over the south-western and part of the north-eastern region, in company with the late Prof. Sedgwick, and had the advantage of discussing the various sections with that distinguished geologist. He could not help being struck with the heterodox character of the present paper, and contrasted the complexity of its classification with the simplicity of Sedgwick's ideas of the deposits referred to. He grouped the subordinate beds together as unimportant divisions of the three grand series—the Lower Calcareous Grit, Coral Rag, and Upper Calcareous Grit. In the authors' classification the term Coral Rag was restricted in its application, and the Upper Calcareous Grit had disappeared from the southern portion of the section. Sedgwick regarded the Weymouth section as the most typical in all England ; and in going north these beds were traceable as far as Oxford. In Central England, from Oxford to Yorkshire, there was a series of clays most varied and instructive, showing the reverse of much of the Coral-Rag area—namely, thin limestones and thick clays. The Ampthill Clay, as this series had been called, showed the fossils of the Coral Rag, but in a certain way comprising Oxford and Kimmeridge Clay fossils. The French geologists are in doubt as to what the Coral Rag is : in the Boulonnais the Kimmeridge Clay and Oxford Clay are greatly modified in mineral character ; and no correlation by fossils is as yet possible. Prof. Seeley stated that M. Rigaux is anxiously looking forward to the publication of this paper in the hope that it will aid in correlating the French series. He remarked that in England the subdivisions of the

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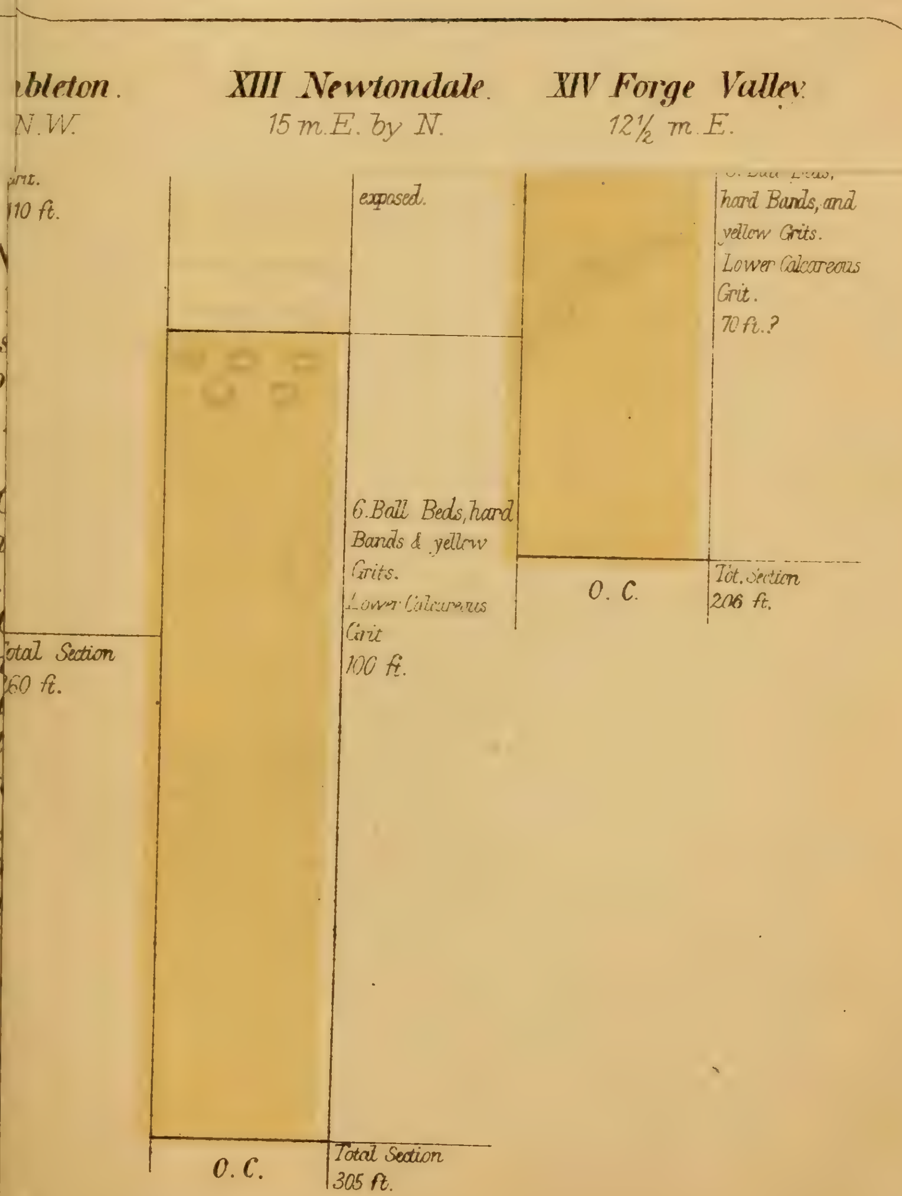
Berkshire Basin.



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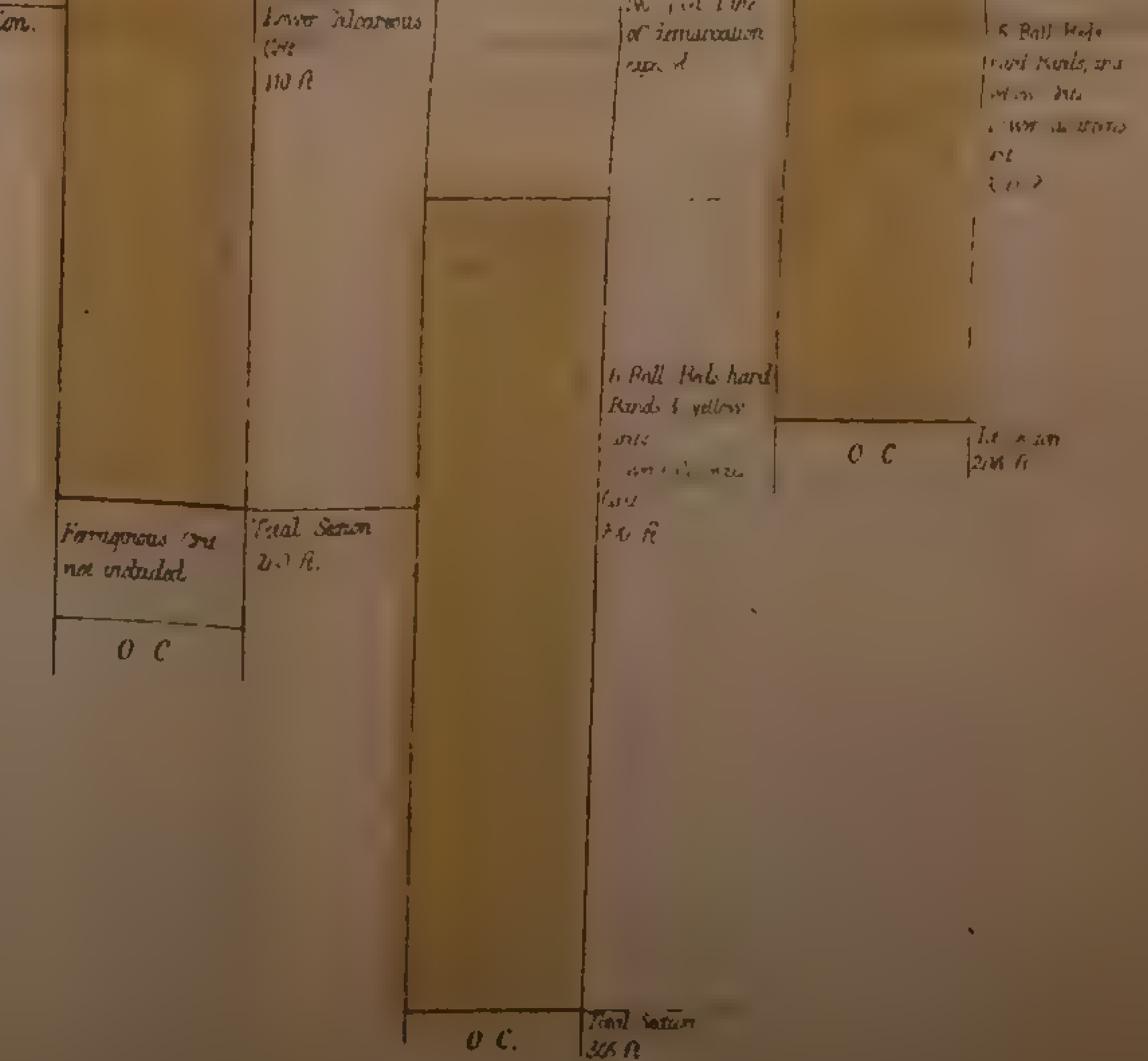
CORALLIAN ROCKS OF ENGLAND.

Table of Comparative Sections by the Rev. J. F. Blake, M.A. F.G.S., and W. H. Hudleston Esq. M.A. F.G.S.



Explanatory Notes.—*These sections, with the exception of No. 7, give the full development of each bed along a surface line varying from a few hundred yards to a distance, in the case of No. 12, of eight miles. As most of the Corallian beds, taken on a large scale, are wedge-shaped, the real thickness of each bed varies materially according to the point selected. Thus in the case of No. 7—Section at Highworth—the entire series shrinks, within a moderate distance in a southerly direction, to about 30 ft. with a complete extinction of some beds, and an increase of others.*

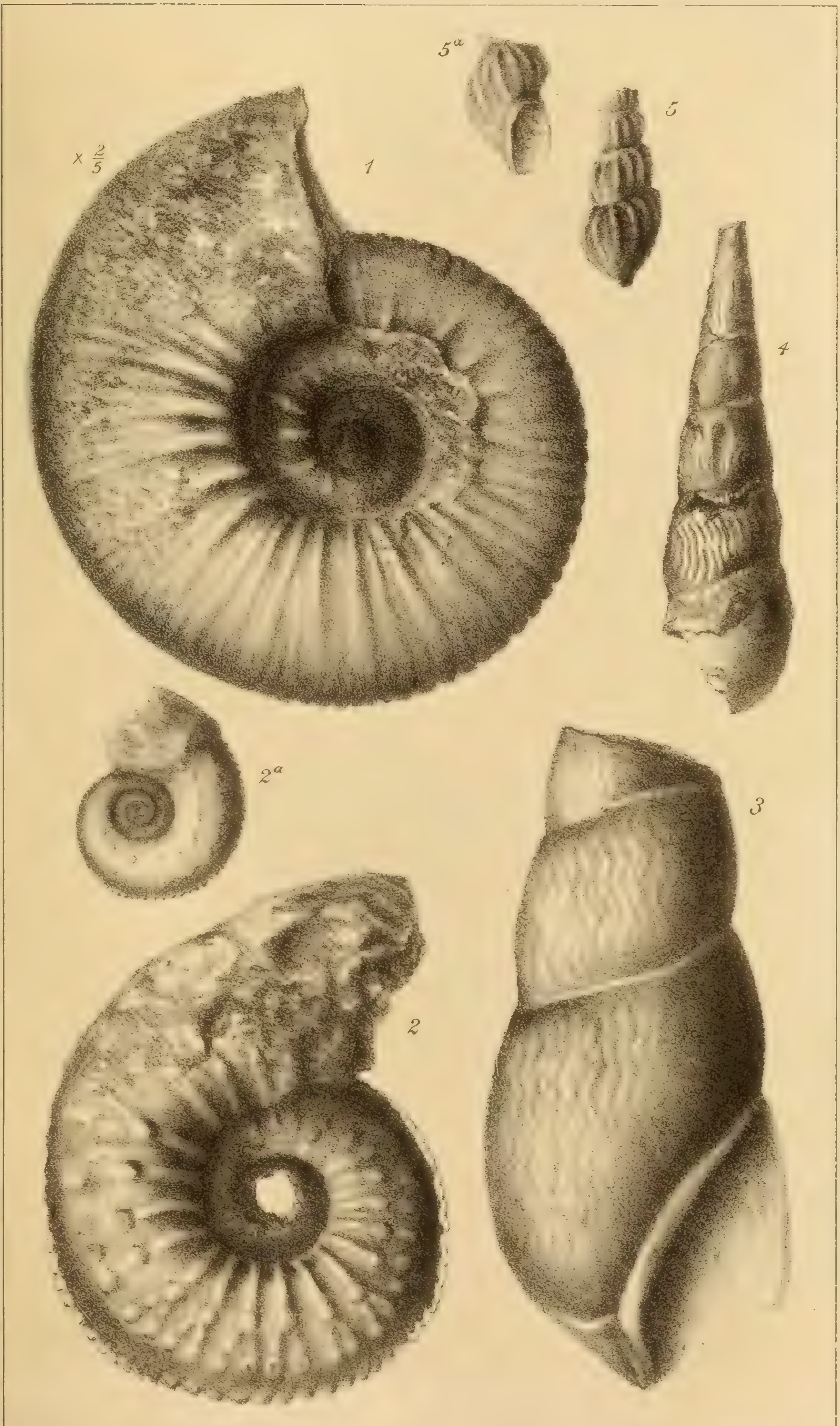
The arrangement adopted brings the top of the chief limestone series of each section upon the same level throughout, and thus enables an estimate to be formed at once, both of the relative volume of the limestones in each, and also of the respective development of the Upper and Lower Groups.

The Upper Group is usually a reddish calcareous grit with variable clays: it includes certain oolitic iron ores. This ferruginous character may be noted in those parts of the Berks-Oxfordshire Range not shown in the sections. it also partly obtains in Yorkshire, where it includes THE UPPER CALCAREOUS GRIT.

The Middle Group comprises the FLORIGEMMA-RAG, *where that rock is developed, and the various limestones which represent or underlie it—sometimes in a double series. It includes* THE CORAL RAG AND CORALLINE OOLITES.

The Lower Group consists, in the South, of yellow grits and clays; in the West Midland, to a large extent, of loosish sand; whilst in Yorkshire it is represented by a great thickness of solid stone. It includes THE LOWER CALCAREOUS GRIT.

Notes on the Separate Sections.—I. is a vertical rendering of the coast section between the points named, a distance of 1½ m.: it represents the development of the series on the south side of the Weymouth anticlinal. II. is a generalized section of the cliff on the opposite side of Weymouth Bay, 3½ m. N.E. of Nothe Point, and on the north side of the Weymouth anticlinal. III. Abbotsbury, also on the north side of the anticlinal, is 10 m. W. by N. of Osmington Mill in the direction of the strike: the section is partly composed from the exposures on Linton Hill (see Fig. 1). IV. is drawn principally from the section in the railway cutting: in the northern portion of the district the Lower Group is better exposed. V. is drawn from exposures in or near the Ironstone workings, and, from information contributed by the manager. The iron ore is only 2 ft. thick at a boring between the workings and the town. VI. is a vertical rendering of the section from Conygre quarry to the east side of Calne, distance 1½ m.: the Lower Group has probably more importance in Bowood Park. No. 2 is not well exposed. Between this line and Wootton Bassett a thin representative of the Upper Group is occasionally seen. VII. is a vertical section. No good exposure of No. 6. VIII. No Upper Group in this locality: the Middle or Limestone Group is inconstant. IX. About 20 ft. of beds are proved in the south pit. X. is a vertical rendering of the surface section from N. Grimston to Burdale, length 1100 yards (see Fig. 22). The sequence of 2, 3, 4 and 5 is proved upon the escarpment; that of 1 and 2 on the dip slope. XI. is, to a certain extent, constructive: the sequence of 1, 2 and 3 is proved on the east side of Malton; that of 5 and 6 on the west side; the exact relation of No. 4 to the Upper and Lower Groups is not quite clear. XII. is a vertical rendering of the surface section across the Hambleton massive, length 8 m. (see Fig. 16); 4 and 5 vary greatly within short distances; the thickness of 5 is a presumed average along the actual line of section; northwards it is 50 ft. thick, and southwards it has thinned out. XIII. gives the development of the series as shown in a transverse valley about the centre of the Tabular Chain: the lower part of 1 includes the "Throstler," here only 4 ft. thick. XIV. Another transverse valley, 5 m. from the coast the Middle Calcareous Grit is perhaps about 8 ft. thick here; it is included in No. 3.



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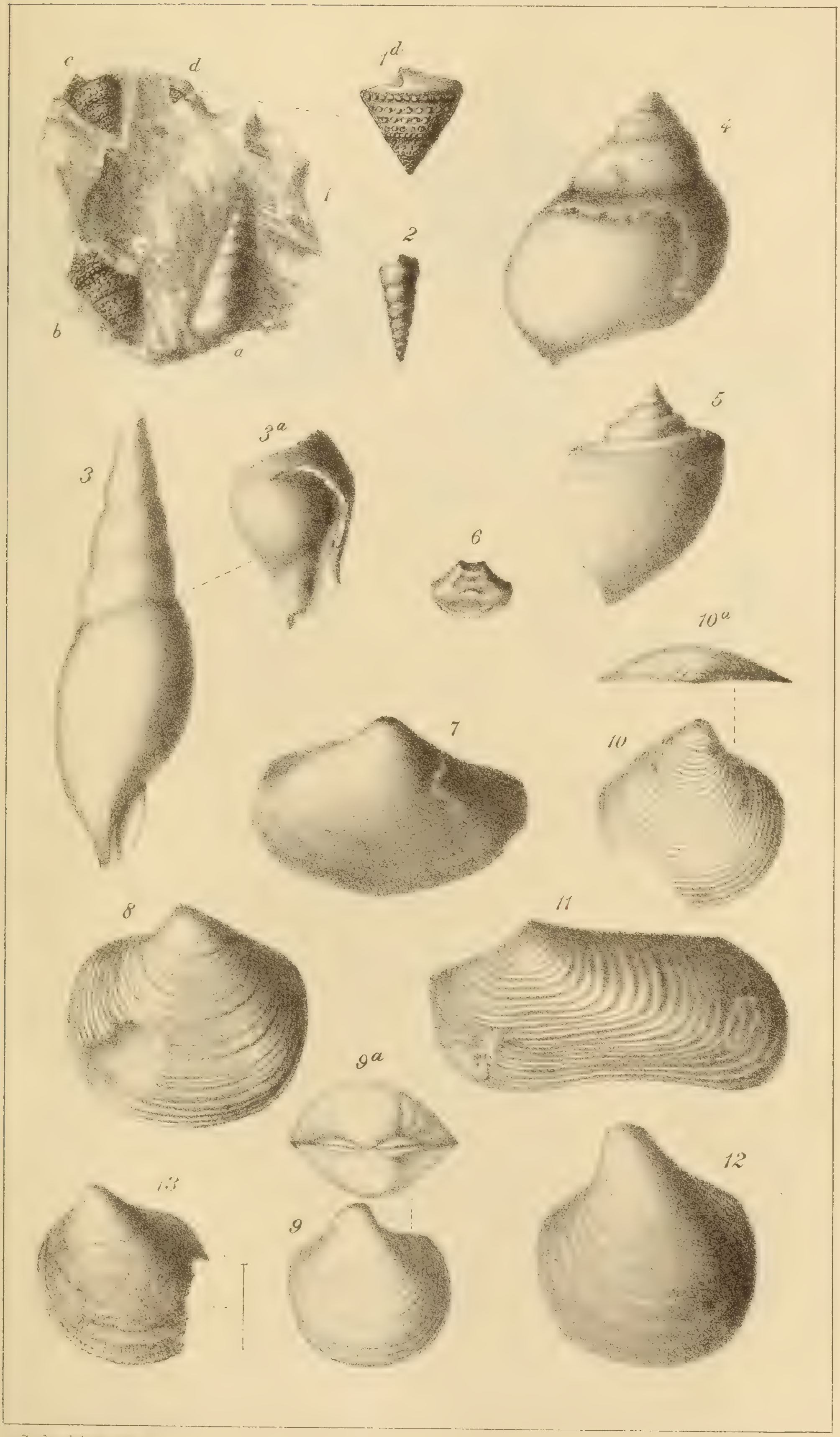

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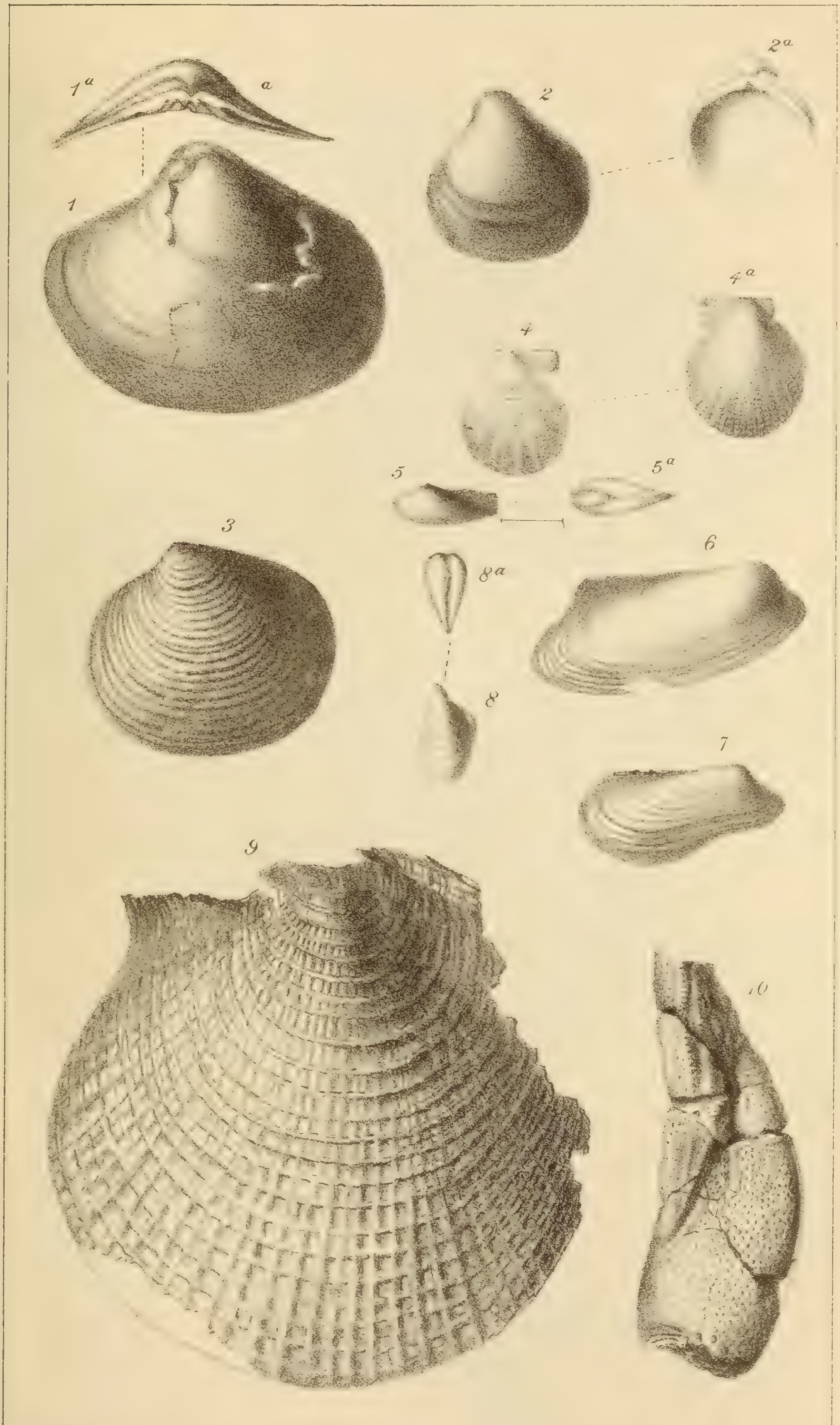

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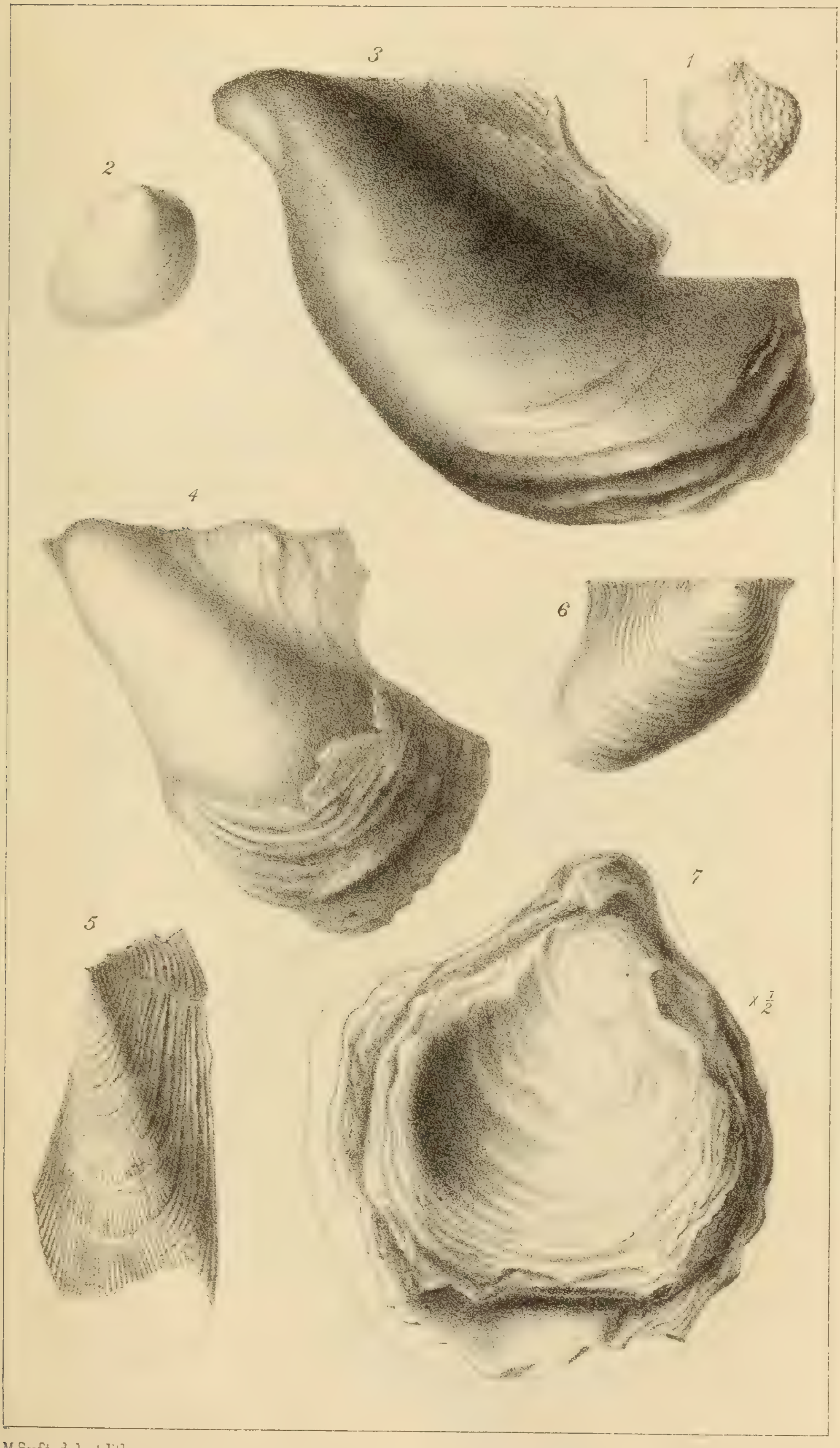

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CORALLIAN FOSSILS

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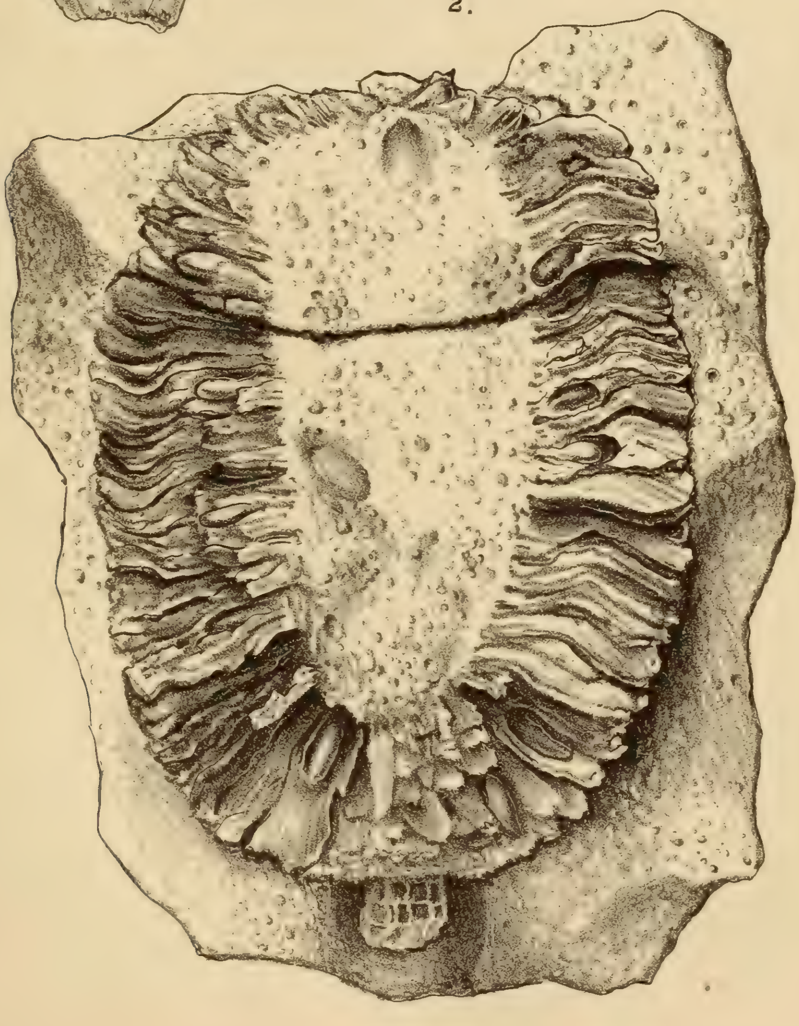
2.



D. Blair lith.

Mintern Bros. imp.

ARAUCARITES HUDLESTONI.

Corallian are very variable, showing frequent fossil and mineral changes; but in France we have a physical basis defined by well-marked fossils capable of being traced on the one hand into Yorkshire, and on the other hand into Dorsetshire, and thus furnishing a means of correlating the two English areas.

Prof. MORRIS spoke of the high value of the paper, as the first complete treatise on the Corallian of England, and pointing out so clearly the great difference in the conditions of deposition of the formation in the northern and southern areas, and the mingling of conditions in the central area. He pointed out that the so-called Corallian occupied different zones in different localities on the Continent, stretching, in fact, from the Oxfordian to the Portlandian inclusive. Oppel regarded the Corallian as part of the Oxford group, and the Supracorallian of the authors as a part of the Kimmeridgian.

The PRESIDENT remarked that the conditions under which the deposits had been formed were evidently those of a shallow sea.

The AUTHORS, in reply, said that they had intentionally omitted all references to continental deposits while our own beds were so imperfectly known. They had considered that the term Coral Rag should be restricted to certain beds which are actually such; and they had correlated southern English beds with Phillips's Yorkshire Calcareous Grit, but had thought it desirable to give them distinct names. Their intention in the paper was simply to give a thorough description of the rocks between the Oxford and Kimmeridge Clays, wherever these might be.

19. *On the* Intrusive Character *of the* Whin Sill *of* Northumberland.

By W. Topley, Esq., F.G.S., Assoc. Inst. C.E., Geological Survey of England and Wales, and G. A. Lebour, Esq., F.G.S., Lecturer in Geological Surveying at the University-of-Durham College of Physical Science, Newcastle-on-Tyne. (Read December 6, 1876.)

(Communicated to the Society by permission of the Director-General of the Geological Survey.)

[Plate XVIII.]

Contents.

1. *Introduction.*—The basaltic rocks of the north of England occur in two forms—as *sheets* lying amongst the sedimentary strata, and as *dykes* cutting through them. The intrusive character of the latter is, of course, undisputed; but there is much uncertainty in the minds of many geologists as to the character of the former.

In this paper we purpose to show, from the detailed work of the Geological Survey, that in Northumberland there can be no doubt whatever as to the intrusive nature of the bed or beds of basalt known as the Whin Sill. This conclusion can be established both by the evidence of individual sections and by the line of outcrop of the trap.

The question of the nature of the Whin Sill is of importance in three ways:—1st, as a point of theoretical geology, bearing upon the history of volcanic action in Britain; 2nd, in reference to the classification of the Carboniferous System; 3rd, in its bearing upon practical mining.

The Whin Sill is best known in Teesdale, especially in the two fine waterfalls of High Force and Cauldron Snout. It also appears along the face of the Penine escarpment, and is beautifully exposed in the "Nicks" which furrow the face of that range. Although this district is known to us, we will not stay to describe it, because it has already much engaged the attention of geologists, especially Professors Sedgwick and Phillips. It is generally supposed that there is but little evidence of intrusion there; but this is not the case; the evidence is plain if one only looks for it, and it was sufficient to satisfy so close an observer and so clear a reasoner as Professor Sedgwick.

One of the finest sections along the Penine escarpment is that at

High-Cup Nick, about 4 miles east of Appleby. Here the Whin Sill (75 feet thick), and the beds above and below it, are beautifully exposed. The roof and floor of the basaltic sheet consist of shale, both equally baked and altered for several feet from the line of contact with the Whin.

As regards this escarpment, the continuous interbedding of the Whin has been simply assumed; the evidence, when carefully examined, tells the other way. Mr. J. G. Goodchild, F.G.S., of the Geological Survey, has proved that the trap is certainly intrusive here. In a letter to us (dated Jan. 27, 1876) he says that at Renwick the Whin "is found at from 250 to 300 feet below the Four-fathom Limestone. In another part it comes immediately below the Scar Limestone; and as one follows the outcrop [southwards] towards Brough, it is found at successively lower horizons, until near Roman Fell it lies on the top of the Melmerby-Scar Limestone. In other words, between Renwick and Brough [19 miles] the Whin Sill cuts through about 600 feet of the Carboniferous Limestone Series."

Mr. C. T. Clough, of the Geological Survey, has recently shown that even at the typical section of High Force itself the Whin can be shown to be intrusive; and he adds:—"I have very little doubt that the more the country is worked over, the more and more evident will the intrusive character of the Whin Sill become*.

It may be well to mention that the term *Whin* is rather loosely used in the north of England. Basalt is so termed; but the word is also applied to the Porphyrite of the Cheviots and to any unusually hard quartzose sandstone. The hard sandstone is sometimes spoken of as "white" or "grey" whin, whilst the Basalt is called "blue whin." The hard cherty sandstone which occurs in the Lower Greensand of West Sussex is called Whinstone; and the term "whin" is applied to hard sandstone in the South-Wales Coal-field. In Leicestershire it is applied to the remarkable bed of trap which occurs at the south-eastern part of the Coal-field, and also to hard sandstone or chert.

In the lead-mining districts of the north of England the various beds are called "Sills." As the miners have always regarded the basalt as a true bed, it has been called the "Whin Sill." It is also sometimes called the "Great Whin Sill," to distinguish it from the "Little Whin Sill" of Weardale. We believe both of them to be branches of the same intrusive sheet.

2. *The Carboniferous-Limestone Series of Northumberland.*—In order that the following details may be understood, it is desirable to give some account of the succession of beds below the Millstone Grit in Northumberland. It is customary to retain for the north of England the old-established divisions of Coal Measures, Millstone Grit and Carboniferous Limestone. These names were first given in the south-west of England, where well-defined divisions corresponding to them exist. But if the Carboniferous Series had been first

* Quart. Journ. Geol. Soc. vol. xxxii. p. 471, 1876.

studied in Scotland or Northumberland, it is very doubtful whether such divisions would ever have been made in those areas; thick beds of sandstone (often coarse and pebbly), and bands of shale, extend right through the series. In the higher part (the Coal Measures) there are good seams of coal; in the lower part (the Limestone Series) there are bands of limestone and seams of coal; in the middle part (the Millstone Grit) there is no limestone, and rarely any coal.

The term "Yoredale Rocks" was introduced by Professor Phillips to designate a series of beds lying between the "Main" or "Great Limestone," and the "Tyne-Bottom Limestone," succeeded below by the "Scar-Limestone Series." The typical section is that in Upper Wensleydale. The Millstone Grit of this author included all beds between the Great Limestone and the Coal Measures, whether they contained limestones with marine fossils or not. They do include such limestones even in North Yorkshire; in Northumberland there are from three to six well-marked limestones within this distance.

The Whin Sill of Teesdale, Alston, &c. lies just below the Tyne-Bottom Limestone, or is always supposed to do so. If this band of trap occupied a constant horizon, it might serve as a convenient boundary, though it would not necessarily be a natural one. It has generally been assumed that such is the case; and the base of the Yoredales has been drawn accordingly in geological maps.

One important result of recognizing the intrusive character and varying position of the Whin Sill is this, that it is no longer to be relied upon as a boundary*. Not only does it shift about, in places lower, more often higher than the supposed base-line, but it sometimes lies above the Great Limestone itself; that is to say, the bed of trap which is supposed to mark the base of the Yoredale Series sometimes lies above the limestone which forms the top of that series. It is very doubtful whether the so-called "Tyne-Bottom Limestone" of the miners is always the same bed; and certainly this limestone cannot be traced northwards through Northumberland. As in this country there is no definite base for the Yoredales, so there is no reason, supplied by the characters of the rocks, for drawing a line here at all. Professor Phillips himself saw this difficulty; for he says:—"In this progressive change of character to the northward, we lose by degrees the distinction of lower scar limestone; and it becomes not only difficult to draw the line for its upper boundary, but doubtful whether it is proper to make such an attempt. In the northern parts of Northumberland it appears

* For a further discussion of this question see G. A. Lebour "On the Limits of the Yoredale Series in the North of England," Geol. Mag. Dec. 2, vol. ii. p. 539, 1875. In this paper the term "Bernician Series" is proposed for the beds lying between the Millstone Grit and the Tuedian Beds or Calciferous Sandstones (the "Valentian Series" of Prof. A. Geikie, MS.). Subsequently to the publication of this paper it was found that the term "Bernician" had been proposed as a division of the Carboniferous Limestone by Dr. S. P. Woodward in 1856; it was adopted by Dr. Karl Mayer in 1874. (See G. A. Lebour, Geol. Mag., Dec. 2, vol. iii. p. 19.)

neither desirable nor possible to separate the lower from the similar middle and upper calcareo-carboniferous groups" *.

In the maps of the Geological Survey, as yet published, all the beds in Northumberland and Durham, below the Millstone Grit, are grouped as the "Carboniferous-Limestone Series." This includes the Yoredales of Phillips and also his Scar-Limestone Series. The lower beds (the Tuedian of Tate, or Calciferous Sandstone of Maclaren and the Geological Survey of Scotland) are not yet surveyed, and it is as yet uncertain where (in Northumberland) the line must be drawn. The Whin Sill is wholly comprised within the Carboniferous-Limestone (Bernician) Series of Northumberland and Durham; it never approaches beds which any one could suppose to be Tuedian.

3. *Bibliography.*—The Basaltic rocks of the north of England are frequently mentioned by the older geological writers on the district; but the question as to whether the Whin Sill is intrusive or contemporaneous does not seem then to have arisen. The Whin is described as "interstratified" and as occurring in "overlying masses," the latter term apparently referring to areas where the Whin has been exposed by denudation, although the exact sense in which it was used cannot always be determined.

The earliest paper claiming special notice here is one by Mr. (now Sir Walter) Trevelyan, published in 1823 †. A careful account is there given of the geology of part of the northern coasts of Northumberland; a map and section accompany the paper, showing how unevenly and irregularly the Basalt lies amongst the strata in that district. The limestone lying *upon* the Whinstone is described as being very crystalline towards and at the point of contact.

Professor Sedgwick printed in the Cambridge Transactions ‡ two valuable papers upon the Trap rocks of Durham. He showed from a consideration of the Teesdale district, in which the position of the Whin Sill is most constant, that there is abundant evidence of intrusion, the beds below being frequently broken and partially enclosed within the Whin, whilst the beds above are sometimes metamorphosed, this metamorphism of the upper beds being most apparent when the Whin is thickest.

Mr. W. Hutton is the only writer who has described in any detail the general range of the Whin Sill of Northumberland §. He regarded it as strictly contemporaneous; and where two or more distinct beds of Whin are known in one district, he supposed that there had been successive eruptions over the ocean-floor. A paper, probably the same, was read before this Society by Hutton, but was published only in abstract ||. In this abstract the anthor is repre-

* Geol. of Yorkshire, Mountain-Limestone District, p. 35, 1836.

† Mem. Wernerian Soc. vol. iv. part ii. p. 253. In the following vol. (p. 475, 1826) Mr. Witham describes the basaltic rocks of the north of England, but without throwing any further light on this question.

‡ Vol. ii. pp. 21 and 139, 1827.

§ Trans. Nat.-Hist. Soc. Northumberland &c. vol. ii. p. 187, 1832. (Read Dec. 19, 1831.)

|| Proc. Geol. Soc. vol. i. p. 341, 1832. (Read Dec. 14, 1831, and Jan. 4, 1832.)

sented as accepting Sedgwick's conclusions as to the intrusive character of the Whin Sill in Teesdale; but this must be an error *.

Professor Phillips, giving most weight to the conformable nature of the beds in Teesdale and along the Penine escarpment, considered the Whin Sill to be of contemporaneous date; and he accounted for the altered nature of the overlying beds by supposing that the heat from such thick masses of lava had not time to escape before these beds were deposited. He admits some eruptive force, but apparently only so far as to allow of the Whin reaching the sea-bottom, over which he supposes it to have flowed †.

The late Mr. G. Tate published several papers on the Geology of Northumberland, particularly on the northern part of the county. Frequent mention is made of the Whin Sill, and illustrations of its intrusive character are given. These papers‡ were published in the Transactions of local societies, or in books relating to Northumberland. Had they been published in works generally accessible to geologists, the question in dispute would probably have been settled years ago.

Of other geologists who, from personal knowledge, admit the intrusive nature of the Whin Sill we may name Mr. Howse, Mr. Kirkby, and the whole of the officers of the Geological Survey to whom the district is known §.

Amongst those who, in published papers, regard it as interbedded and contemporaneous are Professor H. A. Nicholson, Mr. Bewick, Mr. J. A. Knipe, and Mr. N. Wood ||.

The intrusive nature of the Whin Sill is shown on the Maps and Sections of the Geological Survey ¶. In the year 1873 we laid

* The paper read at Newcastle is published in full, and it received additions and corrections by the author before publication. This, therefore, certainly represents Hutton's views correctly; and here he dissents entirely from Sedgwick's conclusions.

† Geology of Yorkshire, part ii. p. 85, 1836. At the Bradford meeting of the British Association, when some of the facts hereafter mentioned were laid before the Geological Section, Professor Phillips admitted that we had proved the intrusive nature of the Whin Sill for the districts described.

‡ The most important paper is that "On the Basaltic Rocks of Northumberland," Proc. Berw. Nat. Club, vol. vi. p. 197. See also papers in vol. iii. pp. 99, 233; Tate's History of Alnwick, vol. ii. p. 461, 1869; and other works.

§ Mr. W. Boyd (Trans. N. Engl. Inst. Eng. vol. ix. p. 185, 1861) described the Whin Sill of the northern part of Northumberland as contemporaneous. He now believes it to be intrusive; Mr. Hedley is also of this opinion.

|| In the paper, as laid before the Society, full reference to all publications on the subject were given. In the discussion which followed the reading of this paper, Mr. W. W. Smyth stated that Mr. Blackwell regarded the Whin Sill as intrusive. We have been unable to find any published opinion by him on the subject.

¶ Sheet 105 N.W. was published in 1871; this map (by the authors of this paper) includes the Whinstone area near Kirkwhelpington. Several sheets of the six-inch map of Northumberland, including parts of the Whin Sill, are published. Sheet 108 of the Horizontal Sections, by Mr. H. H. Howell, was published in 1875; in this the Whin Sill of Great Swinburne is marked as an intrusive sheet.

before the British Association a brief outline of the facts now to be detailed*.

Whilst geologists generally are divided in opinion as to the nature of the Whin Sill, those who are also practical miners are almost unanimous in regarding it as contemporaneous. Doubtless this arises from the fact that in the districts which have been most explored by mining the Whin happens to lie with greatest regularity. But frequently this constancy is assumed without proof; and it is often thought to be proved by reasoning in a circle. The so-called "Little Whin Sill" of Weardale is a case in point. This was always considered to be the "Great Whin Sill;" and therefore the limestone lying on it was called the "Tyne-Bottom Limestone." A miner would have said:—"This is the Tyne-Bottom Limestone; and therefore the Whin is in the usual place." Sir Walter Trevelyan, however, long ago proved this to be mistake, and that the Whin of Weardale lies much higher in the series than the Whin of Alston and Teesdale†.

4. *Stratigraphical Relations of the Whin Sill.*—We have thought it better to select some of the more striking sections which illustrate our views as to the intrusive character of the Whin Sill, than to describe one by one all the sections on which they are based. It must therefore be clearly understood that the evidence here offered represents by no means all that it is in our power to bring forward, but consists of what appears to us to be of sufficient weight to prove our case.

The portion of the Whin Sill to which the accompanying sections (Pl. XVIII.) refer is that which lies between Haltwhistle and Dunstanborough, within which limits it forms an intermittent line of outcrops some 80 miles in length.

In order to give a key to the relative positions of the horizons with which we have to deal, a diagram, to scale, is annexed. To this is added part of Westgarth Forster's well-known "Section of the Strata" in the Alston-Moor district. This section (from the Tyne-Bottom Limestone upwards), it will be seen, does not hold perfectly good throughout the district under our notice, chiefly owing to a considerable increase in thickness in the series in Mid Northumberland.

On entering the county the Whin is for a space lying above the "Great" Limestone, some 700 or 800 feet above its Alston horizon, but returns to its usual Penine position before long, near to which, with fluctuations above and below within about 300 feet, it keeps running at first in an easterly direction, and taking, on nearing the North Tyne, the north-easterly bend to which all the beds of the district are subject. At Low Teppermoor it is seen at about its lowest horizon; and here a short surface break is very well shown. Thence it continues to the N.E. pretty much along the same horizon till it reaches Swinburne Mill, where another surface break occurs accompanied by a rise of a few feet to the next higher bed of lime-

* Brit. Assoc. Rep. for 1873, Trans. Sec. p. 92.

† Trans. Nat.-Hist. Soc. Northumberland &c. vol. i. p. 58, 1831.

stone. From this point the Whin Sill trends almost due north in a fine line of semi-columnar crags as far as Knowes Gate, where it crosses the Wansbeck-Valley Railway. This portion of its course is twice interrupted by surface breaks unattended by change of horizon, at Sweethope and at the Berry Hills. At Knowes Gate this long basaltic range terminates abruptly, reappearing at intervals through a drift-covered country. Parallel to this great ridge, however, and not quite a mile to the east of it (three beds of limestone, with their associated sandstones and shales intervening), is another equally thick (and in places even thicker) but much less regular Whin Sill, which we will call the Eastern Branch, and which runs from Homilton, near Bavington, to Elf Hills, to the N.E. of Kirkwhelpington (see fig. 1). This eastern basaltic sheet is much more subject to breaks than the western one, and towards its northern extremity comes to the surface usually not as a continuous bed, but in bosses or isolated masses of greater or less size.

At Elf-Hills Quarry, where the Four-fathom, or *Saccammina*-Limestone* was until lately wrought, the Whin overlies and breaks through the limestone. But a more interesting case of intrusion was observed by Sir W. Trevelyan a few years back, which is illustrated by fig. 2, from a sketch by us, taken at the time: a thin layer of fine-grained Whin underlies the limestone and sends up strings of trap through the overlying beds.

To the north of Elf Hills there is a broad flat tract of drift-covered land, beyond which the Whin is again seen (at Hartington and Gallow Hill) lying in the same position as the main bed at Elf Hills, between the Great and Four-fathom Limestones. Again there is a broad drift-covered valley, beyond which the Whin is seen at Dike Head. It here seems to come up as a great boss, and lies lower in the series than at Elf Hills. A borehole put down on the south of Greenleighton Farm found the Whin just below the Six-yard Limestone (=Three-yard Limestone of Teesdale).

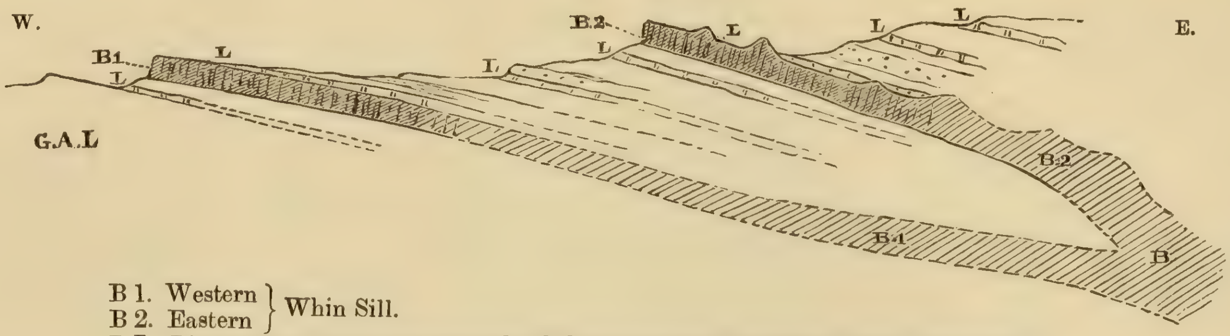
In Fallowlees Burn the Whin lies about 100 feet below the position last mentioned. From this place it can be traced for about a mile to the north, apparently keeping at the same horizon.

At Wards Hill (fig. 3) the Whin lies *above* the Great Limestone. A little below the Great Limestone there is a seam of coal which has been a good deal worked over the north-eastern part of the hill. At one pit the coal was followed for some distance under the Whin, where it was found to be gradually deteriorating and at last was quite caked and worthless. The Whin has then evidently cut through the limestone and has here reached the coal. This is also evident from the surface-mapping; for on the south-east face of the hill the limestone occurs above the Whin, and on the south-west the Whin certainly cuts through the beds, passing through the Great Limestone and the beds below, and at last underlying the coal, which lies about 40 or 50 feet below the Great Limestone.

The Whin is not seen again until we reach the hill N. of Shield-

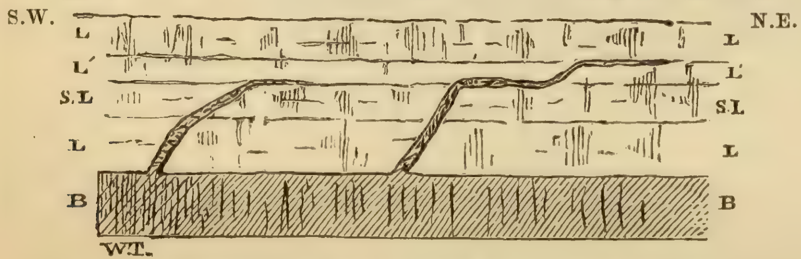
* Through Northumberland, as far north as the river Aln, *Saccamina Carteri*, Brady, appears to occur chiefly in the Four-fathom Limestone.

Fig. 1.—*Sketch Section across both branches of the Whin Sill, showing their probable mode of connexion near Great Bavington* (about 2 miles).



B 1. Western } Whin Sill.
B 2. Eastern }
L L. Limestone of the Northumberland Carboniferous-Limestone Series (Bernician).

Fig. 2.—*Sketch in Elf-Hills Quarry* (1st August, 1871).



B. Branch of Whin Sill, 3 to 4 ft. thick (exposed at intervals), sending strings of basalt into the Limestone.
L′. Bed of impure limestone. L. Good Limestone.
S L. *Saccammina*-beds.

Fig. 3.—*Sketch Section through Ward's Hill.*

B. Whin Sill.
L. Great Limestone.

Dykes Farm, about 4½ miles south of Alnwick. Hence it can be traced northwards, past Rugley, nearly to Alnwick, lying about 100 feet, or rather more, above the Hobberlaw Limestone, which is the lowest good and thick limestone of the series in that district. Here, too, the Whin has its lowest known position, as it lies nearly 1000 feet below the Great Limestone. The beds immediately above the Whin are seen in a stream south-east of St. Margaret's Farm, where they are much altered.

Here we approach the country so well known to the late Mr. G. Tate. The evidences of intrusion here are so abundant, and the Whin has been so well described by Mr. Tate, that we need not repeat the evidence in detail. From Ratcheugh northwards to Dunstanborough the Whin lies in beds and bosses at various horizons, but chiefly about the Great, Eight-yard, and Six-yard Limestones.

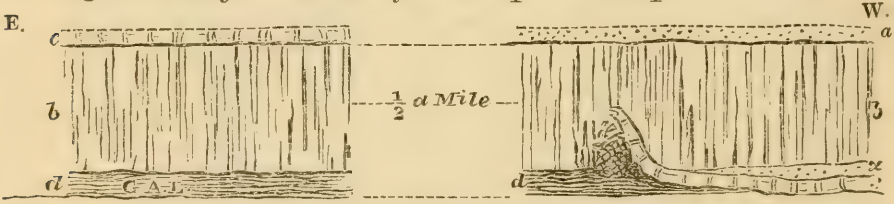
At first one is disposed to believe that the Whin here lies more irregularly than really is the case. But there are a great number of faults separating the beds. Still there can be no question as to the fact that the Whin breaks through the beds, and also that it alters the rocks above it quite as much as it alters those below.

The northern part of the county has been described by Sir W. C. Trevelyan in the early paper already referred to. In Mr. Boyd's paper many stratigraphical details are given, from which it appears that the Whin west of Holy Island lies some 800 feet above the Great Limestone, quite in the top beds of the Carboniferous-Limestone series. In this district the Woodend Limestone (or the Hobberlaw Limestone) lies about 1000 feet below the Great Limestone.

Now, on the south of Alnwick, near Rugley, the Whin lies about 100 feet above the Hobberlaw Limestone; so that comparing the two districts, we find that the Whin lies about 1700 feet higher in the series near Holy Island than it does just south of Alnwick.

At very numerous places along the outcrop of the Whin Sill minor but equally good evidence of its non-contemporaneity is forthcoming. Among these the section at Shepherd's Gap (fig. 4) along

Fig. 4.—*Diagram Section from Shepherd's Gap eastwards.*



a. Sandstone. *b.* Whin. *c.* Limestone. *d.* Shale.

The Limestone seen lying upon the Whin in the eastern portion of the Section is the same as the one shown lying beneath it in the western portion, and being thrust into it. The beds lying above the Whin Sill are seen on the dip-slope of the basaltic sheet at a lower level than the top of the escarpment; it has therefore been necessary to bring them out of their proper plane in order to show them in the sketch. Although the upturned limestone is very clearly shown in the face of the Crag, yet the disturbed beds associated with it are not easily seen. This rearing limestone is all that Hutton shows.

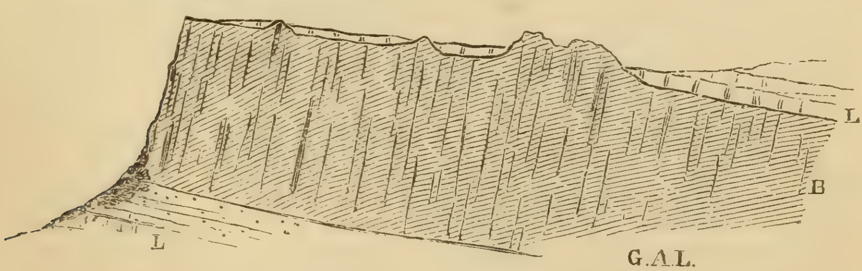
the escarpment of basalt, on the summit of which is built the Great Roman Wall, deserves special mention, first, as being an almost unique example of its kind, and, secondly, because, oddly enough, it has been (very inaccurately, it is true) figured by Hutton in the very paper in which he proved to his satisfaction the contemporaneity of the Whin.

A bed of limestone with an accompanying shale, which has for some distance from the west run regularly below the basalt and parallel to it, is here suddenly forced upwards almost vertically into the Whin, by which it is baked and altered in a very evident manner. Now where this limestone underlies the Whin Sill the latter is capped by sandstone; but immediately after the disturbance just described the limestone and shale are seen overlying the Whin in place of the sandstone, the outcrop of which, however, is in nowise disturbed by the occurrence, and can easily be traced running still parallel to but further above the trap-sheet.

This is merely a case of the Whin Sill being seen actually in the act (*flagrante delicto*) of shifting its horizon; but it has this further interest, that it proves that *at this point* the molten mass was forcing itself from east to west, the change having necessarily been from a lower to a higher horizon. This may have been but a local direction due to the mass having to circumvent obstacles in its progress, or to some other cause; but there are some reasons (*e. g.* the bifurcation to the N.E., the generally greater thickness in that direction, &c.) which would lead us to imagine that this is but a part of a general truth with regard to the position of the original focus of the Great-Whin eruption.

Although, as a rule, it may be said that the upper surface of the Whin is tolerably smooth, yet there are many instances of isolated masses, both great and small, having been thrust up from the main sheet to a greater or less distance through the overlying beds. The eastern branch, important as it is, must, we think, be looked upon as an extreme case of this kind; and between it and small bosses a few yards only in diameter, appearing as little islands through thin layers of limestone capping the Whin, of which there are very numerous examples on the dip-slope of Gunnerton Crags (fig. 5), at Great

Fig. 5.—*Section at Gunnerton Crags, showing the upper surface of the main or western branch of the Whin Sill protruding through the overlying Limestone.*



B. Whin Sill. L. Limestone.

Bavington, at West Hills, and elsewhere, there is every gradation of size and form. It may be noted that although these "extra" outbursts, so to speak, are found occasionally in connexion with the main or western branch of the Whin, yet they are markedly more frequent to the dip of the eastern branch. In other words, *these tokens of ill-restrained energy are commonest where the ejecting force acted most vertically.* And they are moreover more common in the eastern than in the western portion of the Whin Sill's range, or where there was least pressure of overlying rock.

That notwithstanding its great thickness at its outcrop the Great Whin Sill should not have reached the denudation-line along its entire course, is perhaps somewhat surprising. But although in a few doubtful cases, which may be the result of faulting, the clear unbroken continuity of the beds above and below across the lines of the Whinless gaps can leave no doubt in the minds of field-observers that these breaks are distinct facts, that they are but surface breaks no one, we suppose, will dispute.

In its course through South-west and Mid Northumberland the Whin Sill runs more or less in the same direction as the larger faults. It is perhaps owing to this fact that the Whin is here seldom seen to be faulted. At the Stone-Croft lead-mine, near Haydon Bridge, the veins fault the Whin considerably. It is also faulted at Elf Hills, on the north of Hartington, at Wards Hill, and in many places to the north of Alnwick. We do not know of any perfectly clear case, although we have met with some doubtful ones, of the Whin being unaffected by a fault which throws the beds on both sides of it.

It may frequently be noticed that rocks adjacent to the Whin Sill are altered by it unequally. Sandstone is but little altered, shale very much so; limestone is sometimes but little changed, while at other times it is rendered crystalline. Recent experiments, in which one of us has taken part, have proved that shale is a very bad conductor of heat; limestone and sandstone are far better conductors*. We can therefore well understand how it is that shale should plainly show the effects of the Whin, when limestone and sandstone show but little alteration. It has been denied, by some who disbelieve in the intrusion of the Whin Sill, that alteration of the overlying beds has occurred. But of this there is abundant proof in the district which we have described†. The complete list of places where this may be observed is too long for insertion here; but we may mention the following as localities where the facts are particularly well shown:—Milking Gap, Sewing Shields, and Teppermoor on the line of the Roman Wall; West Hills and Three

* Prof. A. S. Herschel and G. A. Lebour, "On the Thermal Conductivities of certain Rocks," Rep. Brit. Assoc. for 1873 (Appendix), p. 223; for 1874, p. 128; for 1875, p. 54.

† Prof. Sedgwick, fifty years back, gave most conclusive evidence of this in Teesdale; and the sections described by him may still be examined; but subsequent writers have mostly ignored, or endeavoured to explain away, his observations. (See especially pp. 162, 177, 178, and 182 of his second paper already referred to.)

Farms near Bavington; West Whelpington, Elf Hills, Shield Dykes, St. Margarets, Ratcheugh, and abundantly in the districts further north.

Fragments of altered rock are frequently found *in* the Whin. We cannot say whether these fragments belong to beds lying above or below; and therefore the fact of included sedimentary strata proves nothing. But the condition of the fragments is important evidence: they are pieces of shale or sandstone, not irregular amorphous masses such as would have occurred if the Whin had been poured over the ocean-floor and had caught up patches of newly deposited sediment in its progress. The shale immediately over the Whin, although greatly altered, is sometimes highly fossiliferous. This could not have been the case had the clayey sediment been laid down over freshly ejected lava.

The altered shale is frequently known as "Whetstone," a term also in use in Scotland for similar beds. When the shale can be used as slate-pencil it is known as "Cam;" Camboe, near Elf Hills, is by some supposed to derive its name from this circumstance.

Altered sandstone often greatly resembles altered or partly decomposed Whin. The surfaces of the Whin are frequently altered by the rocks it traverses quite as much as the rocks are altered by the Whin. This mutual metamorphism, or alteration, is even better shown by the Whin Dykes* than by the Whin Sill.

The Whin Sill frequently rises up in bosses of bare rock from a drift-covered country. Where there is no drift, or only a thin and partial covering, it generally forms the main feature of the immediate district in which it occurs. Its escarpment is not so lofty as that of the thick sandstones, which chiefly lie on lower horizons; but it is usually more bold and precipitous in proportion to its height. The Whin Sill can frequently be distinguished at a distance by the character of the vegetation. Mr. Tate states that the following plants occur in Northumberland only on the basalt—*Mœnchia erecta*, *Sagina subulata*, *Vicia lathyroides*, *Asperugo procumbens*, *Statice limonium*, *Convallaria polygonatum*, *Allium schœnoprasum*, *Scilla verna*, *Sedum anglicum*, *Asplenium septentrionale*, and *A. germanicum*. *Helianthemum vulgare*, although also occurring on the limestone, is very characteristic of the Whin Sill†.

5. *Mineral Characters of the Whin Sill.*—Into this subject we need not enter, inasmuch as Mr. Allport has quite recently done so at length before this Society. Of the specimens described by him ‡ two were from our district. That from Ward's Hill is a good typical example of the Whin Sill generally. That from Elf Hills was from one of the small strings of trap shown in fig. 2 (p. 413). It is by no means a fair example of the trap, being excessively fine in grain, almost resembling a hardened clay; it is moreover much decomposed.

* It may be well to mention that faults in the N. of England are called "dykes" or "troubles." Basaltic dykes are specially distinguished as "Whin dykes" or "Whin troubles."

† New Flora of Northumberland and Durham, p. 35, 1868.

‡ Quart. Journ. Geol. Soc. vol. xxx. p. 552, 1874.

As a rule, we find that the thicker the Whin the coarser the grain of the rock. This is perhaps due to the slower cooling of the thick masses allowing crystallization to develop more perfectly.

The Whin Sill is not often vesicular, and still more rarely amygdaloidal. When it is, it is not more so near the upper surface than elsewhere; nor is it more so than some of the Whin Dykes which traverse the country. No volcanic ash occurs in the district; nor is there any spot which can be pointed out as certainly a vent or neck, up which the trap came.

6. *Age and Origin.*—The foregoing statements have proved that the Whin Sill is newer than the beds of the Carboniferous-Limestone Series in which it lies. But the question of the exact age of the intrusive sheets yet remains to be determined. So far as Northumberland is concerned, the question must remain an open one.

The Whin Sill is older than most of the faults of the district in which it occurs, because these throw trap and sedimentary beds alike. As already mentioned, we have no clear case of the Whin being unaffected by (or later than) any of the faults. The Whin is also clearly older than the mineral lodes of the district. But what the age of faults and lodes may be we do not know. Some of the faults are probably pre-Permian; at least the Magnesian Limestone appears to be unaffected by certain faults which are proved in Coal-workings beneath*. Others, and these generally the large east-and-west faults, are clearly post-Permian. But we cannot generalize as to the age of the faults in this district merely by their direction; and even if we could, the known instances of faults in the Whin Sill are not sufficiently numerous to allow us to apply the test with safety.

In Scotland, Warwickshire, and Staffordshire there are intrusive sheets of trap in the Coal Measures, but none in the adjacent Permians. Negative evidence in these cases strongly suggests that the trap is pre-Permian; and the conclusion thus suggested is generally adopted. Without wishing to call this conclusion in question, we should like to make a few remarks upon this kind of evidence.

If the Permians can be shown to have been deposited upon the *denuded edges of the trap*, the proof is complete. But it is only very rarely that such proof can be given. Generally, the evidence is of this nature:— Carboniferous rocks, in which intrusive sheets of trap now occur, have been disturbed and denuded, and their edges covered up by unconformable Permians. This, however, is not sufficient proof; or rather it is no proof at all; for the trap may have been intruded into the Carboniferous rocks long after the deposition of the Permians. There is evidently a tendency for these sheets of trap to keep along the lines of bedding; otherwise there would never be any doubt as to their character. If the intruding trap began to force its way laterally first through the Carboniferous rocks, it would probably, if possible, stay there. A difficulty here occurs

* See Sheet 105 S.E. of the Geological-Survey Map, and the 6-inch Map of the Durham Coal-field; surveyed by Mr. Howell.

if the rocks have been much disturbed and faulted before the deposition of the Permians. In this case the tendency to keep along the lines of bedding, would doubtless be greatly lessened.

The question turns upon the amount of negative evidence. If we find intruded sheets of trap in Carboniferous rocks in the neighbourhood of unconformable Permians, and never find the trap entering the latter, there is presumptive evidence in favour of the view that the trap is pre-Permian. But this is only negative evidence at best, and, however much there may be of it, it can never amount to proof; nor can it be allowed any weight as against a single fact on the other side.

But in Staffordshire and Ayrshire we are not dependent only on such negative evidence; there many faults which throw Coal Measures and trap alike, do not throw the Permians. In these cases the evidence is positive, and of great force. It gives the age of the trap with sufficient clearness: the trap is newer than the Coal Measures in which it lies; it is older than the faults which throw it; and these faults are older than the Permians *of those areas.*

The Whin Sill of the Penine escarpment approaches to within a mile or two of the Permians of the Vale of Eden; and here an interesting question arises. The Carboniferous rocks are well developed on the west of the Penine fault; but Mr. Goodchild informs us that in no case, so far as is yet known, do they contain any beds of trap, although the beds in which Whin Sill might be expected to occur are there seen. Two explanations of this are possible. It may be because the beds to the west of the escarpment were faulted down to the west before the intrusion of the Whin Sill, and the westerly continuation of the Sill, in beds newer than the Carboniferous, has been removed by denudation: in this case the Whin Sill would be post-Permian.

Another explanation is this:—The Whin may have been injected before the faulting of the beds, but, because of its thinning to the west, it did not reach so far as the Carboniferous beds which lie on the west of the Vale of Eden.

The latter is the more probable explanation; or at least it is the one which may most safely be suggested. The westerly thinning of the Whin Sill, from Teesdale to the Penine escarpment, is a fact which is well proved. The thinning of the Sill to the west is seen in the small transverse valley at High-Cup Nick. The same occurs with the "Little Whin Sill," of Weardale. This is 20 feet or more thick on the east, but it wedges out entirely about 3 miles to the west.

As there are no "necks" on the west of the line of outcrop of the Whin which can have served to give vent to the trap, we must conclude that it came up in some area to the east of its present outcrop. The westerly thinning of the Whin in certain districts also points to the same conclusion.

We have, then, no good evidence in our district as to the age of the Whin Sill; but by comparison with other districts it appears safer to regard it for the present as probably of late Carboniferous, or possibly of early Permian age*. Prof. Sedgwick believed that the Whin Sill had been injected before the deposition of the Magnesian Limestone. Mr. Tate, chiefly from his interpretation of the evidence of faults and lodes, regarded it as "subsequent to the Carboniferous, and prior to the Triassic era."

In this view of the case, it is important to consider the amount of consolidation which the beds had undergone, and the thickness of beds deposited previous to the intrusion of the Whin. The Carboniferous rocks of other districts seem often to have been generally more altered and disturbed by the intruding trap than do those of our area; they seem to have been less fully consolidated, and to have presented less resistance to the eruption of the trap.

So far as we can judge, the rocks of our area had been fairly well consolidated (the clayey sediment had been compressed into shale, and the carbonaceous matter had been fully changed into coal) before the injection of the trap. There must have been a very great thickness of rock overlying the Limestone Series at that time; else we should find, far more often than we do, that the Whin has broken completely through the beds.

The Coal Measures of the Newcastle Coal-field have a thickness of about 1800 or 2000 feet, the highest English Coal-measures not being now represented in this district †. The Whin Sill, where at its highest position in Mid Northumberland, lies below the base of the Coal Measures, from 2000 to 3000 feet, according to the development of the intervening beds. Therefore, if the intrusion took place during the higher Coal-measure period, there would have been a total thickness of from 3500 to 5000 feet of rock overlying the Whin.

It may be a question whether the time which elapsed between the deposition of the beds now found with the Whin, and the pressure of some 5000 feet of superincumbent rock, would have been sufficient to alter the lower beds from original sediment into sandstone, shale, limestone, and coal. If this be admitted, there is still the question whether the pressure would have been sufficient to keep the intruding sheet of lava between the lines of bedding.

It is a fact of some moment, that when the Whin lies high in the series it seems most prone to break through the rocks; but there are many exceptions to this.

If the intrusion took place when the whole country was deeply covered by Secondary rocks, it is not likely that the pressure of from 1000 to 1500 feet of strata, more or less, would make any perceptible difference. But if the intrusion took place during the higher Coal-measure period, when the thickness of overlying rock

* We do not here enter into the question of the relations of the Permian and Carboniferous. In Northumberland and Durham the higher Coal Measures are not present, and the Magnesian Limestone, with the underlying Yellow Sand and Marl Slate, clearly lie unconformably upon such Coal Measures as there occur. Stratigraphically the break is there complete.

† The highest Coal Measures of Northumberland are those just on the north or downthrow side of the famous "90-fathom dyke," near Gosforth and Killingworth. The dyke, or fault, has here a throw of 200 fathoms.

varied from 3500 to 6000 feet, the difference would probably be very important.

The relation which the Whin Dykes of the district bear to the Whin Sill is an interesting question; but it is one upon which little can be said. There is no certain case in Northumberland of a Whin dyke intersecting the Whin Sill; but to the south of Alnwick, near Shield Dykes, there is an instance which strongly suggests this.

The Whin Dykes are generally dykes and nothing more. In only a few cases have they been proved to send out lateral branches amongst the strata. A brief enumeration of some localities in which this has been observed is given by Mr. I. L. Bell in a paper on the chemical alteration of Whin at and near its contact with sedimentary rocks *.

The Whin Dyke which runs from near the coast, past Radcliffe Colliery, Acklington and Cartington, into the Porphyrite of the Cheviots, seems to overflow at Clennel, just before entering the Cheviot country. There are some curious beds of Whin in a shaft at Shilbottle Colliery, south-east of Alnwick; Mr. Tate supposed them to be overflows from a Whin dyke which occurs close by; but whether this is so, or whether they belong to the Whin Sill, cannot at present be proved.

7. *Conclusion.*—The foregoing paper has touched upon several collateral subjects; but the main point has been to establish the intrusive character of the Whin Sill. That this has been injected between the strata, after their deposition and consolidation, is, we think, now sufficiently evident.

The exact geological date at which the intrusion took place cannot be determined. Northumberland offers no conclusive evidence upon the subject; but so far as the evidence in this and other districts goes, it seems probable that the intrusion took place at the close of the Carboniferous period.

Of the relations of the Whin Dykes of Northumberland to the Whin Sill we have no certain knowledge. The dykes may be of different ages; and some of them probably belong to the same period as the majority of the long trap dykes of the south of Scotland, which Prof. A. Geikie has shown to be of Tertiary age.

EXPLANATION OF PLATE XVIII.

Sections of the Carboniferous-Limestone series of Northumberland, showing the positions of the Whin Sill.

Discussion.

Mr. Warington W. Smyth said that he had gone over the district referred to in the paper with Mr. Blackwell, the geologist who first determined the intrusive character of the green-and-white rock

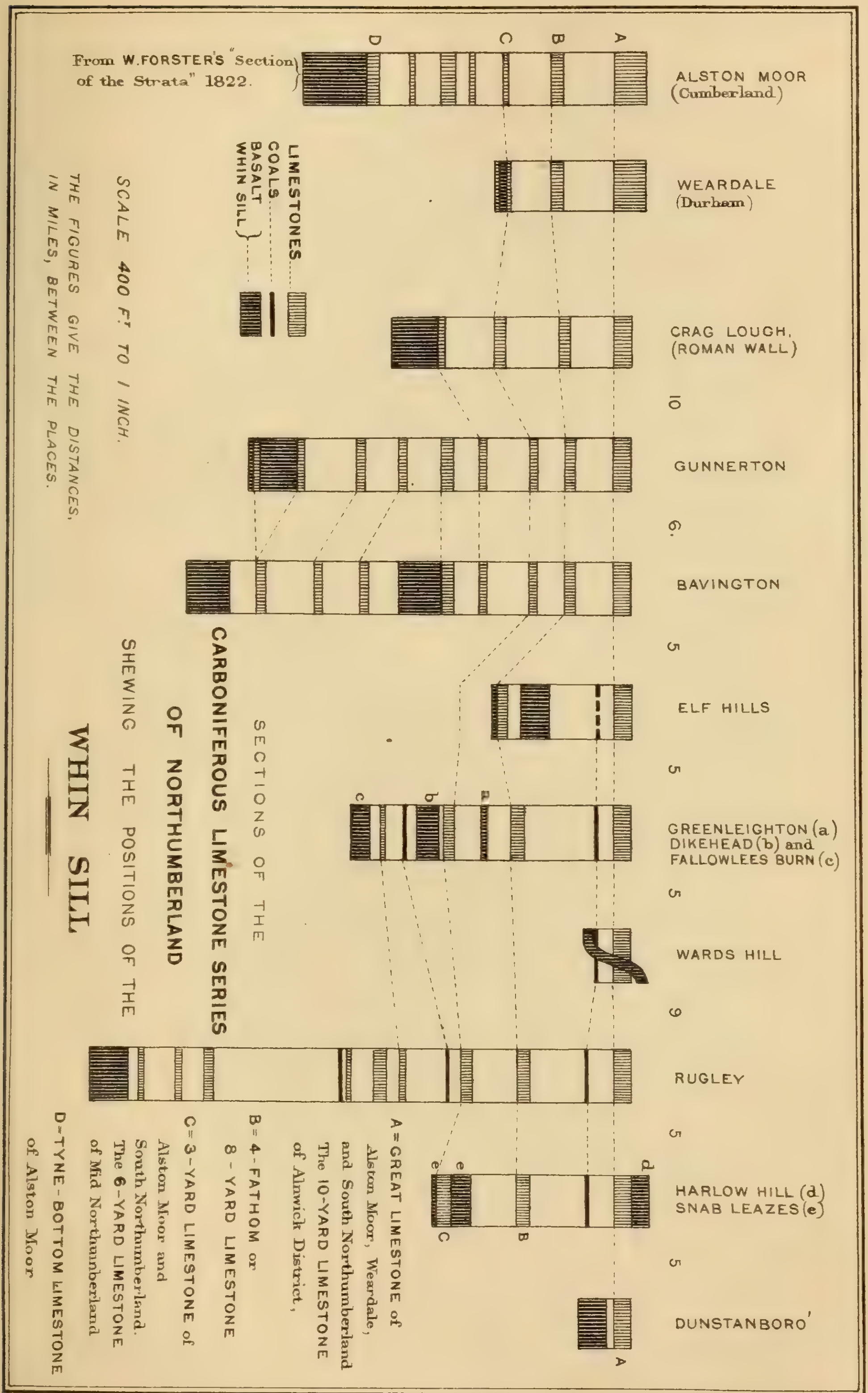
* Proc. Roy. Soc., vol. xxiii. p. 543, 1875. See also a notice by Mr A. L. Stevenson, Trans. N. of Engl. Inst. Eng. vol. xxiii. p. 160, 1874. Mr. Bell refers to the Whin Sill as a "bedded trap;" but probably he does not attach to that term the idea of contemporaneity.

in the neighbourhood of Dudley. Mr. Blackwell was also, he believed, among the first to suggest the intrusive nature of the Whin Sill of Northumberland. It appeared to be a great intruded tongue, not quite horizontal, but approximately so; and it was interesting to see the evidence brought forward by the authors proving its occurrence at various horizons.

Prof. Hughes thought that the intrusive character of the Whin Sill was proved in the sections seen in Hicup Gill and elsewhere along the same escarpment, as the rocks were altered above and below it, and were seen to be traversed obliquely by it in such a manner as could not be explained simply by the thinning out of the sedimentary deposits.

He thought that the Brockram and other New-Red deposits of the Eden valley were the shore deposits of the sea further out, in which sooner or later the Magnesian Limestone of the district west of the Pennine range was formed; that, whatever may have happened in earlier times, there was certainly a great faulting after the deposition of the Lower New Red, so that the cliff, with the Whin Sill exposed in it, did not exist there when the conglomerates known as Brockram were formed; that the beds into which the Whin is intruded do not occur on the S.W. of the Brockram, though it may be that beds of the same age, but very different in character, may occur further north beyond the main mass of Brockram; that the Brockram now exposed was derived chiefly from Mountain Limestone further west, so that the absence of Whin in it goes for nothing; that there is no evidence to show whether or not the Whin has an outcrop under the New Red or runs into it; and on the whole, except we identify it with the dykes which run across the Jurassic rocks to the east, there is nothing proved in that district respecting its age except that it must be later than the Lower Carboniferous.

Mr. Lebour said that Prof. Hughes was right with regard to the absence of the Whin Sill in the southern extension of the western Yoredale rocks. The alteration produced by the Whin Sill differed according to the kind of rock affected by it; and the difference was probably due to the different conductivity for heat of the various rocks.



W. T. Del. Mintern Bros. lith.

20. *On the* Chemical *and* Mineralogical Changes *which have taken place in* certain Eruptive Rocks *of* North Wales. By J. Arthur Phillips, Esq., F.G.S., &c. (Read February 7, 1877).

[Plate XIX.]

At Penmaenmawr, in the county of Caernarvon, six miles south-west of Conway, a crystalline felspathic rock has been erupted through Silurian strata, and rises to a height of 1553 feet above the sea-level, forming a boss-like elevation two miles in length and one in width.

This stone, which is of a greenish-grey colour, is moderately fine-grained, and to the unassisted eye, appears to consist of felspar associated with minute crystals of some dark hornblendic or pyroxenic mineral. The general mass is divided into beds by a series of predominating joints dipping north at an angle of about 45°; and these are again divided by a system of double jointings which are sometimes so developed as to the cause the rock to become distinctly columnar.

On the northern flank of the mountain, where four large quarries have been opened upon it, this stone is extensively worked both for general building-purposes and for road-making. Of these quarries the two more easterly ones belong to Messrs. Kneeshaw, Lupton, and Co., while those situated further towards the west are worked by Messrs. Brundrit and Co. The crystalline rock at the eastern extremity of the outcrop, near its point of contact with the slates, sometimes encloses small schistose fragments, but is fine-grained and frequently assumes a columnar structure.

Here the stone is often so close in texture as to almost resemble chert, and to break with a conchoidal fracture; but particles of kaolinized felspar show that it has, even here, been subjected to a certain amount of alteration.

The rock in the next two more westerly quarries is not only coarser in structure, but its jointings are irregular, and the felspar is less fresh than in the quarry first described; it is nevertheless still a somewhat fine-grained rock, since the largest crystals do not exceed $\frac{1}{10}$ of an inch in length.

At the top of the most easterly of these quarries is a thin foliated deposit, a specimen of which afforded on analysis a somewhat remarkable amount of oxide of manganese.

The stone in the most westerly quarry, which belongs to Messrs. Brundrit and Co., and is situated nearly opposite Beaumaris, is generally fresher in appearance than that from the two quarries last referred to, besides which it is closer in grain and greener in colour.

A comparatively superficial examination of the different varieties of stone obtained from the various quarries at Penmaenmawr is sufficient to indicate that they are probably mere modifications of the same rock partially due to progressive alteration. In order, however, to trace the nature and progress of the successive changes which have occurred, a series of sections from typical specimens of each variety has been cut and examined; and in each case a portion of the rock examined has been subjected to chemical analysis.

Beginning with the fine-grained and least-altered rock from the most westerly quarry, and arranging the specimens in accordance with the apparent extent of their respective changes, the following are the results of their several analyses.

Table showing Composition of variously altered Rocks from the Penmaenmawr Quarries.

	I.	II.	III.	IV.
Water { hygrometric...	·12	·40	·05	traces.
Water { combined	·95	1·82	2·64	4·46
Silica	58·45	60·31	62·24	61·75
Phosphoric anhydride	trace	trace	trace	trace
Alumina	17·08	18·99	18·25	18·88
Ferric oxide..............	·76	1·07	1·05	·52
—— persulphide.........	......	......	·39	·09
Ferrous oxide	4·61	4·31	3·08	3·52
Manganous oxide..........	trace	trace	trace	trace
Lime.......................	7·60	5·81	4·69	3·54
Magnesia	5·15	·83	2·27	1·90
Potassa.....................	1·02	1·67	1·49	1·24
Soda	4·25	4·55	3·79	3·67
	99·99	99·76	99·94	99·57
Specific gravity	2·94	2·79	2·75	2·79

I. *From the most westerly Quarry.*—This rock, which is fine-grained, is distinctly green in colour, and breaks with a conchoidal fracture. Thin sections, when examined in ordinary light, appear to be composed of a transparent base, in which are enclosed greenish yellow but almost colourless crystals of hornblende, together with indistinct crystals of felspar, a little magnetite or ilmenite, and a few rare needles of apatite; each section also usually contains an occasional grain of crystalline quartz. When viewed in polarized light, the transparent base breaks up into a brilliant mosaic of crystals of triclinic felspar, of which the majority are about $\frac{1}{100}$ of an inch in length: many of these exhibit the characteristic striation of plagioclase; but in the more slender crystals a single longitudinal division is alone visible *. Sections of this rock, seen with crossed prisms, afford typical examples of microcrystalline structure.

II. *From the most easterly Quarry.*—This rock, although moderately fine-grained, is decidedly coarser than the foregoing, and is less green in colour. When examined under the microscope, sections are seen to consist of a crystalline aggregation of felspar, hornblende, and quartz, through which are disseminated partially altered crystals of ilmenite, together with, sometimes, a little iron pyrites. The

* In one of the sections examined a group of felspathic crystals $\frac{1}{20}$ of an inch in length, which do not exhibit the structure of plagioclase, is enclosed in the finely crystalline base.

felspar is, in places, so changed as to form an almost amorphous base, which is rendered to a great extent opaque by a pulverulent secondary product of a greyish colour; this may be kaolin, or some hydrous magnesian mineral.

Although this alteration of the felspar frequently interferes with its action upon polarized light, the striation of plagioclase is sometimes distinctly apparent. The quartz contains minute cavities, some of which appear to be full of a liquid, while others are empty; a few enclose bubbles in a state of constant motion. The hornblende, which is usually of a light greenish-brown colour, is moderately abundant, but is seldom very distinctly dichroic *. Occasional needles of apatite are present; and felspar is sometimes observed to protrude into crystalline quartz; while patches of the felspathic base are often enclosed in that mineral.

III. *From the same Quarry as No. II.*—The texture of this rock is of about the same degree of fineness as that of No. I.; but it is lighter in colour, and has evidently undergone more extensive alteration. Under the microscope it is seen to consist of a transparent base, containing grains of quartz, and enclosing numerous indistinct dusky forms, indicating that crystals of felspar of nearly the size of those occurring in No. I. have become almost completely kaolinized. In this mixture are imbedded hornblendic crystals and a little magnetite or ilmenite.

IV. *From Messrs. Brundrit and Co's. eastern Quarry.*—This rock closely resembles No. II., but is coarser in grain, and the felspar is more extensively altered. Sections cut from specimens obtained from this locality appear to contain sometimes a few minute patches of an altered augitic mineral.

The microscopical examination of thin sections of variously altered specimens of this rock indicates that its metamorphism has been attended by a progressive kaolinization of felspar, while the more altered varieties contain a somewhat smaller amount of the hornblendic mineral; on the other hand patches of crystalline quartz become gradually more abundant.

Chemical analyses of the same specimens show that these changes have been accompanied by the removal of lime and magnesia and the formation of hydrated silicates, while the proportion of silica in the altered rock is not necessarily increased. At first sight the latter statement would not appear to be absolutely correct; if, however, we calculate what should be the proportion of silica in rock No. I., if so changed as to contain the amounts of lime, magnesia, and water found respectively in Nos. II., III., and IV., the amount of silica would in the first case be $61\frac{1}{2}$ per cent., and in the two others 61 per cent.

It therefore becomes evident, supposing all the specimens to have had originally a similar chemical composition to that of the practically unaltered rock No. I., that No. II. must have lost 3 per

* The form of these crystals is seldom sufficiently perfect for complete identification; but some of them are strongly dichroic, and their structure is that of hornblende; others, which are very pale in colour, are not distinctly dichroic.

cent. of silica, while Nos. III., and IV. have received respectively an increase of 1·35 and ·77 per cent. of that body.

The proportion of silica contained in all the different portions of the same crystalline rock-mass, however, is never rigorously constant; and consequently, taking into consideration the more or less altered state of the various specimens operated on, they may be regarded as not having materially changed in this respect.

After a careful examination of the unaltered rock No. I., free quartz could be distinguished in very small quantity only, whereas in Nos. II., III., and IV. quartz granules are conspicuously abundant; it therefore appears not improbable that the presence of this mineral may be to some extent due to the crystallization of progressively dissociated silica, although the greater proportion of it may have perhaps formed one of the crystalline constituents of the original rock.

It is worthy of notice that specimens, in the composition of which quartz occupies a conspicuous proportion, do not contain a larger amount of silica than those in which its presence can be barely distinguished by the aid of the microscope. It is likewise to be observed that a few only of the quartz granules contain liquid-cavities, and that under a power magnifying 675 linear the latter are occasionally seen to enclose bubbles in a state of active motion.

On referring to the analyses it will be observed that the proportion of alkalies in the different specimens does not materially differ; this substantially agrees with the observations of Ebelmen, who found that the removal of potash and soda from decomposed pyroxenic rocks was much less complete than that of lime and magnesia*.

This rock, which in chemical composition is intermediate between the basic and acidic groups, corresponds, when almost free from quartz, very closely with the trachydolerites of Abich, who includes under this name not only augitic varieties, but also those containing hornblende alone. In its ordinary condition it is a quartziferous diorite.

The foliated deposit previously referred to as containing oxide of manganese, occurs as a stratified layer at the top of the more westerly quarry belonging to Messrs. Kneeshaw, Lupton, and Co. This band, which is moderately coherent, is of a light reddish brown colour, but is considerably less hard than the crystalline rock upon which it rests. Under the microscope thin sections are seen to consist of an amorphous base stained in places by ferric oxide, and enclosing patches of crystalline chlorite, together with fragmentary crystals of hornblende, of which the outlines gradually merge into the base; it also contains a little pyrites and a few minute spheroidal bodies of a brown colour.

A specimen taken from this band, analyzed in duplicate, afforded the following results (sp. gr. 2·80):—

* Ebelmen 'Recueil des Travaux,' ii. 1–79, quoted by T. S. Hunt, 'Chemical and Geological Essays,' p. 101.

	I.	II.
Water { hygrometric	·73	·73
Water { combined	6·21	6·30
Silica	34·49	34·34
Phosphoric anhydride	trace	trace
Alumina	21·78	21·65
Ferric oxide	19·48	19·31
—— persulphide	·69	·69
Ferrous oxide	trace	trace
Manganous oxide	10·26	10·35
Lime	3·16	3·12
Magnesia	1·75	1·60
Potassa	trace	trace
Soda	1·19	1·24
	99·74	99·33

The presence of a notable amount of manganese in a somewhat similar deposit, has been observed by Von Lasaulx, who found 4·58 per cent. of manganic oxide in a volcanic ash-bed in Auvergne *. In the Penmaenmawr rock the oxygen present is just sufficient to form ferric and manganous oxides; in such cases it is impossible to determine the state of oxidation in which the two metals respectively occur.

The composition of this deposit differs very considerably from that of the neighbouring crystalline rock, as, in addition to a considerable amount of oxide of manganese, there is a large diminution in the percentage of silica.

Sénarmont and Daubrée have shown that water at high temperatures and under great pressure is capable of attacking silicates and of removing from them a portion of their silica; it therefore appears not improbable that this deposit may be the result of a flow of volcanic mud from which a portion of its silica has been thus removed †. Whether oxide of manganese was an original constituent or has been subsequently introduced by infiltration, would be difficult to determine.

An instructive example of the changes which sometimes take place in crystalline rocks, and in which their quarry-water is probably an important agent, is afforded by the "uralite porphyry," or uralitic dolerite of the Mawddach valley near Dolgelly.

An outcrop of this rock is seen near the summit of a hill immediately north of the road a mile below Tyn-y-groes; it is of a greyish green colour, plentifully spotted with black, and consists of a granular base enclosing numerous patches and crystals of uralite, many of the latter being above half an inch in length. The outlines of these crystals are occasionally sharp and well defined, while in other cases they are rounded and gradually merge into the general base. In addition to crystals of uralite this rock encloses some whitish patches of a felsitic material, which occasionally exhibit

* 'Roches Volcaniques de l'Auvergne,' p. 71 (Clermont Ferrand: 1875). Translated by F. Gonnard.

† The basic slaty hornblendic rocks of the neighbourhood of Penzance (Quart. Journ. Geol. Soc. vol. xxxii. p. 165) may have had a similar origin.

indications of being altered crystals. An analysis, in duplicate, of a freshly broken specimen from this locality, afforded the following results (sp. gr. 3·00):—

	I.	II.
Water { hygrometric	·34	·37
Water { combined	2·88	2·74
Silica	46·73	46·51
Carbonic anhydride	trace	trace
Phosphoric anhydride	trace	trace
Alumina	19·28	19·33
Ferric oxide	2·86	2·72
Ferrous oxide	7·57	7·73
Manganous oxide	trace	trace
Lime	10·76	10·81
Magnesia	6·98	7·15
Potassa	·38	·30
Soda	1·96	2·08
	99·74	99·74

When thin sections are examined by transmitted light, they are seen to consist of a colourless base containing a little granular quartz and altered magnetite or titaniferous iron, through which is thickly disseminated a crystalline greenish mineral, together with a greyish dust-like substance frequently observed in altered crystalline rocks. In this mixture are enclosed numerous crystals of uralite of various sizes, as well as a few less distinct forms, some of which are pseudomorphs after plagioclase still occasionally retaining traces of characteristic striation.

The outlines of the larger crystals of uralite are not usually well defined, but have often been attacked by a species of metamorphism, through the action of which they have become externally converted into a greyish pulverulent substance, similar to that contained in the base, by which their angles become gradually rounded and finally disappear. By reflected light, this dust-like product is greyish white in colour, and the more transparent portions of the base appear milky.

The appearance presented by crystals of uralite which have been more or less deeply attacked, will be understood on reference to Plate XIX. figs. 1, 2, and 3, which are after photographs, and are magnified 17 diameters. Fig. 1 represents a twin uralitic crystal which has undergone this change not only around its edges, but also, to a less extent, along a line of crack which is diagonal to the plane of twinning. In fig. 2 this alteration of the crystal has penetrated to a greater depth than in the former case, while fig. 3 is the mere image of a replaced crystal.

The illustrations given will probably be sufficient to render intelligible what has been said on this subject; but there would be no difficulty in preparing, from the ten sections which have been made of this rock, a series beginning with a crystal scarcely attacked on its edges, and passing by imperceptible gradations to a mere dusky shadow of a crystalline form.

It is evident that the crystals under consideration differ essentially in their origin from those which, while possessing the external form of augite &c., are, to a large extent, composed of magnetite or ilmenite; the latter exhibit sharply defined outlines, and, as suggested by Zirkel, were probably formed under conditions similar to those which resulted in the crystallization of the quartziferous limestones of Fontainebleau*. The alteration of the crystals of uralite, on the contrary, begins externally and extends gradually towards the centre.

Among the more indistinct pseudomorphs observed in the sections examined are a few filled with a granular transparent material, containing quartz granules and divided by reticulated lines of minute crystalline aggregations in a way suggestive of the fissures so generally observed in olivine. It may be remarked that this rock is almost identical in chemical composition with the ancient dolerites from the neighbourhood of Penzance, and also that recent observations have shown that the augite in certain Cornish dolerites has become partially transformed into uralite.

EXPLANATION OF PLATE XIX.

(All the figures magnified 17 diameters.)

Fig. 1. Twin crystal of uralite which has undergone alteration around its edges and, to a less extent, along a line of fissure by which it is divided.

Fig. 2. Crystal of uralite, altered to a greater depth than in the former case.

Fig. 3. Uralite crystal which has been entirely removed and replaced by various secondary products.

Discussion.

Mr. Warington W. Smyth stated that he had examined the quarries referred to, but without arriving at such satisfactory results as those brought forward by the author, to whom he felt obliged for several important suggestions. The rock appeared to be mainly all of one variety, though some geologists might perhaps be inclined to subdivide this great mountain-mass. Chemically and commercially, indeed, there is a great difference between the several parts of this mountain. At the western extremity some little variation occurs; but at the eastern end, at Graig-lwyd, there were great differences. Great masses are left unworked from year to year because they do not wear well. These are of a finer grain, and there is no appearance of free silica in them, although it may exist in the other rock; and Mr. Phillips has shown that when free silica is present the rock is more useful. The discovery of the peculiar jointing which enables the rock to be easily cut into "sets," has led to its being largely worked; and there is a great exportation of it to Manchester, Liverpool, &c. The discovery of free silica in the

* Untersuchungen über die mikroskopische Zusammensetzung und Structur der Basaltgesteine, p. 27. Bonn: 1870.

large-grained varieties is therefore very interesting, as is also the determination of the kind of felspar associated with the silica. The paper was a very important contribution to our knowledge of certain rocks which possess much interest both mineralogically and commercially.

Prof. Ramsay said that he was glad to find that Mr. Phillips maintained the broad general views originally set forth by the Geological Survey. He presumed that the author considered the Penmaenmawr rock not to be now, either chemically or mineralogically, by any means in its original state of consolidation from igneous fusion; and he would be glad to know whether any conclusion could be arrived at as to what this state was. He thought its metamorphism might have been assisted by nearness of the rock to the surface, favouring the percolation of surface-water. Continual changes had probably been going on in the Penmaenmawr rock ever since its original formation. He thought that the presence of such large quantities of iron and manganese in the ash, as shown by the author's analyses, might be due to infiltration rather than to these substances being original constituents of the rock.

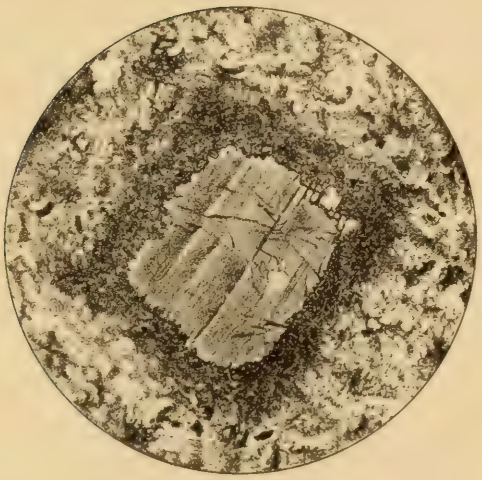
Prof. Judd called attention to the other rock not noticed by the previous speakers, whose remarks were confined to two only out of the three sorts referred to in the paper. He remarked that the uralite-porphyry of North Wales was now for the first time thoroughly investigated, so that we can now compare it with the uralite-porphyry of Predazzo, which appears to be an altered augite-porphyry. The Welsh rock, in the changes round the edges of crystals and in its appearance to the naked eye, differs from the Predazzo porphyry. In the former much more of the characters of the augite crystals is lost. Such careful descriptions and analyses as those given by the author are most important and of the greatest interest to English geologists.

The Author, in reply to Prof. Ramsay's question as to the original state of the rock at Penmaenmawr, said that the least-altered rock was in the quarries opposite Beaumaris, where it exhibited silica, hornblende, and triclinic felspar. It was remarkable that, although in metamorphism free silica appears, the chemical composition of the rock is not altered.

1

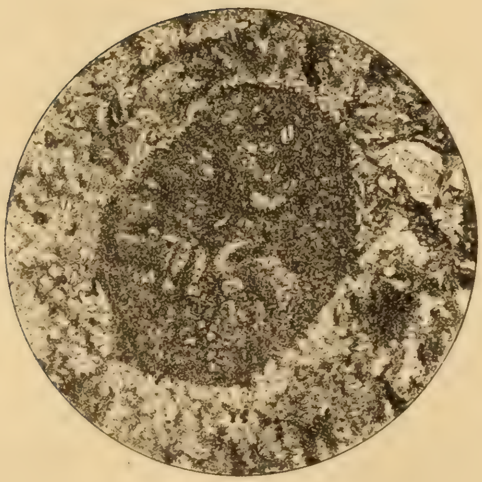
×17

2.



×17

3



×17

Mintern Bros. imp.

ERUPTIVE ROCKS OF NORTH WALES.

21. *On the* Beds *between the* Gault *and* Upper Chalk *near* Folkestone. By F. G. Hilton Price, Esq., F.G.S. (Read March 7, 1877.)

We have no better section of the Upper Cretaceous rocks than at Lydden Spout, which is a name given to a portion of the cliff between Folkestone and Dover.

The chalk cliffs at this locality were carefully measured by Mr. C. E. De Rance, F.G.S. (of H.M. Geological Survey), and myself; and the height was found to be 433 feet above the mean sea-level. The thickness of the beds between the Upper Gault and the first bed of flints (Upper Chalk) is 348 feet.

These beds I propose to divide into three general groups, *i. e.* Chalk Marl, Grey Chalk, and Lower Chalk, the former two corresponding with the *Cénomanien* of D'Orbigny, and the latter with his *Turonien*. As these divisions contain several well-marked lithological bands or beds, I have again subdivided them into six zones and nine beds, distinguishable by their palæontological contents or lithological characteristics.

Mr. Whitaker, in vol. iv. p. 33 of the Geological-Survey Memoirs, quoting Phillips, estimates the Grey Chalk or Chalk Marl at about 200 feet, and describes it as varying in colour and texture, but softer, more sandy, and less compact than the other divisions. He makes his division extend to the top of the thin yellowish bed, the zone of *Belemnites plenus*.

It will be seen from the present paper that I have given the same limits for the Grey Chalk and Chalk Marl together as Mr. Whitaker, and that I have estimated the thickness of those beds at 197 feet; but instead of grouping them both together as Chalk Marl, I have measured the Chalk Marl from the top of the Upper Gault, and have carried it up to the top of the zone of *Plocoscyphia mæandrina*, in all about 24 feet thick. Here I consider the Grey Chalk commences, extending to the top of the *Belemnites-plenus* band (yellowish chalk), and having a thickness of 173 feet. The Lower Chalk is 150 feet thick; it is measured from the top of the *Belemnites-plenus* zone to the Upper Chalk (first line of flints).

Mr. F. Drew has given a short note on this section in Whitaker's 'Memoir' of the Geological Survey, vol. iv. p. 33, in which he has divided it into Chalk Marl, White Chalk without flints, and concretionary (?) nodular chalk. He does not give the thickness of the Chalk Marl.

The "white chalk without flints," of Drew, is 138 feet thick, and equals my bed vi. of the Grey Chalk, the zone of *Holaster subglobosus*, which is 148 feet thick according to my calculations.

The concretionary (?) nodular chalk, 73 feet thick, is capped by chalk without flints and white chalk with few flints.

The concretionary nodular chalk is equivalent to the beds above the *Belemnites-plenus* zone, and is strangely near to Dr. Barrois's description of the "Craie noduleuse à *Inoceramus labiatus*," which he makes 75 feet thick.

The term "white chalk without or with few flints" is probably explained by the lower portion being without flints and the upper part containing but few flints. I draw the line of division about the middle of this bed.

Dr. Charles Barrois, in his able work 'Recherches sur le Terrain Crétacé supérieur de l'Angleterre et de l'Irlande,' has divided this section very similarly to the way in which I have done, by making the following zones:—

1. Marne sableuse à zone de *Pecten asper*, = my bed I. and, he considers, the Warminster beds.
2. Craie marneuse à *Plocoscyphia mæandrina*, = my bed II., chalk marl with *P. meandrina*.
3. Zone à *Ammonites varians* = my beds III., IV., and V.
4. Craie argileuse avec bancs durs à *A. rhotomagensis*, = the lower part, about 93 feet, of my bed VI., grey chalk with *Ammonites rhotomagensis*.
5. Zone à *Belemnites plenus* (craie compacte) = the upper 60 feet of my bed VI.
   These last three zones are included by Dr. Barrois in his "Assise à *Holaster subglobosus*." The true horizon of *Belemnites plenus* (yellowish chalk) he considers a remanié bed; this = my bed VIII.
6. Craie noduleuse à *Inoceramus labiatus*, 75 feet, = 32 feet of my bed VIII., and 43 feet of my bed IX.
7. Craie marneuse à *Terebratulina gracilis* = 75 feet of my bed IX.

It will be seen that his general divisions are the same as mine, with the exception that my sections are rather more in detail.

Like results have attended the labours of Prof. E. Hébert, Dr. Barrois, and MM. Pottier et de Lapparent in the Boulonnais, where the same beds have been examined.

The following is M. Hébert's table indicating his divisions in Normandy:—

<table>
<tr><th></th><th></th><th></th><th>Lydden Spout.</th></tr>
<tr><td rowspan="4">Turonien.</td><td rowspan="4">Craie à Inoceramus labiatus.</td><td>Holaster cor-avium.</td><td rowspan="2">Echinoconus subrotundus and Terebratulina gracilis.</td></tr>
<tr><td>Echinoconus subrotundus.</td></tr>
<tr><td>Inoceramus labiatus.</td><td>Inoceramus labiatus.</td></tr>
<tr><td>Belemnites plenus.</td><td>Belemnites plenus.</td></tr>
<tr><td rowspan="3">Cénomanien.</td><td colspan="2">Craie grise à Holaster subglobosus, 16 m.</td><td>Holaster subglobosus (in part).</td></tr>
<tr><td colspan="2">Grès calcareux à Holaster nodulosus, 18 m.</td><td rowspan="2">Grey Chalk and Chalk Marl.</td></tr>
<tr><td colspan="2">Glauconie sableuse à Holaster suborbicularis, 41 m.</td></tr>
</table>

From the foregoing table it appears evident that the Cenomanian is much more considerable in Normandy than it is with us in the south-east of England—so much so, indeed, that in correlating it with our Folkestone section I have to consider the "Glauconie sableuse à *Holaster suborbicularis*" (which form is a variety of *Holaster lævis*) and the 'Grès calcareux à *Holaster nodulosus*," which equals "*lævis*," as equivalent to our Chalk Marl and parts of the Grey Chalk.

The "Craie grise à *Holaster subglobosus*" may probably be correlated with my bed VI. of *Holaster subglobosus*, although much narrowed.

In his "Turonien" M. Hébert makes one general "assise," subdivided into four zones; the two lower, of *Belemnites plenus* and *Inoceramus labiatus*, are equal to my zones of the same names.

His *Echinoconus-subrotundus* and *Holaster-cor-avium* zones equal my zone of *Echinoconus subrotundus* and *Terebratulina gracilis*, bed IX., together. Prof. Hébert*, in his paper entitled "Comparaison de la Craie des Côtes d'Angleterre avec celle de France," considers the Upper Greensand, Chalk Marl, and Grey Chalk of the coast section at Lydden Spout to be equivalent to the glauconitic marl of the French coast, and the chalk without flints, beds VII., VIII., and IX. of this section, to the lower and middle zone of Chalk with *Inoceramus labiatus* (?).

In the Pas de Calais M. Hébert divides the Chalk Marl and Grey Chalk collectively into four parts, *i. e.*:—

1. Niveau à *Plocoscyphia mæandrina*=my beds 1 and 2.
2. Niveau à *A. varians*=my bed 3.
3. Niveau à *A. rhotomagensis*=my bed 4.
4. Niveau à *Belemnites plenus*=my beds 5, 6, and 7.

The lists of fossils recorded as found by him† in this area are, in the main, the same as I have met with at Folkestone and Lydden Spout.

Bed I. (Chalk Marl).

Immediately resting upon the Upper Gault (bed XI.) is a dark greenish sand, calcareous and clayey, poor in organic remains. The green grains become thinner and fewer about 16 feet up in the deposit, where it is less sandy and the deposit partakes more of the character of marl.

On the hill beneath the Martello Tower No. III. quantities of cream-coloured concretions were met with. This formation can be seen *in situ* near Copt Point, Folkestone, reposing more or less conformably upon the gault. Short pipings of this dark green sand extend only for about 3 or 4 inches into the gault beneath.

The total thickness of this bed near Copt Point in the hill below the Martello Tower III., measured from the top of bed XI. of the Upper Gault, where the green pipings are first observed, up to the base of the whitish marly deposit sometimes called chloritic or glauconitic marl, is about 14 feet; but it is extremely difficult to obtain an accurate measurement. It has usually been roughly estimated as having a thickness of 15 feet in East-Wear Bay. Mr. Topley considers it not to be thinner than 20 feet here.

This dark sandy marl, commonly called Upper Greensand, thins out gradually to the north-west of Folkestone, where only a thin seam of chloritic marl reposes on the gault. Mr. Topley states‡ that "at the foot of Castle Hill it is exposed in a road-cutting, where it

* Bull. Soc. Géol. France, 3e sér. t. ii. pp. 416–428.

† 'La zone à *Belemnites plenus*,' C. Barrois: Lille, 1875.

‡ 'Geology of the Weald,' W. Topley, p. 152.

is only 3 or 4 feet thick, and contains many small phosphatic nodules. The Upper Greensand seems to die out to the west of this point."

The same authority states* that "there is no further exposure of this Greensand until we reach Aylesford, where only about 18 inches of it is found beneath the Chalk Marl. At Burham brick-pit it is less distinct; but green grains and phosphatic nodules occur at the top of the clay."

Owing to the frequent landslips which have taken place in East-Wear Bay, no other entire section that is reliable is to be seen. Its junction with the Chalk Marl can be made out very well upon the shore, where large masses have been thrown down; there it will be observed that this so-called Upper Greensand passes gradually and almost imperceptibly into chalk marl. In the lower parts of the deposits clayey pipings are frequently met with, also iron pyrites in the form of cubes; but the latter are not found in the upper part.

The following fossils have been met with in this bed:—

Stauronema Carteri, *Sollas* (common).
—— lobata, *Sollas*.
Hylospongia.
Plocoscyphia mæandrina (common).
Pseudodiadema, sp.
Inoceramus concentricus ?
—— striatus ?
Avicula gryphæoides (common).
Plicatula inflata.
Pecten orbicularis (common).
Lima globosa (rare).
Cardita, sp.
Nautilus, sp.
Ammonites varians (very rare).
Scaphites æqualis.
Ichthyosaurus campylodon.
Lamna, sp., and Fish-scales.

In the lower portion of this deposit fossils are rarely found at all, owing, probably, to the chemical constituents being unfavourable to the preservation of organic remains. They mostly occur in that portion of the bed which is composed of whitish marl mixed with green grains. The lowest fossil met with was *Hylospongia*. All the fossils that are found in this bed No. I. are Chalk-Marl forms and do not represent the fauna of the Upper Greensand of the West of England at all.

Upon carefully examining this bed, in company with Dr. Charles Barrois, of Lille, I have come to the conclusion that the Upper Greensand is wanting in the south-east of England (unless it be represented palæontologically by the Upper-Gault beds X, and XI., zone of *Ammonites rostratus* of my Gault-section), and that the dark green sandy deposit just now described forms the basement-bed of the Chalk Marl, they being palæontologically the same. I shall therefore propose to do away entirely with the term Upper Greensand for this bed, and henceforth to consider it as the basement-bed of the Chalk, and to unite it with the Chalk Marl, considering it the sandy base of that formation. This is the zone of *Stauronema Carteri*, which only occurs in this bed.

This bed equals the "Niveau de *Pecten asper*," of Dr. Barrois, see his paper on "La Zone à *Belemnites plenus*," Lille, 1875.

At Wissant this bed is extremely rich in fossils; but they are not of the Upper-Greensand fauna.

* 'Geology of the Weald,' W. Topley, p. 153.

Bed II. (Chalk Marl).

The chalk of this bed is very hard and coarse in texture and of a light greyish colour, and is generally known as Chalk Marl, but, owing to the presence of a few green grains near its base, has been called by some geologists Chloritic Marl.

It has a thickness of about 10 feet, and contains several hard bands or reefs of sponges, notably of *Plocoscyphia meandrina*=*Brachiolites labrosus* and *Dendrospongia fenestralis*, which do not occur otherwise than in these very hard bands. Occasionally these sponges are found converted into iron pyrites. I measure this bed to the base of the Grey Chalk, where these hard bands cease to be met with.

Hard concretionary nodules, more or less incrusted with iron pyrites, occur in this bed; they bear every appearance of being much rolled, and have *Ostreæ* and *Plicatulæ* adhering to them.

The Chalk Marl is very fossiliferous; the following is a list of fossils obtained therefrom:—

Plocoscyphia mæandrina (v. common).
Dendrospongia fenestralis (common).
Micrabacia coronula.
Pollicipes glaber (rare).
Cidaris vesiculosa.
Holaster lævis, var. nodulosus (com.).
—— ——, var. trecensis.
Serpula annulata.
Terebratula biplicata.
—— obesa.
Rhynchonella, sp. (crushed).
Inoceramus striatus (very common).
Lima globosa (common).
—— parallela.
——, sp.
Pecten Beaveri.
—— campanensis.
—— elongatus.
—— orbicularis.
Janira quinquecostata.
Plicatula inflata (common).
—— sigillina.
Spondylus Dutempleanus.
—— latus.
Ostrea frons.
Ostrea frons, var. carinata.
Arca fibrosa.
Natica, sp.
Pleurotomaria perspectiva.
Solarium, sp.
Ammonites cenomanensis.
—— falcatus.
—— Mantelli.
—— navicularis.
—— nothus, var. Mantelli.
—— varians.
——, sp.
Nautilus elegans.
—— pseudo-elegans.
Scaphites æqualis.
Turrilites costatus.
—— Scheuchzerianus.
—— tuberculatus.
Edaphodon, sp.
Coprolites of fishes, &c.
Ichthyosaurus campylodon.
Saurocephalus lanciformis.
Acanthopholis horridus.
Wood.

It is remarkable that the remains of *Ichthyosaurus* are only met with in the hard seams, which are mostly made up of sponges: it would appear that the bones of these reptiles became entangled therein.

Mr. Griffiths, of Folkestone, has told me that he has found in this bed Ventriculites of large size, having a diameter of about six inches across the cup, and weighing as much as 14 lb.

This bed is equivalent to the Craie marneuse with *Plocoscyphia mæandrina* of Dr. Barrois.

The Chalk Marl (beds I. and II.) can be well examined in East-Wear Bay, near that part known as the "Pelter." It passes gradually up into a more argillaceous marly chalk, generally termed Grey Chalk. In order to see a fair section of this Grey Chalk, called the "Assise du *Holaster subglobosus*" by Dr. Barrois, in his paper on the zone of *Belemnites plenus*, it is necessary to go as far as Lydden

Spout, some three miles further on, as none of that formation can be seen along the shore in East-Wear Bay. Nearer Folkestone, where it should be *in situ,* the cliffs have suffered so much from landslips that in very few places are the rocks seen *in situ* at all, and then only partially. In many places the undercliff in East-Wear Bay is the result of slips, and is covered over by the rubbish taken out of the tunnel and railway-cutting during the formation of the line to Dover, and thrown down over the cliff.

A very good idea of the extent to which these cliffs are wasting away may be formed by walking along the top from Folkestone Hill to Lydden Spout. A little beyond the Royal Oak Inn, Hougham, which is about 430 feet above the sea-level, I was greatly struck by it, and could not help observing how much the chalk above the South-Eastern Railway tunnel had given away, and was still wasting. In many spots above this line of tunnel large tracts of land had actually slipped down bodily; and the ventilating shafts, after passing Hougham, are quite close to the edge of the cliff. In two instances the land above the tunnel has slipped or sunk to a depth of 5 or 6 feet, and actually broken down the ventilating shafts. Some of the "Fairy rings" were cut in half by the crumbling away of the cliffs, thus indicating that they are older than than the present escarpment. In some parts the tunnel is quite close to the edge of the cliff; and in other parts large masses of chalk have slipped completely over it.

Formerly there was a road along the shore from Folkestone to Dover; but since the South-Eastern Railway Company built out their new pier (which has effectually prevented the shingle coming round, and reclaimed land to the west of it) the full force of the sea now comes round into East-Wear Bay and gradually denudes the soft cliffs composed of Gault and the rubble from the railway-cutting. The road soon ceased to exist, and can only be traced here and there with the old beach beneath it, which is as hard as pudding-stone.

Since this paper was written, a severe landslip occurred in January last, caused during a long continuance of excessive wet weather, by the upper beds slipping down over the Gault. The area of the slip was considerable, extending over nearly 100 acres. It had the effect of pressing up the Gault on the beach into mounds six and seven feet high, of blocking up the Folkestone tunnel of the South-Eastern Railway, and of filling up a cutting of about 200 feet in depth for a distance of fully 200 yards.

At Lydden Spout the whole of the Grey Chalk is seen *in situ*, and is capable of being divided into several well-marked divisions or beds. Its total thickness here is about 170 feet, being measured from the top of the zone of *Plocoscyphia mæandrina* (bed II. of this section) to the base of the grit bed No. VIII., the top of the band of yellowish chalk, the horizon of *Belemnites plenus*.

The Grey Chalk I propose dividing up into three zones, beds No. III., IV., and V. being the zone of *A. rhotomagensis*, bed No. VI. the zone of *Holaster subglobosus*, and bed No. VII. the zone of *Belemnites plenus*. The base of bed III. at this portion of the shore is the usual high-water mark.

Bed III. (Grey Chalk).

Consists of a soft, grey, mottled, marly chalk, having a thickness of eight feet; many hard nodules of chalk occur in this horizon. This bed forms the lower portion of Dr. Barrois's "Niveau à *Ammonites varians.*"

The following fossils may be noted as coming from this band :—

Discoidea subuculum.
Cidaris vesiculosa.
Goniaster, sp.
Pseudodiadema variolare.
Serpula annulata.
Rhynchonella Mantelliana.
Pecten Beaveri.
—— elongatus.
Pecten orbicularis.
Panopæa, sp.
Corax heterodon.
Notidanus microdon.
Oxyrhina Mantelli.
Ammonites varians.
—— rhotomagensis.

Bed IV. (Grey Chalk).

The middle bed of the *Ammonites-rhotomagensis* zone is composed of light-grey, banded, marly chalk, about eleven feet in thickness. Eight feet up in this bed three well-marked bands occur, each being one foot in thickness. The first band consists of light grey chalk, very hard in texture, and poor in organic remains; the second, or middle band, consists of dark grey chalk of soft texture, in which many fossils are met with, notably *A. rhotomagensis* and *A. Mantelli.* Mr. Griffiths states he has found specimens of the former from this bed weighing as much as a hundredweight. Large specimens of *A. lewesiensis* also occur here.

It is worthy of notice that most fossils from this band have the shells well preserved upon them.

The third band is like the first in composition.

This bed is placed in the zone of *A. varians* by Dr. Barrois in his "Assise à *Holaster subglobosus.*"

The following fossils occur :—

Radiolites Mortoni (rare), in the lower 8 feet only.
Cidaris vesiculosa.
Pseudodiadema variolare.
Serpula annulata.
——, a species peculiar to the middle dark band..
Pecten Beaveri.
Pecten elongatus.
—— orbicularis.
—— Raulinianus ?
Ammonites Mantelli.
—— rhotomagensis.
—— lewesiensis.
—— varians.

Bed V. (Grey Chalk).

Commonly known as the "cast"-bed, is of a light French-grey colour, mottled and striped with markings of a darker colour, filled with fragments of comminuted shells and a large assemblage of fossils, many of which resemble the Gault fauna. It is particularly rich in Gasteropoda. I am indebted to Mr. J. S. Gardner for the names of several of the species found in this bed. This chalk is tolerably soft, sufficiently so to be capable of being cut with a knife; therefore the fossils can be readily obtained. It has a thickness of only 2 feet 9 inches; and through this bed the spout of the Lydden flows. The rise of the marly chalk above the sea-level occurs about a mile and a half to the east of the escarpment of Folkestone Hill; and the place is well marked by the breaking-out of a very copious and perennial spring called "Lydden Spout," which issues from the top of these marly beds, a situation probably corresponding to that of the springs which everywhere appear in the interior along the foot of the chalk range*.

This bed, in common with some of the others, is traversed by seams of calcite. The nodules of iron pyrites found in this bed are mostly small, some spherical, some cylindrical with rounded ends, having a smooth surface, silvery and very bright. When broken, they all exhibit a radiating structure from the centre. It is a remarkable fact that the forms of these nodules vary in every band.

These three beds, III., IV., and V., I propose to term the zone of *Ammonites rhotomagensis* and *varians*, which equal Dr. Barrois's zone of *A. varians*. Mr. Jukes-Browne considers this bed equal to the dark sandy building-stone of Burwell near Cambridge.

The following is a list of the fossils:—

Micrabacia coronula.
Pollicipes glaber (rare).
Goniaster mosaicus.
Cidaris dissimilis.
Pseudodiadema ornatum.
—— variolare.
——, sp.
Peltastes clathratus.
Salenia Clarkii.
Hemiaster Morrisii.
Epiaster crassissimus.
Serpula annulata.
Vermicularia umbonata.
Palæga Carteri (rare).
Enoploclytia sussexiensis.
Hoploparia, claws.
Crab, sp.
Terebratulina rigida (nodulated var. very common).
—— striata.
Terebratula squamosa.
Kingena lima.
Rhychonella Grasiana.
—— Mantelliana (common).
—— Martini.
Avicula gryphæoides.
Exogyra haliotoidea.
Lima globosa.
—— aspera.
—— parallela.
Mytilus, sp. nov.
Pecten Beaveri.
—— elongatus.
—— orbicularis.
Janira quadricostata.
—— quinquecostata.
Plicatula pectinoides.
—— sigillina.
Ostrea Normaniana.
—— Rauliniana.
Arca fibrosa.
Arca nana.
Arca carinata.
Pholadomya decussata.
Cardita tenuicosta.
Natica, sp.
Nucula pectinata.
Pleurotomaria, sp.
Voluta semiplicata.
Aporrhais Mantelli.
Rostellaria Pricei.
Fusus, sp.
Emarginula Gresslyi, *P. & C.*
Turbo Triboleti, *P. & C.*
Scalaria Dupiniana.
Cerithium Lallierianum.
—— trimonile.
Ornithopus oligochila.
—— pachysoma.
Dimorphosoma doratochilum.
—— opeatochilum.
—— spathochilum.
Solarium, sp.
—— or Turbo.
Dentalium medium.
Turritella, sp.
Ammonites cenomanensis.
—— Coupei.
—— rhotomagensis.
—— varians.
——, sp.
Ancyloceras.
Nautilus elegans.
—— Deslongchampsianus.
Belemnites plenus, var.
Turrilites costatus.
Ischyodus.
Macropoma, sp.
Pisodus.
Fish-coprolites.
Lamna, sp.
—— subulata.
Oxyrhina Mantelli.

* Dr. Fitton, "On the Strata below the Chalk," Trans. Geol. Soc. vol. iv. 2nd ser.

Bed VI. (Grey Chalk).

The base of this bed is found immediately resting upon the "cast-bed." It is about 148 feet in thickness; the lower portion of it for about 10 feet is slightly lighter in colour than the chalk of the cast-bed, but becomes very much lighter higher up, where it assumes a very light yellowish grey colour; and within a few feet of the top the chalk is of soft texture.

This bed is not so fossiliferous as the "cast-bed." The first 93 feet above it is very poor in organic remains, and is the "Craie argileuse avec bancs durs à *Ammonites rhotomagensis*;" and the upper 55 feet of this bed is the zone of *Belemnites plenus* of Dr. Barrois. *Discoidea cylindrica* and *Holaster subglobosus* are peculiar to this bed; in consequence of the latter being very characteristic and plentiful in it, I propose to call it the zone of *Holaster subglobosus*.

The palates of *Ptychodus polygyrus* and *P. decurrens* are met with towards the top of this zone of a darker colour than those coming from bed IX. of the Lower Chalk.

The nodules of iron pyrites occurring in this bed are round and rusty brown in appearance, never bright.

The following are the fossils met with in the bed:—

Cidaris vesiculosa.
Holaster subglobosus (common only in this bed).
Discoidea cylindrica (only in this bed).
Pseudodiadema variolare.
Goniaster mosaicus (plentiful).
Ophiura ?
Enoploclytia sussexiensis.
Hoploparia, claws of.
Pecten Beaveri.
Pecten elongatus.
—— orbicularis.
Janira quinquecostatus.
Plicatula sigillina.
—— pectinoides.
Ptychodus decurrens.
—— polygyrus.
Fish-remains.
Ammonites, sp.
Turrilites costatus.

Bed VII. (Grey Chalk).

This bed is very well marked, and forms a contrast to the beds above and below, and consists of a yellowish gritty white chalk. In this particular section it is about 4 feet in thickness, and forms the junction between the grey and white chalk.

It is usually termed the *Belemnites*-zone, on account of the frequency of *Belemnites plenus* in this horizon. This bed is about 170 feet above the mean sea-level. Mr. Whitaker, in the 'Survey Memoir,' vol. iv. p. 33, says, speaking of this bed, "Where it rises west of Shakespere's Cliff its separation from bed VI. is not well marked; but further west it is clear, the white being separated from the grey by some very thin yellowish bands.

This bed forms the upper portion of what M. Hébert and Dr. Barrois, in the Pas de Calais, consider the zone of *Belemnites plenus*, which fossil is met with very frequently in this bed; but an elongated form of it occurs in the upper portion of the bed below.

Dr. Barrois * considers that *Belemnites plenus* lived at the end of

* 'La zone à *Belemnites plenus*,' par C. Barrois. Lille: 1875.

the *Holaster-subglobosus* sea-period, but was not widely distributed. At the time of the invasion of the Turonian sea the Upper Cenomanian beds were more or less denuded; and the *Belemnites plenus* which they contained were found rolled, remaniés at the base of the Turonian; they are very abundant there, and form, without doubt, the zone of *Belemnites plenus* of M. Hébert.

It will be seen from my table that this bed is classed as the top bed of the Grey Chalk, which, together with the Chalk Marl at Lydden Spout, has a thickness of 197 feet, including beds from I. to VII. *Hippurites* or *Radiolites Mortoni* appears in this zone, and extends to the base of the Upper Chalk. The palates of *Ptychodus* are, in this band, of a yellow colour; whilst in the other beds of the Grey Chalk, already described, they are darker and almost black. Mr. Whitaker likewise considers this bed the top of the Grey Chalk or Chalk Marl.

There are very few fossils in this bed; the following have been met with:—

Plicatula inflata (which does not go up higher).
Belemnites plenus.
Ptychodus decurrens.
—— polygyrus.

This bed is the *Belemnites-plenus* zone.

Bed VIII. (Lower Chalk).

This bed is about 32 feet thick, and consists of exceedingly hard gritty chalk, made up of comminuted fragments of *Inocerami* and other fossils.

This bed, called the "grit bed," is very readily distinguished from the other zones, as it may be traced for a long distance along the cliffs from Folkestone to Dover above the Warren, standing out beyond the softer beds above and below. The chalk of this bed is so hard as to turn the point of the pick-axe.

At the lower portion of this bed *Discoidea minima* (?) is found in large quantities, succeeded by *Echinoconus subrotundus*, which is only found in that particular line in this bed, it never being met with either above or below it.

Ptychodus decurrens is small in this bed, and in the lower part of it is of a light colour, as in bed VII.; in the higher part of the bed the specimens become darker and larger.

Beds VIII. and IX. I consider to be Lower Chalk. They represent the "Turonien" of D'Orbigny and the *Inoceramus-labiatus* zone of Dr. Barrois, with whose classification of these beds I entirely agree, as here in bed VIII. the *Inoceramus labiatus* makes its first appearance, continuing through bed IX. to the Upper Chalk.

This bed, together with about 43 feet of my next bed, form what Mr. Drew, in Whitaker's 'Memoir,' calls concretionary? (nodular) chalk.

A few fossils appear to be peculiar to this bed, and they are as under:—

Cidaris Bowerbankii.
Salenia granulosa.
Cardiaster pygmæus.
Echinoconus subrotundus (first appearance).
Discoidea minima?
Rhynchonella Cuvieri.
Inoceramus labiatus (first appearance).
Ammonites (two specimens).

The *Salenia* and *Cardiaster pygmæus* are rare; but as the latter is very constant, I propose to call this the zone of *Cardiaster pygmæus.*

Bed IX. (Lower Chalk).

This bed is measured from the top of the "grit bed" No. VIII. to the first line of flints, the Upper Chalk. It has a thickness of 118 feet at Lydden Spout. Its texture is soft; and it is rather a yellowish-white chalk, not quite so pure a white as the Upper Chalk. It is full of fragments of *Inoceramus labiatus.* This bed in the lower 75 feet is equal to Dr. Barrois's zone of *Inoceramus labiatus*, and in the upper 75 feet to the *Terebratulina-gracilis* zone, including the previous bed in the zone.

The following are some of the fossils usually met with in this horizon.

Ventriculites.
Brachiolites quadrangularis.
Discoidea minima ?
Goniaster mosaicus.
Echinoconus globulus.
—— subrotundus.
Cyphosoma simplex.
Terebratulina gracilis (very common).
Terebratula semiglobosa.
Inoceramus labiatus.
—— Cuvieri.
Pecten, sp.
Beryx.
Macropoma.
Ptychodus decurrens.

This zone is to be considered the horizon of *Echinoconus subrotundus* and *Terebratulina gracilis.*

It is somewhat remarkable that most of these zones are the habitats of peculiar and restricted forms of Echinodermata; but two out of the nine beds have no distinctive Urchin.

They may be enumerated as follows:—

IX. *Echinoconus subrotundus.*
VIII. *Cardiaster pygmæus.*
VII.
VI. *Holaster subglobosus.*
V. *Hemiaster Morrisii* and *Peltastes clathratus.*
IV.
III. *Discoidea subuculum.*
II. *Holaster lævis.*
I. *Pseudodiadema,* sp.

The exception is No. VII., which is the *Belemnites-plenus* zone, and bed IV., where *Radiolites Mortoni* is only found. Bed I. certainly contains a *Pseudodiadema*; but that is probably *P. variolare*, common to several of the higher beds.

Before concluding this paper, I take the opportunity of thanking Mr. Jukes-Browne, Dr. Barrois, and others who have rendered me assistance.

List of Fossils.

	Chalk Marl.		Grey Chalk.					Lower Chalk.	
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
AMORPHOZOA.									
Stauronema Carteri, *Sollas*	*								
—— lobata, *Sollas*	*								
Hylospongia, sp., *Sollas*	*								
Ventriculites	...	...	...	...	...	...	...	...	*
Brachiolites quadrangularis, *Smith*	...	...	...	...	...	...	...	...	*
Plocoscyphia mæandrina, *Leym.* (v. com.)	*	*							
Dendrospongia fenestralis (common)	...	*							
ZOOPHYTA.									
Micrabacia coronula, *Goldf.*	...	*	...	...	*				
RUDISTES.									
Radiolites Mortoni, *Mant.* (rare)	...	...	...	*					
CIRRIPEDIA.									
Pollicipes glaber, *Römer* (rare)	...	*	...	...	*				
ECHINODERMATA.									
Cidaris Bowerbankii, *Forbes*	...	...	...	...	...	...	...	*	
—— dissimilis, *Forbes*	...	...	...	...	*				
—— vesiculosa, *Goldf.*	...	*	*	*	...	*			
Cardiaster pygmæus, *Forbes* (rare)	...	...	...	...	...	...	...	*	
Cyphosoma simplex, *Forbes*	...	...	...	...	...	...	...	...	*
Discoidea cylindrica, *Lam.*	...	...	...	...	...	*			
—— minima ? *Desor*	...	...	...	...	...	...	...	*	*
—— subuculum, *Klein*	...	...	*						
Epiaster crassissimus, *D'Orb.*	...	...	...	...	*				
Echinoconus globulus, *Desor*	...	...	...	...	...	...	...	...	*
—— subrotundus, *Mant.* (common)	...	...	...	...	...	...	...	*	*
Goniaster mosaicus, *Forbes*	...	...	...	...	*	*	...	...	*
——, sp.	...	...	*						
Hemiaster Morrisii, *Forbes*	...	...	...	...	*				
Holaster lævis, *Ag.*, var. nodulosus (com.)	...	*							
—— ——, var. trecensis	...	*							
—— subglobosus, *Dixon* (common)	...	...	...	...	...	*			
Ophiura ?	...	...	...	...	...	*			
Peltastes clathratus, *Ag.*	...	...	...	...	*				
Pseudodiadema ornatum, *Goldf.*	...	...	...	...	*				
—— variolare, *Ag.*	...	...	*	*	*	*			
——, sp.	*								
——, sp.	...	...	...	...	*				
Salenia Clarkii, *Forbes*	...	...	...	...	*				
—— granulosa (rare)	...	...	...	...		...	...	*	
ANNELIDA.									
Serpula annulata	...	*	*	*					
——, sp.	...	...	...	*					
Vermicularia umbonata, *Sow.*	...	...	...	...		*			

List of Fossils (*continued*).

	Chalk Marl.		Grey Chalk.					Lower Chalk.	
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
CRUSTACEA.									
Enoploclytia sussexiensis ? *Mant.*	...	...	...	...	*	*			
Hoploparia, sp.	...	...	...	...	*	*			
Palæga Carteri, *Woodward* (rare)	...	...	...	...	*				
BRACHIOPODA.									
Kingena lima, *D'Orb.*	...	...	...	...	*				
Rhynchonella Cuvieri, *D'Orb.*	...	...	...	...	...	...	...	*	
—— Grasiana, *D'Orb.*	...	...	...	...	*				
—— Mantelliana, *Sow.*	...	...	*	...	*	*			
—— Martini, *Mant.*	...	...	...	...	*	*			
——, sp.	...	*							
Terebratula biplicata, *Sow.*	...	*							
—— obesa, *Sow.*	...	*							
—— semiglobosa, *Sow.*	...	...	...	...	...	...	...	...	*
—— squamosa, *Mant.* (common)	...	...	...	...	*				
Terebratulina rigida, *Schlot.* (common)	...	...	...	...	*				
—— striata, *Wahl.*	...	...	...	...	*				
—— gracilis, *Schlot.*	...	...	...	...	...	...	...	...	*
LAMELLIBRANCHIATA.									
(*Monomyaria.*)									
Avicula gryphæoides, *Sow.*	*	...	...	...	*				
Exogyra haliotoidea, *Sow.*	...	...	...	...	*				
Inoceramus concentricus, *Park.*	*								
—— Cuvieri, *Sow.*	...	...	...	...	...	...	...	...	*
—— labiatus, *Schlot.* (common)	...	...	...	...	...	...	...	*	*
—— striatus, *Mant.* (common)	*	*							
Janira quadricostata, *Sow.* (rare)	...	...	...	...	*				
—— quinquecostata, *Sow.*	...	*	...	...	*	*			
Lima aspera, *Mant.* (rare)	...	...	...	...	*				
—— globosa, *Sow.*	*	*	...	...	*				
—— parallela, *Sow.*	...	*	...	...	*				
——, sp.	...	*							
Ostrea frons, and var. carinata, *Park.*	...	*							
—— Normaniana, *D'Orb.*	...	...	...	...	*				
—— Rauliniana, *D'Orb.*	...	...	...	...	*				
—— vesicularis, *Lam.*	*	...	...	...	...	...	...	*	
Pecten Beaveri, *Sow.*	...	*	*	*	*	*			
—— campanensis, *D'Orb.*	...	*							
—— elongatus, *Lam.*	...	*	*	*	*	*			
—— laminosus and var. orbicularis, *Sow.*	*	*	*	*	*	*			
—— Raulinianus ? *D'Orb.*	...	...	...	*					
——, sp.	...	...	...	...	...	...	...	...	*
Plicatula inflata=pectinoides, *Sow.*	*	*	...	...	*	*	*		
—— sigillina, *Woodward*	...	*	...	...	*	*			
Spondylus Dutempleanus, *D'Orb.*	...	*							
—— latus, *Sow.*	...	*							
(*Dimyaria.*)									
Arca fibrosa, *Sow.*	...	*	...	...	*				
—— nana, *D'Orb.*	...	...	...	...	*				

List of Fossils (*continued*).

	Chalk Marl.		Grey Chalk.					Lower Chalk.	
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Arca carinata, *Sow.*	...	...	...	...	*				
Cardita tenuicostata, *Sow*	...	...	...	...	*				
——, sp.	...	*							
Nucula pectinata, *Sow.*	...	...	...	...	*				
Panopæa, sp.	...	...	*						
Mytilus, sp. nov.	...	...	...	...	*				
Pholadomya decussata, *Phil.*	...	...	...	...	*				
Gasteropoda.									
Ornithopus oligochila, *Gardn.*	...	...	...	...	*				
—— pachysoma, *Gardn.*	...	...	...	...	*				
Aporrhais Mantelli, *Gardn.*	...	...	...	...	*				
Cerithium Lallierianum, *P. & C.*	...	...	...	...	*				
—— trimonile, *D'Orb.*	...	...	...	...	*				
Dimorphosoma doratochila, *Gardn.*	...	...	...	...	*				
—— opeatochila, *Gardn.*	...	...	...	...	*				
—— spathochila, *Gardn.*	...	...	...	...	*				
Dentalium medium, *Sow.*	...	...	...	...	*				
Emarginula Gresslyi, *P. & C.*	...	...	...	...	*				
Fusus, sp.	...	...	...	...	*				
Natica, sp.	...	*	...	...	*				
Pleurotomaria perspectiva, *Mant.*	...	*							
——, sp.	...	...	...	...	*				
Rostellaria Pricei, *Woodward* (v. rare)	...	...	...	...	*				
Scalaria Dupiniana, *D'Orb.*	...	...	...	...	*				
Solarium, sp.	...	*	...	...	*				
Turbo Triboleti, *P. & C.*	...	...	...	...	*				
Turritella, sp.	...	...	...	...	*				
Voluta semiplicata	...	...	...	...	*				
Cephalopoda.									
Ammonites cenomanensis, *D'Orb*	...	*	...	...	*				
—— Coupei, *Brongn.*	...	...	...	...	*				
—— falcatus, *Mant.*	...	*							
—— lewesiensis	...	...	...	*					
—— Mantelli, *Sow.* (common)	...	*	...	*					
—— navicularis, *Mant.*	...	*							
—— nothus, var. Mantelli ?	...	*							
—— rhotomagensis, *D'Orb.*	...	...	*	*	*				
—— varians, *Sow.* (common)	*	*	*	*	*				
——, sp.	...	*							
——, sp.	...	...	...	...	*				
——, sp.	...	...	...	...	*				
——, sp.	...	...	...	...	...	...	...	*	
——, sp. (with long tubercles)	...	...	...	...	...	...	...	*	
Ancyloceras	...	...	...	...	*				
Belemnites plenus (*De Blainv.*)	...	...	...	...	...	...	*		
—— plenus, var.	...	...	...	...	*				
Nautilus Deslongchampsianus, *D'Orb.*	...	...	...	...	*				
—— elegans, *Sow.*	...	*	...	...	*				
——, sp.	*	*							
—— pseudo-elegans, *D'Orb*	...	*							
Scaphites æqualis, *Sow*	*	*							

List of Fossils (*continued*).

	Chalk Marl.		Grey Chalk.					Lower Chalk.	
	I.	II.	III.	IV	V	VI.	VII.	VIII.	IX.
Turrilites costatus, *Lam.*	...	*	...	...	*	*			
—— Scheuchzerianus, *Bosc.*	...	*							
—— tuberculatus, *Bosc.*	...	*							
Pisces.									
Beryx, sp.	...	...	...	...	...	...	...	...	*
Corax heterodon=falcatus, *Ag.*	...	...	*						
Edaphodon, sp.	...	*							
Ischyodus, sp.	...	...	...	...	*				
Lamna, sp.	*	...	...	...	*				
—— subulata, *Ag.*	...	...	...	...	*				
Macropoma, sp.	...	...	...	...	*	...	...	...	*
Notidanus microdon, *Ag.*	...	...	*						
Oxyrhina Mantelli, *Ag.*	...	...	*	...	*				
Pisodus, sp.	...	...	...	...	*				
Ptychodus decurrens, *Ag.*	...	...	...	...	...	*	*	*	*
—— polygyrus, *Eg.*	...	...	...	...	...	*	*		
Saurocephalus lanciformis, *Harlan*	...	*							
Coprolites, vertebræ, &c.	...	*	...	...	*	*			
Reptilia.									
Acanthopholis horridus, *Huxley*	...	*							
Ichthyosaurus campylodon, *Carter*	*	*							
Wood	...	*							

Dr. Barrois.	*F. G. H. Price's Divisions and Zones.*			*Drew, in Mem. of Whitaker.*	*D'Orbigny.*
	Upper Chalk.				
Craie marneuse à *T. gracilis*, about 75 ft.	IX.	Lower Chalk, with *Inoceramus labiatus.*	Zone of *Echinoconus subrotundus* and *Terebratulina gracilis*, 118 feet.	Concretionary (?) nodular chalk, 73 feet.	Turonien. 150 feet.
Craie noduleuse à *I. labiatus*, 75 feet.	VIII.		Zone of *Cardiaster pygmæus*, 32 feet.		
B.-plenus zone proper = Zone à *B. plenus* (craie compacte). [Assise à *H. subglobosus*, 169 ft.]	VII.	Grey Chalk.	Zone of *Belemnites plenus*, 4 feet.	Soft bed of 6 feet, with *Belemnites*, Whitaker, p. 33. White chalk without flints, 138 ft.	Cénomanien. 197 feet.
Craie argileuse avec bancs durs à *A. rhotomagensis.*	VI.		Zone of *Holaster subglobosus*, 148 feet.		
Zone à *Ammonites varians.*	V.		2 feet 9 inches.		
	IV.		11 feet. Zone of *A. rhotomagensis* and *varians.*	Chalk marl (thickness not given), say about 30 feet.	
	III.		8½ feet.		
Craie marneuse à *P. mæandrina.*	II.	Chalk Marl.	10 feet. Zone of *Plocoscyphia mæandrina.*		
Marne sableuse=zone of *Pecten asper*, or Warminster beds.	I.		14 feet. Zone of *Stauronema Carteri.*		
	Upper Gault.				

Discussion.

Mr. Whitaker said that it was more than thirteen years since he examined the Dover section, and then these palæontological zones had not been invented; Mr. Drew's note on Lydden Spout was written some years earlier. He was glad that Mr. Price divided the Grey Chalk and Chalk Marl as he had himself suggested in a paper on the Chalk of Beachy Head read before the Society, and published in the Geological Magazine. He had been unable to find the Chalk Rock; and Mr. Price had not met with it; in fact it does not exist here as it does on the northern side of the London Basin, where it occurs between the Upper and Lower Chalk. He objected to the term Chloritic Marl, which is nowhere satisfactorily defined: in one place this name is given to Upper Greensand, in another to the bed forming the base of the Chalk. It has not only been thus applied to different deposits, but is itself a misnomer, inasmuch as it contains no chlorite, the green grains being glauconite. He was glad to see that the term was not employed by Mr. Price. With regard to the "Zone of *Ammonites varians*" spoken of by Mr. Price, he inquired to which of the beds III., IV., and V. the term was applied, or whether it applied to all of them. He regarded the Totternhoe Stone, in which that species was plentiful, as the top of the Chalk Marl. The Burwell stone, which he had not seen, was perhaps the same bed. While the zonification of the Chalk and of other deposits was very valuable when applied to particular sections, its application to great inland stretches of country without continuous sections, when the structure of the deposits could be seen only in occasional pits, was by no means so safe. In every case, however, it was very necessary to be exact with respect to the place of occurrence of fossils.

Prof. Seeley remarked that points of great interest were raised in both Mr. Price's and Mr. Jukes's papers. The former paper was an attempt to give us the palæontological divisions, from a French point of view, side by side with stratigraphical divisions; but he thought that we ought to try to correlate the Folkestone section with other English sections before crossing the Channel. Some beds, wanting here, are no doubt present in other sections. With regard to Mr. Jukes-Browne's paper, he thought that the introductory part called for no remarks, as it treated of matters which every palæontologist must have long ago settled in his own mind. In the latter part Mr. Jukes-Browne adduces fresh evidence in support of certain views which he brought before the Society some time ago, and from which Prof. Seeley, from his own investigations of the ground, dissented at the time. He thought that Mr. Jukes-Browne had completely mistaken the sequence of the beds, and that what he regarded as a vertical succession in his Buckinghamshire section was really a horizontal succession. The essential point of his paper was to prove that the bed commonly called Upper Greensand, near Cambridge, lay unconformably upon the Gault; and he thought that the fauna of the Gault went into that of the Upper Greensand; but his information was mainly derived from coprolite-diggers, and was not trustworthy. In Prof. Seeley's opinion, the differences in the deposits which had led Mr. Jukes-Browne astray were due to relative distance from the land which furnished the materials of the deposits; and he stated that his opinion was founded upon a careful consideration of beds both above and below. Beds in the Gault contain phosphatic nodules similar to those of the Cambridge Greensand; and in both formations these have been rolled and washed about near a shore, and are not in either case derived. What are supposed to be Chalk-Marl fossils peculiar to the deposit are the species which lived in deeper water; what are supposed to be derivative Gault fossils are the species of the Laminarian zone, which, when mineralized with phosphate of lime, were rolled down into deep water and mixed with the others.

Rev. J. F. Blake remarked, with regard to Mr. Price's paper, that he was glad to see an English geologist taking up the palæontological or zonal investigation of our Chalk; but he deprecated the discrimination of so many zones in this series, and expressed grave doubts whether so minute a classification could be at all widely applied. In reply to Prof. Seeley's remarks on Mr. Jukes-Browne's paper, he urged that if phosphatic nodules are found in the Gault, this was another argument in favour of the view that those of the so-called Cambridge Greensand had been washed out of the earlier formation.

Mr. Meyer said that he was well acquainted with the Dover section, which he had carefully measured, and he agreed with Mr. Price as to the absence of the Upper Greensand in these sections. He added that the Chloritic Marl, although a very thin bed, is a reality, and exceedingly rich in fossils. He agreed with Mr. Jukes-Browne in thinking that there was a great break between the Gault and the Chalk Marl in the Cambridge section.

Mr. J. F. Walker maintained that most of the fossils in the Cambridge beds are derived; the bed is of the age of the Chalk Marl, and varies in character owing to the mixture of Gault Clay with it. Some of the Reptiles may be of Upper-Greensand age, having lived on mud banks during the process of the denudation of the Gault.

Mr. H. B. Woodward inquired whether we might not legitimately consider the question of the Chalk conditions having come on earlier in the east of England than in the west. He mentioned that in the western counties we have evidence of shallow-water conditions in the lower beds of the Chalk, while the Upper Chalk, as Mr. Whitaker had pointed out, overlapped the Lower. He stated also that both *Holaster subglobosus* and *Ammonites rhotomagensis* occur in the Chloritic Marl of the west.

Mr. Whitaker defended Mr. Jukes-Browne's views, from his own observations of the country; and stated that Mr. Jukes-Browne had not got all his information from coprolite-workers, but to a very large extent from personal observation.

Mr. Price said that the general concurrence of the speakers left him little to say in reply. For the zone of *Amm. rhotomagensis*, it would be better to adopt the name of "Zone of *Amm. varians*." Professor Seeley urged the correlation with other English beds; but that Mr. Price could not attempt; he had therefore confined himself to the Folkestone section and the French beds. He agreed with Mr. Jukes-Browne in his division of the beds in Cambridgeshire, where, he thought, the coprolite-beds are the equivalents of part of the Chalk Marl and a large part of the Upper Gault.

22. *On certain* Ancient Devitrified Pitchstones *and* Perlites *from the* Lower Silurian District *of* Shropshire. By S. Allport, Esq., F.G.S. (Read May 23, 1877.)

[Plate XX.]

I.

The principal object of the present communication is twofold:—in the first place, to bring under the notice of the Society the occurrence in Shropshire of an extremely interesting series of ancient vitreous and semivitreous lavas, with their associated agglomerates and ashes; and in the second, to show, from an examination of their structure and composition, that originally they were absolutely identical with some of the glassy volcanic rocks ejected during the most recent geological periods.

In a previous paper (published in vol. xxx. pp. 529–567, of the Quarterly Journal) I arrived at the same result as to the identity of ancient and recent volcanic products, from an investigation restricted to the basic group of rocks; and I am now enabled to show that those of the acid type afford equally strong evidence in the same direction.

The discovery of several highly characteristic varieties of glassy rocks and volcanic ashes of Palæozoic age is, I think, a matter of considerable interest from a petrological point of view, more especially as their mode of occurrence and their relations to the surrounding strata afford the clearest evidence that the geological structure of a part of the district in which they occur has hitherto been misunderstood.

On Sheet 61 of the Geological-Survey map a band of "greenstone" is represented as constituting the axis of the somewhat irregular narrow ridge of which Ercal Hill and the Wrekin form the greater portion. It commences half a mile south of Wellington, and extends in a south-westerly direction to a distance of two miles and three quarters. At two points not far from each other the ridge is cut through by deep and narrow gorges, which traverse it from south-east to north-west, or at right angles to its general direction. The isolated hill thus formed by the two ravines is locally known as Lawrence Hill, and is indicated though not named on the map.

At a short distance to the west there is laid down a still larger mass of "greenstone," which extends from the vicinity of Wrockwardine as far as Uppington, and forms a low ridge parallel to that of the Wrekin.

With the exception of some thick beds of indurated ashes which occur in the Wrekin and Lawrence Hill, the principal rock-masses are of similar character in both ridges; and a slight examination with a lens would suffice to show any petrologist that the term *greenstone* is the most inappropriate that could possibly be applied to them. They all belong to a highly acid type, and have not the slightest resemblance whatever to greenstone or any other rock of the basic series. In a large quarry at the south end of Lawrence Hill thick beds of volcanic ash are seen dipping in a northerly direction, at an angle of 55°. Like all the rocks of the range, they have been greatly disturbed and fractured; but the strike of the beds is clearly across the ridge. They here consist of several alternations of coarse and fine material, the whole of which have been highly indurated and otherwise altered. These beds are covered by masses of altered pitchstones and felsites, which are well exposed on the south slope of the hill, on its steep northern face, and also on the opposite crags of Ercal Hill. Returning southwards to the narrow ravine which separates Lawrence Hill from the Wrekin proper, the ash-beds are again exposed in the precipitous face of the latter; the bedding is here massive or obliterated, although the fragmental character of the rock is still perfectly distinct. Further southwards, along the summit of the ridge, beds of the coarser ash are again seen, and may be traced at intervals for a distance of more than six hundred yards. From this point to the south-western termination of the ridge there are comparatively few exposures of rock; and these consist of compact reddish-brown felsite or altered pitchstone—the *compact felspar* of Murchison and others.

On the summit of the ridge, at a short distance to the north of the wood, there is a slight rounded elevation formed by a mass of altered dolerite, which appears to be intrusive; and in the quarry at the south end of Lawrence Hill there are two dykes: one, on the east side, is 12 ft. wide; the other is 14 ft. at bottom, cuts through the lower ash-beds, then bifurcates, and the two diverging branches rise through the upper beds to the surface. The rock forming both dykes is a highly altered basalt.

It is evident, therefore, from an examination of this part of the ridge, that the axis is not formed by a continuous band of greenstone, as hitherto represented, but that in reality it here consists of an extensive series of regularly stratified agglomerates and ashes alternating with amorphous masses of altered pitchstones or felsites.

The general strike of the surrounding strata is north-east; and the central ridge is flanked by masses of quartzite, which are laid down on the map as Caradoc Sandstone, altered by the supposed intrusive greenstone. Whether these rocks be altered Caradoc strata or not, they are clearly unconformable to the stratified ash-beds of the ridge; and I think there is some reason to believe that the latter belong to the older contemporaneous volcanic series so extensively developed in the Lower-Silurian district of Salop and Radnor.

The mass of trap lying to the west of Wellington and the Wrekin is a hard rock which has suffered less from denudation than the soft Triassic sandstones by which it is surrounded; it forms a low hilly tract, usually presenting rounded or flat surfaces, on which several large boulders of granite and felstone have been stranded. These erratics appear to be quite similar in character to those forming the well-known and far more numerous group just north of Wolverhampton. With the exception of some portions at the southern end of the mass, the rock appears to present the same general characters throughout, specimens from the northern end being quite similar to some of those collected at the opposite extremity. It is for the most part a hard compact rock of dark red or brown colour, and is the *compact felspar* and *hornstone* of Murchison, who also refers to one variety as a porphyritic clinkstone.

In order to show clearly the true character and structure of these rocks, it will be necessary, in the first place, to give a short account of their recent analogues; as rocks of this peculiar type are by no means of wide distribution, and some of them have not been previously observed in these islands.

II. Structure of Modern Perlites.

Perlite, spherulitic perlite, perlitic pitchstone, and perlitic obsidian belong, as is well known, to the glassy group of acid rocks, their average amount of silica being at least 70 per cent. In typical unaltered specimens the mass consists of a true glass which has no action on polarized light.

The spheroidal and ellipsoidal balls by which perlite is chiefly characterized have been described by Zirkel *, Rosenbusch †, and Lassaulx ‡ as consisting of concentric laminæ arranged like the coats of an onion—a comparison which may, I think, possibly lead to erroneous ideas as to their real character; for however close may be the resemblance, as seen in thin sections, there is no real analogy between the structure of these perlitic spheroids and that of a tunicated bulb built up of broad scales which surround each other in a concentric manner.

An examination of typical specimens from the old volcanic districts of Schemnitz in Hungary, Meissen in Saxony, and Cabo de Gata on the south coast of Spain shows that the spheroids have not been formed by the superposition of successive laminæ: they are not concretions in any sense of the term; nor is there any thing about them suggestive of any process of progressive construction. When a rather thick section is examined under a low power of the microscope, it is at once seen that the little spheroidal balls are merely portions of the homogeneous glass which have been partially separated from the general mass by the formation of a number of small curved planes of fracture; these are more or less concentric with each other, but vary greatly in size, and are irregularly disposed in various directions round the centre. As these curved planes lie at various depths in the section, some of them appear with a convex or concave surface, according as the slice happens to cut through the upper or lower half of a spheroid. Such being the general arrangement, the lines seldom form closed curves when seen in thin sections. That these lines and curved planes are really fine cracks is clearly shown by the way in which they are frequently filled more or less completely by the in-

* Mikroscop. Beschaff. der Mineralien und Gesteine, p. 365.
† Mikroscop. Physiographie, p. 124.
‡ Elemente der Petrographie, p. 221.

filtration of foreign matter in solution; and that they were caused by the strain produced during contraction of the brittle glass is rendered evident by such examples as the following, in which may be traced nearly every gradation between long rectilinear fissures or joints and those forming the typical perlitic structure. Fig. 1 (Pl. XX.) represents the arrangement observed in a section of perlitic pitchstone from near Meissen. Several roughly parallel joints divide the glass into small columns; and these are again traversed by cross joints, which thus form minute rectangular blocks. In the central one (*a*) a spheroid is formed by four curved lines, which clearly branch off from the lateral joints, and round off the corners of the rectangle. In the upper compartment there are three distinct spheroids; and in the lower one there are two of irregular shape. Fig. 2 is from another part of the same slice. In fig. 3 the formation differs in this respect, that in both columns several spheroids are piled one on the other without any intervening cross joints. In a typical perlite from Cabo de Gata in Granada, there are numerous large spheroids, in which many of smaller dimensions are enclosed (see fig. 4). In nearly all the specimens examined the glass is divided into areas of various sizes and forms by a number of parallel or diverging straight lines (joints), the intervening spaces being frequently crowded with spheroids, many of which are flattened against each other (see fig. 5, Pl. XX.).

An examination of all the facts leads to the conclusion that the perlitic texture is purely a phenomenon of contraction; and I quite agree with Mr. Rutley * that the explanation of the spheroidal structure in basalt recently laid before the Society by the Rev. T. G. Bonney † is a closely parallel case. There is, however, this difference—that, in the case of basalt, the comparatively tough texture produced by the interlacing of its crystalline constituents would enable it to resist the actual fracture so frequently exhibited by the more brittle perlites.

The perlites and other vitreous rocks usually contain numerous minute microliths, which have been described by Zirkel under the names of belonites and trichites; their mode of occurrence and relation to the superinduced spheroidal (perlitic) structure deserve special attention.

The belonites are minute translucent prisms, either colourless or of pale yellow or greenish shades; they occur in immense numbers, and are frequently crowded together in stream-like bands, with their long axes lying in one general direction. Whenever a stream encounters any small crystal of felspar, quartz, or mica imbedded in the mass, the belonites are invariably diverted from their course and bend round it, their axes lying parallel with its sides. Their relation to the perlitic spheroids, however, is totally different; for instead of winding round them, they continue their course uninterruptedly through and across them (see fig. 8). It becomes

* "On some Structures in Obsidian," &c., read before the Royal Microscopical Society, March 1876.

† Quart. Journ. Geol. Soc. vol. xxxii. p. 140.

evident, therefore, that this so-called fluidal structure may be explained as the result of movements imparted to a mass composed of solid crystals and a viscid base—and, on the other hand, that the perlitic spheroids must have been formed subsequently to the solidification of the entire mass.

The trichites are extremely minute and slender hair-like crystals, either straight or bent and twisted into most irregular curved and even zigzag forms. They are usually black and opaque, but when partially decomposed appear of a reddish-brown colour.

Spherulites also frequently occur in glassy rocks. They are globular in form, though quite distinct in character from the perlitic balls or spheroids, with which, however, they are not unfrequently associated. They are seldom very translucent, even in quite thin sections, but invariably polarize light, and exhibit a fine fibrous radial structure. They will be more fully described in the sequel.

These semicrystalline bodies were evidently the last substances formed prior to the solidification of the mass ; for not only are the more perfectly crystallized constituents (felspar, mica, &c.) enclosed in them, but even the streams of microliths also occasionally pass straight through them—a fact which appears to have escaped the notice of previous observers. As regards the general order of formation, the evidence seems therefore to indicate that crystals of felspar, mica, quartz, &c. were enclosed in a viscous glassy magma, which was also crowded with innumerable microliths ; before the mass solidified, the fluidal structure was imparted to it ; and subsequently, during solidification, the radiating spherulites were formed, without disturbing the previous arrangement of the microliths*.

The characters just described are extremely well shown by a single group of minerals in a section of one of the Kremnitz perlites (see fig. 7). Fibrous spherulites are here seen to be traversed by streams of microliths, and also to be penetrated by plates of mica and crystals of felspar. In the figure, one end of a plate of brown mica is enclosed in a spherulite, while the opposite end penetrates a crystal of orthoclase ; the latter interferes with an adjacent spherulite, which is partly formed round it on the left side, and a partially included plate of mica projects from it on the right. It will also be seen that the streams of microliths invariably flow round all the crystals, whether large or small.

Having sketched the most prominent features of comparatively recent perlitic and spherulitic rocks, I will now describe a few of their ancient prototypes.

III. Structure of ancient Spherulitic Pitchstones and Perlites.

As previously observed, the principal rock-masses in the two parallel ridges near Wellington present the same general characters:

* I recently described the occurrence of an analogous case of crystallization without disturbance of previous texture, in one of the altered slates near Penzance. See Quart. Journ. Geol. Soc. vol. xxxii. p. 410.

the one to the west of the Wrekin, however, is the more important for my purpose, as it affords the most interesting and typical varieties, and also supplies the best specimens for examination.

At "Lea Rock," near the south-western termination of the ridge, there is a large quarry near the Shrewsbury road, in which the rock is very well exposed. In one part it is intersected in all directions by numerous joints and cross joints, which cause it to break into small fragments; so that fresh surfaces are difficult to procure. The jointage-planes are generally smooth, and coated with peroxide of iron, and frequently exhibit on their slightly weathered faces numerous fine parallel lines, which are either straight or tortuous, and even exhibit a complicated folding and crumpling, like that seen in crystalline schists. Sometimes, however, they widen out into distinct bands, and then produce a striped or laminated appearance. In some cases the parallel stripes are so distinctly marked that they closely resemble laminæ of deposition, or lines of foliation, and have in fact been regarded as evidence of the original stratification of the rocks here described. An examination of their internal structure shows, however, that they invariably indicate the presence of those remarkable streams of microliths previously described in the Hungarian perlites (p. 453, Pl. XX. fig. 7)*. These finely banded rocks also occur in the Wrekin.

Among the most interesting examples collected in the quarry just mentioned are several varieties of a remarkable spherulitic rock. These exhibit the closest analogy with the comparatively rare though well-known group of volcanic vitreous rocks already referred to, and may, I think, be appropriately described as

Ancient Spherulitic Pitchstones and Perlites.

One beautiful variety of this rock consists of numerous bright-red spherulites set in a grey or yellowish-green matrix. Sometimes they occur singly, and are irregularly scattered throughout the mass; or, as frequently happens, several are crowded together so as to interfere with the development of their regular spherical form; while in other specimens they are arranged in rows, like strings of coral beads, and thus form parallel layers. This is a well-marked feature even in hand specimens; and when the spherulites are closely pressed together, a thin slice exhibits a series of continuous red bands, with undulating outlines formed by the mutual interference of successive contiguous spheres (see fig. 8). This is an extremely hard rock of a bright red colour, and closely resembles some varieties of jasper.

As seen in thin slices, the spherulites (fig. 9, Pl. XX.) usually consist of a circular central disk of bright red surrounded by a colourless ring (distinguished by two shades in the figure); the latter varies greatly in width, and is perfectly continuous with the red portion, of which it is merely the unstained border; and then there is an outer zone of transparent glass (unshaded in the figure).

* For an admirable description of laminated volcanic rocks, see Darwin's 'Geological Observations on Volcanic Islands,' p. 74, second edition.

When examined under the microscope in polarized light, with crossed prisms, the central red spot and its colourless border exhibit a perfectly distinct fibrous radial structure, the central disk still retains its bright red tint, and the colourless border appears of a pale grey, except where obscured by the arms of the black cross. Frequently, however, the red stain extends quite to the edge; and a fibrous red spherulite is then surrounded by a zone of homogeneous glass. Although the fibrous crystals usually radiate from a central point, there are not a few spherulites which exhibit two distinct modifications of this arrangement. In one the fibres are seen to radiate from several points surrounding a felsitic mass of irregular shape; the rays forming the different groups meet each other along diverging straight lines; and the whole is surrounded by a glassy ring. In other cases the spherulites are ellipsoidal, and the fibres usually radiate from a point near one extremity of the axis. Small crystals of felspar are frequently enclosed in the spherulites; but, precisely as in the Hungarian perlite previously mentioned (p. 453 and fig. 7), their position has no relation whatever to the radial crystallization of the substance by which they are surrounded; this is clearly seen in fig. 10, which shows two felspar crystals enclosed in a spherulite.

Another striking resemblance between the ancient and more recent examples is found in the fact that the transparent matrix in which the spherulites are enclosed frequently exhibits a perfectly distinct perlitic texture, as shown here and there in fig. 8, and is also crowded with streams of microliths, which pass straight through the spherulites, precisely as in the Kremnitz rock represented in fig. 7.

The microliths closely resemble the more recent belonites in size and shape; and even the singular and unmistakable trichites, with the same twisted and knotted forms, are abundant in some of my sections. One kind, consisting of strings of minute dots, are the most prevalent, and are precisely similar to those observed in some specimens of spherulitic pitchstone from Schemnitz.

Besides the felspar crystals just mentioned, others are scattered here and there through the matrix, and cause streams of belonites to bend round them. Orthoclase and plagioclase are both present, and are remarkably well preserved; the latter appears to predominate; and the crystals are often beautifully striated.

The rock just described appears to pass gradually into a variety from which the spherulites are absent, but which presents most excellent examples of perlitic structure.

Devitrified Perlite.

The examples in my possession are of a rather dull yellowish-brown colour, and are slightly fissile in one direction. When examined with a lens, a freshly broken surface exhibits numerous small convex and concave faces; and when a thin slice is placed under the microscope a true perlitic structure is at once seen to be as distinct and unquestionable as in any of the more recent glassy rocks. Fig. 6 represents a portion of a thin slice of one of these ancient perlites; and beside it I have placed an equally careful drawing of a typical perlite from Schemnitz (see fig. 5). The older rock has undergone a considerable amount of alteration; and that constitutes the only perceptible difference between them. In some of the Meissen pitchstones the perlitic structure is nearly or quite absent, while in others it is well developed; and it fortunately happens that specimens occur in various stages of alteration.

In one of the red varieties the colour of the mass is due to the infiltration of bright red ferric oxide, which has followed the lines of fissure, and has also stained the glass for a short distance on each side, as represented by the light shade in fig. 1. In the same specimen, however, a yellowish-brown substance here and there takes the place of the red oxide, and shows a marked tendency to aggregation in little spherical nodules. In a brown variety from the same locality, a pale brown flocculent substance is alone present, and has invaded the glass in the same manner but to a far greater extent than in the preceding examples; the parts permeated by it have a distinct action on polarized light; and it is quite evident that a further extension of the process of alteration would impart to the mass a pseudo-felsitic aspect.

The kind of alteration here described has clearly been produced by chemical action; and it has followed precisely the same course as that which has so frequently converted fractured crystals of olivine into serpentinous pseudomorphs.

In the ancient perlite a similar process has been in operation, and has produced the appearance represented in fig. 6. The shaded parts indicate the presence of a yellowish-green substance, which accompanies the lines of fissure and has invaded the glass on each side.

Devitrification of the glassy magma.—In addition to the chemical alteration just described, the original glassy base of these old rocks has also undergone certain molecular changes which it is highly important to notice. A slight examination of the two thin slices represented in figs. 5 & 6 suffices to show the identity of their general character as seen in ordinary light; but when placed under the polarizing microscope between crossed prisms, it is at once seen that the matrix of the Schemnitz rock remains dark, while that of the older one transmits light in many places, and the field of view exhibits an irregular mosaic of light and dark grains.

On rotating the object, some of the dark grains may then be seen to transmit light in certain positions; but the greater number always remain dark; and it becomes evident that the mass consists of a homogeneous glass with numerous doubly refracting patches disseminated through it. The extent to which the two substances prevail varies considerably in different parts of the rock: in some of the highly altered spherulitic varieties there may be seen a perfect mosaic of varying pale shades of colour, while in others the glassy substance predominates. The peculiar character of the doubly refracting portion of the base is extremely well shown when the axes of the Nicols are inclined to each other; by a slight rotation of the object alternately to right and left, the previously well-defined granules gradually assume shadowy indefinite forms of variable dimensions, alternately appearing and disappearing; while the perlitic curved lines are seen to pass continuously through them, and even the minute belonites and trichites appear with opposite ends enclosed in two of the adjacent pseudo-granules.

When the devitrification appears to be complete, and a granular mosaic structure the most distinct, there is not the slightest appearance of any such fragmental character when examined in ordinary light. Under all powers of the microscope the matrix then seems to be a perfect glass traversed by straight or tortuous streams of microliths and intersected by the perlitic fissures already described.

Although these investigations show conclusively that certain molecular changes have taken place, it should not be overlooked that the structure resulting from devitrification differs in character from that of a true felsite; and I think the rocks here described afford no evidence in favour of the view held by Vogelsang and others, that the base of the so-called quartz-porphyries may have been originally of a glassy nature.

The thin sections are frequently traversed by narrow veins, which pass through all the constituents, as shown in fig. 10. A fine fissure has here cut through the matrix, a spherulite, and an enclosed crystal of felspar. In all cases these veins appear to consist of the same substance as the devitrified matrix; and when the latter is penetrated by one of them, it is impossible to distinguish the one from the other except in certain positions of the prisms, when the continuity of the vein may still be detected.

Quartz-veins are not uncommon; and in some parts of the spherulitic rock chalcedonic nodules are rather abundant.

Although the microscopical structure of these rocks is in itself decisive as to their origin, I may add that their chemical composition is also in perfect accordance with their other characters. Mr. J. A. Phillips kindly made for me an analysis in duplicate of a specimen of the devitrified perlitic pitchstone, with the results shown in the following Table, in which I have also included analyses of two Miocene perlites:—

Spec. grav. 2·62.	I.	II.	III.	IV.
Water	1·47	1·46	3·50	2·90
Silica	72·18	72·19	72·52	73·00
Alumina	14·46	14·44	13·72	12·31
Ferric oxide	1·78	1·59	2·08 (Ferric and Ferrous oxide)	2·05 (Ferric and Ferrous oxide)
Ferrous oxide	0·91	0·91		
Oxide of manganese	trace.	trace.		
Lime	0·92	0·93	1·15	1·20
Magnesia	trace.	trace.	0·45	1·47
Potash	6·10	6·14	5·68	5·96
Soda	1·92	1·96	1·15	1·36
	99·74	99·62	100·25	100·25

I., II. Ancient Pitchstone; analyzed by J. A. Phillips.

III. Perlite, from Hlinyik, near Schemnitz; analyzed by Von Sommaruga, quoted by J. Roth *.

IV. Pearlstone (Hungary); analyzed by Rammelsberg †.

An inspection of a list of analyses shows that there is quite as close an agreement between these examples of ancient and Tertiary perlites as can be found in a series of the latter only; and as this similarity of chemical composition exists notwithstanding the alteration to which the older rocks have been subjected, it may be inferred that in this instance, as in others, the changes have been almost entirely molecular, little or nothing having been taken from or added to the mass.

Intimately associated with the characteristic devitrified pitchstone there occurs a hard compact variety of a dark red colour and semi-vitreous aspect, with a subconchoidal fracture and sharp cutting-edges. Some specimens show a banded structure, even to the naked eye; while others, apparently amorphous, exhibit under the microscope most interesting examples of fluidal structure, but with no indications of perlitic or spherulitic formations. These also appear to consist of devitrified glass, and are found to pass into masses of ordinary "hornstone" or "compact felspar," which were probably never in a vitreous condition.

A close examination of very thin slices shows that the red colour of these rocks is entirely due to the diffusion of hydrous ferric oxide through the mass; a magnifying power of 800 enables one to perceive that the matrix consists of a colourless glassy substance crowded in parts with minute yellowish-red specks, which have the appearance of a fine dust even under the highest powers. In many cases the colouring-matter clearly has its origin in minute ochreous patches presenting crystalline forms with ragged outlines, from which the red stain has spread in all directions.

Indurated Volcanic Agglomerates, and Ashes.

An examination of the stratified fragmental rocks of Lawrence Hill and the Wrekin leaves no room for doubt as to their real character.

The various beds consist for the most part of a breccia composed of small angular and slightly rounded fragments of compact red felsite and altered pitchstone, quite similar to those forming the masses with which they are associated; these, together with other materials, have been cemented together, and now form an extremely hard rock, which frequently exhibits manifest signs of subsequent alteration. Fragments of larger size, however, are not uncommon; and in one of the coarser ash-beds a block of beautiful spherulitic pitchstone, 8 inches in diameter, was found imbedded in the mass. A vertical slice of one of the finer ash-beds exhibits under the microscope a series of thin layers composed of angular

* Beiträge zur Petrographie. Berlin, 1869.

† Die Gesteins-Analysen. J. Roth. Berlin, 1861.

fragments of pitchstone, in some of which small crystals of orthoclase and plagioclase are surrounded by streams of microliths, while others have a felsitic or crypto-crystalline texture and are crowded with minute crystals of felspar. A few fragments of spherulites have been detected; and there are also great numbers of broken felspar-crystals scattered through the mass; some of the thin layers are, in fact, almost wholly composed of abraded felspar crystals, with small fragments of microcrystalline trap disseminated among them.

At one time some of these ashes must have been slightly vesicular; for they now contain many cavities whose walls are coated with chlorite, and the interior filled with crystalline quartz. In a few cases calcite and quartz are associated together. There are also some interesting examples of microscopic cavities filled with calcite and epidote; bright yellow prisms of the latter project from the walls and cross each other in various directions, the intervening spaces being filled in with the calcite. Pale lemon-coloured epidote is by no means uncommon in the coarser ash-beds; it usually occurs in fan-shaped groups of flat prisms, which exhibit delicate bright tints in polarized light. In all the descriptions of the optical characters of this mineral which have come under my notice, it is said to be strongly dichroic; this, however, is certainly not the case with any of the numerous examples of pale yellow epidote which I have observed in these rocks, and in the altered syenites of Leicestershire and other localities.

The masses of rock here described represent a portion only of a series of similar products which have been erupted along an old line of volcanic action; porphyritic and other varieties occur at Charlton Hill and Caer Caradoc near Church Stretton: while in the hilly district to the west there are still traces of old volcanic vents, accompanied by a most interesting variety of basic and acid lavas, which I hope to describe on a future occasion.

Conclusion.

The results arrived at in the present memoir may be briefly summed up as follows:—

1. The highly characteristic internal structure of some of the rocks affords the clearest proof of their original vitreous condition; for the peculiar perlitic and spherulitic formations, with their associated microliths, have never been observed except in connexion with the obsidian or pitchstone varieties of volcanic glass.

2. It appears also that, in the older as in the younger series, there is the same gradation between the vitreous and stony varieties; and as the perlitic and other glassy rocks are well known to be subaerial volcanic products, the rocks here described afford strong evidence that during the earlier geological periods volcanic action was of the same kind and produced the same results as in more recent times. I will only add, in conclusion, that probably no one who examines a good series of the Schemnitz rocks, or the beautiful rhyolites of the Euganean Hills, will fail to recognize among

their numerous varieties the precise analogues of the ancient volcanic rocks of Shropshire.

EXPLANATION OF PLATE XX.

Fig. 1. Portion of a thin slice of perlitic pitchstone from Meissen. The narrow shaded bands represent an incipient alteration along the lines of fissure.
2. Another portion of the same slice.
3. Part of a thin slice of perlite from Schemnitz.
4. Perlitic spheroid from Cabo de Gata, see p. 452.
5. Section of perlite from Schemnitz, showing parallel and cross joints, with general grouping of the perlitic spheroids, see p. 452.
6. Ancient perlitic pitchstone, "Lea Rock," near Wellington, showing a similar original structure. The shaded parts represent a green-coloured product of alteration, see p. 456.
7. Section of spherulitic perlite from Kremnitz, described p. 453.
8. Section of spherulitic pitchstone from Lea Rock, containing bands of spherulites and streams of microliths in a transparent perlitic matrix.
9. Diagram of spherulite, described p. 454.
10. Spherulite in ancient pitchstone, Lea Rock, containing two crystals of felspar, and traversed by a vein filled with a substance having similar optical characters to the devitrified matrix, see p. 457.

The figures faithfully represent the originals as seen with the magnifying powers indicated, with the exception of the fibrous crystallization of the spherulites, which is, of course, greatly exaggerated.

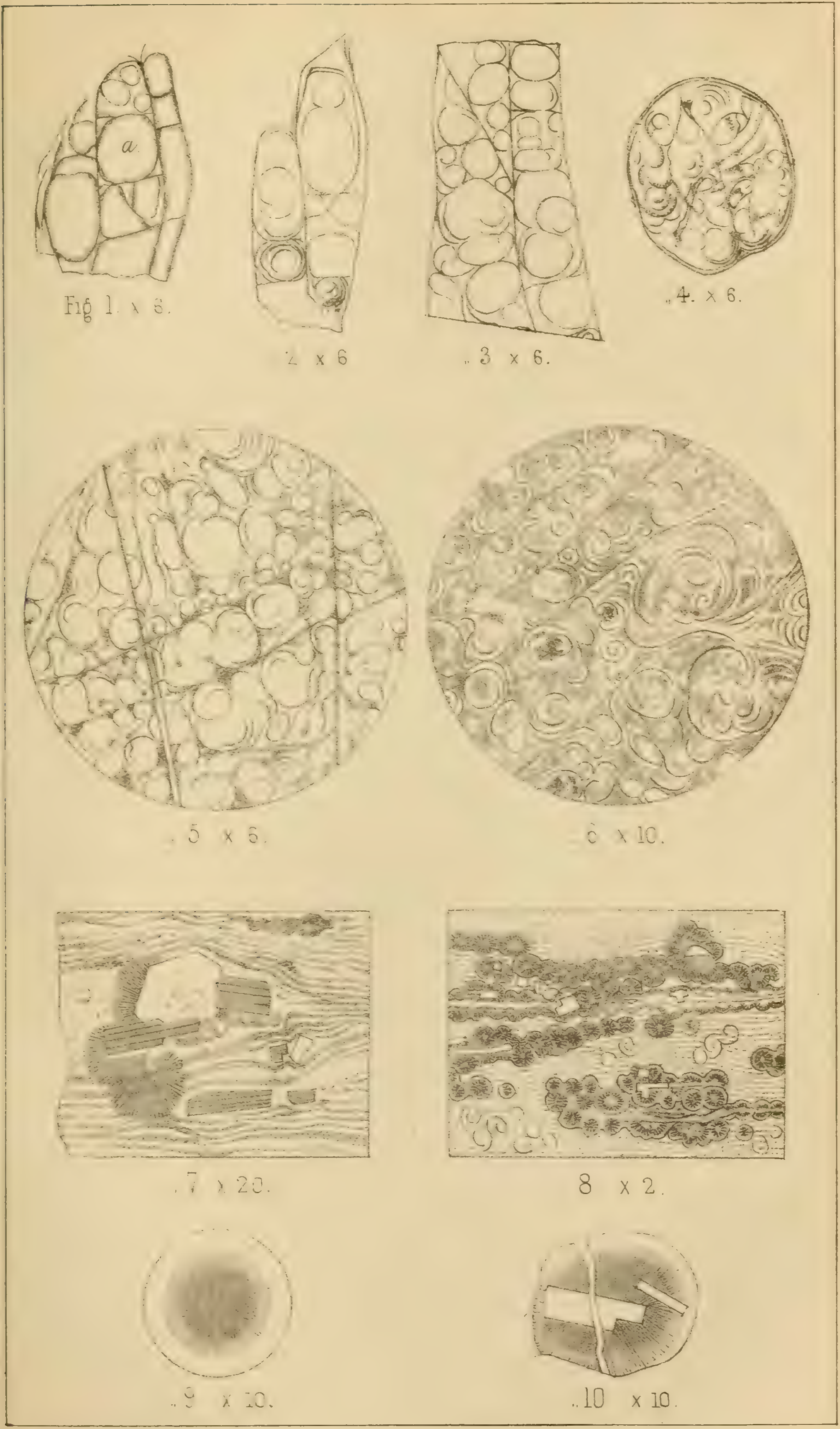
Discussion.

Mr. Warington W. Smyth thought that, with regard to the rocks of the Lizard Point, Mr. Bonney's paper would carry conviction to the minds of many who had been led to different views by the works of previous writers. The facts brought forward seemed to correlate these rocks with others which have been examined in Sweden and Norway, in the south of Spain, and in Elba.

Prof. Judd, referring to Mr. Allport's paper, said that the similarity of these ancient rocks to those of Tertiary times extended to the most minute details. The unity of character so long ago recognized among stratified rocks of different ages was now being extended to the igneous rocks; and these also would in time be correlated according to their respective ages.

The President inquired whether Mr. Bonney had met with indications of gas-passages in the serpentinous rocks, such as might simulate *Eozoon*.

Rev. T. G. Bonney stated that he had examined the serpentines of Elba. With respect to Mr. McPherson's paper referred to, he said that some of that gentleman's figures might be taken as representing the Lizard serpentines. In reply to the President he stated that he had seen gas-passages, but nothing resembling *Eozoon*, although in the first stages of the decomposition of olivine the nummuline layer sometimes seemed to be simulated. For his own part he believed in the organic nature of *Eozoon*.



S. Allport, del.

PITCHSTONES & PERLITES FROM SHROPSHIRE.

23. *On the* Strata *and their* Fossil Contents *between the* Borrowdale Series *of the* North of England *and the* Coniston Flags.

By Robert Harkness, Esq., F.R.S., Professor of Geology in Queen's College, Cork, and H. Alleyne Nicholson, M.D., D.Sc., F.R.S.E., Professor of Natural History in the University of St. Andrews. (Read March 21, 1877.)

Introduction.

In the following communication we propose shortly to consider the various groups of strata which intervene between the great volcanic series (Borrowdale Rocks) of the Lake-district and the well-marked band of sedimentary rocks to which Prof. Sedgwick applied the name of the "Coniston Flags." In so doing we shall have occasion to note, in a general way, the physical characters and relations of the successive deposits in question; but we shall have to draw attention more especially to the organic remains which they contain and to some indications thus afforded as to their precise age and position in the geological scale.

The base of the great Silurian series of the north of England is constituted, as is well known, by the "Skiddaw Slates," a thick mass of sediments, originally in the condition of black mud, clearly proved by their fossil contents to be of the age of the "Arenig group" of Wales. Succeeding the Skiddaw Slates there occurs a great series of volcanic products, termed by Prof. Sedgwick the "green slates and porphyries," to which we have elsewhere given the name of "the Borrowdale series." These consist of ashes and breccias, alternating with ancient lavas, a portion of the series being subaerial, whilst part is of submarine formation.

Throughout the greater part of this extent, for a thickness of some thousand feet, the Borrowdale series has hitherto proved unfossiliferous; fossils, however, make their appearance in a thin band of calcareous ashes near the summit of the group (Harkness and Nicholson, Quart. Journ. Geol. Soc. vol. xxii. p. 480).

In some places, as at Style-End Grassing, between Long Sleddale and Kentmere, this band consists of brownish or bluish grey shales, and it is separated from the Coniston Limestone by a bed of trap. In other spots, as at Sunny Brow, between Ambleside and Coniston, the bed is siliceous and gritty in nature. At Millom the same fossiliferous band is recognizable, and is not only ashy in its character, but is surmounted directly by strata belonging to the Coniston Limestone series without the intervention of traps. Lastly, there are places, such as the east side of Long Sleddale and the southern declivity of Wansfell, where the same beds can be readily recognized, having the same relation to Coniston Limestone, similar to the ordinary ashes of the Borrowdale series in their ordinary character, and exhibiting no traces of fossils beyond the presence of innumerable cavities filled, or partially filled, with rusty peroxide of iron, apparently due to the decomposition of organic remains.

It is not our purpose to discuss here the position and age of these "Style-End Grassing beds," as they may be called. It may, however, be noted that the fossils which they have yielded are Bala types, such as *Calymene Blumenbachii*, Brongn., *Orthis vespertilio*, Sow., and *Petraia æquisulcata*, M'Coy. This is of interest as indicating that the volcanic activity of which the Lake-district became the theatre subsequent to the deposition of the Skiddaw Slates, continued to prevail, at any rate, up to the later portion of the Bala period.

Resting, apparently with perfect conformity, upon the Borrowdale rocks a series of deposits occur which we wish more especially to discuss here.

These deposits may be grouped in the following ascending order:—

1. Dufton Shales.
2. Coniston Limestone and Shales.
3. Graptolitic Mudstones, or Skelgill beds.
4. Knock beds.

1. Dufton Shales.

The "Dufton Shales" are but locally distributed, though they constitute a well-marked group of muddy sediments underlying the Coniston Limestone proper and its associated shales. They do not appear in any recognizable form beneath the main line of the Coniston Limestone in the Lake-district itself. They do not seem to occur in the Sedbergh district; nor have they been recognized in Ravenstonedale or Ribblesdale; but they are very well developed in the Silurian area which includes the Cross-Fell range.

Here they are seen in four principal exposures, owing to the folding and faulting of the strata, viz.:—Swindale Beck, near Knock; Pusgill and Dufton-Town dykes, near Dufton; Harthwaite Gill, near Keisley; and at the Smelt Mill, near Hilton.

The thickness of the Dufton Shales in these localities probably exceeds 300 feet. They consist of dark flaggy shales with a rough cleavage, sometimes (as in Swindale) having brownish or greenish ashy beds intercalated among them. These shales are readily distinguished from those associated with the Coniston Limestone, being usually darker in colour, and more flaggy, and having a less perfect cleavage. Near their base they have two bands of nodular limestones in them; these are well seen in Swindale Beck.

The Dufton Shales are richly fossiliferous throughout, this being the case with the ashy beds before referred to, as well as others of the series.

The fossils are, for the most part, characteristic Bala types; and the entire deposit may be regarded as forming, palæontologically, the base of the Coniston Limestone.

The following is a list of the principal fossils which have been collected in these beds:—

Fossils of the Dufton Shales.

ACTINOZOA.

1. *Petraia*, sp. Swindale.
2. *Chætetes*, sp. An incrusting, submassive species, commonly growing on Orthocerata. Thin sections show that the tubes are furnished with a few remote tabulæ. Surface characters unknown. Common at Pusgill along with *Discina corona*, Salt., sp., *Bellerophon bilobatus*, Sow., &c.

ANNELIDA.

1. *Conchicolites gregarius*, Nich. This singular form is found abundantly along with the incrusting species of *Chætetes* just spoken of, attached to the outer surface of Orthocerata, in the *Discina-corona* bed.

BRACHIOPODA.

1. *Leptæna transversalis*, Wahl. Smelt Mill, Hilton.
2. *Strophomena expansa*, Sow. Harthwaite Gill, Dufton.
3. *Leptæna sericea*, Sow. A small variety of this shell with fewer principal radii than the normal form, and of about half its size, occurs very abundantly in Pusgill, and less commonly in all the other localities.
4. *Orthis testudinaria*, Dalm. Swindale and Pusgill.
5. *Discina* (*Trematis*) *corona*, Salt. This fine Brachiopod occurs abundantly, though in a more or less fragmentary condition, in a single stratum in Pusgill, along with *Orthocerata*, *Conchicolites gregarius*, *Bellerophon bilobatus*, &c.
6. *Lingula tenuigranulata*, M'Coy. Pusgill.
7. —— *ovata*, M'Coy. Pusgill. Both these *Lingulæ* seem to be confined to the stratum with *Discina corona*.
8. *Orthis biforata*, Schloth. Dufton-Town dykes.
9. *Strophomena rhomboidalis*, Wilckens. Pusgill.
10. *Orthis vespertilio*, Sow. Dufton-Town dykes.

HETEROPODA.

1. *Bellerophon bilobatus*, Sow. Pusgill.

CEPHALOPODA.

1. *Orthoceras*, sp. A smooth form resembling *O. baculiforme*, M'Coy. Common at Pusgill, in the *Discina-corona* stratum.
2. *Oncoceras*, sp. Not uncommon at Pusgill, in the same bed as the preceding.

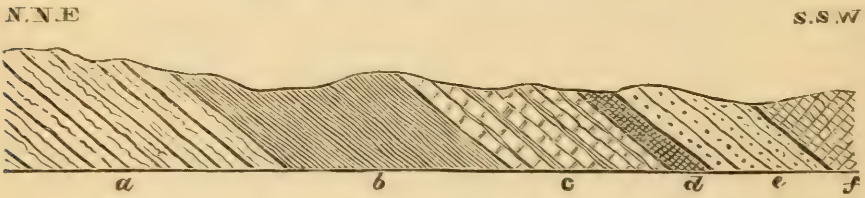
CRUSTACEA.

1. *Calymene Blumenbachii*, Brongn. Very abundant in Pusgill and Dufton-Town dykes, less so in Swindale.
2. *Trinucleus concentricus*, Eaton. Very abundant in Pusgill and Dufton-Town dykes, less abundant in Swindale.
3. *Cybele verrucosa*, Dalm. Dufton-Town dyke.
4. *Ampyx nudus*, Murch. (?) Rare in Pusgill.
5. *Lichas laxatus*, M'Coy. Pusgill.
6. *Illænus Bowmanni*, Salt. Swindale and Hilton.
7. *Encrinurus*, sp. Pusgill.
8. *Beyrichia Wilckensiana*, Jones. Abundant in Pusgill in the *Discina-corona* bed, and also in the ashy beds in Swindale.
9. *Primitia semicircularis*, Jones & Holl. In ashy beds. Swindale.

The predominance in the Dufton Shales of such Brachiopods as *Strophomena expansa*, *Leptæna sericea*, *Orthis testudinaria*, *O. vespertilio*, *O. biforata*, and *Lingula ovalis*, together with the abundance of such trilobites as *Calymene Blumenbachii*, *Trinucleus concentricus*, *Cybele verrucosa*, *Illænus Bowmanni*, and *Lichas laxatus*, can leave no doubt as to the correctness of the inference that these rocks belong to the Bala or Caradoc age. The presence of what appear to be unequivocal ashes which contain some of these fossils high up in the series at Swindale also deserves attention as showing that the volcanic forces which gave rise to the ashes and lavas of the Borrowdale group still maintained an intermittent activity during the deposition of the Dufton Shales. There would thus appear to have been no break of continuity between these shales and the underlying Borrowdale rocks—a conclusion which is further borne out by the substantial identity between the fossils of the Dufton Shales and those of the Style-End Grassing beds.

The annexed section (fig. 1) exhibits the stratigraphical relations of the Dufton Shales in Swindale Beck, where, as before stated, they are very well exposed.

Fig. 1.—*Sketch Section of the Strata in Swindale Beck, near Knock.* (Length rather more than half a mile.)



a. Ashes belonging to the Borrowdale series. *b*. Dufton Shales.
c. Coniston Limestone. *d*. Graptolitic mudstones.
e. Knock beds (green and purple slates).
f. Black flags with *Monograptus colonus*, Barr., probably Coniston Flags.

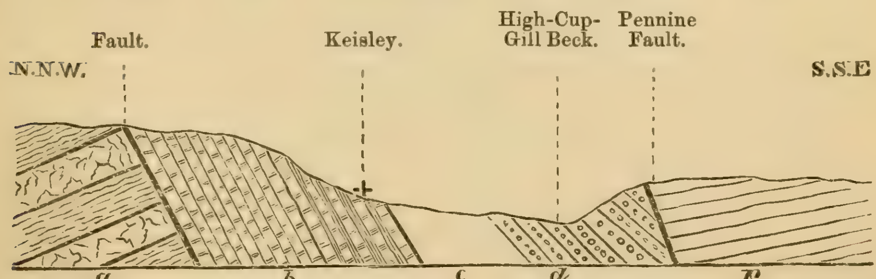
2. Coniston Limestone.

The "Coniston Limestone," notwithstanding its comparatively small vertical extent, has long occupied the position of being the best-defined and most universally recognized of all the divisions of the Lower Silurian series of the north of England—a position which it owes to its easily recognized lithological characters, and to the number of organic remains which it has yielded. It is unnecessary here to recapitulate the geographical range of the Coniston Limestone. Its main line of outcrop crosses the Lake-district in a direction from S.W. to N.E., running from Millom on the one hand to Shap Wells on the other. It is more or less developed in Ravenstonedale, Dentdale, the Sedbergh valley, near Ingleton, in Ribblesdale, at Ireleth, at High Haulme, in Furness, and at various points in the Lower Silurians which lie to the south-west of the Cross-Fell range.

Lithologically the term "Coniston Limestone" is somewhat misleading, as it is never wholly calcareous in its composition, and the calcareous element is occasionally almost wanting. In its most typical form, as seen in its range between Long Sleddale and Broughton Mills, in Furness, the Coniston Limestone consists of hard grey or bluish grey, cleaved, and often highly calcareous shales, containing numerous nodules or thin but distinct bands of limestone. In some places the beds of limestone are the most largely developed; and in other places the shales predominate; but the two elements of the group are usually intermixed, and alternate with one another indefinitely. At some localities, again, as at Ash Gill, near Torver, and at the head of Appletreeworth Beck, the shales are largely developed at the expense of the limestone, and are sufficiently thick to have been extensively worked for slates. At Keisley, near Dufton, again, the series is almost calcareous, and the shales appear to be entirely confined to its upper portion. Finally, at Beck and Waterblain, near Millom, the group consists of an upper series of cleaved fossiliferous shales, in the lower part of which a great thickness of limestone is developed, discontinuously, in the form of great lenticular masses of a purely calcareous nature.

In its intimate characters the limestone of the Coniston Limestone group differs greatly in different localities. Usually it presents itself as a hard, compact, greyish blue, grey, or nearly black limestone, which, in thin sections prepared for the microscope, exhibits a subgranular matrix in which fragments of Crinoids, Corals, or Brachiopods are imbedded at intervals. At Keisley (fig. 2), where we have most carefully examined it, three principal varieties may be distinguished:—(1) a hard, compact, greyish blue limestone with the microscopic characters and general aspect of the ordinary variety of the limestone just alluded to; (2) a reddish or pink compact marble with numerous patches of white calcite, both portions of the mass appearing, in microscopic sections, to be crowded with minute organisms and fragments of larger fossils; (3) a light-coloured, whitish blue or white, coarsely crystalline limestone, which is seen, in thin sections, to be composed of innumerable fragmentary organic remains and microzoa; imbedded in transparent calcite, and having large crystals of calc-spar with their characteristic cleavage-lines shooting through the mass in various directions.

Fig. 2.—*Sketch Section of the Coniston Limestone at Keisley, near Dufton.* (Length rather more than one third of a mile.)



a. Borrowdale series. *b.* Coniston Limestone.
c. Barren ground, occupied in whole or in part by the Graptolitic mudstones.
d. Knock beds (pale slates). *p.* Permian strata.

At Shap Wells, close to the medicinal spring, occurs a singular band of Coniston Limestone, to which we shall have occasion to refer again.

The band in question is a calcareous *breccia* composed of innumerable fragments of various rocks, mostly under a quarter or half an inch in diameter, imbedded in a calcareous matrix. Thin sections of this rock are very difficult to prepare, owing to the large number of angular fragments of quartz which they contain; in addition to which there are numerous fragments of limestone, felspathic ash, and perhaps traps, the cementing matter of the whole being a granular limestone apparently devoid of fossils. That this breccia is more or less altered by the near vicinity of the Shap granite cannot be doubted, the more so as the graptolitic mudstones are seen in an unequivocal form about 200 yards to the south of the breccia, with numerous graptolites, but so highly indurated as to have become almost flinty in their fracture. In connexion with this we may briefly refer to the microscopic characters of the more highly metamorphosed Coniston Limestone, about a quarter of a mile from the mineral spring, near the top of the Blea Beck. Here the Coniston Limestone is penetrated and apparently overlain by a mass of felstone, doubtless emanating from the granite of Wastdale Crag. In the immediate vicinity of this intrusive mass, the limestone is converted into an olive-green splintery rock, which shows, in microscopic sections, particles of iron pyrites and disseminated specks of a dark green mineral (hornblende?), together with a few traces of minute fossils. At a distance of a few yards from the felstone this limestone presents itself as a dark grey crystallized rock, which is shown by thin sections to be completely granular, with hardly any indications of fossils.

About two miles west from Shap Wells, at a short distance to the south-west of the farm-house of Wastdale Head, the Coniston Limestone exhibits itself in a very highly metamorphosed condition. Here, in the course of a small stream flowing from the north, a small patch of the limestone occurs, having a white colour and a crystalline structure. A few feet to the north of this patch a small exposure of rock is seen, having a gneissic character, the particles of which are very crystalline. This gneiss is very nearly in contact with the south-west portion of the Wastdale-Crag granite. It is probably either metamorphosed shales of the Coniston Limestone, or of the representatives of the Dufton Shales.

The white crystalline limestone has peculiar features. It has a fine scaly structure, with a pearly lustre, and resembles fine-grained *Schiefer spar*. It contains within it *Idocrase*; and in the upper portion, where it has been subjected to the action of the water of the stream, the idocrase almost remains alone, the carbonate of lime having been removed*.

* Idocrase or Vesuvian, as the latter name implies, is a rather common mineral in connexion with the volcanic products of Vesuvius, being often found in a crystalline limestone ejected from this volcano. It also occurs in the metamorphic Lower Silurian Limestone in Glen Laion, Aberdeenshire, and

The metamorphic limestone of Wastdale Head has above it rocks which also exhibit changes, the effect of the influence of the Wastdale-Crag granite. These appear in the form of rocks banded white and black with a pseudo-gneissic structure, the black bands beginning to prevail higher up in the series until hard dark-grey strata prevail, having lighter beds associated with them. These light-grey rocks are very compact, showing no traces of lamination, and possessing a conchoidal fracture. They are translucent on the edges, and, but for their colour, would be referred to the *Helleflint* of the Swedes, or to some form of felstone, were it not for their bedded character, which is very manifest. These rocks are intersected by an Elvan dyke emanating from the granite. This Elvan dyke effervesces with acids, from the presence of carbonate of lime derived from the metamorphic limestone, which has infiltrated itself into the interstices of this dike.

The fossils of the Coniston Limestone are numerous, but usually not well preserved. Sometimes they occur in great numbers, and in a state of good preservation, in the limestone itself, as is the case at Keisley. Usually the limestone is nearly destitute of fossils, and the palæontologist is obliged to have recourse to the shales associated with the limestone, in which the fossils, though numerous, are greatly distorted by cleavage. Without quoting here the lists of fossils from the Coniston Limestone given by M'Coy (Palæozoic Fossils) and by Salter (Cat. Cambr. and Sil. Fossils), we subjoin a list of the more important in our own collections, which have been mostly obtained from the limestone of Keisley, near Dufton.

Fossils of the Coniston Limestone.

Actinozoa.

1. *Petraia*, sp. Keisley.
2. *Chætetes*, sp. A small dendroid form, such as is usually called *Stenopora fibrosa*, var. *ramulosa*: the surface is unknown; but it is perhaps referable to *Chætetes Fletcheri*, E. & H. Keisley.
3. *Heliolites insterstincta*, Linn. Pool Wyke.
4. *Halysites catenularis*, Linn. Keisley.
5. *Petraia æquisulcata*, M'Coy. Millom and Long Sleddale.

Polyzoa.

1. *Fenestella* (?) *assimilis*, Lonsd. Keisley.
2. *Ptilodictya costellata*, M'Coy. Millom.
3. *Ptilodictya*, sp. Keisley.

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likewise in the metamorphic Liassic Limestone in the Isle of Skye. In Ireland it is met with among the metamorphic Lower Silurian Limestones of Donegal, at Derrylougham, Barnes Gap, and elsewhere in that county. Its occurrence at Wastdale Head is the first instance of this mineral having been found in England. It consists of silicates of lime and alumina, with small portions of oxide of iron and magnesia—a composition very likely to result from metamorphic action on a limestone such as the Coniston Limestone.

Brachiopoda.

1. *Strophomena corrugatella*, Dav. Keisley.
2. — *rhomboidulis*, Wilckens. Keisley.
3. —— *deltoidea*, Conrad. Keisley.
4. —— *expansa*, Sow. Keisley.
5. *Orthis biforata*, Schloth. Keisley.
6. —— *calligramma*, Dalm. Keisley.
7. —— *flabellulum*, Sow. Keisley.
8. —— *Actoniæ*, Sow. Keisley.
9. —— *vespertilio*, Sow. Keisley.
10. —— *porcata*, M'Coy. Keisley.
11. —— *elegantula*, Dalm. Skelgill Beck.
12. *Discina? corrugata?*, M'Coy. Keisley.
13. *Triplesia? monilifera*, M'Coy. Keisley.
14. *Atrypa imbricata*, Sow. Keisley.
15. *Leptæna tenuicincta*, M'Coy. Keisley.

Cephalopoda.

1. *Orthoceras vagans*, Salt. Keisley. Abundant.

Crustacea.

1. *Sphærexochus mirus*, Beyrich. Keisley.
2. *Cheirurus juvenis*, Salt. Keisley.
3. —— *bimucronatus*, Murch. Keisley.
4. —— *gelasinosus*, Portl. Keisley.
5. —— *cancrurus*, Salt. Keisley.
6. —— *octolobatus*, M'Coy. Keisley.
7. *Lichas laxatus*, M'Coy. Keisley.
8. —— *hibernicus*, Portl. Millom.
9. *Illænus Davisii*, Salt. Keisley.
10. —— *Bowmanni*, Salt. Keisley.
11. —— *Rosenbergi*, Eichwald. Appletreeworth Beck.
12. *Calymene Blumenbachii*, Brongn. Keisley. Rare.
13. *Agnostus*, sp. A form somewhat resembling *A. trinodus*, Salt. (= *Trinodus agnostiformis*, M'Coy), in shape and size, but having its whole surface tuberculated. Not uncommon at Keisley.
14. *Phacops* (*Chasmops*) *macrourus*, Sjögren. This characteristic Bala species is the *Odontochile obtusicaudata* of M'Coy; but it wants the surface-granules of the true *P. obtusicaudatus*, Salt. Fine tails, though somewhat distorted by cleavage, are not uncommon at Appletreeworth Beck.
15. *Phacops apiculatus*, Salt. Appletreeworth Beck.
16. *Ampyx Sarsii*, Portl. Keisley.
17. *Remopleurides*, sp. A large form allied to, but apparently distinct from, *R. longicapitatus*, Portl. Not uncommon at Keisley.
18. *Proëtus*, sp. The free cheeks only are known, and resemble *P. latifrons*, M'Coy. Keisley.
19. *Bronteus*, sp. Pygidia only known. Keisley.
20. *Beyrichia impendens*, Jones. Appletreeworth Beck.
21. *Primitia protenta*, Jones. Appletreeworth Beck.

No one can analyze the preceding list of fossils and entertain any doubt as to the geological horizon of the Coniston Limestone. Whether or not it be in the *precise* position of the Bala Limestone of Wales is a point which may admit of doubt; but it is the precise equivalent of the limestone of the Lower Silurian of Portraine, co. Dublin, and also of that of the Chair of Kildare (see Appendix), regarded as unquestionably of Bala age. This is shown conclusively by the Brachiopods, and especially by Trilobites of the following forms—*Sphærexochus mirus*, *Cheirurus juvenis*, *C. cancrurus*, *C. gelasinosus*, *C. octolobatus*, *Lichas laxatus*, *L. hibernicus*, *Illænus Bowmanni*, *I. Davisii*, *Phacops macrourus*, *P. apiculatus*, constituting amongst the latter a characteristic assemblage of Caradoc or Bala types. It is somewhat curious that of the two commonest and most characteristic Trilobites of the Dufton shales, *Calymene Blumenbachii* is hardly known in the Coniston Limestone, and *Trinucleus concentricus* is generally absent. The latter occurs plentifully in the "*Trinucleus*-shales" of Prof. Hughes, a locally developed group at the summit of the Coniston Limestone in the Sedbergh district. The evidence to be derived from the Brachiopods is equally conclusive with that of the Trilobites, all the common forms being characteristic species of the Bala formation; but it is not necessary to enter into further details on this point.

It remains briefly to consider the conditions under which the Coniston Limestone series was deposited. On this matter we wish especially to indicate that there seems to be good evidence that the volcanic activity which produced the vast mass of ash, breccias, and lavas constituting the Borrowdale series, though greatly mitigated in intensity, had not entirely died out during the period of the deposition of the Coniston Limestone and Dufton Shales, but continued to operate at occasional intervals. It would seem probable that the Lake-district was not entirely submerged at the time when the Coniston series began to be laid down, but that a portion of the volcanic region remained above the level of the sea, its vents occasionally giving exit to showers of volcanic ashes or even currents of lava. If this hypothesis be established, it would follow that there was no breach of continuity between the close of the Borrowdale series and the commencement of the Coniston series, but that the two groups of rocks are intimately related, and in point of fact actually overlap one another in time. The principal grounds which at present appear to indicate the correctness of this hypothesis may be briefly stated as follows:—

(1) The intercalation in the Borrowdale series, close to its summit, of a band of fossiliferous shales containing Bala species, proves that the volcanic energy of this period still continued in force at a time when the sea was peopled with well-known Bala Brachiopods and Trilobites. The shales in question (Style-End Grassing beds) are usually separated from the Coniston Limestone proper by a mass of lava; but they are undoubtedly to be regarded as, palæontologically, a portion of the Coniston series.

(2) The presence of beds of ashes, containing numerous fossils, high up in the Dufton Shales at Swindale, near Knock, proves similarly that the volcanic eruptions of the preceding period had not entirely ceased at the time when the Dufton shales were in course of formation, and these shales, as we have seen, belong palæontologically to the Lower Coniston group, and are only a local development of the base of the Coniston Limestone itself.

(3) The presence, near the summit of the Coniston Limestone itself, at Shap Wells, of a calcareous breccia containing numerous fragments of ash proves that an eruption took place towards the close of the period during which the Coniston Limestone was deposited. Nor does the site of this eruption appear to have been very far removed from Shap Wells itself; for the microscopic investigation of this breccia indicates that some of the older and previously formed beds of the Coniston Limestones were broken up by this outburst, and were thrown over the sea-bottom along with innumerable fragments of ash, the whole being subsequently cemented together by calcareous ooze to constitute the singular stratum in question.

(4) The presence in the Coniston Limestone in the Sedbergh district, as shown by Prof. Hughes, of interbedded felstones, proves conclusively the occurrence of volcanic eruptions contemporaneous with the deposition of the limestone, in this area at any rate, if not elsewhere.

(5) By the supposition we have brought forward a satisfactory explanation is obtained of a certain amount of apparent discordance between the Coniston Limestone and the underlying volcanic Borrowdale rocks. This discordance, so far as it exists, might be set down as due to a want of conformity; but we do not think that this is its true explanation.

If the views we entertain be correct, it is rather due to the fact that the Coniston Limestone was deposited round the shores of the volcanic nucleus of the Lake-district very much after the fashion that a modern limestone might have been in process of formation for thousands of years off the coasts of Sicily. In such a case beds of limestone would wrap round sheets of lava so as to be apparently transgressive thereon, or might be interstratified with strata of tuff, of ash, or of volcanic rocks. Any seeming discordance between the calcareous series and the volcanic products would be due, not to absolute unconformability, indicating a lapse of time, but simply to the difference in the method by which the two groups were formed. In spite of any apparent discordance, both groups would belong to the same period, and in part they would be actually contemporaneous.

If these inferences be confirmed by further researches, it will follow that the Borrowdale rocks must be regarded as being of Lower-Bala age. As the Skiddaw slates are unquestionably Arenig, and the Coniston Limestone equally unquestionably Bala, the only other view which could be taken as to the Borrowdale series would be to refer them to the Llandeilo. Apart, however, from the considerations just mentioned, this view is rendered unlikely by the fact that the great series of Llandeilo rocks developed in the south of Scotland appears to be wholly free from intermixture with contemporaneous igneous matter. We can hardly suppose that such could possibly have been the case, if the Llandeilo strata of the southern uplands of Scotland had been in process of formation at a time when the closely adjoining region of the Lake-district was the scene of the intense volcanic activity which gave birth to the Borrowdale series.

3. Graptolitic Mudstones.

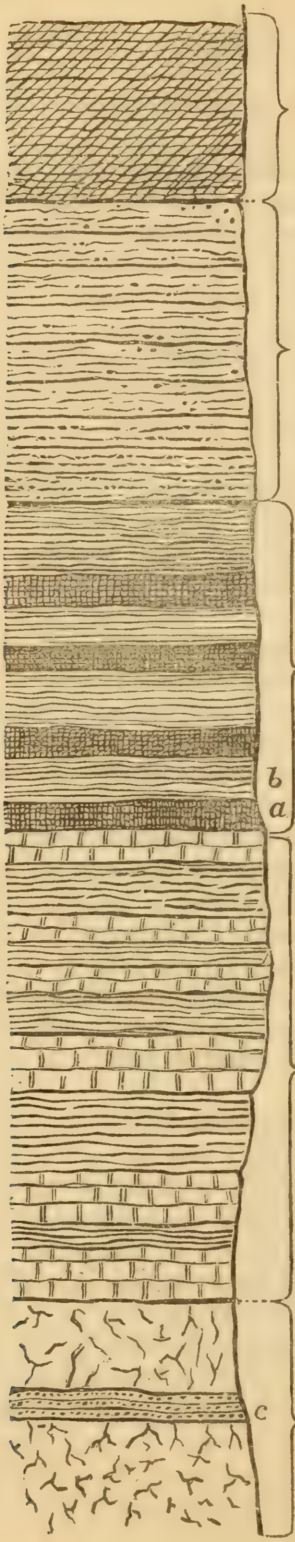
Resting directly upon the Coniston Limestone, in every locality where the summit of the latter has been recognized, is a series of dark-coloured Mudstones and grey Shales, which, though of small vertical thickness, are of especial interest from the organic remains which they contain. These beds were originally described by us (Quart. Journ. Geol. Soc. vol. xxiv. p. 296); and to them was applied the name "Graptolitic Mudstones," as indicating their general mineral character and the predominant fossils which they yield. Subsequently, as an alternative local name, the title "Skelgill Beds" was proposed by one of us for these strata, from the farm of High Skelgill, near Ambleside, where they are typically developed (Nicholson and Lapworth, Rep. Brit. Assoc. Bristol, 1875). As before stated, immediately above the highest member of the Coniston Limestone these Graptolitic Mudstones come on. The finest sections of the series, however, are to be found on both sides of Long Sleddale, in Skelgill Beck, near Ambleside, in Appletreeworth Beck, and in Swindale Beck, near Knock.

Many other localities exhibit the same beds; but they are generally badly exposed, and, from their comparatively soft nature, they often become so far worn down as to be indicated simply by a depression immediately following the outcrop of the limestone.

In their mineral characters the Graptolitic Mudstones are so well marked that they may be recognized by this alone, apart from the detection of their characteristic fossils. They consist of dark-coloured, often nearly or quite black Mudstones, which are sometimes anthracitic, the joints of which are characteristically iron-stained. These dark Mudstones are replete with beautifully preserved Graptolites, and alternate in successive bands with lighter and darker grey or even sometimes greenish shales, both the light and dark bands being more or less cleaved. Annexed is a diagrammatic sketch (fig. 3) showing the succession of the strata at Skelgill, where the Graptolitic Mud-stones are admirably exhibited.

In our earlier researches in the Graptolitic Mudstones we devoted ourselves principally to the black bands containing Graptolites, a large number of species of these organisms being described by one of the present writers from this group (Nicholson, Quart. Journ. Geol. Soc. vol. xxiv. p. 521). More recently an examination has been made, in greater detail, of the grey bands which interstratify the dark-coloured graptolitic layers, with the gratifying result that these have been proved to contain a considerable number of fossils of higher organization than Graptolites. We append a list of the more important species of Graptolites, and of the other fossils at present known as occurring in this series.

Fig. 3.—*Diagram showing the vertical Succession of the Silurian Strata in Skelgill Beck, near Ambleside.*



Fossils of the Graptolitic Mudstones.

GRAPTOLITIDÆ.

1. *Climacograptus teretiusculus*, His. Everywhere.
2. *Diplograptus pristis*, His. Long Sleddale.
3. —— *palmeus*, Barr. Skelgill.
4. —— *tamariscus*, Nich. Skelgill.
5. —— *confertus*, Nich. Skelgill.
6. *Monograptus Sedgwickii*, Portl. Skelgill &c.
7. —— *Nilssoni*, Barr. Skelgill &c.
8. —— *spinigerus*, Nich. Long Sleddale.
9. —— *intermedius*, Carr. Skelgill.
10. —— *gregarius*, Lapw. Skelgill.
11. —— *discretus*, Nich. Long Sleddale.
12. —— *sagittarius*, His. Mosedale &c.
13. —— *lobiferus*, M'Coy. Skelgill.
14. —— *turriculatus*, Barr. Long Sleddale.
15. —— *fimbriatus*, Nich. Skelgill.
16. —— *triangulatus*, Harkn. Skelgill.
17. *Rastrites peregrinus*, Barr. Skelgill &c.
18. —— *distans*, Lapw. Long Sleddale.
19. *Retiolites perlatus*, Nich. Long Sleddale.

ACTINOZOA.

1. *Favosites*, sp. A form resembling young specimens of *F. gothlandica*, Lam., but with only a single row of large mural pores, each of which is surrounded by a raised margin on each of the prismatic faces of the corallites. Known by casts only. Skelgill Beck.
2. *Favosites*, sp. A form with smaller corallites than the preceding, and having the walls perforated with numerous minute irregular mural pores; corallum pyriform. Known from casts only. Skelgill.

BRACHIOPODA.

1. *Strophomena expansa*, Sow. Skelgill.
2. *Orthis vespertilio*, Sow. Skelgill.
3. —— *flabellulum*, Sow.? Skelgill.
4. —— *elegantula*, Dalm.? Skelgill.
5. ——, sp. A small indeterminable form. Skelgill.

CEPHALOPODA.

1. *Endoceras proteiforme*, Hull. Skelgill.
2. *Orthoceras angulatum*, Wahl. Skelgill.

CRUSTACEA.

1. *Agnostus trinodus*, Salt. Skelgill.
2. *Phacops apiculatus*, Salt. Skelgill.
3. *Cheirurus bimucronatus*, Murch. Skelgill.
4. *Harpes Flanagani*, Portl. Skelgill.
5. *Calymene senaria*, Conr. (?). A single imperfect example only. Skelgill.
6. *Trinucleus fimbriatus*, Murch. Skelgill.
7. *Discinocaris*, sp. A Phyllopod with a concentrically striated, nearly circular carapace, nearly resembling *D. Browniana*, H. Woodward, from the Llandeilo rocks near Moffat. Not uncommon in the Mudstones at Skelgill and Poolwyke.

All the more highly organized fossils of the above list were obtained from beds unequivocally belonging to the Graptolitic Mudstones. Some of them, such as *Endoceras proteiforme* and the species of

Discinocaris, are found in the darkest and most highly fossiliferous graptolitic zones. The Trilobites were obtained exclusively from a dark grey band lying between two graptolitiferous bands, about ten feet above the highest bed of the Coniston Limestone.

Lastly, all the Brachiopods, with the exception of a common but undetermined *Orthis* of small size, were procured from a single band, the position of which is shown with absolute clearness at several points in the course of Skelgill Beck.

The highest bed of the Coniston Limestone in this locality is fortunately actually a limestone, and not merely a calcareous shale; and it is seen at various points to be directly overlain by a thin band of the characteristic black Mudstone, not more than six or eight inches in thickness, containing numerous Graptolites (*Climacograptus* &c). The direct contact and juncture of the limestone and the above-mentioned graptolitiferous band can be observed at various spots; and the latter is at once surmounted by a dark grey shale, about eighteen inches in thickness, from which Graptolites are almost entirely absent, but in which the great majority of the Brachiopods were obtained; and this shale is immediately succeeded by a second graptoliferous band. The shale affording the Brachiopods is highly cleaved; and these shells are, unfortunately, so much distorted as to render their determination a matter of considerable difficulty. The Trilobites, on the other hand, occur in a zone several feet higher in the series, surmounted in turn by other graptolitiferous beds, and they are so well preserved as to admit of ready and complete identification.

Any doubt which might have been previously entertained as to the precise age of the Graptolitic Mudstones seems to be removed by the fossils recently obtained from these beds.

It has been already mentioned that these Mudstones were to be regarded as of Lower-Silurian age; and the materials at present in our hands appear entirely to confirm this view. Leaving the evidence afforded by the Graptolites to be considered separately, it is impossible to doubt that the fauna of the Mudstones is essentially a Lower-Silurian fauna. Amongst the Trilobites *Agnostus trinodus*, *Phacops apiculatus*, *Calymene senaria*, *Trinucleus fimbriatus*, and *Cheirurus bimucronatus* are characteristic Bala forms; and all of them, with the exception of the last mentioned, are exclusively confined to rocks of Lower-Silurian age. *Harpes Flanagani*, the sole remaining form that we have been able to determine with certainty, is a Bala type from Tyrone and Desertecreat. The *Discinocaris* is closely allied to if not absolutely identical with *D. Brouniana*, a well-known fossil from the graptolitic Lower Silurians near Moffat.

Of the Cephalopoda the singular *Endoceras proteiforme* is a characteristic fossil of the Trenton Limestone (Llandeilo-Caradoc) of North America, and *Orthoceras angulatum* ranges from the Bala to the Ludlow group. The Brachiopoda, even when so much distorted as to be specifically indeterminable, have nevertheless a distinct Lower-Silurian facies; and *Orthis vespertilio* with *Strophomena expansa* are characteristic types of the Bala rocks. Lastly, the few corals which have been found are not such as to give any guide to the age of the strata, all that can be said being that they belong to a type not hitherto recognized in the underlying Coniston Limestone.

The clear evidence borne by the Crustacea, Brachiopoda, and Cephalopoda as to the Lower-Silurian age of the Graptolitic Mudstones, is still further substantiated when we consider the characters of the Graptolites themselves, by far the most abundant fossils in this series. Without entering into any minute analysis of the Graptolites found in these rocks, it may at once be stated that they constitute an assemblage of forms of an unequivocally Lower-Silurian aspect. This is proved by the presence, in abundance, of representatives of the Diprionidian genera *Diplograptus* and *Climacograptus*, by the remarkable variety of the species of *Monograptus*, and by the presence of the genus *Rastrites*. At the same time, that the Graptolitic Mudstones are not low down in the Lower Silurian series is equally clearly shown by the total absence of the genera *Didymograptus* and *Dicranograptus*.

As regards the *species* of Graptolites, *Climacograptus teretiusculus*, *Diplograptus pristis*, *D. palmeus*, *D. tamariscus*, *Monograptus Sedgwickii*, *M. triangulatus*, *M. spinigerus*, *M. intermedius*, *M. gregarius*, *M. sagittarius*, *M. fimbriatus*, *M. lobiferus*, *M. Nilssoni*, *Rastrites peregrinus*, *R. distans* are all found in the Moffat shales of the south of Scotland, and are more especially characteristic of that division of the Moffat shales to which Mr. Lapworth has given the name of the "Birkhill Group." Thus nearly three fourths, or seventy-five per cent., of the total number of Graptolites known in the Mudstones, including all the common and characteristic species of the group, can be specifically identified with forms which serve to mark the Lower Silurian rocks of the southern uplands of Scotland, the position of which has never been questioned.

Taking all the various fossils now known from the Graptolitic Mudstones together, it is impossible to doubt that the balance of the palæontological evidence is overwhelmingly in favour of the view that this formation is of Lower-Silurian age.

Such being the case, the Graptolitic Mudstones must correspond in position with the highest beds of the Bala series or with the lower portion of the Llandovery group; and this is the direction in which we believe all the evidence tends. As to the precise physical relations between the Graptolitic Mudstones and the subjacent Coniston Limestone, we are of opinion that the two groups are strictly conformable to one another. Not only are the Mudstones invariably found in their proper position, resting upon the limestone, as seen when there are sections of these groups, but no discordance can be detected, as regards the dip and strike, between the two series where they cannot be seen in actual contact.

Moreover (and this appears to us to be an argument of the greatest weight) it cannot be shown that there is any overlap of the Graptolitic Mudstones upon the Coniston Limestone, the former always resting, so far as we have seen, upon the highest bed of the latter.

If it be remembered that along one line of outcrop alone, from Appletreeworth Beck to Shap Wells, the Graptolitic Mudstones can be traced almost continuously succeeding the limestone for a distance of about twenty-four miles, it will be seen to be almost impossible that any want of conformity, however slight, could exist without there being, at the same time, a transgression of the Mudstones over the Limestones. It is true that, owing to the circumstance that the calcareous matter of the Coniston Limestone series is disposed in the form of irregular lenticular masses or concretionary layers, the lithological character of the bed immediately below the Mudstones is not invariably the same, being at one time a limestone and at another a calcareous shale. This, however, is due to an irregularity of deposition which obtains throughout the entire limestone series; and we have failed to find any evidence that the Graptolitic Mudstones ever rest upon any of the lower beds of the Coniston Limestone. As the latter group is of small thickness, and as its main line of outcrop is a very long one, such an overlap must occur, supposing unconformity to exist; and in all probability we should even find the Mudstones passing across the limestones and resting upon the older Borrowdale series.

The absence therefore of any unobserved overlap is, under the circumstances, the strongest possible proof that the Mudstones are entirely conformable to the Coniston Limestone.

That the Graptolitic Mudstones constitute a geological horizon of a definite character, and of much more than mere local importance, is shown by the fact that they can be recognized in Ireland in circumstances similar to those under which they occur in the north-west of England (see Appendix). They have also been recognized in Sweden, in Carinthia, and in Bohemia, while future researches will doubtless bring corresponding strata to light in other Lower-Silurian regions.

In Sweden Dr. Linnarsson has shown (Geol. Mag. June, 1876) that the so-called "Upper Graptolitic Schists" are the equivalents in that country of the Graptolitic Mudstones of the north of England. These Upper Graptolitic Schists, as seen in Westrogothia and Ostrogothia, are the highest Silurian rocks exposed to view, so that they add nothing to the evidence as to the age of the Coniston Mudstones.

In Scania, however, they are overlain by undoubted Upper Silurian beds; and in Dalecarlia they are surmounted by a locally developed limestone (the "Leptæna Limestone" of Tornquist), which appears to form either the summit of the Lower Silurian or the base of the Upper Silurian, being in turn covered by the undoubted Upper Silurian "*Encrinurus*-beds." Upon the whole, therefore, the evidence to be derived from the Swedish area entirely corroborates the view that the Graptolitic Mudstones are of Lower-Silurian age.

In Carinthia, beds corresponding precisely with the Graptolitic Mudstones have been described by Dr. Guido Stache (Die Graptolithen-Schiefer am Osternig-Berge in Kärnten); and the parallelism of the two deposits has been fully noticed by this distinguished observer. Unfortunately the succession of the Silurian strata in the Osternig is still so obscure as not to permit of any safe conclusions being drawn as to the precise stratigraphical horizon of these beds, though Dr. Stache concludes that they stand on the borderland between the Lower and Upper Silurians.

In Bohemia we find the representatives of the Graptolitic Mudstones in the "Colonies" of Barrande's Étage D and in the *lower* portion of the Étage E of the same eminent palæontologist.

These beds, as is well known, are referred by M. Barrande to the base of the Upper Silurian.

Without, however, entering fully into this question here, and disregarding the strong evidence which we now hold as to the Lower-Silurian age of our Graptolitic Mudstones, we would simply point out that M. Barrande himself fully admits that the succession of Silurian life in the Bohemian area was *later*, stage by stage, than in the northern European and British areas. Thus he supposed that the Bohemian area was peopled with a general *Lower*-Silurian fauna at a time when the North European and British areas were peopled with a general *Upper*-Silurian fauna, and he employs this supposition to explain the phenomena of the "Colonies." Admitting therefore that the "Colonies" and the lower portion of Étage E are Upper Silurian, it would in no way follow that the corresponding Graptolitic Mudstones of the north of England are also Upper Silurian. On the contrary, by M. Barrande's own theory, the Graptolitic Mudstones *ought* to be *Lower* Silurian, being thus "homotaxeous," but not "contemporaneous" with the lower part of Étage E of Bohemia. We thus see that the evidence to be derived from Bohemia, though apparently at conflict with our views as to the age of the Graptolitic Mudstones, is, when fully analyzed, an additional argument in favour of our conclusions.

4. Knock Beds.

The Graptolitic Mudstones are succeeded by a series of strata for which the name of "Knock beds" has been proposed (Nicholson & Lapworth, Rep. Brit. Assoc. Bristol, 1875), on account of their excellent development in Swindale Beck, near Knock. Lithologically the Knock beds present a singular uniformity wherever they are found, enabling them to be recognized with the greatest readiness. They consist principally of pale green, fine-grained slates, extremely ashy in their appearance, exhibiting numerous dendrites, and very commonly containing crystals of cubic pyrites. Along with these greenish slates are often well-marked bands of red and purple slates of the same grain and texture as the preceding; and occasionally there is met with a thin band having a grey or even a nearly black colour, though this is exceptional. The general strike and dip of the Knock beds conform with those of the underlying Graptolitic Mudstones; and there is, at present, no clear evidence of any want of conformity between the two groups.

The Knock beds have been subjected to a varying but always a high amount of cleavage; and fossils, though by no means wholly unknown in them, are almost always more or less distorted. At Knock they have yielded only two Graptolites, viz. *Monograptus priodon*, Bronn, and *M. broughtonensis*, Nich. & Lapw. At Skelgill, and on the high ground between this place and the vale of Troutbeck, they have afforded many specimens of small Brachiopods (*Orthis* and *Discina*) and minute Lamellibranchs. These, however, occur only in the form of external and internal casts; and, as yet, no conclusion has been arrived at concerning their specific forms.

The Knock beds are directly surmounted by the well-known and well-marked group the "Coniston Flags," a series of strata corresponding to the "Denbighshire Flags" of North Wales, and which have been clearly shown, more especially by the researches of Prof. Hughes, to be of Upper-Silurian age. As to the exact age of the Knock beds, it is not to be denied that sufficient evidence is yet wanting on which to found any positive or final opinion. They rest upon the Graptolitic Mudstones, which we have shown to be placed nearly or quite at the summit of the Lower Silurian; and they are overlain by the Coniston Flags, which are quite or nearly the base of the Upper Silurian. It is therefore clear, from their physical position, that the Knock beds must be either the basement series of the Upper Silurian, or the summit series of the Lower Silurian, or a group of passage-beds between these two.

The palæontological evidence at present obtained is not enough to justify us in adopting definitely any one of these hypotheses. So far as it goes, the evidence tends to favour the view which regards them as the base of the Upper Silurians—the only two species of Graptolites observed being forms common to the overlying Coniston Flags, whilst there appears to be a complete absence of the genera and species characteristic of the Graptolitic Mudstones.

Further researches, however, will undoubtedly add to the fauna of this group of beds, and enable its position to be determined with greater precision.

In the meanwhile it can only be said that the conclusion to which the few known fossils point is corroborated by the strong lithological resemblance between the "Knock beds" and the "Tarannon Slates" of Wales. We cannot, therefore, be far wrong in provisionally regarding the Knock beds as the base of the Upper Silurian series of the Lake-district, in which case the Graptolitic Mudstones will constitute the highest portion of the Lower Silurians of the same area.

APPENDIX.—*The Irish Representatives of the Coniston Limestone and its associated Rocks.*

Lambay Island and Portraine, co. Dublin.

On referring to a geological map of the British Isles it will be seen, from the strike of the Coniston Limestone in the southern portion of the Lake-district, and after it disappears under the newer rocks west of Millom, that its occurrence might be looked for in Ireland, where rocks appertaining to the Bala series are seen.

On the coast of the co. Dublin, the nearest locality where such rocks could be expected to appear, they are absolutely seen in the direct line of strike of the Coniston Limestone of the north-west of England.

On Lambay Island, two and a half miles east from the mainland, in the south-east portion of the island, we have part of the Coniston series forming a synclinal, though exhibiting many of the same features and the same fossils which this group of rocks in the Lake-district affords. Here are grey limestones succeeded by concretionary bands called by Mr. Du Noyer "coarse Conglomerates" (Explanations of Sheets 102 & 112 of the Maps of the Geological Survey of Ireland). This "Conglomerate" is described as "composed chiefly of rounded pebbles and boulders of grey Silurian Limestone, either fossiliferous or not, with fragments of dark cleaved slate, grey grit and greenish grey greenstone, and ash; in one instance a boulder of an older Silurian Conglomerate was discovered, in which were rolled pebbles of a dark green close-grained greenstone, the base being a grey limestone containing Silurian fossils." (Note by Mr. Jukes:—"Some of the Silurian corals were attached by their bases to the pebbles, showing that they had grown on them, just as corals may now be seen growing on pebbles or fragments of rocks along a tropical shore.") "The matrix of the Kiln-Point Conglomerate is a black mud; and throughout the deposit are irregular slaty layers." "When we get lower into the mass we lose the conglomerate, and find nothing but pure dark grey slates, which, near Raven's Well, are found to contain Graptolites and thin calcareous fossiliferous bands" (p. 48).

It is also stated that at Kiln-Point the "grey Silurian Limestone is a wedge-shaped mass of lumpy layers, with thin bands of dark grey earthy shales between them, all very much contorted and resting on the porphyritic greenstone, which has evidently come up under them while in a pasty condition from heat, as it sends veins and strings into the lower beds of the limestone, and often enclosing fragments derived from it." Other circumstances indicate volcanic activity during the deposition of these limestones, even to a greater extent than has been recognized in the Lake-district.

These limestones have below them rocks intimately related to those of the Borrowdale series of the north of England, which are doubtless the equivalents of the latter.

At Portraine, on the mainland, immediately opposite Lambay, there is seen, on the coast, one of the finest sections of the Coniston Limestone and its associated rocks which occurs in the British Isles.

Portraine is about two miles east of Donabate Station, on the Dublin and Drogheda Railway. On reaching the coast an exposure of rock is seen a little east of the coast-guard station. This consists of a purple conglomerate, largely made up of quartz pebbles, which has been designated Old Red Sandstone; but it is more probably the basement conglomerate of the Carboniferous formation. As such it has its representatives well exposed under the Carboniferous Limestones along the eastern margin of the Lake-district, and also under the Pennine escarpment.

A short distance east of the conglomerate a porphyry, having a delicate purple tint and containing well-developed crystals of a greenish white felspar, occurs. This porphyry is similar to that which forms the bulk of Lambay. Its purple tint is doubtless due to staining from the purple conglomerate which, in some places, overlies it.

Fragments of a similar purple porphyry are met with in the Lake-district near Caldbeck; and in some spots this porphyry is seen *in situ* overlain by purple conglomerates, when it manifests the same tint as the Portraine porphyry.

The Portraine porphyry is succeeded by traps and ashes; and these are seen to occur to beyond the farm-house on the coast.

At the farm-house the coast trends for a short distance south-east. A little beyond this the ash-beds begin to exhibit trappean fragments in them, the ashes assuming the nature of ash-breccias. The trap fragments, however, are not the only substances which the ashes contain; calcareous nodules also make their appearance in them.

Patches of black shale, which show no traces of volcanic origin, are also associated with the ash-beds; and these black shales afford Graptolites (*Climacograptus teretiusculus*). These ash-breccias with calcareous nodules and graptolitic shales prevail in greater abundance higher in the series; and in the cliffs under the Martello tower they are seen to be succeeded by fine green-coloured shales so much affected by cleavage that their bedding can scarcely be made out. There are some small faults indicated by Mr. Du Noyer as occurring between where the porphyry is seen and where the green shales make their appearance. These, however, are not of sufficient importance to render the section difficult to interpret. The green shales contain limestone nodules in bands which, though much contorted, indicate distinctly the lines of bedding of the shales, these shales being, no doubt, of ashy origin. Fossils occur in these nodules and also in those which are found in the ash-breccia; and these fossils are distinctly of a Bala type.

The "conglomerates," before referred to as seen on the south-east side of Lambay Island, are a portion of the ash-breccia series. They afford the same fossils, and they have the same graptolitic shales accompanying them.

As regards the horizon in which the nodular ash-breccias occur, as compared with the rocks of the north of England between the Borrowdale group and the Coniston Flags, it would seem that they must be placed on a parallel with those of Style-End Grassing and with the more amply developed Dufton shales. To the latter they are in part allied by their black shales, and to the former by their ashy nature. They indicate more violent volcanic activity in the locality of their deposition than the Dufton shales, but less powerful igneous influences than in the case of the Style-End Grassing ash-beds, where no black shales occur.

Nodular limestone bands have been referred to as making their appearance in the highly cleaved and contorted green shales. Near the top of these shales the limestone bands become more predominant, and the nodules gradually change into continuous layers succeeded by thicker strata, the whole forming a finely developed mass of Coniston Limestone, in some parts very fossiliferous. The higher beds of the series, however, again assume a nodular form; and at the top of the group a very singular deposit is seen. This bears some resemblance to the nodular ash-breccias; the nodules, however, prevail to a much greater extent.

This bed is so conglomeratic in its aspect as to appear, at first sight, a mass of this nature overlapping the Coniston Limestone. This, however, is clearly not the case, as there occurs underneath this curious nodular bed a mass of a somewhat similar kind, the two being separated from each other by apparently ashy shales in which nodules of limestone are seen.

This singular nodular mass is probably near the horizon of the band of limestone which occurs at Shap Wells as a calcareous breccia.

Dark-coloured rocks are seen resting conformably on the nodular limestone. In their nature these rocks have a great affinity to the Graptolitic Mudstones of the Lake-district. They occur in cliffs which are very inaccessible, and therefore could not be well searched for fossils. Judging from their mineral aspect (and this is a well-marked feature in the Graptolitic Mudstones), we are disposed to refer them to this position.

The rocks south of the Coniston Limestone of Portraine form a synclinal trough. Here the strata are more accessible than where the black shales occur. They consist of *fine-grained greenish-coloured shales*, having dark grey rocks intercalated with them. The former, as regards their nature, are identical with the green rocks of the Knock beds. Their position also allies them with the latter strata; and they are succeeded by hard grey rocks having a close resemblance to the Coniston Flags. Taking the Portraine section collectively, the nature, the arrangement, and the fossils contained in the rocks here are such as to justify us in referring them to positions lying between the Borrowdale group and the Coniston Flags of the north of England.

To the south of the synclinal alluded to, the continuity of the Portraine section is broken, the coast being for a short distance sandy.

Beyond this sandy area the Bala rocks again appear in the form of ashes and traps, the latter being the most abundant.

Grange Hill and the Chair of Kildare.

The line of strike before alluded to, if continued south-west from Portraine, would bring us to another area where the Coniston Limestone and its associated rocks are seen. This area is in the co. Kildare, about three miles north of the town of Kildare; and here the rocks are, in part, well exhibited. Their nature and arrangement have been described by the officers of the Irish Geological Survey (description of Map 35, N.E.). The hill of Grange, where these rocks are best seen, consists principally of porphyries, traps, and ashes, the latter at one spot affording abundance of fossils of Bala age. The porphyries have a great affinity to those of Portraine and Lambay; and the traps and ashes are intimately related to those of the east coast of Ireland.

The western side of the hill of Grange consists of Coniston Limestone, well seen in the portion of the hill known as "the Chair of Kildare" and its immediate surroundings. Judging from its strike, this limestone would appear to be brought against the underlying igneous rocks by means of a fault. Although the limestone and igneous rocks are well exposed, the strata which overlie the former cannot be recognized in the hill of Grange.

Though provided with the six-inch Map, on which Mr. Du Noyer recorded his observations, through the kindness of Prof. Hull and Mr. O'Kelly of the Irish Geological Survey, the rocks succeeding the limestone could not be determined by us. The occurrence of dark shales about this position was indicated on the Map, but the places where they are represented no longer show them.

The exposures seem to have been in ditches; and they are now covered up. On the west the Coniston Limestone is cut off by a fault, "the last traces of it being seen on the south-west brow of the Chair hill."

A short distance south-west of the Chair, a hill called Dunmury occurs. The composition of this hill is altogether different from that of the hill of Grange, neither limestone nor volcanic products being found in connexion with it.

On the eastern side of this hill, and on the western side of the road to Kildare, near a well, a very dark-coloured compact rock, exceedingly like the Graptolitic Mudstones, is seen; and rocks of a like nature occur westward.

The exposures of rock on this hill, however, are very poor; Mr. Du Noyer records, on the map, the appearance of purple and green rocks on the west of the road south of the well above referred to. These cannot now be seen; and it is probable they were exposed when the surface of the road was levelled. Judging from Mr. Du Noyer's observations, these purple and green rocks appear to be nearly akin to the Knock beds. Should this be the case, and taken in connexion with the occurrence near them of strata resembling the Graptolitic Mudstones, it would seem that the rocks of Dunmury hill represent these two series.

It is also to be remarked that the outline of this hill differs greatly from that of the hill of Grange.

The contour of Dunmury bears a much greater affinity to the hills of the north-west of England composed of rocks above the Borrowdale series than to such as are made up of members of this portion of the Bala group.

Discussion.

Prof. Hughes regretted that the more important fossils were not upon the table, as he thought an examination of them, or of the matrix, might suggest some explanation of the difficulties. He questioned the discovery of *Orthis vespertilio*, *Trinucleus*, &c. in the Graptolitic Mudstones; and with regard to the sections drawn by the authors, he said he had not carried away quite the same impression of the stratigraphical position of the beds in the area described. He thought that the Coniston Limestone could seldom be considered as one distinct mass of limestone, but that concretionary bands of varying thickness and number appeared at various horizons in a mass of shale in which different fossils locally prevailed at different horizons. By this kind of evidence it was almost but not quite certain that the Graptolitic Mudstones and their basement-beds did rest on different parts of the Lower Series, *e.g.* at Skelgill, on the limestone bands, and near Coniston, on the Ash-Gill Flags. In the Craven district he had found a conglomerate at the base of the Coniston-Flag Series, but no Graptolitic Mudstones. In the Sedbergh district a similar conglomerate seemed distinctly to underlie the Graptolitic Mudstones. He allowed that the facies of the Graptolites was very like that of the Lower Series, but pointed out that Barrande had got the very same group in his E, *e*, *i* at the base of his Upper Series.

He further pointed out that there were in North Wales two sets of pale slates, one near the top of the Lower Series, the other near the base of the Upper, and probably derived at second hand from older volcanic rocks. Only the Upper were well marked in the Lake-district; and these were the Knock beds of the authors.

Mr. De Rance stated that he had spent two years in mapping the rocks of the Volcanic (Borrowdale) series underlying those under consideration. He agreed with Prof. Hughes, that the fossiliferous calcareous band referred to by the authors belonged to the Coniston Limestone, and not to the underlying volcanic rocks, as stated by them. And he remarked that in tracing the outcrop of the Coniston Limestone across country, it was found to rest upon different and successive members of the underlying volcanic series, which plunge under it with varying direction of strike and amount of dip, the unconformity being so marked between the two sets of rocks that occasionally the volcanic series appear to have obtained a dip, been denuded, and faulted before the deposition of the overlying Coniston series.

Mr. Hicks differed from Prof. Hughes as to the value of the paper, which he regarded as at all events opening a question on which other observers might be induced to bring forward their views. He inquired whether Mr. De Rance's statements showing unconformity at the base of the Coniston series did not conflict with the views of Prof. Hughes. He thought that there was no occasion to be surprised at repetitions of beds in such a district. In some sections there is no visible unconformity between the base of the Upper and the top of the Lower Silurians, whilst in others a real or apparent unconformity occurs. He expressed much surprise at some of the fossils from the Mudstones, and remarked that *Trinucleus fimbriatus* is a true Lower-Silurian form.

Mr. ETHERIDGE remarked that, as many geologists have worked over the area referred to in the paper, and have differed so much in their results, it is very difficult to come to any definite conclusion. The Mudstones possess a fauna belonging to the Caradoc beds and low down in the Bala series. He agreed with Prof. Hughes that there are more than one series of pale slates. It occurred to him that there must be some mistake in the determination of the species in the Graptolitic Mudstones; and yet all the interest of the paper hinges upon them. The Coniston Limestones have a well-recognized position.

24. Supplementary Notes *on the* Fauna *of the* Cambridge Greensand. By A. J. Jukes-Browne, Esq., B.A., F.G.S. (Read March 7, 1877.)

[Plate XXI.]

In a paper read before the Society in January 1875, I discussed the relations of the Gault and Chalk Marl in Bedfordshire and South Cambridgeshire, and endeavoured to show that the fossil contents of the so-called Cambridge Greensand are for the most part remaniés and have been derived from the upper beds of the Gault.

The conclusions arrived at were briefly these:—that the Upper Greensand does not extend further in a north-westerly direction than West-end Hill near Cheddington in Bucks; that stratigraphically the Cambridge Greensand is of no importance, being a mere nodule-bed at the base of the Chalk Marl; that it rests unconformably upon denuded Gault; that a greater portion of the fauna belonged originally to the Upper Gault; that the remainder, really belonging to the bed itself, are species proper to the Chalk Marl rather than to the Upper Greensand.

A full list of the species then known as existing in the formation was appended; and the derived forms were therein separated from those presumed to be indigenous to the Greensand itself. This list was mainly prepared from an examination of the large collection of fossils in the Woodwardian Museum; and my investigations resulted in the determination of many species that were previously unnamed in that collection, and in the identification of others which had been wrongly named. All these species were separately noticed, with remarks upon their determination and synonymy.

These observations, however, were by no means intended as an exhaustive study of the fauna of the Cambridge Greensand. Many specimens remained which it was not then possible to identify; and some of them appeared to be altogether new and undescribed; the consideration of these was purposely deferred until I should be able to obtain more information regarding them.

Two years have now elapsed, during which I have had the opportunity of inspecting many more specimens both from this and from other Cretaceous beds; and I am now better able, therefore, to offer some remarks upon these forms.

At the same time it is with considerable hesitation that I venture to name and place on record four species which do not appear to have been hitherto described; for I consider the establishment of such new forms as a very serious matter, and one upon which too much care cannot be spent.

It was, I think, Professor Forbes who remarked that few are aware how many species have been named from single and often broken specimens. Now it is obvious that such species cannot be of the same intrinsic value as those which are founded upon a number of perfect examples; neither can they be of the same use or importance to the comparative palæontologist. We are led, therefore, directly to the conclusion that some species are of more palæontological value than others; and it may be worth while considering a little more fully the other circumstances by which this value is modified or increased, especially as I am not aware that any one has recently discussed the conditions under which new species may be constituted, or given any directions to those intending to name and describe such forms as may appear to have been previously unnoticed.

The importance of a proposed new species must greatly depend, I think, upon the following circumstances:—

1. The number of specimens examined (whether many or few).
2. The number of localities where it has been found.
3. The extent to which the original shell or test has been preserved.
4. The amount of difference between it and nearly allied species of the same genus.

In the first place it is evident that a species founded on a single specimen, however well preserved, has not the same value as one the description of which has been drawn from an examination of many individuals. Much, however, will depend upon the character of the fossil; and supposing all the other conditions to be very favourable, if it is in a good state of preservation, retaining all its parts, and if it be markedly different from any other species, so that it is unlikely to be merely a monstrosity or local variety, then its intrinsic value is much enhanced; but at the same time it remains of little use when considered as a member of the fauna to which it is added; for, being found only at one locality, it cannot be utilized in a comparison of one fauna with another, but must always be omitted from such calculations.

Again, new species which have been described from single imperfect specimens in the state of casts, and even those founded on casts which are abundant and perfect so far as they go, are, as a rule, very unsatisfactory; for it is only in exceptional cases that the cast indicates the form and ornamentation of the shell with which it was covered. In cases where the cast does give such evidence its description is perhaps of some value; but where the casts are nearly smooth while the test was probably ornamented, as in Bivalve shells, Echinoderms, and many Gasteropods, it is worse than useless to describe them; for it is often impossible to compare them properly with specimens from other deposits which retain the shell, and the result is an unnecessary multiplication of specific terms: it is far easier to give a specific name to such casts than it is to disprove their title to the same.

Again, it is exceedingly difficult, even where specimens are abundant and their state of preservation good, to be quite sure that the form has never been elsewhere described. If not known in the British Isles, it may have been figured and described on the Continent; and the number of books, monographs and memoirs which ought to be searched is really very great. Moreover this is not always sufficient to guard against error, which can only be completely avoided by personal inspection of the foreign species to which it appears most nearly allied.

It is in such work, when the differences between nearly allied forms, described under different names, have to be carefully weighed and estimated, that the value of the fourth and last test of a good species is appreciated; the comparative value of such species is still more felt by any one who is instituting a comparison between similar faunas in different countries; for a given species, or varieties of the same, may actually exist in both formations, but, owing to their passing under different names, the fact may be disguised, and thus the number of species common to both is greatly underrated. To take an example, there are three species of *Pecten* to be found in the Cambridge Greensand, viz.:—*P. orbicularis*, Sow.; *P. Barretti*, Seeley; *P. Raulinianus*, D'Orb. Now those recently quoted from the Gaize of the Ardennes and Meuse are:—*P. laminosus*, Mant.; *P. Dutemplei*, D'Orb.; *P. Raulinianus*, D'Orb.; *P. asper*, Lam.; *P. hispidus*, Goldf.; and *P. Galliennei*, D'Orb. At first sight there appears to be only one species common to the two formations, viz. *P. Raulinianus*; but when it is known that *P. laminosus* is only a variety of *P. orbicularis*, and *P. Barretti* of *P. Dutemplei*, it is seen that all the Cambridge forms are represented in France.

It may, of course, be disputed that the two species are severally merely varieties of the two others; and I will admit that it is to a great extent a matter of opinion; but there can be no doubt that the species are respectively very closely allied, while with some of the others, such as *P. asper* and *P. Raulinianus*, they hardly possess any specific character in common; it is therefore very misleading that *P. Barretti* and *P. Dutemplei*, for instance, should be kept as distinct as if their differences were as great as those between the latter and *P. asper*. The only solution of this difficulty is, I believe, to be found in the more extended use of varietal names, and consequently of a trinomial nomenclature; the form would then be expressed as *Pecten Dutemplei*, var. *Barretti*.

The new species subsequently described are:—

Turrilites nobilis.
Natica levistriata.
Nautilus, sp. nov.
Lima interlineata.
Nerita nodulosa.

Viewed by the criterion of the conditions above mentioned, it will be found that the *Natica* is of the most palæontological value, since several specimens have been found both at Cambridge and Folkestone; the *Lima*, of which three specimens have been examined, comes next in importance; the *Nerita* is only described from a single imperfect specimen, but it is a remarkable species and belongs to a genus that is rare in Cretaceous beds; the *Turrilites* is of least value, since it is founded upon a cast, and I have, indeed, had grave doubts whether it was worthy of being placed on record. The

Nautilus I have described, but have not named, since the characters of its original shelly covering are hardly indicated on the casts, although these form a very common fossil in the Cambridge Greensand.

In conclusion, I may state that I regard the description of any of these species as of far less importance than the recognition among the fauna of other previously known species, and the demonstration of the identity of the separately named forms.

A few errors and misapprehensions which had crept into my former notes are now corrected.

Regarding the general conclusions arrived at in my former paper, I will only say that my opinions have been confirmed by subsequent experience during the progress of the Geological Survey in Cambridgeshire; the only point in which I am disposed to alter the views previously expressed is with regard to those fossils which are preserved in light phosphates. Similar nodules and fossils are found in the uppermost beds of the Gault both at Folkestone and in Bedfordshire; and I now consider them to have been derived from this horizon, very few, if any, of the phosphate nodules having originated in the bed where they are now found. I regard, therefore, a still larger proportion of the Cambridge fossils as derived, the invertebrate fauna of the Greensand itself being very small and only numbering 36 species.

CEPHALOPODA.

Belemnites plenus, Blainville.

This name was admitted into my former list in consequence of three or four specimens being so named in the Woodwardian Museum. A subsequent examination, however, in company with M. Ch. Barrois, of Lille, has convinced me that they do not belong to this species, since none of them exhibit the peculiar truncation of the alveolar end, which is its great characteristic. They bear most resemblance to large specimens of *B. ultimus* or *attenuatus*.

Nautilus arcuatus, Desh.

Nautilus arcuatus, Desh. Mém. Soc. Géol. France, vol. v. pl. xviii. fig. 1.

This species is described as inflated towards the middle, with rounded and subangular back, *without any umbilicus*; chambers as wide as high and very sinuate (très-arquées); siphon situated a little below the middle; test thin and nearly smooth.

It somewhat resembles *N. Fleuriausianus*, but has still more enveloping whorls, different chambers, and a differently situated siphon, that of *N. Fleuriausianus* lying close upon the inner whorl.

Several casts agreeing in every respect with the figure and description of *N. arcuatus* have been found in the "Nodule-bed," though they are by no means common. They are easily distinguished from all others by the absence of any umbilicus, and by the pinched-up back; this character is very conspicuous in the inner whorl, but becomes gradually less in the later chambers.

The species was found by Leymerie in the Gault of the Département de l'Aube; but I have not seen it quoted from any other locality.

NAUTILUS INÆQUALIS, Sow.

Nautilus inæqualis, Sow. Min. Conch. pl. lx. lower figs.

Nautilus Clementinus (?), Pict. & Camp. Ste. Croix, vol. i. pl. xix. fig. 1–5 (nec D'Orb).

If the figure and description of M. d'Orbigny's *Nautilus clementinus* be compared with those of Pictet and Campiche, I think it will be evident that the two are really different species, supposing, of course, that the figures are correct representations of the original specimens. This can only be decided by an inspection of the types, which I have not had an opportunity of making; it is remarkable, however, that both the figured forms appear to be represented among the Cambridge *Nautili*. Those agreeing with the *N. Clementinus* of D'Orbigny are large and somewhat compressed, oblong in cross section, not inflated, but rather flattened near the umbilicus, which is small. Those resembling the figure of Pictet and Campiche are more inflated, and broader in proportion to their length, with a larger umbilicus bordered by a low keel (which, however, is not so marked as in *N. expansus*); the siphuncle is situated close to the inner edge of the chamber. Both forms have numerous close-set chambers, about 16 being visible; but the latter does not appear to attain so large a size as the true *N. Clementinus*.

The smaller and more inflated form certainly appears to exist in the Folkestone Gault, and when obtained thence has, I believe, been usually referred to the *N. inæqualis* of Sowerby, with the meagre description and poor figures of which it sufficiently agrees. If, therefore, I am correct in the above surmises, the *N. Clementinus* of Pictet and Camp. becomes a synonym of *N. inæqualis*, Sow. The inequality of the chambers in the young shell, and the increasing propinquity of the septa being, however, the ordinary mode of growth in the genus, its designation seems rather meaningless.

NAUTILUS n. sp.

Cast oblong, umbilicated, chambers few, only 12 being generally visible, and the last ones being as high as they are wide; the septa are consequently wide apart, sinuate and bent back near the umbilicus; siphuncle situated outside the centre and about one third of the distance from the outer edge.

This is the commonest form of *Nautilus* among the Cambridge coprolites, but does not seem to agree with any previously described. Casts of the umbilicus seem to indicate that the shell had faint longitudinal striæ crossed by the lines of growth. Until, however, the shell has been found and the *Nautili* of the Gault more thoroughly investigated, it will be safer not to give a name to the above-described casts.

In size, number of chambers, and position of siphuncle they resemble *N. Bouchardianus*; but the septa of the latter are described as straight.

AMMONITES RHAMNONOTUS, Seeley.

A. rhamnonotus, Seeley, Ann. & Mag. Nat. Hist. ser. 3, xvi. p. 233, pl. xi. fig. 7.

A. navicularis, var. *nothus*, Seeley, *tom. cit.* p. 232.

A. gardonicus, Hébert & Munier-Chalmas (Bassin d'Uchaux), Ann. des Sc. Géol. tome vi. pl. 4. figs. 1, 2.

In 1875 (Quart. Journ. Geol. Soc. vol. xxxi. p. 286) I pointed out that the fossils indicated by the second of the above names had a closer relationship with *A. Mantelli* than with *A. navicularis*, but had also some characters in common with *A. dispar*, D'Orb., as figured and described by MM. Pictet and Campiche.

In the same year Prof. Hébert published his description of the Bassin d'Uchaux, in the appendix to which he described and figured the young and old forms of an Ammonite from the Gault of Valbonne under the name of *A. gardonicus*. The resemblance between these and some of the Cambridge specimens is very great, the young form being very like the *A. rhamnonotus* of Mr. Seeley, while the older individual approaches nearly to that called by him *A. navicularis*, var. *nothus*. A comparison of the descriptions given by Prof. Hébert and Prof. Seeley respectively will show how closely *A. rhamnonotus* and *A. gardonicus* are allied. After describing the young form, M. Hébert observes, "in older individuals the ribs pass over the back, and only present three slight elevations, which sometimes finish by disappearing altogether."

Mr. Seeley says:—"On the back the ribs are rather less distinct, and each bears in its centre a small sharp tubercle. In a younger state there are also tubercles at the extreme edge of the back, which seem to disappear with a diameter of twelve lines."

Another common characteristic is that only some of the ribs spring from the umbilicus, the intermediate ones arising from near the middle of the whorl; this, however is also the case with the ribs ornamenting the so-called *A. navicularis*, var. *nothus*; and there are specimens now in the Woodwardian Museum which plainly connect this with the former. In one of these the earlier ribs are frequent and rounded, while the later ribs are wider apart and become rudely nodulated; in others the tubercles appear to be lost with age, as in Prof. Hébert's specimen; another form resembles the fragment named *A. Wiestii* by Sharpe. In view, therefore, of the great variation exhibited in this series of specimens, I propose that they be all considered as varieties of one species, for which Mr. Seeley's name *A. rhamnonotus* has the priority.

[Since the above was written I find that Mr. Seeley has obtained casts of *A. gardonicus* and placed them in the Museum, identifying them at the same time with his *A. rhamnonotus*; this identity may therefore be regarded as established.]

There is another form, however, with which they have some relations, viz. *A. sexangulatus*, Seeley. To the figured type of this they have little resemblance; but other specimens which Mr. Seeley has recently referred to this species are very like them, and, if he is not mistaken in these later determinations, I think the above name must also be added to the synonymy of *A. rhamnonotus*. It is possible that the two originally described specimens may really be a distinct species; but I am more inclined to consider that these constitute a strongly marked variety of this variable form, for which the varietal designation *sexangulatus* may be conveniently retained.

In thus proposing to group under one specific name several forms which, in their extreme modifications, are very unlike one another, I am only following the plan suggested by Mr. Seeley himself in his excellent paper on the Cambridge Ammonites, in which he describes numerous varieties of the four types, *splendens*, *auritus*, *Raulinianus*, and *Studeri*, regarding these as but subspecies of a larger group, for which he suggests the name of *A. permutatus*.

Ammonites cœlonotus, Seeley.

A. cœlonotus, var., Seeley, Ann. & Mag. Nat. Hist. 3rd ser. vol. xvi. p. 238, pl. x. fig. 3.

A. valbonnensis, Hébert & Mun.-Ch. in Description du Bassin d'Uchaux, Ann. des Sc. Géol. tome vi. pl. 4. fig. 3.

It may be well to call attention to the identity of these two shells, separately figured and described in the two publications above mentioned. Mr. Seeley describes two varieties of his species; but the figures are unfortunately very poor. They are, however, sufficiently recognizable; and had Prof. Hébert seen them, he would probably not have described his *A. valbonnensis* as a new species. One advantage, however, has been derived from his oversight, namely the presence of an excellent figure of this variety in the Annales des Sciences Géologiques; it might almost, indeed, have been taken from a specimen now in the Woodwardian Museum. I would suggest, therefore, that it hereafter stand under the name of *A. cœlonotus* var. *valbonnensis*.

Ammonites acanthonotus, Seeley.

A. acanthonotus, Seeley, Ann. & Mag. Nat. Hist. 3rd ser. vol. xvi. p. 234, pl. xi. fig. 5.

After describing this peculiar form, Mr. Seeley remarks that a slight inflation extends all round one side of the whorl; "but," he says, "from the near resemblance the shell has to *A. glossonotus*, I am not inclined to give that weight to the distortion it otherwise would have. The late Dr. S. P. Woodward, in 1862, regarded this shell as a monstrosity of *A. lautus*, Sow., a view with which I cannot agree."

In my opinion, however, there can be no doubt that Dr. Woodward was right in considering this supposed new species as simply a monstrosity, although he was probably wrong in referring it to *A. lautus.* It appears to me to be *a malformed individual of the species A. auritus,* the dorsal tubercles of one side being atrophied and thus allowing those of the other side to take a more median position. In every other detail of form and ornamentation it agrees with *A. auritus*; and there are now in the Woodwardian Museum other partially atrophied forms which clearly show the way in which this particular specimen came to possess such deceptive characters.

The other individual which shared the tablet of *A. acanthonotus* is a very different form, being large, strong, and inflated; it is, in fact, a similarly distorted specimen of *A. Studeri*, Pict. & Camp. The collection also possesses some interesting deformities belonging apparently to *A. vraconnensis* or to other varieties of *A. Studeri.* It is clear, therefore, that *A. acanthonotus* must be struck out of future lists of Cambridge fossils.

I may also call attention to a similarly malformed species, *A. Ramsayanus*, figured in Sharpe's Chalk Mollusca, and described at page 51. One side of it bears a very great resemblance to that named *A. Woodwardi* by Mr. Seeley, *tom. cit.* p. 236, pl. xi. fig. 3.

SCAPHITES HUGARDIANUS, D'Orb.

Scaphites Hugardianus, D'Orb., Héb. & Mun.-Ch., *loc. cit.* p. 117, pl. v. fig. 7.

Scaphites Meriani, Pict. & Camp., see Quart. Journ. Geol. Soc. xxxi. p. 287, pl. xiv. fig. 1–3.

I was glad to observe that MM. Hébert and Munier-Chalmas also regard these two forms as varieties of one species, distinguishing them at the same time from *S. æqualis* as I had done in my former note on the Cambridge Scaphites. I ought to have given the preference to D'Orbigny's name.

TURRILITES WIESTII, Sharpe.

The casts which in 1874 (see Quart. Journ. Geol. Soc. xxxi. p. 289) I identified as belonging to this species, appear in reality to be somewhat intermediate between *T. Wiestii* and *T. costatus*, or rather to hold such a relation to both forms as we might expect were it the common progenitor of both. It resembles *T. Wiestii* in most particulars, especially in the position and number of the tubercles; these, however, are developed from indistinct costæ, which are continued under the base of the whorls; and their impress is seen on broken casts. In the typical *T. Wiestii* the tubercles are not connected by such elevations or ribs.

From *T. costatus* it differs by its narrower whorls and their greater spiral angle, as well as in the position of the tubercles, though, as I have elsewhere remarked, the ribs and tubercles of *T. costatus* appear to be very variable in their position.

Although it is sufficiently distinguished from *T. Bergeri* by only possessing three rows of tubercles instead of four, yet there are many characters common to the two species; and it must be remembered that tubercles are sometimes represented by ribs as in *T. costatus*.

Altogether I consider that the above-mentioned species hold such relations to one another as make it only reasonable to suppose that they have been produced by descent with modification.

The Cambridge form might receive the name of *T. cantabrigiensis*.

? TURRILITES EMERICIANUS, D'Orb.

Turrilites Emericianus, D'Orb. Pal. Fr. pl. cxli. figs 3–5.

The Woodwardian Museum possesses a small dextral cast, which appears to be referable to the above species, or is, at any rate, very closely allied to it.

Only two whorls are preserved; but these are sufficient to show its low squat growth, and to distinguish it from *T. Hugardianus*. These whorls are rounded and ornamented with about 24 simple straight ribs, running down into the umbilicus, which is wide and ample.

TURRILITES ELEGANS, D'Orb.

This species does not yield a very well-marked cast; several specimens, however, have passed through my hands which greatly resembled it; one of these is now in the Museum at Jermyn Street.

TURRILITES NOBILIS, new sp. Pl. XXI. fig. 1.

Cast rather large, dextral, whorls full and rounded, crossed somewhat obliquely by 26 to 28 well-marked ribs, each bearing three small tubercles; the lower row of these is only seen on the body-whorl, being sutural in the whorls above. The ribs appear to run under the base, and to converge towards the umbilicus, their impressions being seen on the broken uppermost whorl.

The spiral angle is very small; and the whorls were probably numerous, as in *T. Hugardianus*, from which it is easily distinguished by the rows of tubercles. The specimen above described was collected during the progress of the Geological Survey; and the last whorl of a cast apparently belonging to the same form is preserved in the Woodwardian Museum. The actual shell is unknown, but was probably thin, as in other *Turrilites*; so that its characters are sufficiently delineated by the cast: I have therefore thought that the species might safely be described and named. From *T. Wiestii* it is distinguished by the broader whorls and less prominent tubercles, in this respect approaching *T. Escherianus*.

GASTEROPODA.

Aporrhais, Da Costa.

An excellent account of this genus and its fossil forms, hitherto included under the heads of *Rostellaria* and *Pteroceras*, is given by Mr. J. S. Gardner in the 'Geological Magazine' for 1875, Dec. ii. vol. ii. p. 49. He concludes by dividing them into four generic or subgeneric groups, viz. *Aporrhais*, *Ornithopus*, *Tridactylus* and *Dimorphosoma* (*tom. cit.* p. 394).

Aporrhais marginata, Sow.

Rostellaria marginata, Sow. Geol. Trans. vol. iv. pl. xi. fig. 18.
Rostellaria Orbignyana, Pictet & Roux, pl. xxiv. fig 4.
Pterodonta marginata, Seeley, Ann. & Mag. Nat. Hist. 1861, vol. vii. pl. xi. fig. 2.
Pterodonta longispira, Seeley, *tom. cit.* pl. xi. fig. 3.

In the papers above referred to, Mr. Gardner has carefully investigated the history of *A. marginata*, and has demonstrated its identity with *A. Orbignyana*, the cause of their separation having been that the lower keel was not clearly shown in the original engraving of the former. This being so, when Mr. Seeley (at p. 283) says of his supposed *Pterodonta longispira* that it almost as closely resembles *A. Orbignyana* as *P. marginata* does *A. marginata*, it is evident that there cannot be much difference between the two species referred to *Pterodonta*.

Further, it is to be remembered that both were described from *imperfect casts*, without any trace of the original shell, so that the characters were necessarily indefinite.

Moreover, from an examination of Mr. Carter's specimens, I am inclined to think that in the case of *P. marginata* the supposed notch is only an accidentally exaggerated inflection of the concavity below the keel, and that it is not the impression of any definite internal tooth-like ridge.

The figure of *P. longispira* is stated to be slightly restored from specimens in the same collection; these, however, appear to have been mislaid, and are not now to be found; I cannot, therefore, say more than that the circular hollow represented in the figure is unlike that caused by the vertically elongated ridge shown in D'Orbigny's figures of *Pterodonta*, and that the other characters of the figure appear to be those of *A. marginata* (*Orbignyana*).

Further evidence must therefore be forthcoming before the presence of *Pterodonta* in the bed can be regarded as ascertained.

Ornithopus, Gardner.

Mr. Gardner has proposed the above name (Geol. Mag. dec. 2, vol. ii. p. 394) to include the small shells which have hitherto been grouped under the recent genus *Pteroceras*.

There can, I think, be no doubt that they merited a new generic designation, and that they do not properly belong to the family of the Strombidæ at all. The Aporrhaidæ (with which they are now classed) should, I think, constitute a distinct family, intermediate between Cerithiadæ and Strombidæ, and probably representing the branch from the former which led to the development of the latter.

Ornithopus retusus, Sow., sp.

Rostellaria retusa, Sow. Geol. Trans. ser. 2, iv. pl. xviii. fig. 22.

Rostellaria bicarinata, Desh. Mém. Soc. Géol. Fr. vol. v. pl. xvii. fig. 14.

Pteroceras globulatum, Seeley, Ann. & Mag. Nat. Hist. 1861, vol. vii. pl. xi. fig. 1.

(?) *Aporrhais bicornis*, Pict. & Camp. Ste. Croix, 1864, pl. xciv. figs. 8, 9.

In the 'Geological Magazine,' 1875, p. 52, Mr. Gardner carefully describes this species, and calls attention to the great resemblance between it and that figured by Pictet and Campiche under the name of *A. bicornis*.

With regard to *P. globulatum*, I was inclined to look upon it as a distinct form, and communicated this opinion to Mr. Gardner in 1875; I have since had the opportunity of inspecting the specimens in Mr. Carter's large collection; and these have convinced me that *P. globulatum* should be considered as a dwarf race of *O. retusus*.

I believe therefore that, although one or more of the above-mentioned forms may be viewed as a definite local variety, yet, the same specific description being applicable to all of them, they should be regarded as constituting a group, of which *O. retusus* may be taken as the type.

Ornithopus histochilus, Gardn.

Aporrhaïs histochila, Gardner, Geol. Mag. 1875, pl. vii. figs. 5, 6.

In March 1875 I forwarded to Mr. Gardner some casts from the Cambridge bed, which had been referred to *Pteroceras Fittoni*, asking him at the same time whether this species had ever been obtained from the Gault. This question he answered in the negative, but remarked at the same time that although the specimens sent were very like *P. Fittoni*, yet they still more closely resembled an undescribed form from the Upper Greensand of Devizes which he intended shortly to investigate. The result of his researches appeared in the July number of the Geol. Mag., where he figured and described this form under the name of *Aporrhaïs histochila*, noting its occurrence in the Upper Greensand at Cambridge, and in the *Gault of Folkestone*.

The species is allied to *A. Fittoni* and *A. retusa*, Mr. Gardner including them all in his proposed genus *Ornithopus*. Thus, therefore, another Cambridge form proves to be identical with a Gault species, though in this case it happens to be found in the Upper Greensand as well.

MESOCHILOTOMA STRIATA, Seeley.

Mesochilotoma striata, Seeley Ann. & Mag. Nat. Hist. ser. 3, vol. vii. p. 284.

The single specimen to receive which the above genus and species have been proposed, is a small cast, not half an inch long, and imbedded in phosphate, so that only one side of it is exposed to view.

It is, moreover, imperfect, both the apical and anterior portions being broken off, so that only parts of four whorls are visible. The outer lip is therefore not present, although Mr. Seeley describes it as having "a notch which forms a keel round the middle of the whorl;" this keel he states to be crossed by the lines of growth; and perhaps it was from the evidence these would afford that he presumed the outer lip to have been notched.

These lines are not very distinct; there is no doubt, however, about the presence of the keel and of the faint striæ above and below it; but in my opinion the keel bears a greater resemblance to that on some forms of *Aporrhais* than to that of *Pleurotomaria.* Mr. Seeley believes it to have had a short canal; but he adds, "I have not yet seen the canal, and only predict its being short from an examination of the broken uppermost whorl."

Now, so far as such a small and badly preserved specimen enables me to judge, I should be inclined to consider it the cast of a small *Aporrhais carinella*, a species which has just such a median keel with striæ above and below. At any rate Mr. Seeley's description would apply equally well to the shell above mentioned; and it is certainly much more likely to belong to this than to an entirely new genus and species, for the existence of which no other evidence is forthcoming.

BRACHYSTOMA ANGULARE, Seeley, sp.

Scalaria angularis, Seeley, Ann. & Mag. Nat. Hist. ser. 3, vii. p. 286, pl. xi. fig. 9.

Brachystoma angularis, Gardner, Geol. Mag. dec. 2, vol. iii. p. 160, pl. iv. fig. 11.

In 1861 Mr. Seeley described an imperfect cast in the collection of Mr. J. Carter under the name of *Scalaria angularis*, one side only of two whorls being visible on this specimen; another fragment in the Woodwardian Museum exhibited the three uppermost whorls of the spire.

There was also in the Museum a fine and nearly perfect cast, which, from the slight keel on the body-whorl, I supposed to be a new species of *Aporrhais*; and last year I obtained a second specimen, but never suspected their identity with *S. angularis.* Having, however, sent one of these to Mr. J. S. Gardner, he forwarded me a specimen from the Gault of Folkestone in which the shell was preserved, asking me to compare it with the Cambridge casts, as he suspected they all belonged to the same species. A careful inspection of the several specimens proved this surmise to be correct, Mr. Seeley's types answering exactly to the middle and upper portions of the Gault specimen, which also possessed the angulated body-whorl of the other Cambridge casts.

The shell was consequently described by Mr. Gardner under the generic name of *Brachystoma*, and its affinities with the Aporrhaidæ duly pointed out.

CHEMNITZIA TENUISTRIATA.

Cerithium tenuistriatum, Seeley, Ann. & Mag. Nat. Hist. 1861, vol. vii. pl. xi. fig. 6.

Pyrgiscus tenuistriatus, Gardner, Geol. Mag. dec. 2, vol. iii. p. 112.

In his valuable paper on Cretaceous Gasteropoda above referred to, Mr. Gardner describes some scalariform shells similar to the *C. tenuistriatum* of Mr. Seeley, referring them all to Philippi's genus *Pyrgiscus*, and deprecating at the same time the union of such forms with the genus *Chemnitzia*.

The reason which he gives for the revival of this genus, viz. the want of columellar plaits, can hardly be regarded as sufficient, especially as I find on referring to the 'Enum. Molluscorum Siciliæ,' vol. ii. p. 136,' that Philippi himself acknowledged its identity with the *Chemnitzia* of D'Orbigny.

It is difficult to understand why palæontologists have ignored the existence of the latter genus in Cretaceous rocks, when it is recorded from Jurassic beds, and known in Tertiary and Recent times; and I cannot help thinking that many of the so-called *Scalariæ* are in reality *Chemnitziæ*.

Mr. Gardner's own description of *Pyrgiscus* is almost identical with that of *Chemnitzia* in Woodward's 'Manual of the Mollusca,' p. 239; and it essentially differs from *Scalaria* in the form of the mouth, and by its incomplete peristome.

It is remarkable that the two other species described by Mr. Gardner are from the Folkestone Gault and the Blackdown beds respectively; they are certainly all very closely related, and may, I think, turn out to be varieties of the same form when more specimens come to be compared.

TURBO PICTETIANUS, D'Orb. Pl. XXI. figs. 3–5.

Turbo Pictetianus, D'Orb. Pal. Fr. vol. ii. pl. clxxxiv. figs. 8–10; Pict. & Roux, Grès Verts, pl. xix. fig. 1.

Turboidea nodosa, Seeley, Ann. & Mag. Nat. Hist. ser. 3, vol. vii. p. 289, pl. xi. fig. 14.

The figures of *Turbo Pictetianus*, both in D'Orbigny and Pictet & Roux, fail to give an adequate idea of this shell; and if Mr. Seeley had never seen specimens he may be forgiven for not having recognized the identity of the Cambridge fossil with the Perte-du-Rhône form.

Specimens now in the Woodwardian Museum, however, leave no doubt of this identity: those from the Perte du Rhône which retain the shell agree entirely with Mr. Seeley's type, which has the shell converted into phosphate of lime, and is preserved in Mr. Carter's collection.

D'Orbigny's figure does not express the rugose lamellæ underneath, which coexist with the striæ said to be characteristic; the nodules also are made too regular and too distinctly *double*, whereas they are only elongated or bilobed.

Mr. Seeley's figure of the under surface is very good; but the side view gives too high an elevation, and the base is badly drawn; the nodulations, again, are too distinctly *single*; on the specimen itself they are more irregular, more elongate, and may have been bilobate. The side view of this and also of a Rhone specimen are given in Pl. XXII. figs. 3 & 5.

Those from the Perte du Rhône vary much in height, some having the elevation of *T. nodosa*, others being low and resembling that called *T. expansa* by Mr. Seeley. One individual of the Cambridge *T. expansa* shows protuberances on the cast caused by the tuberculations of the shell; they are probably only varieties of the same species.

Trochus cancellatus, Seeley.

Comp. *Turbo indecisus*, D'Orb. Pal. Fr. p. 230.

I think MM. Pictet and Campiche must have been mistaken in referring any Cambridge specimens to *T. Tollotianus*. I have recently had an opportunity of comparing them with specimens from the Perte du Rhône; and though these are somewhat similar to *T. cancellatus* in shape, yet they are quite smooth, showing neither spiral lines nor cancellated markings; neither is there any trace of the occasional varices.

I am inclined to think therefore that *Trochus cancellatus* is a distinct species, and that *T. Tollotianus* does not exist in the Cambridge Greensand. I may mention that it was by a mistake that the latter name was inserted in the Explanation of plate xiv. appended to my former paper (Quart. Journ. Geol. Soc. vol. xxxi. p. 313).

[Since writing the above I have seen the collection of D'Orbigny's types at the Jardin des Plantes in Paris; and among these I found specimens named *Turbo indecisus*, which appear identical with *T. cancellatus*; one of them shows the longitudinal markings, and another the full cancellations, in the same variable way as the Cambridge casts exhibit them. D'Orbigny, p. 230, says that it occurs at Eocragnoles, Perte du Rhône, and Clansaye, but that he only knew the internal cast.]

Natica levistriata, new sp. Pl. XXI. fig. 6.

Shell globose; spire moderately high; whorls flattened above, so as to produce a slight angulation which runs round the spire: below this on the body-whorl there are 10 or 11 slightly elevated spiral striæ. The angulation may be otherwise described as the highest of these ridges. There are very few striated *Naticæ* known from Cretaceous beds; and this appears to differ from all of them. The above description is from a specimen in the national collection, from the Gault of Folkestone. It has the shell partially preserved; but where this is absent a cast is disclosed of the same shape and dimensions as those from the Cambridge bed (fig. 6), which in my previous paper (p. 292) I provisionally referred to *N. Rauliniana*, D'Orb.

Nerita nodulosa, new sp. Pl. XXI. figs. 7, 8.

Shell very thick; spire depressed; whorls angulated and flattened above, ornamented when young with numerous small ribs, which proceed from the spire and, passing over the head, run vertically for a short way down the side of the whorls; they are then broken up into small nodules or tubercles. As the shell increases in growth, however, the upper parts of the ribs also become nodulose, so that near the mouth the ornamentation is entirely changed; large, irregular, nodulose tubercles are developed on the keel, apparently by the union of two or three ribs; and above each, on the flat portion of the whorl, are two smaller nodules. At the same time the outer lip is enlarged, flattened, and applied against the inner whorls, somewhat as in recent *Neritæ*.

A single specimen only is known, in the cabinet of J. Carter, Esq. Length about 13 lines, breadth 9 lines, height unknown; and the lower part of this is broken away, so that the characters of the base cannot be ascertained.

Although the fossil above described is unique and imperfect, yet so much of the original thick shell is retained; and this is so remarkable in its shape and ornamentation that I have thought some account of it might be published.

At the same time I have had great difficulty in deciding to what genus it probably belongs. It might almost be referred to *Straparollus*, or *Euomphalus*; but the angle which the outer lip makes with the inner whorl is greater than in these genera, and leads to the conclusion that the last whorl was considerably produced below. This is the case with a shell named *Nerita rugosa* by MM. Briart and Cornet (Meule de Bracquegnies, pl. iii. figs. 50–52), which the Cambridge fossil appears to much resemble in shape and general features.

N. rugosa has thick, radiating ribs of a uniform character, each ending in a nodular projection at the keel, below which the shell is smooth; the base is not umbilicated; it is thus specifically different, though it appears to be generically identical. Whether, however, they are true *Neritæ* some doubt may be entertained.

Pleurotomaria regina, Pict. & Rx.

Pleurotomaria regina, Pict. & Roux, Grès Verts, pl. xxiv. fig. 2.

Casts of this species are among the fossils from the Perte du Rhône recently placed in the Woodwardian Museum; and from them I have been able to identify certain low, closely whorled forms which are not uncommon among the Cambridge *Pleurotomariæ.* They are easily distinguishable from casts of *P. Rouxi* or *P. Rhodani* by their flat or slightly concave base.

In the abundance of its *Pleurotomariæ* the Cambridge Greensand resembles the continental Gault Supérieur; and it is remarkable also that most of the species appear to be identical.

Pleurotomaria Itieriana? Pict. and Rx. Pl. XXI. fig. 2.

Casts of a more elevated species are often found, having 3 or 4 whorls ornamented with a spiral rib corresponding to the sinus-band; the base is flattened; and the general form resembles that of *P. Itieriana*, Pict. and Rx. pl. 22. fig 3. The same fossil also occurs in the Gault of Folkestone; but I have never seen it named. I also possess what I believe to be a unique specimen of a reversed variety, apparently belonging to this species; the whorls are more separated, as is frequently the case in sinistral forms, see Pl. XXI. fig. 2.

LAMELLIBRANCHIATA.

Pecten aptiensis, D'Orb.

Pecten interstriatus, D'Orb. Pal. Fr. vol. iii. pl. ccccxxxiii. figs. 1–5; and Pict. & Roux, Grès Verts, p. 516, pl. xlvi. fig. 4; subsequently named

Pecten aptiensis, D'Orb.

Pecten Dutemplei, D'Orb. Pal. Fr. pl. ccccxxxiii. figs. 10–14; and Pictet & Roux, Grès Verts, p. 516, pl. 46. fig. 4.

Pecten Barretti, Seeley, Ann. & Mag. N. H. ser. 3, vol. vii. p. 118, pl. vi. fig. 1.

I cannot help thinking that these three forms are much more nearly related to one another than has hitherto been supposed.

All three are about the same size, have nearly the same number of ribs, and are characterized by similar interstitial striations.

Of *P. Barretti* Mr. Seeley says, "the left valve is ornamented with some 48 radiating, rather depressed ribs, of which about a dozen are subordinate, the remainder nearly equal; all are imbricated. The interstitial spaces are very finely striated, those in the centre longitudinally, and those of the sides obliquely, reminding one of *P. aptiensis*. On the flat valve the ribs appear less prominent and more numerous." I cannot see that it has any resemblance to *Pecten Espaillaci*; nor do I think the latter existed with it, the specimen so named in the Woodwardian Museum being only a large individual of *P. Barretti* preserved in a lighter-coloured phosphate. There is no doubt, however, of its close affinity with *P. aptiensis*; indeed it becomes a matter of doubt whether the differences are sufficiently great to justify its being considered a separate species.

The upper and lower valves of *P. aptiensis* differ similarly in the number of ribs: D'Orbigny gives 20 to 23 as the number on the upper (convex) valve, and 46 on the lower; Pictet and Roux, however, reckon the number on the upper valve as 35 to 38, but have not seen the lower valve.

Pecten Dutemplei is said to have about 40 or 50 ribs on the upper valve; "and a small simple linear rib occurs between these ribs, *but not regularly.*" This arrangement is better shown in Pictet and Roux's figure than in that of D'Orbigny; and the number of ribs given by the latter, viz. 70 to 80, is probably an exaggeration.

Both *P. aptiensis* and *P. Dutemplei* have the same curious oblique striation across the interspaces, and are in all other respects very like one another, the chief difference mentioned by D'Orbigny being the presence of the occasional intermediate simple rib on the latter species.

Now occasional simple ribs are also distinctly visible on some specimens of *P. Barretti,* especially on that previously referred to as having been mistaken for *P. Espaillaci. P. Barretti*, therefore, would appear to be most nearly allied to the Gault form of the species, viz. *P. Dutemplei.*

Mr. Seeley finds some differences in the ornamentation of the ears; but his remarks regarding them (p. 119) are not very clear: neither does the variation seem very important; for the combination of transverse and radiating lines is very frequent on the ears of allied species, and sometimes one set of markings, sometimes the other, stands out more prominently, according to growth and state of preservation.

All the differences above noted are merely slight variations from the earlier type of *P. aptiensis*, under which head I think both *P. Dutemplei* and *P. Barretti* should be ranged as varieties. The latter has been found by Mr. H. G. Fordham in the Greensand at Swanage.

PECTEN RAULINIANUS? D'Orb.

Pecten Raulinianus, D'Orb. Pal. Fr. iii. pl. ccccxxxiii. figs. 6–9.

A specimen recently placed in the Woodwardian Museum is about the same size as *P. Barretti*, but possesses very different characters. No interstitial striations are visible; the ribs are numerous, and ornamented with closely set, narrow, lamellated imbrications. It appears to agree more closely with *P. Raulinianus* than with any other known to me; indeed, as far as can be seen, in ornamentation it agrees exactly with that species.

PECTEN SUBACUTUS, D'Orb.

Pecten subacutus, D'Orb. Pal. Fr. p. 603, pl. 435. figs. 5–10.

This species has about 25 simple ribs, ornamented with squamose elevations set at short intervals; the ribs are rounded on the upper valve, but more angular and acute on the lower; slight striations run down each side of the ribs into the interspaces, which are nearly as broad as the ribs.

It is a very rare *Pecten* at Cambridge; and most of those I have seen were much worn, so that the ribs appeared quite plain; but a specimen in the Woodwardian Museum presents the characters above mentioned. The ribs are strongly marked on the casts; the shell varies in length from 13 to 17 lines. D'Orbigny gives it as a Turonian form; but it appears also to occur in the Gault Supérieur of Cheville ('Renevier,' p. 163).

LIMA RAULINIANA, D'Orb.

Lima Rauliniana, D'Orb. Pal. Fr. iii. pl. ccccxvii. figs. 5–8.

This species bears a considerable resemblance to *Lima aspera*, Mant.; and the Cambridge specimens have hitherto been confounded with that form.

Great differences, however, are discovered on a close examination. *L. aspera* has wide, flattened ribs, separated by very narrow interspaces, mere grooved lines, in fact, which are pitted at intervals.

L. Rauliniana has low rounded ribs with peculiar imbrications, and the interspaces are nearly as wide as the ribs. M. d'Orbigny's description is correct so far as it goes; and fig. 7 shows the peculiar ribs "sur lesquelles sont comme des tuiles obliques en dehors, espacées et alternes;" he does not, however, mention the ornamentation of the interspaces; these are not pitted, but crossed with irregular transverse grooves or striations, very minute and closely set.

The main characters of the shell may be thus described:—valves nearly equal and equiconvex, each bearing between 40 and 50 low rounded ribs, interrupted occasionally by the lines of growth; the ribs are ornamented with elongate imbrications, projecting slightly over their inner side, viz. over the left side of one half of the ribs, and over the right side of the other half, on each side of a median line, where the ribs divaricate; when worn, the ribs appear to be simply notched; the interspaces are grooved in the way above mentioned.

The specimens are generally preserved in the lighter-coloured phosphate, which at one time I thought had been formed *in situ*; I have since, however, been led to think that these phosphates have also been derived, but probably from rather higher beds of the Gault than those from which most of the black nodules came.

Lima Rauliniana is found in the Gaize or Gault Supérieur of the Paris basin; and casts of similar shape are quoted from Cheville by Prof. Renevier ('Faune de Cheville,' p. 163); but I am not aware that it has been previously discovered in England.

LIMA INTERLINEATA, new sp. Pl. XXI. fig. 10.

Shell transversely oval, or obliquely quadrate; valves equiconvex, and each ornamented with 10 or 11 strong rounded ribs radiating from the umbo; interspaces wide and flat, marked with a few distinct longitudinal lines, which vary in number from 1 to 5, but are most numerous on the more central interspaces. There appear to have been several stronger striæ or small ribs on the anterior side or buccal region; but the shell is here worn off.

The species, indeed, is very rare; and only a few portions of the shell remain on that figured, which measured $1\frac{1}{2}$ inch by about $1\frac{1}{8}$ inch. The shell appears to have been moderately thick; and the ribs stand out in strong relief on the cast.

It somewhat resembles *L. Galliennei* of D'Orbigny; but this species is wider, is much more compressed, and is strongly striated over both ribs and interspaces—characters which sufficiently distinguish it.

BRACHIOPODA.

Rhynchonella sulcata, Park.

Rhynchonella sulcata, Park, Geol. Trans. ser. 1. vol. v. p. 59; Dav. Cret. Brach. pl. x. figs. 18–36.

The varieties of this species are very numerous, all gradations being found between the large and sparsely ribbed shells, and the smaller forms which bear numerous closely set ribs. The specimen noticed in my previous paper as *R. compressa* (really *dimidiata*) may be only another extreme variety. Mr. Davidson, to whom it has since been sent, remarks that it is much more transverse than any *R. sulcata* which has come under his notice, and that it is very like some forms of *R. dimidiata*; but for all that he would not be surprised if it were only a compressed and abnormal form of *R. sulcata*, so difficult is it to state positively to which species a single and isolated individual belongs.

Those shells previously known as *R. latissima* are now considered to be *R. dimidiata*, var. *convexa*; but the Cambridge specimens may after all be only an extreme variation of *R. sulcata*.

ACTINOZOA.

Trochocyathus angulatus, Duncan, sp.

Smilotrochus angulatus, Duncan, Suppl. Cret. Corals, pl. vii. figs. 7 and 8.

In 1867 Prof. Duncan described as new forms two species of corals from the Cambridge Greensand, referring them to the genus *Smilotrochus*; one of these, *S. elongatus*, I have previously shown to be really a *Trochocyathus*, by discovering that it possessed epitheca, exhibited a columella, and was clearly pediculate—that it was, in fact, identical with *Trochocyathus conulus* of Edw. and Haime.

I had not then any proof that the second species, *S. angulatus*, belonged to the same genus, though I regarded it as exceedingly likely. Having recently, however, split open many specimens of this coral, I have ascertained that it possesses as distinct a columella as its larger congener, though, of course, shorter in proportion to the squat growth of the species.

Edwards and Haime's description, viz. "columella well developed, composed of prismatic or twisted processes disposed fascicularly or in a single row," applies equally to both species.

Although I have never seen a *T. angulatus* with distinct epitheca and expanded base, yet, judging from the analogy of *T. conulus*, it is reasonable to suppose that they were originally present; indeed it is exceedingly rare to find even a trace of the costulate wall, their usual condition being that of dark phosphate casts.

Range of the species mentioned in the foregoing notes as not previously identified in the Cambridge Greensand:—

	Gault, English or Foreign.	Upper Gault of England.	Vraconien or Gault Supérieur.
Nautilus arcuatus, *Desh.*	*		
—— inæqualis, *Sow.*	*		
Turrilites elegans, *D'Orb.*	*		
? —— Emericianus, *D'Orb.*	*		
Ornithopus histochilus, *Gardn.*	*	*	
Brachystoma angulare, *Seeley*	*		
Turbo Pictetianus, *D'Orb.*	*	...	*
Pleurotomaria regina, *Pt. & Rx.*	*	...	*
? —— Itieriana, *Pt. & Rx.*	*	*	*
Pecten Raulinianus, *D'Orb.*	*	*	*
—— subacutus, *D'Orb.*	* ?	...	* ?
Lima Rauliniana, *D'Orb.*	*	...	*

Names of those to be struck out of former list:—

Belemnites plenus, *Blainv.*
Ammonites dispar, *D'Orb.*
—— acanthonotus, *Seeley.*
Pterodonta marginata, *Seeley.*
—— longispira, *Seeley.*
Pteroceras Fittoni.
Mesochilotoma striata, *Seeley.*
Trochus Tollotianus, *Pt. & Rx.*
Turboidea nodosa, *Seeley.*
Turboidea expansa, *Seeley.*
Spondylus Dutempleanus, *D'Orb.*
—— truncatus, *D'Orb.*
Lima aspera, *Mant.*
Hemiaster asterias (=Epiaster).
Sarcinula favosa (=Isastræa).
Cidaris clavigera, *König.*
Chenendopora = Pharetrospongia, *Sollas.*

EXPLANATION OF PLATE XXI.

Fig. 1. *Turrilites nobilis*, new sp., Geological-Survey collection, phosphate cast.
2. A reversed *Pleurotomaria*, probably *Pl. Itieriana*, Survey collection.
3. *Turbo Pictetianus*, D'Orb. (*Turboidea nodosa*, Seeley), a unique specimen in the cabinet of Mr. James Carter, F.G.S.
4. *Turbo Pictetianus*, D'Orb., a phosphate cast.
5. *Turbo Pictetianus*, D'Orb., a Perte-du-Rhône specimen retaining the shell, from the Woodwardian Museum.
6. *Natica levistriata*, new sp. From a phosphate cast in the Woodwardian Museum. Circumstances have prevented the delineation of a specimen showing the shell.
7, 8. *Nerita nodulosa*, new sp. From a unique specimen in the cabinet of Mr. J. Carter, F.G.S.
9. *Lima Rauliniana*, D'Orb. Magnified view of a portion of the shell.
10. *Lima interlineata*, new sp. From a specimen in the Woodwardian Museum. Fig. 10*a* shows a portion of the shell on the other side.

For the Discussion on this paper see p. 446.

CAMBRIDGE GREENSAND FOSSILS.

A. S. Foord del. et lith.

Mintern Bros. imp.

25. *On the* REMAINS *of* HYPSODON, PORTHEUS, *and* ICHTHYODECTES *from* BRITISH CRETACEOUS STRATA, *with Descriptions of* NEW SPECIES. By E. TULLEY NEWTON, Esq., F.G.S., of H.M. Geological Survey. (Read June 6, 1877.)

[PLATE XXII.]

DR. MANTELL in the year 1822, in his 'Geology of Sussex,' described and figured certain fossil bones, obtained from the Upper Chalk near Lewes, as the parts of an unknown fish (p. 241, pl. 42). These remains, which it appears were all obtained from one block of chalk, consisted of an upper jaw with teeth, including the maxilla and præmaxilla, with a vertebra and an indeterminable bone. The maxilla, which is there referred to as a lower jaw, is said to "contain twelve smooth pointed teeth. These are slightly convex, very brittle, and possess a glossy surface. The three anterior ones are gently curved; their fangs are hollow, and placed in sockets that extend almost to the base of the jaw. The nine posterior teeth are of a lanceolate form, and probably destitute of fangs, appearing as if attached to the jaw by anchylosis."

The appearances which led Dr. Mantell to think the posterior teeth differed from the anterior ones, must, I think, have been due to the condition of the specimen, the teeth of which are somewhat obscured by the matrix; for, after a comparison with other specimens, I see no good reason for thinking that the teeth of this jaw differ otherwise than in size.

The præmaxilla, which has the remains of "five tusks or defences," is broken away from the maxilla.

Prof. Agassiz, in the year 1843 ('Poissons Fossiles'), without definitely characterizing his genus *Hypsodon*, alludes to Dr. Mantell's description, and then proceeds to describe the fossil from the Chalk of Lewes, which he calls *Hypsodon lewesiensis* (vol. v. p. 99, pl. 25 *a*. fig. 2). This specimen consists of a large left mandible imbedded in a block of chalk, with what appear, from their position, to be portions of the right mandible, maxilla, and præmaxilla. The mandible is alluded to as being "very thick, with twelve large prominent teeth, placed somewhat apart, the anterior ones being nearer together than the hinder ones. The upper jaw has large teeth in front, which appear to be implanted in the intermaxillaries, and form several rows at the end of the jaw."

A portion of a cranium is next described (pl. 25 *a*. fig. 1); and this Prof. Agassiz thought might belong to the same individual as the previous specimen, being from the same locality. There is a quadrate bone (pl. 25 *b*. fig. 4), and several other bones, upon the same block. Part of a lower jaw is then alluded to and figured (pl. 25 *b*. fig. 3). This, it is said, appears to have belonged to an individual of large size; the teeth, which are not less than 1¼ inch in height and ⅓ of an inch in thickness, are all vertical and very pointed.

Dr. Mantell's specimens are again mentioned and refigured (pl. 25 *b*. fig. 1 *a*, *b*). It is certainly somewhat difficult to understand why Prof. Agassiz should have referred all these specimens to one species; for a comparison of his figures shows a most marked difference between the specimen first described and those subsequently alluded to. If the mandibles represented by plate 25 *a*. fig. 2, and plate 25 *b*. fig. 3, be compared, it will be seen that in the former the teeth are uniform in size and placed some distance apart; while those in the latter are very irregular in size and crowded together, some of them being very much larger than the others. The first mandible, as represented in the figure, shows much of its under-surface, its massiveness being as great in a horizontal as in a vertical direction. Anteriorly the ramus narrows as it turns inwards to meet its fellow at the symphysis, so that the front part of the jaw is much narrower, both vertically and horizontally, than is the hinder part. The second mandible (pl. 25 *b*. fig. 3), although much broken, is evidently seen from the side; and there can be little doubt that its thickness was chiefly in a vertical direction.

Again, the maxilla and præmaxilla of the first specimen (pl. 25 *a*. fig. 2) differ very considerably from those afterwards alluded to (pl. 25 *b*. fig. 1). It might be thought that these differences were partly due to the different positions of the specimens; but such is not the case, for a comparison of the originals (now in the British Museum) shows the differences to be even more decided than they appear to be in the figures.

In Dixon's 'Geology of Sussex,' published in the year 1850, a small lower jaw is figured (pl. 32*. fig. 9); and although not described in the text, it is named in the references to the plates (p. xiv) *Hypsodon minor*. An examination of the original specimen (also in the British Museum) shows that this mandible, besides being smaller than Agassiz's type of *H. lewesiensis*, is proportionally deeper in a vertical direction, and much thinner; the teeth also have a different character. In all these particulars this little jaw resembles the second mandible alluded to by Agassiz (pl. 25 *b*. fig. 3); and therefore, while the specimens referred to *H. lewesiensis* were all regarded as one species, it was perfectly consistent to refer this jaw to the same genus, although it is now found necessary to remove it to another.

Prof. Cope has more recently made known to us several new forms of fishes from the Cretaceous Rocks of the Western Territories (see more especially the Report of the U.S. Geological Survey of the Territories, vol. ii. 'Cretaceous Vertebrata,' 1875). To receive these he has found it necessary to establish several new species and genera, which have not hitherto been recognized in this country. In his family Saurodontidæ he includes six genera, of which he gives the following synopsis (*l. c.* p. 189):—

Synopsis of Genera.

I. Jaws without foramina on the inner face below the alveolar margin.	
a. Teeth cylindric.	
Teeth of unequal lengths; some of them greatly developed	*Portheus.*
Teeth of equal lengths	*Ichthyodectes.*
aa. Teeth compressed, knife-like.	
Teeth of unequal lengths; some of the anterior greatly developed	*Erisichthe.*
Teeth equal	*Daptinus.*
II. Dentary bones pierced by foramina below the alveolar border.	
Teeth with subcylindric crowns	*Saurodon.*
Teeth with short, compressed crowns	*Saurocephalus.*

Immediately after this synopsis Prof. Cope says:—"There are some other forms to be referred to this family, whose characters are not yet fully determined. Thus *Hypsodon*, Agass., from the European Chalk, is related to the two genera first named above, but, as left by its author in the '*Poissons Fossiles*,' includes apparently two generic forms. The first figured and described has the mandibular teeth of equal length. In the second, they are unequal, as in *Portheus*, to which genus this specimen ought, perhaps, to be referred. * * * * Retaining the name *Hypsodon* for the genus with equal mandibular teeth, its relations to *Ichthyodectes* remain to be determined by further study of *H. levesiensis*. The view of the superior walls of the cranium given by Professor Agassiz presents characters quite distinct from what I have observed in *Portheus*. A species of *Ichthyodectes* from the chalk of Sussex, England, is figured, but not described, by Dixon in the 'Geology of Sussex.'"

From this it is seen that Prof. Cope fully recognized the difference existing between the various specimens referred to *H. lewesiensis* by Agassiz. A comparison of the figures given by Prof. Agassiz of Dr. Mantell's specimen (pl. 25 *b*. fig. 1) with Prof. Cope's figures (*loc. cit.* pls. 39, 41, and 42. fig. 1) will show, I think, conclusively the close affinity between them. The peculiar form of the maxilla and præmaxilla, and the large teeth implanted in the latter, correspond so closely in the two, that at first sight they might be thought to belong to the same species.

Having, in the light of Prof. Cope's memoir, carefully examined Agassiz's type specimens, and compared them with the fish-remains described in the following pages, I am convinced of the necessity of dividing *Hypsodon lewesiensis* as suggested by Prof. Cope; and it is proposed to retain this name for the specimens first described by Agassiz, and upon which the species and genus are really founded (Poiss. Foss. vol. v. pl. 25 *a*. figs. 1, 2, and 4), and to remove Dr. Mantell's specimens and certain others (Poiss. Foss. pl. 25 *a*. fig. 3, and 25 *b*. figs. 1 *a*, 1 *b*, 2. and 3) to the genus *Portheus* of Cope.

HYPSODON LEWESIENSIS, Agassiz.

Hypsodon lewesiensis, Ag. Poiss. Foss. 1843, vol. v. p. 99, pl. 25 *a.* figs. 1, 2, and 4, pl. 25 *b.* figs. 4 and 5.

This species will still be typified by the specimens from the Lewes Chalk indicated above; but the limitations which are proposed render it necessary to modify Agassiz's description. The lower jaw, of which only the anterior part is preserved, is very massive, its thickness being as great horizontally as vertically. Anteriorly the jaw rapidly decreases in size, and, after making a very definite curve inwards to meet its fellow, terminates in a small, slightly swollen symphysis. Twelve teeth * are preserved; and these are placed at intervals in one row. The spaces between them are obscured by matrix: and it is possible that some of these were occupied by teeth; but, judging from the spaces existing in the upper jaw, it would seem unlikely that the teeth were ever in a continuous series. The teeth are hollow, conical, curved, all very nearly of the same size, and apparently ankylosed to the jaw; probably they have fangs implanted in definite sockets. There are no definite indications of a vertical succession as observable in the genus *Portheus*.

The maxilla is imperfect; where it is broken across it shows a triangular section and a very considerable horizontal thickness. In its present condition it is provided with seven or eight teeth similar to those of the mandible, and arranged in a single row. A well-marked facet, evidently for articulation with the præmaxilla, extends from the anterior part of the outer surface, upwards and backwards, indicating that the latter bone overlapped the maxilla for a considerable distance, and in a manner quite unlike what obtains in *Portheus*.

The form of the præmaxilla cannot be clearly made out; but it evidently has a greater length and horizontal thickness than in *Portheus*, while its vertical dimensions are apparently much less. The outer edge of the broad dentary margin still retains four or five teeth similar in form to those of the maxilla; within these, and separated from them by a distinct space, there are two somewhat larger teeth. Prof. Cope, judging from the figure of the present specimen, seemed to think it might be allied to his genus *Ichthyodectes*; but from what has been said above it will be obvious that such is not the case. The form of the lower jaw is certainly more like that of *Saurodon*; but I am far from being convinced of the propriety of placing it in the group of the Saurodontidæ.

The skull figured by Agassiz from the Chalk of Lewes may possibly belong to the same species; but there is no direct evidence to prove this. If this is truly the skull of *Hypsodon lewesiensis*, then its characters and those of the vertebræ found with it and other bones, upon the same block of chalk, are additional evidence of the distinctness of *Hypsodon* and *Portheus*; for while this skull is broad

* Some of these teeth appear to have been lost since Agassiz's figure was drawn.

and depressed, that of *Portheus* is narrow and compressed; the vertebræ also are shorter than in *Portheus*, and have not the large lateral pits or depressions.

Portheus, Cope.

This genus was established by Prof. Cope to receive certain large fossil fishes from the Cretaceous formations of the Western Territories. The genus is fully described; and the more important characters by which it is separated from other genera of the Saurodontidæ are thus given (*loc. cit.* p. 190):—"Teeth subcylindric, without serrate or cutting edges, occupying the premaxillary, maxillary, and dentary bones; sizes irregular; the premaxillary, median maxillary, and anterior dentary teeth much enlarged. No foramina on inner face of jaws. Teeth on the premaxillary reduced in number. Opercular and preopercular bones very thin. Cranial bones not sculptured."

The only examples of this genus at present known in Britain are also from Cretaceous formations; and by far the most perfect specimen with which I am acquainted is the one from the Gault of Folkestone described below as *Portheus gaultinus*, and preserved in the Museum of Practical Geology. There are numerous fragments of jaws belonging to this genus in several provincial Museums and private collections; but their affinity with *Portheus* appears not to have been recognized hitherto.

Prof. Cope's synopsis of distinctive specific characters will help to make more clear the descriptions of new species in the following pages.

Synopsis of Species.

a. Two premaxillary teeth:
- Maxillary arch thin, deep, with narrow anterior condyle; large maxillary teeth five; third mandibular tooth large, behind a cross groove .... *P. molossus.*
- Maxillary large teeth three; third mandibular small, without cross groove in front of it .... *P. thaumus.*

aa. Three to five premaxillary teeth:
- Maxillary arch stout, deep, with heavy anterior condyle; larger teeth five .... *P. lestrio.*
- Maxillary arch thick and shallow; larger teeth five ...... *P. Mudgei.*

aaa. Premaxillary teeth unknown:
- Maxillary bone deeply concave; small.......................... *P. arcuatus.*

As the representatives of this genus in England are chiefly known to us by fragments of upper and lower jaws, it is particularly convenient to have this synopsis, which is founded upon the characters of the teeth and jaws. Prof. Cope, having had better and more numerous specimens than we possess, has selected these as prominent features, the characters here pointed out being accompanied by other differences in various parts of the skeleton.

PORTHEUS MANTELLI, n. sp.

Unknown fish, Mantell, Geology of Sussex, 1822, p. 241, pl. 42.
Hypsodon lewesiensis, Agassiz, Poissons Fossiles, 1843, vol. v. pl. 25 *b*. figs. 1 & 2.

It is proposed to give the above name to the specimen from the chalk of Lewes, which was first described by Dr. Mantell as an unknown fish, and subsequently included by Agassiz in his species *H. lewesiensis*, as already mentioned.

The possession of five teeth in the præmaxilla shows that this specimen cannot be referred to either *P. molossus* or *P. thaumus*, which have only two premaxillary teeth; and the same character allies it to *P. lestrio* and *P. Mudgei*. From the former it differs not only in the shape of the maxilla, but also in the size and number of the teeth—*P. lestrio* possessing about forty maxillary teeth, while in *P. Mantelli* there is only evidence of twelve; and, even if the intermediate spaces were naturally occupied by teeth, which is quite possible, yet even then the total number of maxillary teeth could not have exceeded twenty four, and was probably less. These teeth in *P. Mantelli* are absolutely larger and stouter than those in the *P. lestrio* figured by Cope, although the specimen itself is not half the size.

Unfortunately there appears to be no figure of *P. Mudgei*; but, judging from the description, it differs from the present species not only in having four of the premaxillary teeth large instead of three, but also in the massiveness of the entire jaw, and in the difference in form of the maxilla; the maxillary teeth also do not appear to have been so large proportionally as in *P. Mantelli*.

The large specimen represented by Agassiz in plate 25 *b*. fig. 3 of his 'Poissons Fossiles,' vol. v. has all the appearance of being part of a mandible of a large species of *Portheus*; but there is no evidence to connect it with the maxilla of *P. Mantelli*, or with any other species.

There is in the British Museum (no. 39063) a large *Portheus* maxilla from the Chalk (formerly in Dr. Bowerbank's collection), which has large teeth, in some respects like those of *P. Mantelli*; but as both ends are imperfect, a close comparison cannot be made. The straightness of the dentary margin, however, seems to point to its being a distinct species.

A fragment of a very large *Portheus* jaw, probably a lower one, from the Chalk of Warminster, also preserved in the British Museum (no. 46389), must have belonged to a species as large as Cope's *P. lestrio*. The teeth are much broken; but portions of five are preserved: they are oval in section, the central largest one having a diameter of about $\frac{7}{10}$ of an inch, and when perfect must have measured fully 4 inches in length, including the fang.

PORTHEUS DAVIESII, n. sp. Pl. XXII. fig. 13.

This species is founded upon a specimen in the British Museum from the Lower Chalk near Maidstone (?). It consists of a right maxilla with the outer surface and teeth in a remarkably good state of preservation, but wanting the posterior extremity. Upon the same block of chalk there is a vertebra and a rod-like bone with a falcate extremity, which may, perhaps, be a post-clavicle.

This maxilla has proportionally a greater vertical thickness than has that of either of the species of *Portheus* described by Prof. Cope or mentioned in this communication. The upper margin is slightly convex from before backwards, and posteriorly has a well-marked groove. The lower or dentary margin is strongly and regularly convex; in its present condition it is provided with twelve straight teeth; the anterior three are small, the median one rather larger, and the remaining eight intermediate in size. The spaces observable between some of these are occupied by alveoli, and may have borne teeth when the jaw was perfect. If such was the case, then so much of the maxilla as is preserved may have possessed fifteen or sixteen teeth; at present there are twelve *in situ*. Anteriorly the bone presents a very rugose surface for articulation with the præmaxilla. The piece of bone attached to the upper portion of this surface is probably no part of the præmaxilla, although occupying its position. The space between the posterior margin of the premaxillary articulation and the first maxillary tooth, shown in figure 13, appears to have been naturally edentulous. The outer surface is flattened and marked by ramifying vascular channels, which pass in a backward and downward direction from foramina situated towards the anterior part of the bone.

This maxilla differs from those of all other species of this genus at present known, in its proportionally greater vertical thickness, in the convexity of the dentary margin, and also in the more uniform size of its teeth. In this last character some approach is made to the genus *Ichthyodectes*; but the larger size of the middle tooth seems rather to ally it to *Portheus*; and in the absence of the præmaxilla, by which its affinities could be more definitely determined, it is thought best to place it in the latter genus.

The vertebra, imbedded in the same block, is deeply biconcave; and the sides present large cavities, similar to those in the vertebræ of other species of *Portheus*.

The rod-like bone has not the character of a rib, nor the appearance of a pectoral spine; but it is quite possible that it may be a ventral spine or a postclavicular bone.

The specific name proposed for this specimen is intended as a mark of respect for my friend Mr. W. Davies, of the Palæontological Department in the British Museum, to whom I am indebted for the kind manner in which he has facilitated my examination of the specimens in the national collection.

PORTHEUS GAULTINUS, n. sp. Pl. XXII. figs. 1–12.

Mrs. Elizabeth Warne has recently enriched the Museum of Practical Geology by the presentation of a very fine specimen of a *Portheus*, which was obtained through Mr. E. Charlesworth, from the Gault of Folkestone. This specimen includes the greater part of upper and lower jaws of both sides, with a considerable portion of the brain-case and bones of the ethmoidal region, also several vertebræ and fragments of bones which cannot be identified. The generic relationship of this specimen to the American *Portheus* cannot be doubted; specifically it is so closely allied to *P. lestrio*, Cope, that one might at first be inclined to refer it to that species; but, besides its much smaller size, it exhibits certain peculiarities which prevent its being regarded as the same. Each of the parts will now be considered separately.

Maxilla and Præmaxilla.—These two bones are represented by Plate XXII. figs. 2 and 9, *mx* & *pmx*; they are so closely fitted together that, it is evident, no movement could have been possible between them. The maxilla extends forwards on the inner side of the præmaxilla to within an eighth of an inch of the front border of the latter bone, which thus comes to lie altogether upon the outer side of the maxilla. The outer surface of the præmaxilla is convex; its hinder border is deeply and irregularly serrated, so that its junction with the maxilla is very distinctly seen. At the lower part of this junction there is a groove which terminates in a deep notch upon the dentary margin. The anterior border is convex, and terminates above in a rounded process; immediately behind this, and therefore upon the upper margin, there is a notch, from which the upper border curves backwards and downwards, and is continued into the serrated posterior border. The dentary margin appears nearly straight in a side view; from below it is seen to be provided with five alveoli (Pl. XXII. fig. 9), the second and third being much larger than the others; and the teeth which they supported were probably not less than an inch in length, as indicated by the dotted lines (Pl. XXII. fig. 2). Upon the left side the 1st, 3rd, and 4th alveoli support functional teeth, while in the 2nd the tooth has scarcely reached the level of the margin, and the 5th seems to be occupied by bony matter. Upon the right side the 2nd, 4th, and 5th have functional teeth, while in the 1st and 3rd the teeth have not reached the level of the margin.

It has already been pointed out by Prof. Cope, that *Portheus* had a vertical succession of its teeth; and this is well shown in the present specimen, both in the præmaxilla, maxilla, and mandible. While the teeth were being thus continually renewed, the alveoli supporting them appear to have been persistent; and not only so, but they seem to have maintained their relative sizes; for while some of the alveoli are completely filled by the fangs of the teeth they support, others, of equal size, contain teeth in various stages of growth, and not nearly filling their cavities.

Apparently as a consequence of this vertical succession, the teeth are very irregular, and it is not easy, especially in a side view such as figure 2, to determine whether the small teeth are fully grown ones, or are large teeth only partly grown. It becomes necessary therefore to consider the relative sizes of the alveoli and their teeth in order to know whether the latter are fully developed. The importance of knowing this will be obvious when it is remembered that the relative sizes and number of the teeth have been regarded as important specific characters.

The maxilla has two articular surfaces at its upper and front part; the anterior of these is laterally compressed and placed on the inner side of the process of the præmaxilla, with a deep depression intervening. The posterior articular surface lies immediately behind and above the præmaxilla. It is this one which articulates with the palatine bone. The upper margin of the maxilla is strongly grooved, probably on account of its articulation with the suborbital bones. Towards its posterior end it is gradually reduced in thickness; both maxillæ, however, are slightly broken in this region. The dentary border is concave at its anterior part and nearly straight posteriorly. The anterior nine or ten alveoli are small (about $\frac{1}{16}$ inch diameter); these are succeeded by ten or twelve larger ones (about $\frac{1}{8}$ inch diameter); behind these there are indications of perhaps eighteen or twenty small ones. Most of the teeth are broken off; but those which remain are somewhat curved inwards—a character also indicated in Cope's figures of *P. lestrio*, but not alluded to in the text.

The right maxilla has a small portion of another bone attached to the upper edge of its posterior extremity, which may be the representative of the *jugal bone*.

Comparing these maxillæ and præmaxillæ with those of *P. lestrio* (*l. c.* pl. 42, fig. 1), it will be seen that the general contour is not the same. In the present specimen the præmaxilla is directed more obliquely backwards, its anterior process is more prominent and placed further forward, leaving a greater space between it and the posterior maxillary articular surface. The groove and notch between the maxilla and præmaxilla are not seen in the figures of *P. lestrio*. The larger teeth of the maxilla are placed further backwards in our specimen; and consequently the convexity of this margin is further from the præmaxilla.

Mandible.—The *dentary* portions of both rami are preserved, and, as in other species of this genus, are remarkable for their great vertical depth and compressed form. A small portion of the *articular* bone of the left side is preserved (fig. 1, *art**); but that of the right is altogether wanting. The outer surface of the dentary has a deep groove towards the lower margin. The anterior portion is swollen, especially its upper part, to accommodate the large anterior teeth. There are depressions upon this surface, which probably indicate the extent to which the articular bone penetrated the dentary portion. A few vascular channels may be traced radiating from a point close to the anterior end. The lower margins are mostly broken away, on account of their being very thin below the

* This figure has been reversed.

groove, as is shown by the part which is still preserved. Anteriorly the mandible is truncated by the peculiar symphysis, which occupies nearly the entire depth of the jaw (Pl. XXII. fig. 6), and, as seen in a side view (figs. 1 and 5), is set obliquely to its general direction. The symphysial surfaces are rugose, and show that cartilage must have occupied a space between the two rami. The dentary margin presents two depressions and three prominences (fig. 1), the latter marking the positions of the larger teeth. Anteriorly there are two large teeth (nearly $\frac{1}{4}$ inch diameter), which are succeeded by a small one (about $\frac{1}{16}$ inch diameter) and two of median size (about $\frac{1}{8}$ inch diameter). Next follow three large teeth, the first and last as large as, or larger than the two at the front of the jaw. Succeeding these there are eleven teeth preserved *in situ*, and spaces for probably six or seven others; they vary in size from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch diameter. The thinning away of the dentary bone behind these teeth shows clearly that it terminated here; and the total number of teeth, therefore, could not have exceeded twenty-six or twenty-eight. The teeth are slightly oval in transverse section; and the portion projecting above the jaw is highly polished. The larger teeth, when held so as to catch the light, show very obscure annular markings. The greatest peculiarity of these teeth is the remarkable manner in which their extreme points are bent inwards. This is not seen when the jaw is viewed from the side, but is very marked when the teeth are seen from before or behind (figs. 1 *a*, 1 *b*). This character of the teeth does not appear to be present in *P. lestrio*; for Prof. Cope makes no mention of it, although he speaks of one of his specimens as having nearly complete dentition; and such an evident peculiarity could not have escaped observation.

Hyoid.—Prof. Cope says with regard to the hyoid of *Portheus* and its allies (*l. c.* p. 185):—“Little can be said respecting the *hyoid apparatus* in this family. Some inferior branchihyals, preserved in *Portheus thaumus*, are short flat rods. Two long flat bones, in place between the dentaries of a *P. lestrio*, appear to be the distal ceratohyals. They terminate in some crushed basihyals, and are covered with minute teeth *en brosse* on the inner faces and superior margins.”

Several elements of the hyoid apparatus are preserved in the Gault specimen, and occupy very nearly their normal positions, being wedged in between the rami of the mandible. These bones are partly shown in Plate XXII. fig. 1, but are much better seen from the opposite side when the right ramus is removed (fig. 5). The form of the large bone thus seen (*ch*), and the position which it occupies, indicate that it is the right *ceratohyal* (the left bone is in place, but hidden in this view). These bones are very thin and compressed, especially at their anterior extremities. Posteriorly each has a considerable vertical extent; but this gradually decreases anteriorly for about $\frac{4}{5}$ of its length; then the anterior fifth suddenly widens again to nearly the same dimensions as the posterior part, and terminates in a fanlike extremity. Both ends of this bone have a smooth outline, indicative of a cartilaginous articulation with the hypo- and epihyals, the anterior being convex and the posterior concave. The lower margin has a groove, which is widest and deepest at the narrow part of the bone, and is gradually lost before reaching the hinder end; the posterior three fourths of an inch of this margin being a thin, sharp edge. The upper margin is a thin edge from end to end.

Immediately in front of the ceratohyals there are portions of three or four bones which, from their position, seem to be the double *hypohyals* (basihyals of some authors); but this is uncertain, as they are broken, and their true form cannot be made out. There are no traces of any *branchiostegal rays.*

The bone marked *bh* in figure 5, which is below the hypohyals, is compressed anteriorly, but becomes stouter and rod-like posteriorly. Just above these letters the upper margin is expanded laterally into two short wings, having a deep groove between them. The hinder edge of this bone seems to be naturally flattened on each side, and is wedged in between two fragments of bone (*cl*, *cl'*) which appear to be the anterior extremities of the *clavicles.* The bone *bh* is, in all probability, the *basihyal* (glossohyal), which has been thrown out of place. If, however, the two fragments of bone (*cl*) are really the ends of the clavicles (and there appears to be no good reason for doubting this), then the bone *bh* occupies precisely the position of an *interclavicle*; and it is not a little remarkable that this peculiarity should occur in a group of fishes having other saurian characters.

Lying between the two ceratohyals, and, indeed, hidden by them until they were separated in the process of cleaning the specimen, there is an extremely thin bone, almost equalling them in size (Pl. XXII. fig. 8).* Its hinder end is broken off; but otherwise it is perfect. The form and position of this bone, lying, as it does, in the reentering angle of the hyoid arch, show clearly that it corresponds to that which Dr. Parker has called the "basibranchiostegal." One feature of this bone which deserves notice is, that its upper portion is covered with thin scale-like plates, which at first might be thought to be the scales. A closer examination, however, shows that such is not the case, but that they are dental armatures. Near the anterior and upper part of the bone there are a few plates (fig. 8, *a*) marked by ridges and grooves which are directed upwards and forwards; and when these are examined with a microscope the surfaces appear smooth and dense in structure. Passing backwards these plates are found gradually to lose their ridges, and about the middle of the bone have their surfaces marked by irregular granulations, which are visible with a pocket-lens. Towards the hinder part of the bone there are a number of smaller plates with radiating ridges (fig. 8, *b*); and when magnified, their entire surfaces are seen to be covered with small pits; these are the bases of minute teeth, some of which are still in place, and others may be seen lying around. At the anterior part of the bone, and

* Fig. 8 has by some mishap been drawn upside down.

extending to its lower margin, there are pitted plates similar to those last mentioned, but without the radiating ridges (fig. 8, *c*). This dental armature of the "basibranchiostegal" is most likely of the same nature as that mentioned by Cope as occurring upon the inner surfaces of the ceratohyals of a *P. lestrio*, and is to be compared to the minute teeth found upon various parts of the mouth in the pike and other fish; but it is certainly peculiar to find it so far down upon the sides of the bone, which, it would seem, must have stood up in the floor of the mouth as a prominent crest between the hyoid bones. A dried specimen of the branchial arches and tongue of a Tunny, preserved in the Museum of the Royal College of Surgeons, shows similar plates very distinctly.

Palato-quadrate arcade.—Parts of the anterior and posterior extremities of this series of bones are preserved in the present specimen. Lying across the left ceratohyal there are portions of two bones (Pl. XXII. fig. 1, *qu* and *pt*). The front edge of the one marked *pt* is a natural free margin; its posterior portion underlies the second bone *qu*, and is partly united to it by a dentate suture. The upper, lower, and hinder margins of the second bone *qu* are broken; and inferiorly it shows the commencement of a sudden thickening. In all probability these bones are parts of the *pterygoid* and *quadrate* bones, and the thickening of the lower portion of the hinder one is really the commencement of the articular condyle.

The front portion of this arcade is represented by the greater part of the *palatine* bone (Pl. XXII. fig. 2 *pl*), which has that peculiar conformation of its anterior part termed by Prof. Cope the "malleolus;" this has a smooth surface above for articulation with the prefrontal, and another below for articulation with the maxilla. A small rugose surface upon the outside of the malleolus appears to have formed part of the external facial surface; but, with this exception, the palatine bone was covered by the suborbital bones, parts of which are still to be seen. The hinder part of the palatine is broken off; but so much as remains lies close upon the upper margin of the maxilla. Internally it is partly hidden by a pitted bony plate, to which many minute teeth are still attached.

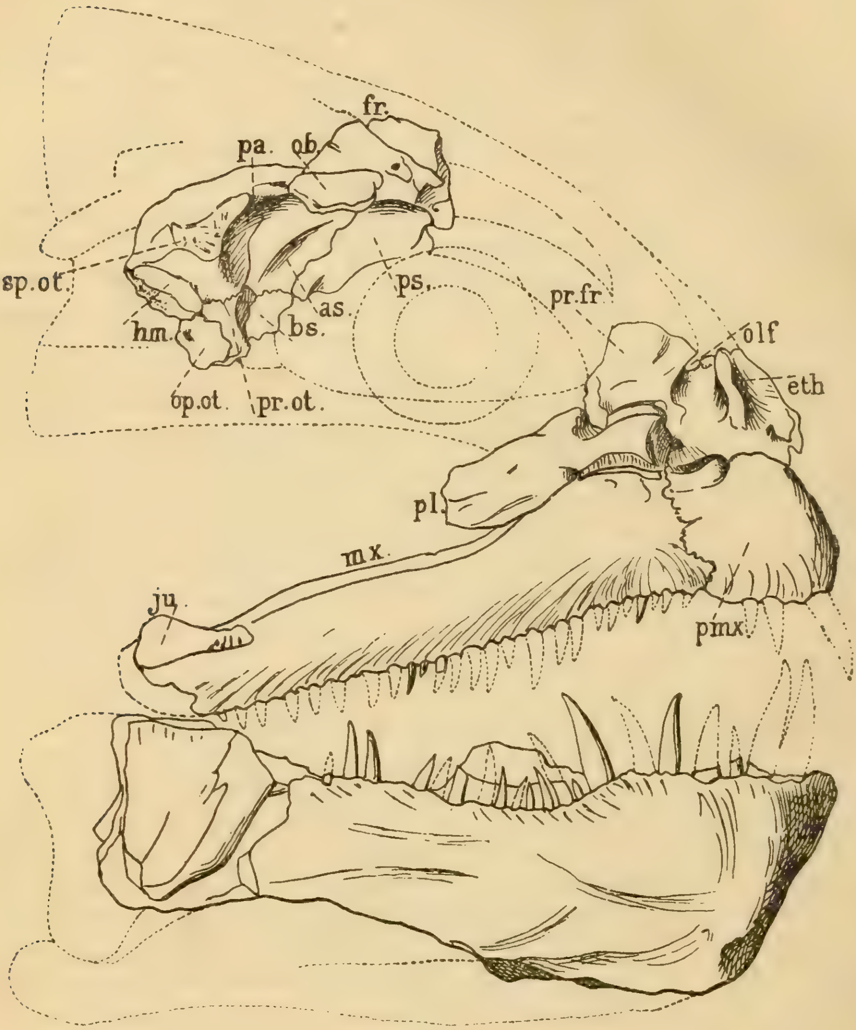
Ethmoidal region.—This is represented by a mass of bone which it would have been extremely difficult to determine, but that it retains a surface for articulation with the right palatine, and has fixed to its front portion fragments of the anterior articulations of both maxillæ. These landmarks not only show the nature of this bony mass, but also allow its relation to the bones just mentioned to be clearly made out (*eth.* &c. fig. 2). The sutures between the various parts are so obscure that little can be said as to the form of the constituent bones. There are portions of both *prefrontals*, the *vomer* (?), *ethmoid*, possibly a part of the *parasphenoid*, fragments of the *maxillæ*, and of certain dermal bones. The prefrontal appears to have been *perforated* for the passage of the olfactory nerve (*olf*). The bone which is referred to the vomer has no traces of teeth upon it; and it may be that it is the front part of the parasphenoid (fig. 3, *vo*).

Brain-case.—Certain bones forming part of the brain-case were obtained with this specimen, and are represented upon Plate XXII. fig. 4. Although somewhat broken and compressed, they are sufficiently well preserved to show that the walls of the brain-case were completely ossified. The sutures are so obscure that the determination of the homologies of the various parts is no easy task; however, some of the elements can be identified with more or less certainty. There can be no doubt that the fragment marked *hm* is the proximal portion of the *hyomandibular*; and the bone lying in front of it, and to which it is attached (*sp.ot*), can only be the *postfrontal* (*sphenotic*). The upper part of this is broken. The next bone below (*pr.ot*) is perforated anteriorly by a large foramen (probably for the 5th nerve), and occupies the position of the *prootic*, being wedged in between the bones which are believed to be the *basisphenoid*, *alisphenoid*, *postfrontal*, and *opisthotic*? Attached to the hinder part of the *prootic* there is a portion of a bone (*op.ot*) which appears to be either the *opisthotic* or *exoccipital*; but as all the parts behind this are wanting, its true homology cannot be determined. If this fish possessed an opisthotic, then the bone in question is that *otic* element; but if, as Prof. Cope thinks, *Portheus* had no opisthotic, then this bone must be the exoccipital. The *basioccipital* and *parasphenoid* are wanting. The bone marked *bs* seems to be one side of the upper forked part of the *basisphenoid*, occupying, as it does, precisely the position of the Y-shaped bone in the pike, which Prof. Huxley has referred to the basisphenoid ('Elements of Comparative Anatomy,' 1864, p. 169). Following upwards from the front part of this bone there is another (*as*), which, from its relations to the surrounding elements, is most probably the *alisphenoid*. The anterior part of the *basis cranii* is formed by the bone marked *ps*, which occupies the position of, and probably represents, both the *presphenoid* and *orbitosphenoids*. Seen from below, this bone is broad posteriorly and narrowed anteriorly, with a median rugose, pear-shaped convexity upon the under surface. From the sides are given off broad winglike expansions, which pass upwards to meet the *frontal* bone. These wings sweep round anteriorly, so that they meet in the middle line. The bone (*fr*) in front and above the one last mentioned is probably a portion of the *frontal*; from the outer side of this, and just above what must have been the orbit, there is a downward process, having upon it a bone with a rugose surface, *o b*, which it is thought may, perhaps, be a *supraorbital*, but is most probably one of the hindermost of the series of bones which surrounded the orbit. The form of the upper part of the frontal seems to indicate that this region of the skull was raised into a prominent crest; and this is a character which Prof. Cope has shown to exist in other species of the genus.

Whether the bone in the region of the letters *pa* is a portion of the *parietal* or not it is impossible to say; but certain it is that immediately below the letters this bone is suturally united with the one which has been called *alisphenoid*.

The sclerotic is well ossified, and parts of four or five plates are preserved; but neither of them is sufficiently perfect to show its precise form.

Hypothetical restoration of the skull of Portheus gaultinus
(see Pl. XXII. figs. 1, 2, & 4).



bs. Upper portion of basisphenoid.
as. Alisphenoid. *pa.* Parietal region. *ps.* Presphenoid.
fr. Frontal. *sp.ot.* Sphenotic (postfrontal). *pr.ot.* Prootic.
op.ot. Opisthotic or exoccipital. *ob.* Supraorbital.
pmx. Præmaxilla. *mx.* Maxilla. *ju.* Jugal. *pl.* Palatine.
pr.fr. Prefrontal. *eth.* Ethmoid. *olf.* Perforation for olfactory nerve.

The outline of the entire skull has been introduced in the annexed woodcut, to render the relative positions of the parts more intelligible. The relation of the bones of the ethmoidal region to the maxilla and præmaxilla is quite certain; for, although now separated, the broken surfaces show precisely how they fit together. The direction of the outline-base of the skull is determined chiefly by the direction of the under surface of the vomer. In placing the brain-case in the position it occupies, regard has been paid to Prof. Cope's figures of *Portheus*, as well as to the form of the component bones of the specimen; but its relation to the other parts must only be taken as approximately correct. The outline of the upper and back parts is, of course, purely conjectural. The lower jaw has been placed low down, out of position, so as not to interfere with the maxilla.

The skull has been slightly crushed, in a lateral direction, during the process of fossilization; it is quite certain, however, that it was naturally of a very compressed form.

Vertebræ.—The six vertebræ belonging to this specimen agree, in their general characters, with those which have been referred to the American species; but, at the same time, they present certain peculiarities. The length of each vertebra is about four fifths of its width; the terminal faces are deeply concave, and communicate by a small foramen in the centre, as shown in figure 12. One very obvious feature of these vertebræ is the flattening of their lower surfaces; but, as there are slight ridges towards the terminal faces, this is not so clearly seen in figure 11 as in the specimens. Probably this flattening would not be found in the hinder dorsal vertebræ. The basal portions of the neural arches are left attached to the centra; and are imbedded in deep pits, one upon each side of the middle line. They do not appear to have been ankylosed to the centra; for the division between the two is clearly seen. The neural canal is small, the part preserved not measuring more than the fourth of an inch in width. Low down upon the sides of the vertebræ, the enlarged heads of the ribs are seen to be attached to the centra, in the same way as the neural arches—that is, by being sunk in deep pits, but not ankylosed. A large and deep depression, reaching almost to the centre of the vertebra (fig. 12, *l d*), is seen upon each side between the neural arch and the rib (fig. 10). This depression is largest in the hindmost of these vertebræ, and smallest in the anterior one. The three vertebræ which appear to have been furthest from the head have a second much smaller depression upon each side, placed below the larger one; and this also is largest in the hindmost vertebra. Judging from the American species, this loss of the lateral depressions in the front vertebræ of this series shows them to belong to the anterior dorsal region; and probably few intervened between them and the skull.

Several other pieces of bone were obtained, but they are too fragmentary for determination. Two or three of them may, perhaps, be parts of the clavicles, and another possibly a portion of the parasphenoid; while two others may, perhaps, be pieces of pectoral spines.

Locality and Distribution.—As already stated, the specimen above described was obtained from the Gault of Folkestone; but the particular bed from which it came cannot be ascertained. Portions of a pair of mandibles, evidently belonging to this species, but only about half the size of the Gault specimen, are preserved in the British Museum (No. 40146); and these are from the Lower Chalk of Halling. Fragments of this species are also to be found among the fish-remains from the Cambridge phosphatic deposits.

Ichthyodectes, Cope.

This genus, as defined by Prof. Cope (*l. c.* pp. 189 and 205), includes those forms which, while agreeing with *Portheus* in their main characters, differ from that genus in having the teeth nearly equal in size throughout. The only English specimens referable to this genus with which I am at present acquainted, are:—the one figured in Dixon's 'Geology of Sussex' (pl. 32*. fig. 9), and named (without any description) *Hypsodon minor*; and the small jaw from the Toulmin-Smith collection described below, *I. elegans*. The first of these is referred to by Cope (*l. c.* p. 206), and considered by him to belong to the genus *Ichthyodectes*. An examination of the original, which is now in the British Museum (No. 28894), confirms this determination. Parts of both rami of the mandible are preserved; and while the right side (that figured by Dixon) has the teeth most perfect, the left side, most fortunately, has the articular portion preserved; and this exhibits the peculiar form found in *Portheus* and *Ichthyodectes*. The uniform size of the teeth allies it most closely to the latter genus.

Ichthyodectes minor, Egerton. (Pl. XXII. fig. 14.)

Hypsodon minor, Egerton; Dixon's 'Fossils of Sussex,' pl. 32*. fig. 9, p. xiv.

The specimen above alluded to, which was obtained from the Chalk of Sussex †, seems to be more closely allied to *I. anaides* and *I. ctenodon* than to either of the other species described by Prof. Cope; but it differs from these, and, apparently, from all the other species, in the possession of remarkably straight teeth, which are not curved inwards as is usually the case. The teeth are hollow; and there is evidence of about eighteen in each ramus, not reckoning the spaces between them, which are in most cases occupied by alveoli, and possibly by broken teeth, the total number of alveoli being about thirty to thirty-three. The alveolar margin is nearly straight, with a slight convexity towards its anterior end. Upon the outer surface, towards

† There is no locality with this specimen at the British Museum; and none is mentioned in Dixon's 'Sussex;' but in Prof. Morris's Catalogue, page 330, it is given as "Chalk, Sussex?; Charing."

its lower margin, there is a deep depression, as in the genus *Portheus*; and below this the jaw becomes much thinner. The upper and lower margins are nearly parallel throughout the extent of the dentary element; but behind this the depth of the jaw becomes much reduced, the facet of the articular bone being at a much lower level than the alveolar margin. The symphysis must have resembled that of the Gault *Portheus*; and its length could not have been much less than the greatest depth of the jaw.

The specimen represented by fig. 14 is the left ramus of the jaw figured by Dixon, some of the teeth being completed from the right side.

Ichthyodectes elegans, n. sp. Plate XXII. fig. 15.

There is in the British Museum (No. 41687) a small specimen of a left lower jaw from the Toulmin-Smith collection, which was obtained from the Lower Chalk of Dorking. This specimen measures 3 inches in length in its present condition; but the articular portion is wanting. When the piece of chalk containing the specimen was first broken open the jaw itself was split from end to end in such a manner that the roots of all the teeth were exposed. One half was then imbedded in plaster of Paris, and the chalk removed so as to expose the inner surface of the jaw, which is represented in figure 15. Only a few of the teeth are seen in this half; but they have been restored in the figure by reference to the counterpart, in which all the roots and several of the crowns are still preserved. The upper margin, which appears to be entire, forms a regular curve from the hinder end to near the front, where it is interrupted by a projection, similar to that in *I. hamatus*, Cope. This projection bears a small tooth directed obliquely backwards, and therefore in a different direction from the rest of the teeth, which are inclined forward at a considerable angle. The remains of from twenty-five to twenty-eight teeth can be traced along the jaw; they are all very nearly of the same size, as shown by the regularity of the fangs, and were hollow, long, and slender, with a decided inward curvature. The symphysis is deep, as in other species of the genus. The lower margin is incomplete. The articular bone is altogether wanting; but the dentary portion appears to be nearly complete posteriorly.

This mandible differs from that of any species of *Ichthyodectes* hitherto described in the curve of its alveolar margin and in the obliquity of its teeth. The mandibles of the American *I. prognathus*, Cope, and *I. multidentatus*, Cope, however, are not at present known; it is possible therefore that this specimen may belong to one or the other of these species; but, until this point can be settled by the acquisition of better specimens, it has been deemed advisable to let the English species be known by a separate specific name.

EXPLANATION OF PLATE XXII.

(All the figures on this Plate are reduced one-half linear, except figs. 1*a*, 1*b*, 8*a*, 8*b*, 8*c*, and fig. 15, which are otherwise marked. The dotted outlines simply indicate probable restorations, except in the case of fig. 3.)

Portheus gaultinus, n. sp.

Fig. 1. Outer surface of left lower jaw, hyoid, &c. The teeth which are preserved in the specimen are shaded in this figure; those which have been broken are restored in outline; *den*, dentary; *art*, portion of articular; *ch*, ceratohyal; *qu*, part of quadrate. This figure has been reversed in order to make it correspond with fig. 2.

1*a*, 1*b*. Two teeth viewed from behind to show the incurved points. Natural size. The outlines placed beside these, to show their oval form in section, are a little too large.

2. Outer surface of right upper jaw, with ethmoid &c. in their natural positions. Teeth restored in outline, as in fig. 1: *pmx*, præmaxilla; *mx*, maxilla; *ju*, jugal; *pl*, palatine; *pr.fr*, prefrontal; *eth*, ethmoid; *olf*, perforation for olfactory nerve.

3. Bones of ethmoid region seen from below: *eth*, ethmoid; *mx*, fragment of anterior articular process of maxilla, which is lodged in a deep excavation of the ethmoid; *prfr*, these letters point to the surface of the prefrontal, which articulates with the palatine; *vo*, anterior portion of vomer (?)

4. Outer surface of right side of brain-case: *b s*, upper portion of basisphenoid; *a s*, alisphenoid; *pa*, parietal region; *p s*, presphenoid; *fr*, frontal; *sp.ot*, sphenotic (postfrontal); *pr.ot.* prootic; *op.ot*, opisthotic or exoccipital; *ob*, supraorbital (?).

5. Inner view of left lower jaw with hyoid &c. *in situ*: *den*, left dentary; *ch*, right ceratohyal; *hh*, hypohyals; *cl*, *cl'*, portions of clavicles; *bh*, basihyal.

6. Front view of the symphysial surfaces of the two mandibular rami.

7. Mandible seen from above, with the hyoid bones between the rami: *den.* left dentary; *ch*, *ch*, ceratohyals; *hh*, *hh*, hypohyals; *bbs*, basibranchiostegal; *pt*, pterygoid; *qu*, quadrate.

8. View of left side of basibranchiostegal; *a*, *b*, *c* show the positions of the plates enlarged in the next three figures. This figure is unfortunately placed upside down.

8*a*. Portion of one of the plates with ridges and grooves, enlarged 7 diameters.

8*b*. One of the radiating pitted plates, enlarged 10 diameters.

8*c*. A small portion of another pitted plate, with minute teeth *in situ*, enlarged 45 diameters.

9. Right and left maxillæ and præmaxillæ seen from below, the two sides in their natural relation to each other.

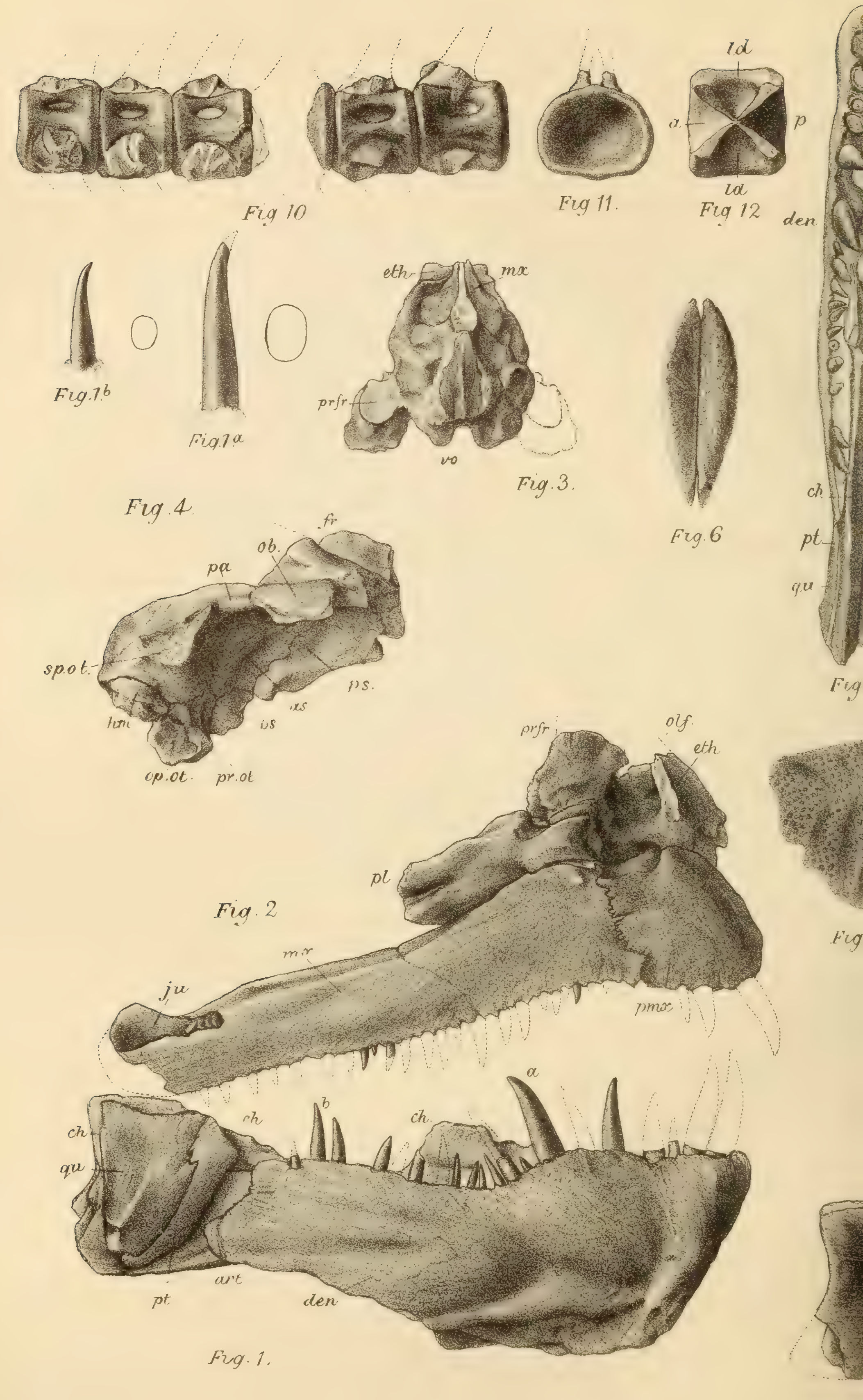
10. Side view of five dorsal vertebræ, showing the bases of the neural arches, the lateral depressions, and the enlarged heads of the ribs.

11. The third vertebra of fig. 10, seen from behind.

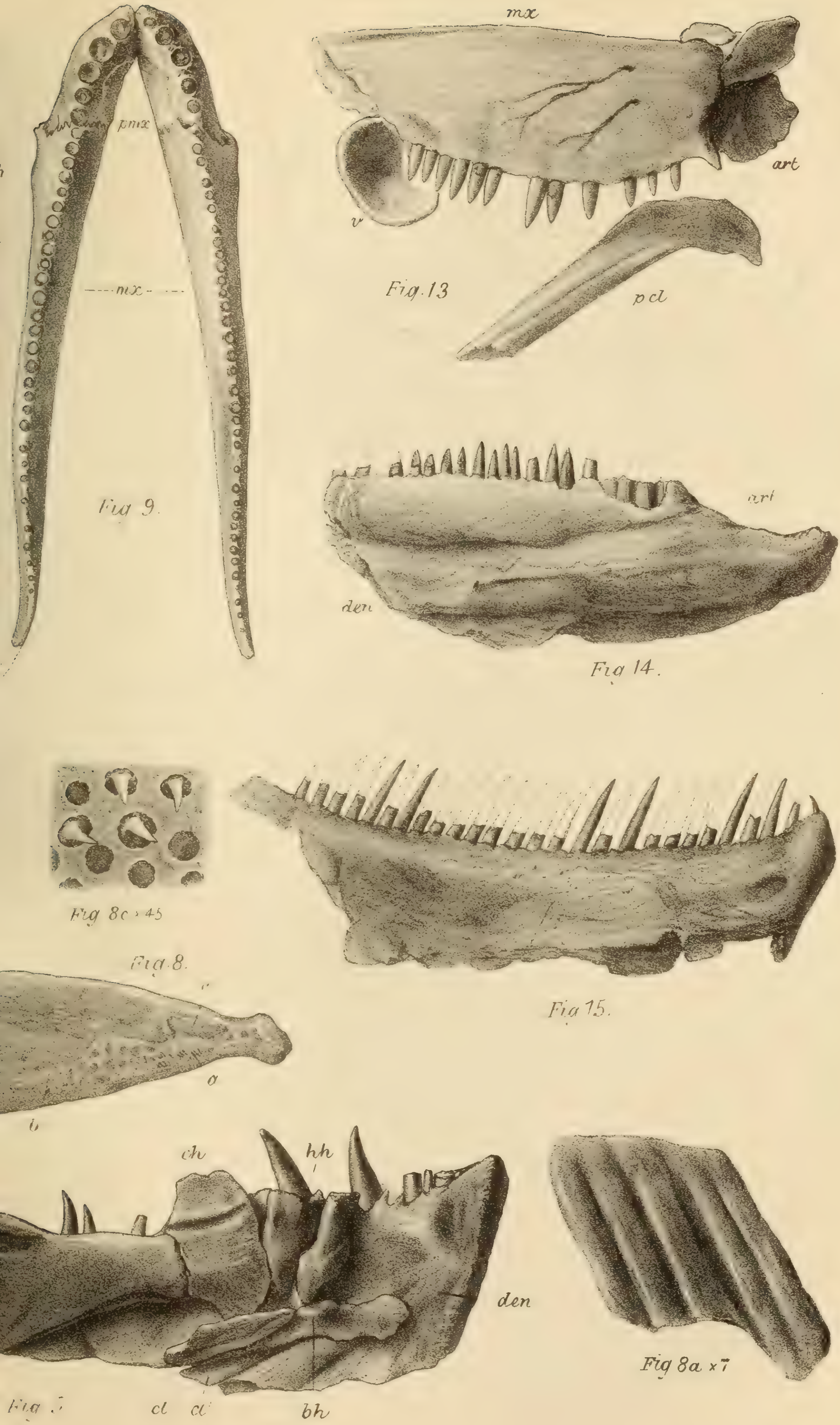
12. Section through another dorsal vertebra, seen from above: *a* and *p*, anterior and posterior concavities; *l d*, lateral depressions.

Portheus Daviesii, n. sp.

Fig. 13. Outer surface of upper jaw &c.: *mx*, maxilla, the hinder part broken; *art*, surface of maxilla for articulation with præmaxilla; *v*, vertebra; *p.cl*, postclavicle or ventral spine.



C.L Griesbach lith.



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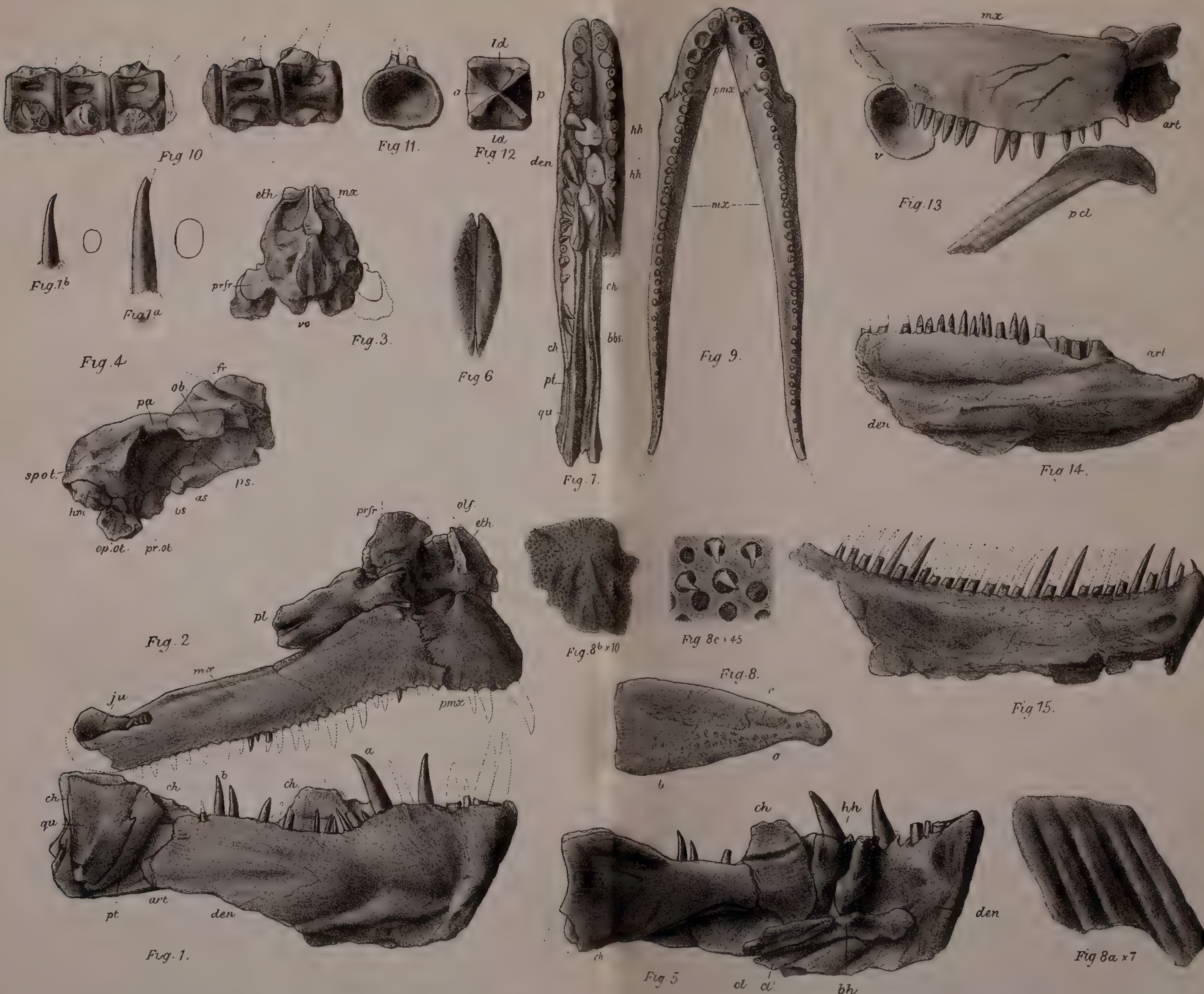


C.L. Griesbach lith.

M&N Hanhart imp

PORTHEUS AND ICHTHYODECTES.

Ichthyodectes minor, Egerton.

Fig. 14. Outer surface of left ramus of mandible. This is the left ramus of the specimen figured by Dixon in his 'Geology of Sussex,' pl. 32*. fig. 9: *den*, dentary; *art*, articular (the articular surface for the condyle of the quadrate is immediately below the letters *art*).

Ichthyodectes elegans, n. sp.

Fig. 15. Inner surface of dentary bone of left ramus of mandible. Natural size. The teeth have been drawn from the counterpart of the specimen.

26. Remarks *on the* Coal-bearing Deposits *near* Erekli (*the ancient* Heraclea Pontica, Bithynia). By Rear-Admiral T. Spratt, C.B., F.R.S., F.G.S., &c. (Read May 23, 1877.)

Towards the end of March 1854, after the combined fleets of England and France had entered the Black Sea, as coal was known to be procured by the Turkish Government from the south coast, near Erekli (the ancient Heraclea), I was ordered to proceed there, and examine and report upon its quality and fitness for the use of war-steamers; for although two or three cargoes of the coal were seen at Constantinople by some naval engineers, the quality appeared to be so inferior as coal (from being so mixed with slate and rubbish), that a general opinion prevailed that it was only a better quality of lignite than that procured from the Tertiary deposits of the Sea of Marmora and the Archipelago.

It was therefore of first importance to ascertain the age of the Erekli coal-beds, as well as the quantity that could be procured from them with sufficient economy and of sufficiently good quality for the use of our war-ships for steaming at high speeds.

I could obtain no fragment of a fossil from the coal at Constantinople that I examined, nor any information regarding the deposits associated with them; for, although M. Tchihatcheff had shown that rocks of the Devonian age existed, no mention was made of these coal-deposits or of any Carboniferous strata in the neighbourhood, in his valuable work on Asia Minor, published in 1853. I now find, however, that M. Schlehan had, in the 'Zeitschrift der deutschen geologischen Gesellschaft' for 1852, given a full description of some patches of Carboniferous deposits that had recently been examined by him near Amasny, and from which he gives a list of seven genera of Carboniferous plants.

I also find that M. Tchihatcheff, in his description of Asia Mino published in 1867, has noticed M. Schlehan's account of these Carboniferous strata at Amasny, and has also given a list of fossils sent him by Mr. Barkley from the coal-beds at Kosloo, as he had not been able to visit the district.

Leaving Constantinople in H.M. ship 'Spitfire,' then under my command, on the evening of March 27th, I passed Erekli the following morning, and proceeded at once, as the weather was favourable, to the bay and valley of Kosloo, about thirty miles further to the eastward, where the coal was being worked for the Turkish Government under the direction of an English engineer, Mr. John Barkley.

Steaming thus along this open coast between Erekli and Kosloo, I saw that a succession of narrow valleys, confined between narrow and steep ridges from 500 to 1500 feet high, ran north and south at right angles to the coast, up to a curving ridge of limestone that seemed to be 3000 feet or more in height, and distant from four or five to ten or twelve miles.

Extensive forests and underwood covered the larger portion of these ridges and valleys, especially towards the interior; whilst near the coast the valleys were less wooded, and were in parts cultivated; but the cultivation was very sparse.

The position of Kosloo was recognized by the few houses forming the settlement that stood near the shore of the little bay, as well as by the heap of coal, about 9000 tons, accumulated near it ready for shipment when the anchorage in the bay was considered safe for the coast-craft that removed the coal to Erekli (as the local dépôt) before transhipment for Constantinople,—the favourable season for this not commencing, in general, before the middle or end of May.

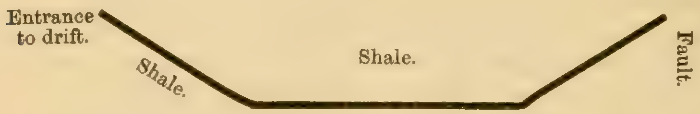
I anchored in the little bay of Kosloo about noon, at about a quarter of a mile from the shore, and was immediately joined by Mr. Barkley, who I found had been in charge of the district, as its Manager, for the last three years. With him there were four Englishmen as foremen of the miners, who were chiefly natives, Sclavonians and Hungarians. But during this time Mr. Barkley's English colony of artificers, first introduced by him, had suffered greatly from the malignant fever that prevailed in the autumn months all through the district, as usual throughout Asia Minor—several having died, and others having been obliged to return home.

Having completed arrangements for the immediate shipment of about 100 tons of the screened coal, so as to fairly test its steam-generating properties on my return voyage to Constantinople, I landed with Mr. Barkley and proceeded up the valley with him to examine some of the mines or seams that were being worked by him; for, as the seams were seen cropping out on the sides of the valley between the associated shales and schists, they were worked by simple horizontal drifts or slightly inclined tunnellings into the hill, as far as the seams were thus traceable.

From the beach I found a tramway leading up the valley for a distance of nearly two miles, with branches to the different drifts or mines then being worked.

During the remainder of this and the following day I examined the different seams worked under Mr. Barkley, and entered three or four mines or drifts that were then being so worked, as also one or two that had already been worked out in consequence of faults (or "troubles" as they are technically termed) that cut off the continuance of the seam, and left no indication whether it was the result of a downcast or otherwise.

These drifts extended from about 100 to nearly 400 yards only into the hill; for the district was so disturbed by faults and displacements, which occurred at every 200 or 300 yards, that several had already been worked as far as practicable, and few extended a greater distance before a fault was met with; and as the seams corresponded on both sides of the valley the same difficulties also occurred in respect to the frequency of faults in both. One of them, on the west side, that had been so worked out, Mr. Barkley informed me, was found to be bent both downwards and upwards, as well as being partly horizontal in the central portion, somewhat in this form:—

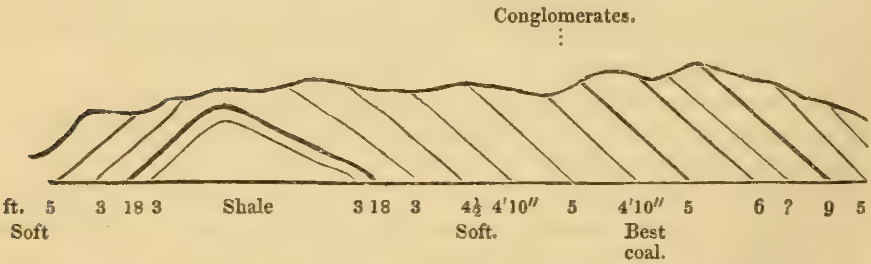


On the west side of the valley the coal-seams were not so plainly seen cropping out at the surface, nor so numerous as in the eastern ridge, where there were no less than eleven or twelve seams thus existing, of varying thickness and quality.

The extent in which this number of beds or seams occur on the east side of the valley is about two miles; the seams being interstratified with shales, sandstones, and conglomerates of quartz-pebbles, with thin bands of clay occasionally, and also with thin bands of ironstone, the whole comprising a considerable thickness of these Coal-measures. See following sketch section:—

Sketch Section of the Coal-bearing deposits near Erekli.

(Length about 2 miles.)



The following are the details of one of the seams now being worked in the upper part of the valley:—

Overlying shale. Dip 26° S.E.

	Thin band with fossil plants.
22 inches.	Coal, of good quality.
7 inches.	Shale.
14 inches.	Coal-seam, very good.
5 inches.	Shale.
36 inches.	Coal-seam, good.
2 inches.	Clay.
Uncertain.	Shales and sandstones.

From this seam I was so fortunate as to procure a few fragments of fossil plants that seemed to be unmistakably of the true Coal-measures; and thus the important difference between them and the lignites of the Levant was at once evident to me. In the roof of this mine I observed an impression of what appeared to be an almost circular leaf, that measured nearly 4 feet in diameter.

Mr. Barkley informed me that in one of the mines trunks of trees had also been found *in situ*, the diameter of which never exceeded about one foot,—the outer part of these trunks being converted into pure coal, whilst the interior or core was composed of pure shale, thus indicating their hollow or soft pithy heart, like large tree ferns &c.

The remains of plants were, however, rare. I was fortunate in finding some fragments amongst the heaps of refuse near the mouth of some of the drifts; and I was indebted for some others to Mr. Barkley, who kindly gave them to me so as to lead to the true identification of the age of this singularly isolated patch of the true Coal-measures, as they have proved to be. The fossils I then procured are now for the first time exhibited; for, although they were sent to England to my lamented friend Edward Forbes, for identification, at the same time as my report was sent to the Admiralty, by some mischance the box containing them was detained in some Custom House until the end of 1854 or beginning of 1855, and only reached him shortly before his removal from the Museum in Jermyn Street to Edinburgh, and consequently just previous to his death; so that only an extract from a hasty letter to him, sent at the same time, has ever been published in reference to my examination of these Black-Sea coal-beds. This appeared soon after his arrival in Edinburgh, in the 'Edinb. New Phil. Journ.,' 1855, pp. 172, 173.

The fossils themselves have, fortunately, remained at the Jermyn-Street Museum since that time; and, on recently inquiring about them through the General Curator, Mr. Reeks, they were readily found. A list of them has been kindly made by Mr. Etheridge to accompany these long delayed remarks upon this important coal-district; and as there are ten genera of fossil plants amongst them, they will more fully establish the age of these beds than has hitherto been done. For, although a brief visit was made to Erekli and to the Kosloo Valley (by sea) by Mr. Poole, soon after the extract from my letter appeared in the Edinburgh Journal, that gentleman has only briefly referred to the existence of the Coal-deposits, without giving any details.

This fact, and the special interest that has recently sprung up in reference to the East, has induced me to think that a fuller description of these coal-bearing deposits and of the district in general, such as my notes and private journal enabled me to give, were now desirable, in a general as well as in a geological point of view.

I was informed by Mr. Barkley that the coal-bearing deposits extended to the eastward of Kosloo to within a mile of Amasny, and were found in almost every intermediate valley. On the west side of Kosloo they extend to within three or four miles of Erekli, thus embracing an area of nearly fifty miles east and west, and from three to ten or twelve miles north and south. Their northern margin terminates on the coast, and therefore must pass under this part of the Black Sea for an unknown and probably considerable extent. But the entire area is characterized by great disturbances and numerous faults.

The existence of these coal beds was first brought into notice about the year 1838 or 1840; but they were not systematically worked by the Turkish Government until five or six years before my visit, although Croat squatters worked at some of the best-developed and most easily worked seams near the coast, for some years previous to this time.

The following are the names of localities near to Kosloo where coal was known by Mr. Barkley to exist, with a description of its quality:—

Okoosnu, five miles from Kosloo. Several seams exist near the summit of the mountains, at two and a half miles from the coast, quality both good and bad, and are being worked by Croats.

Yani Arman. Coal obtained from the hills by Croats, but the quality indifferent.

Doomooz Dereh. Contains a seam of coal 8 feet thick and of good quality, but deteriorating rapidly by exposure. Was being worked by Mr. Barkley.

Zungledek. Has seven or eight workable seams of varying quality, and all lying at various inclinations. Once worked by Croat squatters, but now abandoned by them, from the difficulties encountered in consequence of being so disturbed, and of their want of capital to meet these difficulties.

Baluk and Uzulmas. The coal in this valley is similar to that in the Zungledek. One seam exists at two miles from the sea, which is 12 feet thick and of good quality. The coal at Uzulmas is nine miles from the coast.

Feeling it necessary, or rather desirable, to see something of the coal-bearing deposits in the neighbourhood, I started on the morning of March 30th with Mr. Barkley to ride across the intervening district between Kosloo and Erekli, where I ordered my ship to meet me, the distance being nearly thirty miles.

A short delay occurred in the time of starting, in consequence of an explosion of gas in one of the mines, on the miners first entering it soon after daylight, by which three native miners were rather severely burnt, one poor fellow especially so, in the face and neck. This was only the second instance of the kind that had occurred since Mr. Barkley had been in charge of the mine.

In reference to the geology of the district crossed in our ride to Erekli, I feel that, from the distance of time since it occurred, I can simply give a few extracts from my private journal, without attempting to enlarge or enter into details. Deep drifts of snow lay on some parts of the route, where the road ascended over the higher parts of the ridges crossed, and thus hid some of the beds and associated shales &c. from view and examination.

After ascending for half an hour the western ridge bounding the Kosloo valley, where a mass of limestone decidedly overlies the coal-bearing deposits, we reached and followed the backbone of a ridge nearly 2000 feet above the sea, where the shales and schists composing it appeared to be but little inclined from the horizontal position, but whether conformable or not with the former or latter could not be determined; and after crossing two valleys, with a small hamlet in each, we descended into the valley of Karditch at three and a half hours from Kosloo.

In our descent on the east side of it we came upon the coal-bearing beds, dipping to the S.W. at angles of 40° and 50°, and at about three miles from the coast. We had also seen coal-seams in the other valleys we had crossed, but situated nearer the sea.

To the southward of Karditch masses of limestone appeared on both sides of the valley, with the coal-bearing deposits, apparently dipping under them. But as these latter deposits were inclined at all angles, sometimes the relative superposition of these beds was not identifiable without a more perfect examination. Considerable local disturbances seemed to exist here, as the result of proximate volcanic action; a dyke of igneous rock, although somewhat resembling an altered shale, seemed to form the crest of the ridge near the village of Karditch, and dipped at an angle of 60° and upwards S.W. and S.S.W.

To the westward of Karditch we crossed several valleys leading to the coast, in which coal existed. In one of these, near the village of Aliagazzi, there were two seams, now being worked by Croat squatters, the dip of one of which seams was as much as 70°.

At another valley and village called Arnout-keni, there was a seam of good coal, between 8 and 10 feet thick, that had not yet been worked.

In all these valleys and intervening ridges I found that the Coal-seams and associated shales, &c. represented a series of anticlinally and synclinally disposed undulations of the beds, indicative of great lateral as well as local pressure and disturbance, the anticlinal summits of these flexures having been considerably denuded of the continuing strata.

The view to the southward, over these parallel ridges, where attainable on our route, from being for the most part clothed with dense forests of oak, beech, and wild fruit-trees, and from being devoid of any conspicuous peak or mountain until nearer Erekli, resembled the broad waves of the ocean, and were in unexplored beauty—in apparently primeval condition.

In this part, and also near Erekli, we found the shales over which the road passed much decomposed and soft, as well as showing metamorphic action from volcanic influence, the focus of which seems to be at or near Erekli, as I shall show by a brief description of the locality, which I was enabled to examine during the two following days, before my return to Constantinople; for as Erekli was the dépôt to which the coal was sent from the localities at which it was procured along the coast, chiefly in small coasters, for transhipment to Constantinople in vessels of larger burden, it became important that my Report should be accompanied by a survey of the only secure anchorage near the Coal-bearing district.

On the Geology of Erekli.

The Acropolis and part of the town walls of Heraclea stood upon the crest and slopes of a bold and almost isolated hill rising from the east side of the bay, formed by the promontory of land to the north-west of it, now called Cape Baba, but anciently the Acherusian Peninsula by Xenophon; for this city was the place from which he embarked for Greece, with his army, after his celebrated retreat.

The summit of this hill (Acropolis) consists of a capping of reddish indurated shale, a few feet only in thickness, and overlying stratified beds of tuffs, greenstone, volcanic mud, and trachyte conglomerates, by the outburst of which the reddish shales were evidently uplifted and altered in their colour and character; but Mr. Poole calls it sandstone, no doubt from a too hasty examination.

A portion of the same altered shales, or rather marls, appears also at the base of the Acropolis, near the shore, on its west side—likewise to the north and eastward of it, with the lavas intermediate.

A valley to the south of the Acropolis, in which is a large part of the modern town of Erekli, separates it from another hill over the coast, which is composed of whitish and grey marls, belonging, no doubt, to the same group as the indurated stratum capping the Acropolis, and the altered marls existing at its base.

These white and grey marls dip to the south-west at an angle of 30°, except on the east side of the hill, near the large burying-ground at its base, where they are nearly vertical, and where they are much discoloured and decomposed through contact with the trachyte conglomerates and stratified lavas which have burst out beneath them.

The age of these marls I was not able to ascertain, as the only fossil obtained from them was an oyster, too friable, however, to be preserved, but sufficient to show that they were of marine origin. From the form of the oyster I was disposed to consider the deposit to be of Miocene, or perhaps an earlier age.

In the promontory to the north and north-west of Erekli the volcanic productions of tuffs, trachytes, and basaltic conglomerates prevailed, having in some parts both uplifted and also overflowed the marine marls.

It is perhaps worth noticing, in concluding these remarks upon the volcanic character of the locality, that the ancients must evidently have recognized the plutonic or igneous origin of these lava-beds, notwithstanding their general stratified condition; for Xenophon states that a cavern was shown in the Acherusian Peninsula that led to the gates of Hades, and from which Hercules drew forth Cerberus, the guardian of its portals.

Strabo says it lay to the north of the town, and was two stadia deep; but I could hear of no such cavern in the neighbourhood. Yet it is possible that some traces of an extinct crater or volcanic vent may exist here, where, as I have shown, lavas and beds of igneous production appeared to have covered some extent of the neighbouring district.

A cavern, however, penetrates into the Acropolis hill for 300 or 400 yards, but seems to have been wholly artificial, and was perhaps originally a quarry for building-stone.

Notes on the Fossil Plants from Kosloo.
By R. Etheridge, Esq., F.R.S., F.G.S.

Admiral Spratt's collection consists entirely of plants, the whole of them of undoubted Coal-measure age. The genera and many of the species are precisely those of the Coal-measures of Britain.

Twenty-six specimens occur in the collection :—

4	*Lepidodendron*	10 genera, 26 forms.
1	*Lepidostrobus*	
9	*Calamites*	
1	*Sphenophyllum*	
3	*Pecopteris*	
1	*Sphenopteris*	
1	*Neuropteris* (?)	
3	*Sigillaria*	
2	*Stigmaria*	
1	frond, like *Glossopteris sphenophyllum*	

4	B.	Lepidodendron Sternbergii (?).	
	F.	" sp. Cast only.	
	I.	" selaginoides, or closely allied thereto.	
	M.	" sp.	
1	R.	Lepidostrobus, or densely packed head of *branch* of *Lepidodendron*.	
9	C.	Calamites dubius.	
	H. O.	" allied to *C. cistii*.	
	K. K*a*.	" allied to *C. dubius*.	
	L.	" undulatus.	
	S.	" Suckowii, or dubius.	
	W.	" probably *C. nodosus*.	
3	C*a*.	Pecopteris plumosa.	
	G.	" sp.	
	P.	" allied to *lepidorhachis*.	
1	E.	Sphenopteris allied to *S. dissecta*.	
2	A.	Neuropteris (?)	In underclay.
	A.	Sphenophyllum	
3	T.	Sigillaria.	
	U.	Sigillaria.	
	X.	" hexagona.	
3	V.	Stigmaria ficoides.	
	Q.	" "	
	Y.	Like *Glossopteris*.	
26			

Discussion.

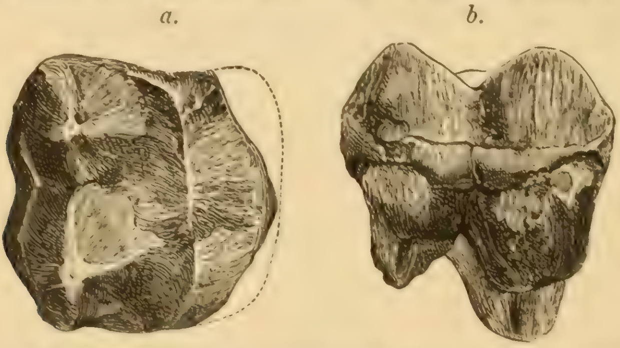
Mr. Etheridge stated that the fossils and rocks were undoubtedly truly of Carboniferous age, and from our ordinary experience would be regarded as rather low down in the series. He noticed the species of plants which occurred among Admiral Spratt's specimens, and dwelt especially on the presence of *Stigmaria ficoïdes*. He also referred to the existence among them of what appeared to be a species of *Glossopteris*, and said that although this genus of ferns had been regarded as peculiarly Jurassic in Western Europe, it had been discovered in what appeared to be true Carboniferous deposits in Queensland by Mr. Daintree, and hence its occurrence in a similar position in this intermediate locality was particularly interesting.

27. NOTE *on the* OCCURRENCE *of the* REMAINS *of* HYÆNARCTOS *in the* RED CRAG *of* SUFFOLK. By WILLIAM HENRY FLOWER, Esq., F.R.S., F.G.S., Hunterian Professor and Conservator of the Museum at the Royal College of Surgeons. (Read June 6, 1877.)

IN the rich collection of Red-Crag fossils gathered together during the course of many years in the neighbourhood of Waldringfield by the Rev. H. Canham, now through the joint liberality of Sir Richard Wallace and Mr. Canham located in the Ipswich Museum, is a very perfect mammalian tooth, which has been placed in my hands for identification. It proves to be the right upper first true molar of an animal of the genus *Hyænarctos* of Falconer & Cautley.

In the Quarterly Journal of the Geological Society, vol. xxxiii. No. 129 (Feb. 1, 1877), at p. 133, it is recorded that, at the meeting of the Society held on November 22, 1876, "Mr. Charlesworth stated that he had obtained from the Crag a tooth which had been pronounced by Mr. W. Davies, of the British Museum, to come nearest to that of *Hyænarctos* among known Mammalia." The tooth referred to by Mr. Charlesworth is now in the collection of Mr. William Reed, M.R.C.S., of York, who has obligingly sent it to me for exhibition to the Society. It is the corresponding upper molar of the opposite side, and so like that of Mr. Canham's collection that, except for being perfectly unworn, it might almost have belonged to the same individual.

Tooth of Hyænarctos *from the Red Crag* (*in Mr. Canham's Collection*).



a. Upper surface. The dotted line represents the outline of the complete tooth in Mr. Reed's collection. *b.* From the side.

The tooth first mentioned is in very fair preservation, being only slightly worn at the prominent apices of the cusps. It has no matrix adhering to it, and is less rolled and waterworn than many of the teeth from the Crag, having a considerable proportion of each of the three roots remaining; whereas these, being composed of softer tissues than the enamel-coated crown, are generally absent, as in Mr. Reed's specimen. On the other hand, considerable portions of the enamel have been chipped off from the inner edge of the crown, while in the latter, which was derived from a younger animal, the crown is absolutely perfect.

Having compared Mr. Canham's tooth with the corresponding one of the original specimen of *Hyænarctos sivalensis*, Falc. & Cautl., from the Sewalik Hills, now in the British Museum, I can detect no appreciable difference—certainly none which would warrant, in the absence of other evidence, the imposition of a new specific name. The dimensions are identical; and so are the general contours of the margins, and the form and position of the cusps. At first sight a considerable difference is apparent in the outline of the inner edge, as seen when looking down on the grinding-surface; but this arises from the defective condition of the enamel noticed above, portions both of the anterior and posterior angles of the inner border having been lost, and giving the appearance of an angular rather than straight inner margin. The Sewalik animal was older, and the tooth more worn, which may account for the absence, or, at all events, less distinct evidence of the fine striation of the surface of the enamel, in lines converging to the apices of the cusps, which is beautifully seen in both the Crag teeth.

The Sewalik specimen was first described by Cautley and Falconer, in the 'Asiatic Researches,' vol. xix. p. 193 (1836), under the name of *Ursus sivalensis*; and it is certainly very closely allied to the true bears, though in its dentition somewhat less specialized than the modern representatives of the group. It has no particular affinity with *Hyæna*, as the name by which it is now generally known might be supposed to indicate. In an unpublished plate of the 'Fauna Antiqua Sivalensis,' executed about 1848, the species is designated *Ursus* (subgenus *Hyænarctos*) *sivalensis* *; and the same name must have been used by Falconer and Cautley before that date, as it is quoted in Owen's 'Odontography,' p. 503 (1845), although in 1842 Dr. Falconer objected to Blainville's proposed removal of the animal from the genus *Ursus*†. In 1837 Wagner gave the name of *Agriotherium*, and in 1841 Blainville both *Amphiarctos* and *Sivalarctos*, to *Ursus sivalensis*; so that, strictly speaking, all of these names have the priority to Falconer's; but, as Gervais remarks, "toutefois le mot *Hyænarctos* a prévalu." It is adopted in Pictet's 'Traité de Paléontologie,' vol. i. p. 18.

Remains of an animal of the same genus have been found in the Pliocene marine sands of Montpellier, and described and figured by Gervais ‡ under the name of *Hyænarctos insignis*, though the specific distinctions between them and those from the Sewalik Hills are not very striking. As I found by direct comparison in the Paris Museum, the first true molar differs from the Crag teeth in having the two inner cusps more distinctly separated, instead of constituting an

* C. Murchison, in Falconer's 'Palæontological Memoirs,' vol. i. p. 329.

† See 'Palæont. Mem.' vol. i. p. 328.

‡ 'Paléontologie et Zoologie Française,' 2nd. edit. (1859).

almost undivided antero-posterior ridge, as they do in the latter and apparently in the Sewalik animal. A smaller species (*H. hemicyon*) has been found at Sansans, Gers, and a single tooth in a bed, like the last-named, referred to Miocene age, at Alcoy, in Spain *.

According to Mr. Lydekker † a nearly perfect mandible of *Hyænarctos sivalensis* has recently been discovered by Mr. Theobald, and will be figured in the 'Palæontologia Indica.'

Discussion.

Dr. Murie remarked upon the interest attaching to the wide distribution of this animal, and inquired whether Prof. Flower agreed with Prof. Gervais in adopting the name of *Hyænarctos*.

The President remarked that the fact of the extension of the genus *Hyænarctos* into Spain had already been brought before the Society by a Spanish geologist. The question of the age of the remains of *Hyænarctos* in Asia and Europe was one of great interest. If the family had a great range and the genus also (and great horizontal concurs with great vertical range), then probably *Hyænarctos* had a very long geological life, and may have survived the great changes which attended the upheaval of the Sewalik Hills.

* See Gervais, *op. cit.*

† 'Records of the Geological Survey of India.' No. 1 (1877), p. 33.

28. Observations *on* Remains *of the* Mammoth *and other* Mammals *from* Northern Spain. By A. Leith Adams, M.B., F.R.S., F.G.S., Professor of Zoology, Royal College of Science, Dublin. (Read January 24, 1877.)

My friend Mr. O'Reilly, Professor of Mineralogy to the Royal College of Science, Dublin, has kindly permitted me to examine a collection of fossil remains made by himself and Professor Sullivan, of Queen's College, Cork, when engaged in surveying the mineralogy and geology of the province of Santander.

The conditions under which the remains were found are fully detailed in the able reports of these gentlemen, published in the 4th volume of the 'Atlantis,' and reprinted in a separate volume entitled 'Notes on the Geology and Mineralogy of the Spanish Provinces of Santander and Madrid.'

It appears that, during the sinking of a shaft in search of calamine in limestone underlying the dolomite of the valley of Udias, the workmen, at about 12 metres from the surface, suddenly broke into a cavern of considerable dimensions. At the north end of the cavity was a mound of soil which had fallen down a funnel blocked up at the time of the discovery by surface-soil and débris. Close to this mound were found many bones of mammals and birds. The remains were either partially or entirely buried in calamine, which covered the floor and formed an enormous bed of variable thickness. It appears, therefore, not only from the large funnel, which was evidently the original opening, but also from the remains, that the cavern was an enlarged joint or rock-fissure, into which the entire carcasses or else the live animals had been precipitated from time to time.

The following, I am informed, does not represent the entire produce of the cave (or, as it is named, the Dolores Mine). The authors refer further to a long curved tooth, oval in transverse section, possibly the canine of *Hippopotamus*.

This identification of remains of the Mammoth in Spain is, as far as I know, the first authenticated instance of the kind, and therefore important in relation to the southern distribution of the species; for although the elephant-remains found in many parts of Europe have been referred to the latter, it is well known that teeth of *Elephas antiquus*, *Elephas meridionalis,* and the so-called *Elephas armeniacus* have been confounded with molars of the Mammoth. Moreover the asserted presence of remains of *Elephas africanus* in Pleistocene deposits * near Madrid is another highly important incident in connexion with Spain, whilst Mr. Smith, of Jordan Hill, discovered a molar of *Elephas antiquus* at Gibraltar †.

* Lartet, Atti dell' Acad. di Scienz. tom. vii. p. 223.
† Falconer & Busk, Palæont. Mem. vol. ii. p. 557.

The following remains belonging to Professor O'Reilly's collection I have been enabled to identify.

ELEPHAS PRIMIGENIUS.

1. A portion of a mandible containing the sockets of two molars on either side. The descending ramus and coronoid process, with the diasteme and portions of the alveoli, are deficient. The jaw is evidently that of a young elephant, and probably belonged to the owner of the following molars. It has the round oval chin of the Mammoth.

There are a few laminations of tusks, but of no use for descriptive purposes.

2. A right upper first true molar, about half-worn. It is entire excepting the loss of the tips of the fangs. There is a broad pressure-mark, or hollow, of the advancing tooth behind. The crown holds 12 plates and 2 talons in a length of 5 inches. The maximum breadth of crown is 2·3 inches.

The enamel of the plates is thicker than usually observed in Arctic specimens, and in that respect is more like mammoths' teeth from the brick-earth of the Thames valley. There is, moreover, a greater roughening of the outer surface of the enamel, which on the worn disk produces a faint crimping not generally observed in northern specimens; otherwise the tooth is undistinguishable from the same molar of the mammoth.

3. Two fragments of germ molars:—

a. A fragment of an upper tooth, holding 8–9 posterior ridges, including a broad, flat, digitated talon. The plates are of precisely the same character as in the preceding tooth, but longer and broader.

b. Three plates and posterior talon of a similar tooth to *a*, and most probably the fellow of the opposite maxilla. These two fragments are probably portions of the second or successional molars of the same individual as the owner of the first true molar and the above mandible.

4. *a*. A left os innominatum of a young elephant, the unions of the three elements being unankylosed. There is a loss of only a portion of the posterior aspect of the ilium and distal extremities of the ischium and pubis. The contour of the thyroid foramen is nearly entire, showing the narrow upper portion which characterizes this opening in the Mammoth and Asiatic elephant as compared with that of *E. africanus*. The obturator notch is also broader than in the latter. The bone has altogether the character of the same part of the Mammoth. The acetabulum is 16 centimetres in diameter by 8 centimetres in depth.

b. Fragment of the ischium, right side, probably of the same individual as the owner of *a*.

5. *a*. Portion of a left femur two feet in length extending from behind the great trochanter to the condyles. The bone has the slender character of the thigh-bone of the Mammoth, agreeing, moreover,

with it in the longer neck and wider interspace between the condyles as compared with the African elephant. The former character is shown in a drawing taken by Mr. O'Reilly on the spot where the remains were discovered, and from other femora from the same cavern and not now in his possession; they are of the left side, and represent a youthful and a full-grown elephant.

b. A fragment of about a foot of the distal extremity of a right femur, including condyles, and of possibly the same individual as that of the first-named fragment.

6. A portion of a right radius, showing about 6 inches of the proximal extremity. Evidently, from the round and smooth shaft, it belonged to an adolescent individual.

BOS PRIMIGENIUS?

1. Fragments of large horn-cores of different individuals.
2. A right ramus, without teeth. Length 18 inches.
3. A right scapula, showing glenoid cavity, a fragment of the spine, and the greater portion of the body. The glenoid cavity is 2·8 inches by 2·2 inches.
4. The proximal half of a radius and ulna, right side. The breadth of the articular surface of the former is 4 inches.
5. Several dorsal and lumbar vertebræ of an individual about the same dimensions as the owner of the preceding bones.
6. *a.* An entire left femur, recently broken. Length 19 inches; width of head 3 inches. Antero-posterior diameter of distal extremity 6·6 inches. Smallest diameter of the shaft 2·1 inches.
   b. A lower half of a right femur of evidently the same animal.
7. Entire right and left tibiæ. Length 16·5 inches.

These bovine remains appear for the most part to have belonged to one individual; and, as in the case of the elephant, bones of young and immature individuals predominated, from which it might be inferred that from inexperience they would have been more likely than the adult animal to fall into gaping rents.

CERVUS ELAPHUS?

1. Fragments of beam, brow-antlers, and snags of a large stag, of about the dimensions of a full-grown horn of red-deer.
2. Humerus of right side, with loss of the proximal and distal epiphyses, youthful.
3. Fragments of ribs.
4. Dorsal and lumbar vertebræ, with entire sacrum.
5. Nearly entire ossa innominata.
6. Right and left entire femora, each 12 inches in length.
7. Left tibia entire, 13·5 inches in length.

These cervine remains agree with the same bones of *Cervus elaphus,* and very probably in great part belonged to one individual.

Discussion.

Mr. Warington W. Smyth referred to a visit which he had paid some years ago to the part of Spain referred to in the paper, and described the curious characters of the rocks, and the occurrence in them of extraordinary caverns of great depth.

Mr. Evans inquired how near to the spot in question remains of *Elephas primigenius* had been found in the south of France. He also inquired whether the small curved tooth might not be the tusk of a little Elephant.

The Author, in reply, stated that the Mammoth had occurred in France near Lyons, where Dr. Falconer had identified teeth in the museum. In Western Europe the species had not previously been met with south of the Pyrenees. Some of the bones were in red soil; one femur was incrusted with calamine. The small tooth was of a form which seemed to show that it was the canine of a *Hippopotamus*; and there was no reason why it should not be so.

29. *On* MAUISAURUS GARDNERI (*Seeley*), *an* ELASMOSAURIAN *from the* BASE *of the* GAULT *at* FOLKESTONE. By HARRY GOVIER SEELEY, Esq., F.L.S., F.G.S., &c., Professor of Geography in King's College, London. (Read February 7, 1877.)

[PLATE XXIII.]

THE Gault hitherto has yielded but scanty remains of animals referable to the Reptilia and to the Palæosauria; so that more than ordinary interest attaches to the discovery, in a comparatively perfect condition, of remains belonging to a genus found hitherto only in New Zealand, which may be regarded as distinctive of the deposit. The remains of this Plesiosaurian were first found. rolled and abraded, at the foot of the cliffs; much of the caudal region of the animal may therefore have disappeared by attrition, and by the gradual decay of the bones as exposed in the clay, which has partly invested them with selenite. These bones were sent by Mr. Griffith, the well-known Folkestone fossil-collector, to J. S. Gardner, Esq., F.G.S., who traced them to their place in the Cliff, about 15 or 16 feet from the base of the Gault, and undertook excavations which have resulted in the discovery of a tooth, of the vertebræ of the neck and back, the principal bones of the limbs, and portions of the pectoral arch. The head, the tail, the pelvic bones, and the smaller bones of the limbs, together with most of the ribs, have not been found; and it is possible that some of these parts of the skeleton may have become severed before the specimen was covered up in the deposit, Mr. Gardner having used all possible efforts to discover the missing remains. The neural arches appear to have been united to the centrums; and several vertebræ were extracted by Mr. Gardner with the neural arches entire; but, from the brittle condition of the fossils, it was not found easy to preserve the specimens in an unbroken condition.

There is necessarily some uncertainty about the exact generic determination of this Plesiosaurian; for the bones which might have cleared away all doubt are not well preserved. It is probable that it may be referable to *Mauisaurus*, which was about as large; and I have referred it to that genus, partly because it is a Cretaceous fossil, and partly because in vertebral characters and form of limb-bones it approximates closely to that genus; while what remains of the pectoral arch does not sanction its location in *Elasmosaurus*.

Elasmosaurus platyurus is regarded by Professor Cope as having been 45 feet long, one half of which length was formed by the neck, in which 69 vertebræ are preserved, and from which 3 more are supposed to be lost. The dorsal region is supposed to have contained 24 vertebræ, of which 14 are preserved, while in the tail there are supposed to have been 51 vertebræ, of which 21 are preserved, giving a total of 147 vertebræ. Mr. Gardner's fossil gives no indication of this enormous number of vertebræ or length of neck; but the vertebræ are quite as large, and are larger than in any British long-necked Plesiosaurian hitherto described.

THE TOOTH. (Pl. XXIII. fig. 1.)

The tooth is perfect, and measures $1\frac{3}{4}$ inch in length. The crown is $\frac{3}{4}$ inch long; it is curved inward and backward, and is flattened somewhat on its external aspect. The crown terminates in a point, and is marked with fine close-set parallel striations rather finer than is common among Plesiosaurs. The fang continues to expand for half its length, and then contracts somewhat towards the base, so that the convex anterior outline of the tooth is an arc of a smaller circle than the concave posterior border. It is difficult to estimate the size of the head from a tooth; but it probably did not exceed a foot in length.

THE VERTEBRAL COLUMN.

The earliest vertebra preserved is an early cervical with the neural arch and cervical ribs ankylosed to the centrum. These short ribs give a subtriangular appearance to the articular surface, which is modified a little by the lateral widening of the neural arch. The antero-posterior length of the centrum is $1\frac{1}{16}$ inch; the depth of the centrum is $1\frac{1}{8}$ inch; and its breadth on the anterior face is $1\frac{3}{8}$ inch. The articular face is flattened, moderately concave, and most compressed from front to back at the base of the neural arch. The base of the centrum is marked with an elevated median ridge. The short ribs are given off from the inferior lateral corners of the centrum, and, as usual, are directed outward, backward, and downward. The neural canal is large and vertically ovate; the neural arch is constricted from side to side at the base of the neural canal; it has a subquadrate aspect as preserved, but is too imperfect for description. I am aware of no data on which to determine the number of vertebræ which were anterior to this one, or which intervened between it and the next preserved.

The second of the series has the centrum nearly 3 inches long, with the articular ends flattened and slightly concave, and the margins of those surfaces slightly rounded. The centrum has an elongated constricted appearance, and has the compressed, elongated, elevated, articular area for the cervical rib at the base of the lateral aspect; but the specimen is too badly preserved to admit of measurement.

Many vertebræ are missing between the second and the next preserved; for although the third is only $3\frac{1}{2}$ inches long, it has nearly twice the transverse diameter of the second. The articular faces, still a little concave, are transversely ovate, about $3\frac{3}{4}$ inches wide, with the centrum $2\frac{3}{4}$ inches deep in front and deeper behind. The edges of the articular margin are slightly bevelled. The base of the centrum has a strong median ridge, which becomes broader towards each articular surface. On each side of the base, between this ridge and the rib, is a large impressed crescentic area. The transverse width of the base of the centrum external to the ribs is $2\frac{7}{8}$ inches. The bases of the ribs are strong, elevated, and directed chiefly downward. The sides of the centrum are smooth, concave from front to back, and moderately convex from above downward, and extend vertically for 1 inch above the ribs; the neural arch is confluent with the centrum, and unites with it by a large compressed squamose base, which fits into an impressed concave area.

The fourth specimen is $3\frac{3}{4}$ inches long; and the whole centrum is somewhat larger, with flatter articular faces and deeper excavations on the base of the centrum. The fifth, a trifle longer, shows the neural canal as a deep channel, concave from front to back, and at least an inch wide. The articulation for the rib is nearer towards the anterior margin of the centrum, where the process is thicker than posteriorly; as fractured it is $1\frac{7}{8}$ inch long. The seventh centrum is 4 inches deep and about $\frac{1}{4}$ inch wider; so that the articular face has become more circular. This surface is much flatter, but now has a shallow central concavity an inch in diameter. The centrum is $4\frac{1}{2}$ inches long; its basal excavations are more elongated, and the upper part of the centrum is more compressed. The eighth centrum is larger in the articular faces. The neurapophyses are remarkably extended from front to back, and greatly compressed, each being less than $\frac{1}{4}$ inch thick. On the base, separated by the rounded median ridge, are two large oval nutritive foramina about $\frac{3}{4}$ inch apart. The bases of the ribs grow stronger and are $\frac{7}{8}$ inch in depth. The tenth centrum is $4\frac{1}{4}$ inches long, with the articular face as deep and $5\frac{1}{8}$ inches wide, though the width over the articulations for the ribs is somewhat less. In the eleventh the base for the rib has become more ovate and larger, and the base of the neural canal has increased with the size of the vertebra, the neural arch being 2 inches wide externally behind.

The thirteenth vertebra has the neural arch well preserved (Pl. XXIII. fig. 2). The centrum is 4 inches in antero-posterior length. Its anterior face is $5\frac{3}{4}$ inches wide and about $4\frac{1}{2}$ inches deep. It has a central depression 2 inches broad, margined by an elevated rounded rim, between which and the circumference is a second concave area in the form of a ring, but less deep. The posterior articulation is 6 inches broad and $4\frac{1}{2}$ inches deep; it has the transversely oval central area shallow, but without the elevated rim. The base of the centrum is $4\frac{1}{4}$ inches long; it is convex from side to side, with an obtuse median ridge. The distance between the articulations for the ribs is $5\frac{1}{4}$ inches. The articular surface for the rib is subcircular, $1\frac{3}{4}$ inch deep, and nearly $1\frac{1}{2}$ inch from front to back; this area is $\frac{3}{4}$ inch from the posterior margin and more than $1\frac{1}{2}$ inch from the anterior margin of the centrum. The lateral area above the articulation for the rib is flattened, concave from side to side, and scarcely concave in depth. And the neural arch rises steadily from the side of the centrum without any break to a height of $10\frac{1}{2}$ inches, being imperfect superiorly. The neural arch is much compressed from side to side. The posterior zygapophyses hang entirely behind the posterior articular face of the centrum; they are close together, being separated by a vertical slit. The processes are imperfect; as preserved each is $1\frac{1}{2}$ inch long and fully $\frac{7}{8}$ inch wide. These oblong facets look downward and slightly outward. The neurapophyses are greatly compressed from side to side. The neural spine is more compressed in front than behind, the base of its posterior margin is parallel to the posterior face of the centrum; it hangs backward, and measures in the upper part $\frac{3}{4}$ inch in width. The external width of the neural arch in its middle is $1\frac{3}{4}$ inch.

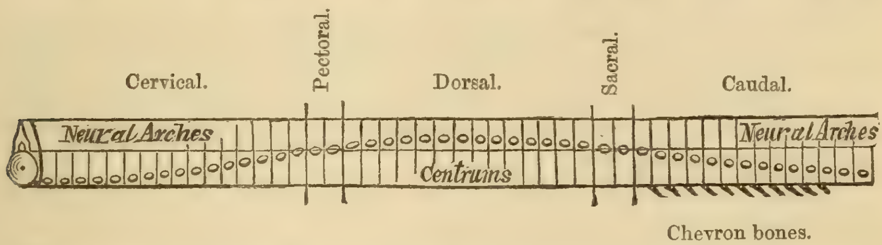
Fourteenth to seventeenth—as the articular tubercle for the rib begins to ascend the side of the centrum the tubercle becomes a little prolonged and is rounded. The eighteenth vertebra (Pl. XXIII. fig. 3) has the base of the neural arch preserved; its compressed anterior margin is nearly flush with the anterior face of the centrum, but as it ascends it extends forward. The face of the centrum is $6\frac{5}{8}$ inches wide. The articular facets for the ribs are nearly on the middle of the sides of the centrum; and the base accordingly becomes more rounded from side to side, and is nearly flat from front to back. The tubercle for the rib now steadily ascends the side of the centrum, leaving the base perfectly rounded. The nineteenth has the centrum 4 inches long at the base and $3\frac{1}{2}$ inches long superiorly (Pl. XXIII. fig. 4). The articular surface is more than usually flattened, 6 inches broad, and $4\frac{1}{2}$ inches deep. The transverse process was deep and narrow, placed posteriorly, and formed mainly by a downward and backward prolongation of the neural arch. This shows that the true neck is ended, the vertebra belonging to the two or three which form a transition between the cervical and dorsal series, which are conveniently named pectoral. The twentieth and twenty-first show similar characters; only the transverse process increases in size and depth, and rises higher.

Several of the dorsal vertebræ are so similar that one may be taken as a type (Pl. XXIII. fig. 5). It is well preserved, except that the neural spine is broken away. The centrum measures $4\frac{3}{8}$ inches in length along the visceral surface from back to front; but in the line of the neural canal it only measures a little over 3 inches. Under the neural canal the articular face is $5\frac{1}{8}$ inches deep, and as preserved is $5\frac{1}{2}$ inches wide in the middle. The vascular perforations on the base of the centrum are $1\frac{3}{4}$ inch apart; the bone between them is remarkably convex. Below the neural arch the sides of the centrum converge greatly, measuring less than 3 inches transversely. The arch shows the vertically ovate neural canal; the base of the neural spine is narrow, compressed, and directed backward; and the broken transverse processes are directed outward and upward. The height from the base of the centrum to the shoulder of the transverse process is $7\frac{1}{2}$ inches. The transverse processes are compressed from front to back, about 2 inches deep at their origin, and 1 inch wide; they are twisted so that the superior margin is inclined forward and the inferior margin inclined backward. The whole neural arch is a good deal compressed from back to front. The later dorsal vertebræ are slightly shorter, and the articular face of the centrum becomes rather smaller. The nutritive foramina become small circular pits rather further apart. In all about 40 vertebræ have been collected, of which about 14 are dorsal.

So far as can be judged from the size of the vertebræ, this species was rather larger than the *Elasmosaurus platyurus* of Prof. Cope, and is therefore the largest long-necked member of the order Plesiosauria which has been discovered.

Since different writers have different methods of fixing the limits of the several regions of the vertebral column, which results in an undesirable confusion of characters of the species described, I venture to offer the following diagram as a convenient guide to uniformity in this particular, and as representing the characters of the divisions of the vertebral column which I have described in this and other

Diagram of the Divisions of the Vertebral Column in Plesiosaurs.



The curved line of small arches shows the position of the articulation for the rib in the several regions of the body.

Plesiosauria, in so far as they depend upon the position of the articulation for the rib upon the centrum, or upon the neural arch.

Many of the dorsal ribs of *Mauisaurus Gardneri* have a strong lateral crest at the proximal end, which makes the bone subtriangular in section. The fragments have a considerable curve; but none are sufficiently perfect for description.

The bones of the pectoral arch are unfortunately imperfect. A fragment of a coracoid is 13 inches long, and 10 inches wide, as preserved; it does not show generic characters. The bones met in the median line anteriorly, as usual, but appear to have diverged posteriorly. Some fragments of scapula (?) appear to be not unlike the scapula of *Murænosaurus*, but are imperfectly preserved. Dr. Hector mentioned to me that he thought it possible for the scapulæ of *Mauisaurus* to have been convergent forward, and that they may not have been directed outward as in his figure (Trans. New-Zeal. Inst. vol. vi. 1874, pl. xxix.).

The humeri and femora have both been found. From the great size of the neck-vertebræ, and the decrease in size of the dorsal vertebræ, as they approach the sacral region, I am disposed to conclude that the humeri were larger than the femora. The humerus is 13 inches long and imperfect proximally. Midway between the proximal and distal ends the transverse width of the shaft is 7 inches. At about 4 inches from the proximal end the shaft is $3\frac{3}{4}$ inches thick; but distally it becomes compressed and is apparently to some extent crushed from above downward, though an uncompressed fragment is 3 inches in thickness. The internal aspect is concave in length, and the external aspect convex. Both lateral margins appear to have been moderately concave; but the anterior margin is imperfect distally; if preserved it would probably have made the bone $9\frac{1}{2}$ inches wide. The distal articular margin for the bones of the forearm is nearly straight; and the surface for the radius does not make an angle with the surface for the ulna. The bone was unusually massive, and relatively to the vertebræ is much longer and broader than in Dr. Hector's *Mauisaurus Haastii*.

The femur is imperfect at both ends. The fragment preserved is 13 inches long. The proximal end of the bone is nearly cylindrical and about 4 inches in diameter. The anterior margin of the bone is very slightly concave, so as to be nearly straight; the posterior outline is deeply concave.

The phalanges appear to have been compressed from above downwards and unusually long. Only one has been found (Pl. XXIII. fig. 6) imperfectly preserved; it is about $4\frac{1}{2}$ inches long, $1\frac{1}{2}$ inch wide where most constricted in the middle, and was probably 2 inches wide at the extremities.

In the lower dorsal region of the animal about a peck of ovate and rounded pebbles occurred, varying in size from a diameter of a quarter of an inch to a length of nearly two inches. They are chiefly of opaque milky quartz. Several are of black metamorphosed slate, and a few of altered fine-grained sandstone and hornstone, some of the pebbles showing a veined character, such as might be derived from the neighbouring Palæozoic rocks of the North of France. Pebbles being of such rare occurrence in the Gault, it would seem natural to account for these associated stones on the hypothesis that they were swallowed by the animal with food, as is the case with certain living reptiles and birds. If this view should be held admissible, it would suggest that as the teeth were too small for any thing but prehension, a structure analogous to a gizzard, or the stomach of an edentate, may have used these pebbles to assist in breaking up or crushing the food on which this Saurian lived.

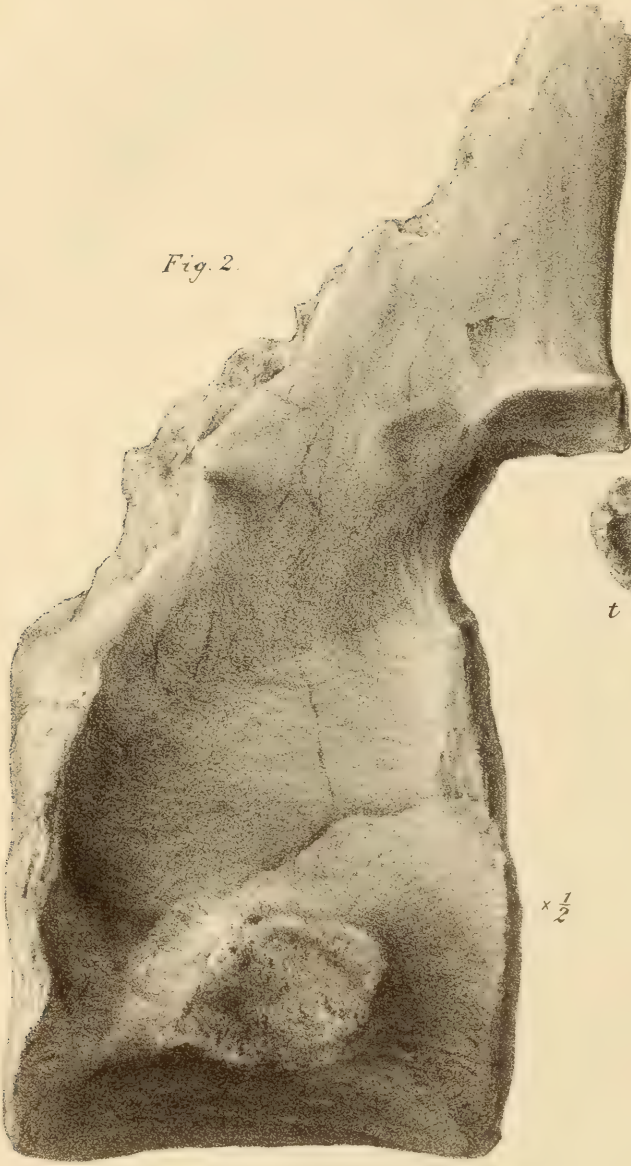
EXPLANATION OF PLATE XXIII.

Bones of *Mauisaurus Gardneri* from the Gault of Folkestone.

The figures of the vertebræ are half the natural size.

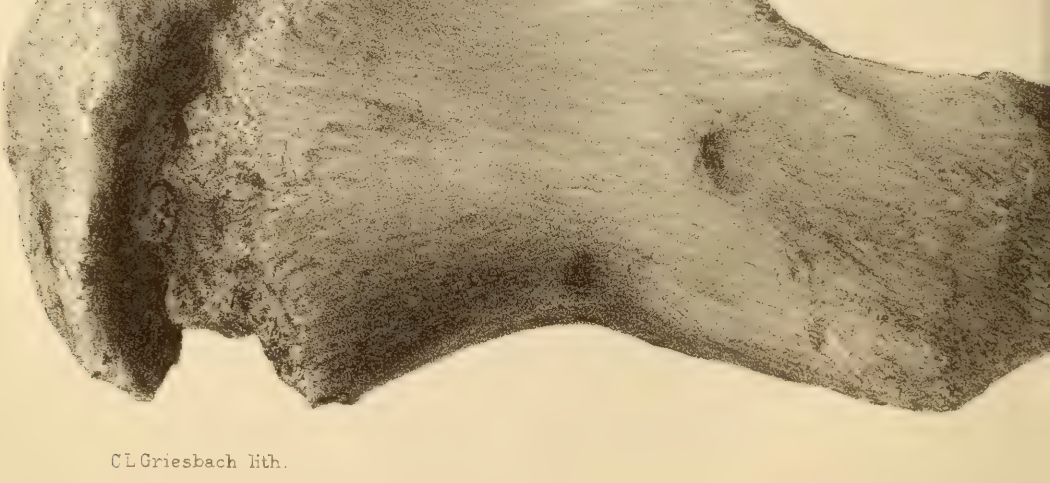
Fig. 1. Prehensile tooth, of the plesiosaurian type. *a*, crown; *b*, fang. Nat. size.
2. Middle cervical vertebra, side view.
3. Late cervical vertebra, with the pedicle (*t*) for the ribs rising above the sides of the centrum.
4. Pectoral vertebra with the pedicle for the rib formed partly by the centrum and partly by the neural arch.
5. Dorsal vertebra, showing the broken transverse processes (*t*), and base of the neural spine. In the British Museum.
6. Phalange, imperfect; natural size.

Fig. 2.



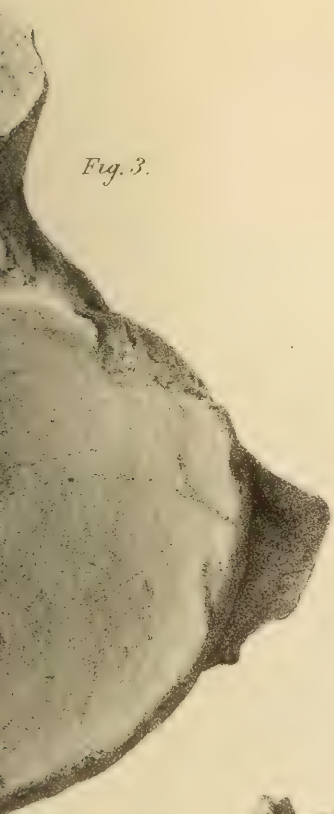
× 1/2

Fig. 6.



C L Griesbach lith.

Fig. 3.



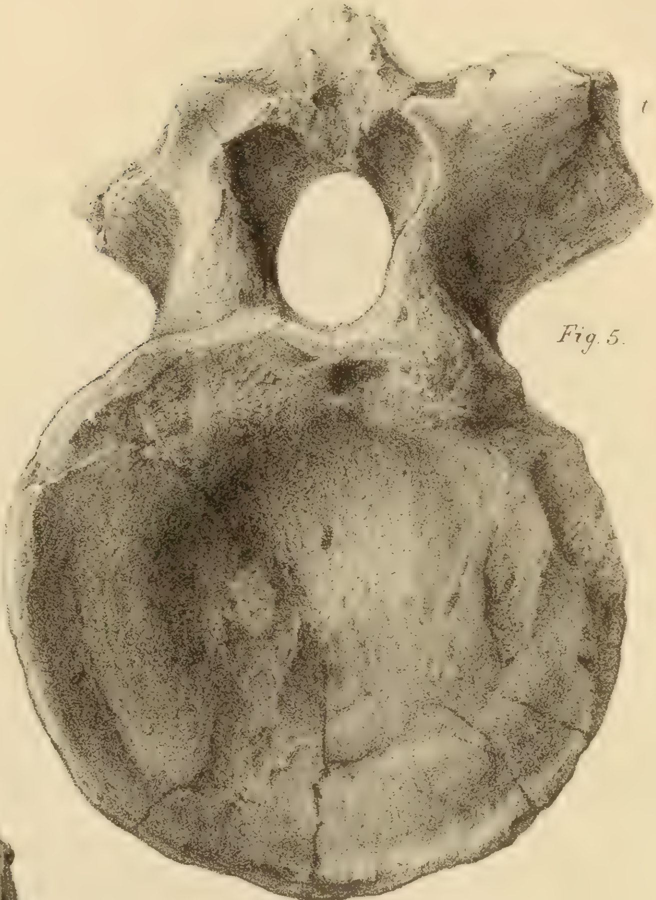


Fig. 5.

Fig. 4

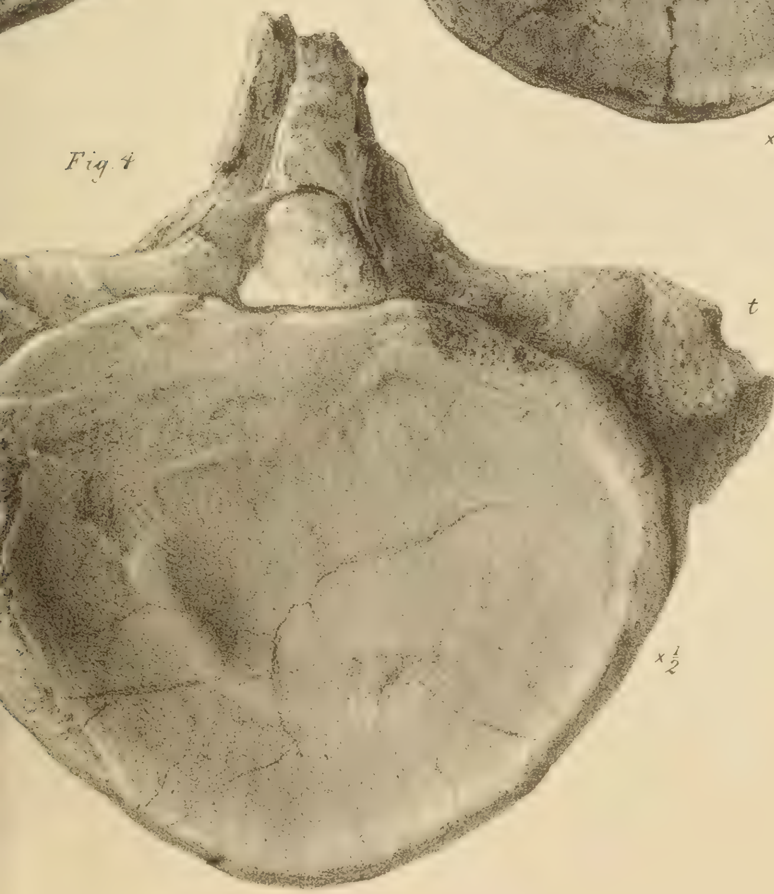
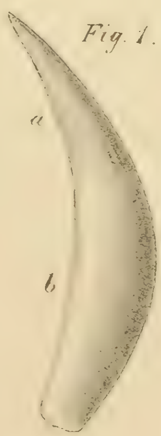


Fig. 1.



C. L. Griesbach lith.

M & N. Hanhart imp.

MAUISAURUS GARDNERI.

DISCUSSION.

Mr. GWYN JEFFREYS, with reference to the habits of the Walrus, stated, on the authority of Prof. Torell, that it feeds on the *Mya truncata*, a mollusk which lies buried in gravelly mud. In order to get this mollusk, it has to grub up the mud with its tusks, and takes up the mud and pebbles along with the *Mya* into its mouth.

Mr. J. S. GARDNER said he regretted that all the vertebræ of the Saurian had not been brought for exhibition, as the smallest of the cervical vertebræ would have shown more plainly the great disproportion existing between them and the vertebræ of the trunk, and thus have given a better idea of the great length of the neck. He remarked that the bones, when *in situ*, were very fragmentary, and some had oysters adhering to them, showing that they had been long exposed before fossilization. He stated that pebbles were exceedingly rare in the Gault, and suggested that the reptile may have been stranded, and that the pebbles became entangled in its carcass.

Mr. J. W. HULKE believed, with the author, that the remains indicated a new species of larger size than any previously found in this country. In the long, tapering neck, the lateral position of the articular head of the limb-bones, and the form and structure of the cervical ribs, he noticed resemblances to the large Kimmeridge *Plesiosaurus* (*P. Manselli*) which he brought under the notice of the Society several years ago, and which he thought would fall into Prof. Seeley's subgenus *Murænosaurus*. With regard to the pebbles, he suggested that the animal may not have swallowed them as an aid to the comminution of food in its stomach, but that they were introduced in the stomachs of fish which it had swallowed. The flesh and, subsequently, the bones of these would be digested and absorbed, whilst the indigestible stones, if the stomach of the *Plesiosaurus* was like that of Crocodiles, would be unable to pass through the small pyloric opening into the intestine, and must permanently remain in the stomach.

The AUTHOR briefly replied.

30. *On the Agassizian Genera* Amblypterus, Palæoniscus, Gyrolepis, *and* Pygopterus. By Ramsay H. Traquair, M.D., F.R.S.E., F.G.S., Keeper of the Natural-History Collection in the Edinburgh Museum of Science and Art. (Read May 9, 1877.)

What is an *Amblypterus*? What is a *Palæoniscus*? How do we distinguish them? What special reasons have we for referring any of our smaller Carboniferous fishes to the one or the other genus? These are questions to which, I fear, few collectors of Carboniferous fossils could offer very definite answers, and for the very good reason that the definitions of these two genera, which are found in the works usually consulted by palæontologists, are, it must be owned, of a somewhat unsatisfactory nature.

Gyrolepis and *Pygopterus* also are terms frequently met with in lists of fossils from British Carboniferous localities. But by what characters do we distinguish *Gyrolepis* as a genus? Or what are the special marks which justify us in assuming any of our larger Carboniferous Palæoniscidæ to be generically identical with the *Pygopteri* of the Magnesian Limestone and Kupferschiefer? Here, again, we shall find our subject enveloped in an obscurity which can only be dispelled by fresh and careful original observation in a field which, since the days of the illustrious Agassiz, has been comparatively little trodden.

The present communication embodies the results of my own recent investigations into these subjects, though there is room and need for much additional inquiry, as is self-evident from the nature of the remains with which we have to deal.

Amblypterus *and* Palæoniscus.

The definition of *Amblypterus* given by Agassiz in his "Tableau synoptique" is as follows:—

"Toutes les nageoires très-larges et composées de nombreux rayons, P. très-grandes; A. large; D. opposée à l'intervalle entre les V. et l'A.; point de petits rayons sur le bord des nageoires, excepté au lobe supérieur de la queue. Ecailles médiocres" *.

Of *Palæoniscus*, on the other hand:—

"Toutes les nageoires médiocres, de petits rayons sur leurs bords; D. opposée à l'espace entre les V. et l'A. Ecailles médiocres; quelques espèces en ont d'assez grandes, et le corps plus large et plus court que les autres. Il y a toujours de grosses écailles impaires en avant de la D. et de l'A" †.

Both genera are elsewhere stated to have the teeth "en brosse extrêmement fine" or "en brosse" ‡. The statement as to the

* Poissons Fossiles, vol. ii pt. 1, p. 3. † Ibid. p. 4.
‡ Ibid. p. 30, p. 42 &c.

absence of fulcra on the fins of *Amblypterus*, save on the caudal, was corrected a few pages further on, though they are here said to be "si extraordinairement petits qu'on peut à peine les entrevoir à l'œil nu" *. Large azygos scales in front of the median fins are also declared to exist in *Amblypterus*; so that the only differences remaining between that genus and *Palæoniscus* are the large size of the fins and the minuteness of the fulcra in the former—differences, indeed, not of a very substantial character, as will be presently shown.

As regards the structure of the fins, their rays were believed by Agassiz to be covered with scales in some species of *Palæoniscus* (*P. Voltzii*, *Blainvillei*), not so in others (*P. Freieslebeni*), and in *Amblypterus* †—a difference which, if it did really exist, would certainly be sufficient, not to distinguish *Amblypterus* from *Palæoniscus*, but to demand the separation of the latter into two distinct genera. The scaly appearance of the fins in some so-called *Palæonisci*, however, is entirely deceptive, and arises solely from the form and arrangement of the minute joints of the rays themselves.

In the works of most other authors, such as Pictet, Giebel, and Quenstedt, we shall likewise fail to find any thing satisfactory as regards the discrimination of the genera in question—though Goldfuss, in 1847 ‡, pointed out that *Amblypterus macropterus*, Ag. (Bronn, sp.), possessed large conical teeth, its dentition being, therefore, not "en brosse," according to the previously received definition of the genus. A similar observation has also been more recently made by Messrs. Hancock and Atthey in the case of *Palæoniscus Egertoni*, Ag. § Agassiz himself had previously described the teeth of *Amblypterus punctatus* as being "en cônes obtus." The only distinction we can lay hold of at all is the large size of the fins in *Amblypterus* and their medium size in *Palæoniscus*; but in this respect the greatest differences exist in the large assemblage of species which have been referred to the latter genus. And as regards this point, the vagueness of Agassiz's own ideas is well illustrated by the arbitrary manner in which he distributed certain British Carboniferous species between the two genera; for the fins of his *Palæoniscus striolatus* and *Robisoni* are proportionally just as large, and their fulcra just as minute as those of his *Amblypterus neuropterus*, and one of the two species which he included under the name of *Amblypterus punctatus*; in fact the resemblances which those fishes bear to each other are so close that their being placed in different genera is simply inadmissible.

Only by Troschel || was a bold attempt made to define these genera upon strictly zoological principles, though only with partial

* Poissons Fossiles, vol. ii. pt. 1, p. 29.
† Ibid. pp. 42, 43.
‡ Beiträge zur vorweltlichen Fauna des Steinkohlengebirges.
§ Ann. & Mag. Nat. Hist. (4) vol. i. pp. 358, 359.
|| "Beobachtungen über die Fische in den Eisennieren des Saarbrücker Steinkohlengebirges." Verh. naturh. Ver. preuss. Rheinl. lxiv. 1857, pp. 1–18.

success. He showed, however, very clearly that Agassiz's genus *Amblypterus* contained at least two very distinct types:—first, that of *A. macropterus*, in which the scales are striated, and the teeth large and conical, with an outer row of smaller ones, and for which he proposed the new generic term *Rhabdolepis*; second, that of *A. latus*, in which the scales are smooth, and the teeth minute and slender, without interspersed laniaries; and to this he limited the name *Amblypterus*, the character of the dentition being more in accordance with the original definition of the genus. *A. Agassizii* Münster, *A. striatus*, Ag., and *A. ornatus*, Giebel, he considered as probably belonging to *Rhabdolepis*; while, as regards *A. neuropterus* and *punctatus*, Ag., he expressed a suspicion that they might perhaps appertain to new and peculiar genera. Palatal teeth were found by him both in *Rhabdolepis* and *Amblypterus* proper; and this character he thought might possibly serve to separate *Amblypterus* from *Palæoniscus* on the supposition that they are absent in the latter. The following summaries of characters are given at the conclusion of his paper:—

"*Rhabdolepis*, Troschel. Grosse conische Zähne in einer Reihe in den Kiefern; hechelförmige Gaumenzähne; Schuppen mässig und gestreift. Flossen gross.

"*Amblypterus*, Agass., Troschel. Zähne hechelförmige in den Kiefern; zahlreiche Gaumenzähne. Schuppen mässig und glatt. Flossen gross mit kleinen Fulcra.

"*Palæoniscus*, Agass. Hechelförmige Zähne in den Kiefern. Keine Gaumenzähne? Flossen mässig mit deutlichen Fulcra. Schuppen gestreift oder glatt."

The distinction here drawn between *Rhabdolepis* and *Amblypterus* cannot be gainsaid; but as regards *Palæoniscus* it is simply impossible to prove the *absence* of palatal teeth in the large assemblage of species referred to that genus, if, indeed, in any of them, considering the state of preservation in which their heads usually occur. Other characters must then be sought whereon to found a satisfactory diagnosis, or to throw light on the question which naturally arises as to whether the Agassizian *Palæoniscus* may not, like his *Amblypterus*, include more than one generic type. Troschel, indeed, concludes his paper with the observation, "Es ist wahrscheinlich dass nach Analogie mit *Amblypterus*, auch die Gattung *Palæoniscus* in zwei Gattungen gespalten werden muss, je nachdem die Schuppen gestreift oder glatt sind."

Nevertheless, in a recent work *, Professor J. V. Carus has again fused together *Amblypterus* and *Rhabdolepis*, to which he also adds as synonyms *Gyrolepis*, *Colobodus*, and *Tholodus*. His definitions are as follows:—

"*Amblypterus*, Ag. (incl. *Gyrolepis*, Ag., *Rhabdolepis*, Troschel, *Colobodus*, Ag., *Tholodus*, H. von Meyer). Schwanz kurz, Flossen gross, vielstrahlig; unterer Rand des Schwanzes mit doppelten Fulcralreihen. Kohlenformation bis zur Trias. Arten: *A. macropterus*, Ag., u. a.

* Handbuch der Zoologie, Bd. i. 2te Hälfte, p. 591 (Leipzig, 1875).

"*Palæoniscus*, Ag. (*Palæothrissum*, Blainv.). Flossen nur mittelgross; Strahlen stark; Kopf gewöhnlich aufgetrieben; Fulcren wie *Amblypterus*. Kohle bis Trias. Arten: *P. Freieslebeni*, Ag., *P. comptus*, Ag., u. a."

Now, if by "Schwanz" is meant the caudal fin with its prolongation of the body along the upper lobe, that part is certainly no shorter in the Agassizian *Amblypteri* than in his *Palæonisci*; nor, generally speaking, is the head more "aufgetrieben" in the one than in the other. In describing the *Amblypterus Agassizii* of Münster, Agassiz himself states that "la mâchoire supérieure forme une saillie arrondie au-dessus de la mâchoire inférieure, saillie qui résulte probablement, comme dans les *Palæoniscus*, du développement considérable de l'ethmoïde. Jusqu'ici j'avais cru ce caractère exclusivement propre aux *Palæoniscus*, n'ayant vu que peu d'exemplaires du genre *Amblypterus* dont la tête fut assez bien conservée pour ne me laisser aucun doute sur sa forme"*. Differences of dentition being altogether ignored, we are thus thrown back on the size of the fins and the number of their rays, the unsatisfactory nature of which, as diagnostic marks, I have already alluded to; in fact, if other characters are not to be taken into account, it may become a very delicate matter to decide as to whether a given small heterocercal fish has fins large enough for an *Amblypterus* or small enough for a *Palæoniscus*!

Zoologists, however, will hardly be prepared to accept the ideas of generic comprehensiveness expressed in the reunion of *Rhabdolepis* with *Amblypterus*, any more than the location by Prof. Carus of the Palæoniscoid fishes (with the exception of *Cheirolepis*) among the Lepidotini as a mere "subfamily;" for if *Rhabdolepis* be not generically distinct from *Amblypterus*, neither is *Palæoniscus*, nor *Acrolepis*, nor *Elonichthys*, and in fact, to be consistent, nearly the whole of the Palæoniscidæ would have to be merged in one huge genus. But if, on the other hand, we are to deal (according to our information) with extinct as with living forms, then the line of investigation begun by Sir Philip Egerton and by Troschel must be continued, the generic characters of *Amblypterus* and *Palæoniscus* reinvestigated and more accurately defined, their species redistributed, and, if need be, new genera instituted for those which cannot be included in the one or the other, according to the conception of a "genus" current among modern zoologists.

The results to which I have arrived, after a careful study of a very large number of specimens of Palæoniscidæ, both British and foreign, seem to me certainly to require still further modifications of the prevalent ideas respecting the characters and limits of the genera in question, as well as those regarding the extent of their stratigraphical disibution.

* Poissons Fossiles, vol. ii. pt. 1, pp. 105–106.

Amblypterus.

The species referred to *Amblypterus* in the "Poissons Fossiles" certainly fall into at least five distinct types:—

I. Type of *A. latus*, Ag. (Genus *Amblypterus*, Ag., restricted). The body is rather deep; the scales smooth; the fins large and many-rayed, with minute fulcra; the dorsal placed a little further back than in the next type; the caudal powerful. The suspensorium is not so oblique as in the Palæoniscidæ in general; hence the position of the operculum is more vertical, and the gape proportionally less extensive. There is no small plate (suboperculum) intercalated between the operculum and the interoperculum. The teeth are minute and very slender; there are no large conical laniaries; hence the term "en brosse" is here more applicable than in any other genus of Palæoniscidæ.

To this type the title *Amblypterus* should be strictly limited as recommended by Troschel; but I must also add that I am unable to see any tangible grounds of distinction between these forms and the smooth-scaled *Palæonisci* of the type of *P. Duvernoyi*, whose reception into the genus *Amblypterus* is therefore to be recommended. To this point I shall, however, return further on under *Palæoniscus*. *A. latus* and *lateralis* are characteristic fossils of the Lower Permian strata of Saarbrücken and Lebach; and the other species, which I propose to unite with them generically, also occur in strata of similar age in Germany, Bohemia, and France; so that *Amblypterus* must be deleted from the list of Carboniferous genera, in spite of the length of time during which geologists have been accustomed to look upon it as one of the characteristic forms of the Coal-period.

II. Type of *A. macropterus*, Ag. (Genus *Rhabdolepis*, Troschel). The scales are moderate, finely striated; the fins large, many-rayed, with minute fulcra; the dorsal placed nearly opposite the interval between the ventrals and the anal, the base of the ventrals not specially extended; the caudal powerful. In each jaw there is a row of stout conical laniary teeth, external to which is a series of smaller ones. The dentition, thus quite conformable to that in *Acrolepis* or *Pygopterus*, would alone be sufficient to demand the separation of these forms from the true *Amblypteri*; but careful examination reveals still further differences in the structure of the head. The suspensorium is very oblique, the operculum small; and between it and the square-shaped plate hitherto considered as "suboperculum," but which I have now come to look upon as interoperculum, there is another of a narrower form (suboperculum).

For fishes of this type, which have as yet only occurred in strata of Lower-Permian age, the genus *Rhabdolepis* of Troschel must be maintained. The presence of the subopercular plate distinguishes this genus from *Elonichthys* of Giebel, the form and extent of that plate as well as the shorter base of the ventral fins from *Cosmoptychius* (mihi).

III. Type of *A. striatus*, Ag. (Genus *Cosmoptychius*, Traquair).

The body is rather deep; the scales and cranial bones striated; the fins are large, many-rayed; their fulcra small; the dorsal is nearly opposite the interval between the ventrals and the anal; the base of the ventrals is long. The operculum is narrow and pointed below; a small triangular subopercular plate, whose anterior superior angle is produced upwards in a narrow linear process lying along the anterior margin of the operculum for some distance, is intercalated between the last-named bone and the anterior part of the upper margin of the interoperculum. The laniary teeth are sharp, conical, moderate in size, and pretty closely set, with a series of smaller teeth outside.

The peculiar characters of the *Amblypterus striatus* of Agassiz render necessary the institution for it of a new genus, which I propose to denominate *Cosmoptychius*, being in some respects intermediate between *Rhabdolepis* and *Elonichthys*, but differing from both in the extended bases of the ventral fins. In the last respect, as well as in the form of some of the bones of the head, it resembles *Cheirolepis*, though of course differing very widely from that genus in other respects. As yet we are only acquainted with one species of *Cosmoptychius*, which has been found only in the Lower Carboniferous strata (Calciferous Sandstone series) of the neighbourhood of Edinburgh.

IV. Type of *A. nemopterus* (Genus *Elonichthys*, Giebel). The scales are moderate, striated or striato-punctate; the median fins, and sometimes also the paired fins, are large and many-rayed; their fulcra small; the rays of the pectoral articulated; the base of the ventrals not extended; the dorsal situated nearly opposite the interval between the ventrals and the anal; the caudal powerful. The suspensorium is very oblique; there is no subopercular plate intercalcated between the operculum and the interoperculum. There are large conical laniary teeth intermixed with and internal to a series of smaller ones.

To this type belong the *A. nemopterus* of Agassiz, and one of the two species which he confounded together under the name of *A. punctatus* (Poiss. Foss. Atlas, vol. ii. tab. 4 *c.* figs. 3 and 5). Between these and at least two others referred to *Palæoniscus* by Agassiz, viz. *P. striolatus*, Ag., and *P. Robisoni*, Hibbert, it is, as already mentioned, simply impossible to draw any generic distinction. The same must be also said of his "*Pygopterus*" *Bucklandi*, which resembles *Pygopterus* in hardly any thing save its large size. *Palæoniscus Egertoni*, Ag., agrees also very closely, save in the structure of the pectoral fin, in which the principal rays do not commence to be articulated for a little distance from their origin. Of *Amblypterus Portlockii*, Egerton, I have only seen fragments; but, so far as these go, they seem to show that this species belongs to the same type with the others named above, as probably also do *Palæoniscus Brownii* of Jackson and *P. peltigerus* of Newberry.

As these fishes can be included in none of the three genera already defined, nor yet in *Palæoniscus*, in the sense in which that generic term must now be employed, it remains to be inquired if they constitute a new generic type or may be received into any other genus already known. If we now turn to the genus *Elonichthys* of Giebel*, we shall find that that author characterized the fishes (*E. Germari*, *crassidens*, and *lævis*, from the Coal Measures of Weltin, near Halle) which he referred to it, as standing in the middle between *Palæoniscus* and *Amblypterus*, allied to the former by their fulcrated fins, and to the latter by the large size of these organs, as well as by the aspect of their thick striated scales, "which remind us of certain *Amblypteri*." From *Palæoniscus*, however, he considered them to differ in the want of the "scaly covering on the fins," and from both in the dentition, which consisted of an external series of minute teeth comparable to the "Bürstenzähne" of *Amblypterus*, between which larger ones of a slender conical shape were seen, "wie ich dieselben weder bei den Palæonisken noch Amblypteren finde." But, unfortunately for this diagnosis, the fins of *Palæoniscus* are no more covered with scales than those of any other genus belonging to the family, nor are the fulcra wanting in any of the species which have been classed under *Amblypterus* †, and, finally, it has been shown that more than one of Agassiz's "*Amblypteri*" possess large laniary teeth quite similar to those of *Elonichthys*. But although Giebel's conceptions of its relationship to other Palæoniscoid forms were thus somewhat imperfect, I have convinced myself, by a careful examination of the type specimens in the museum of the University of Halle, that the genus *Elonichthys* is quite tenable, and that to it the *Amblypterus nemopterus* of Agassiz and the other forms referred to above as specially allied to that species are properly referable. Though closely resembling *Rhabdolepis*, it differs in the absence of the subopercular plate; the operculum is also usually more largely developed; while from *Amblypterus*, as restricted by Troschel, the dentition and the greater obliquity of the suspensorium are obvious marks of distinction. From *Palæoniscus*, to which some of the species were referred to by Agassiz, it is distinguished by the large size of the fins, and by the possession of more differentiated laniary teeth in the jaws. Nearly related to *Acrolepis*, it differs from that genus in the anterior covered area of the scales being reduced to a very narrow margin; but from *Pygopterus* it is widely separated by the

* Fauna der Vorwelt, vol. i. pt. 3, pp. 249–251.

† It is remarkable that Agassiz's error in the 'Tableau Synoptique,' as to the absence of fin-fulcra in *Amblypterus*, "except on the upper lobe of the tail," though corrected by himself in his general description of the genus, has nevertheless been repeatedly copied into the works of subsequent writers, such as Pictet (Pal. 2nd ed. vol. ii. p. 181), Eichwald (Leth. Rossica).

Giebel, it is true, in his definition of *Amblypterus* (op. cit. p. 251), does not mention the absence of fulcra as a character; but nevertheless on this ground ("durch die Anwesenheit der Fulcra nur an der Schwanzflosse") he transfers Agassiz's *Palæoniscus Duvernoyi* to this genus. In this transference I quite agree with him, as will be seen further on, but not on that account, the fulcra being obviously present in well-preserved fins of that species. This has been vigorously pointed out by Troschel, who, referring to a specimen in the Bonn Museum, speaks of the fulcra on its anal fin as being "so schön sichtbar, wie man es nur wünschen kann" (*op. cit.* p. 17).

form of the anal fin and the structure of the pectoral. In *Pygopterus* the dorsal is placed nearly opposite the commencement of the anal, commencing only a little in advance of the latter, which is possessed of a remarkably extensive base, being produced posteriorly in a fringe-like manner; the principal rays of the pectoral are also unarticulated till towards their terminations. It is true that in *E. Egertoni* and one or two other species still undescribed, these rays are not articulated to the same extent as in *E. nemopterus*, &c.; but I feel rather reluctant, on that ground alone, to multiply the number of genera.

V. Type of *A. punctatus*, pars (Genus *Gonatodus*, Traquair). Under the name of "*Amblypterus punctatus*" three imperfect specimens of fish from the shales of Wardie, near Edinburgh, were figured by Agassiz in the 'Poissons Fossiles.' One of these is a head with the anterior part of the body (Atlas, vol. ii. pl. 4 *c*. fig. 4); the second (*ibid.* fig. 5) wants the head, shoulders, and extremity of the tail; the third (*ibid.* fig. 3) displays the entire caudal fin, but is obliquely cut off just in front of the dorsal and anal. But a comparison of these specimens with an extensive series of entire fishes from the same beds establishes the fact that the *Amblypterus punctatus* of Agassiz was founded upon fragments of two distinct fishes, the specimen showing the head, but without the hinder part of the body, being not only specifically, but even generically, distinct from the other two, in which we have the hinder part of the body without the head. The latter belong to the genus *Elonichthys* and to a species closely allied to *E. striolatus* and *E. nemopterus*, which I propose to call *E. intermedius*; but for the former the peculiarity of the dentition requires the institution of a new genus, for which I propose the name *Gonatodus* *, retaining for the type species the original term "*punctatus*." For although the enlarged representations of scales given by Agassiz (*tab. cit.* figs. 6–8) are taken from one of the specimens referable to *Elonichthys*, yet the name is indeed applicable to both species; and as the characters of the head and teeth are those which specially distinguish *Amblypterus punctatus*, according to Agassiz's conception, from his *A. nemopterus*, with which he contrasted it as occurring in the same beds, it is, I think, more appropriate to retain his specific name for the fish of which those peculiarities are characteristic.

The peculiar dentition of *Gonatodus* was first correctly described by Mr. R. Walker in a fish from the shales of Pitcorthie, Fifeshire, to which he gave the name of *Amblypterus anconoæchmodus* †, a species which is evidently most closely allied to the *G. punctatus* of Wardie, and possibly identical with it. I have, however, enjoyed no opportunity of comparing with the latter any actual specimens of the Pitcorthie fish.

The teeth of *G. punctatus* are from $\frac{1}{20}$ to $\frac{1}{24}$ inch in length in specimens measuring from 5 to 6 inches: their form is cylindrical, but

* γόνυ, knee, and ὀδούς, tooth.

† Trans. Edinb. Geol. Soc. vol. ii. pt. 1 (1872), pp. 118–124.

suddenly narrowing near the extremity to an acutely pointed apex. Each tooth is also first inclined a little inwards, then bent outwards at an obtuse angle; finally, by another curvature, the apex comes to point upwards in the mandibular teeth, downwards in those of the maxilla. The teeth are also closely set in one row of nearly uniform size: there are certainly no larger teeth inside this row; nor have I seen any trace of smaller ones outside. Mr. Walker describes the teeth of the lower jaw of the Pitcorthie fish as "placed alternately one close to the outside margin; the next to it is fully half its own thickness further in, and so on the whole length of the bone." Of this arrangement I have seen nothing more in the Wardie specimens than occasional indications. By Agassiz the teeth of *G. punctatus* were described as being "en cônes obtus," an appearance due to their being only seen in antero-posterior vertical section in the specimen he examined, their peculiar flexures and pointed conical apices being there invisible. Nor do I find any evidence that they were arranged "sur plusieurs rangées," at least as far as the maxilla and dentary of the mandible are concerned, though it is probable that additional teeth were present in the palate.

The dorsal fin in *Gonatodus* is placed rather further back than in *Elonichthys*, the middle of its base being opposite the commencement of the anal; both dorsal and anal are large and triangular; the base of the ventrals is short. All the fins are composed of very numerous rays, which are closely jointed, including in that respect also the principal rays of the pectoral. The suspensorium is not so oblique as in most genera of Palæoniscidæ, but more so than in *Amblypterus*.

A new species of this genus (*G. macrolepis*, Traq.), characterized by its very large and nearly smooth scales, has recently turned up in the Blackband Ironstone of Gilmerton. As yet the genus is only known from the lower division of the Carboniferous formation in Scotland.

I regret that I have had no opportunity of forming any independent opinion as to the affinities of the Triassic species *Amblypterus Agassizii* of Münster, *A. ornatus* and *latimanus* of Giebel, or of that from the cupriferous sandstones of Kargala in Russia, named *A. orientalis* by Eichwald, and can only say regarding them that, from the descriptions given, they do not seem to belong to the genus *Amblypterus* as restricted by Troschel. *A. Olfersi* has been already referred by Agassiz himself to the Teleostean genus *Rhacolepis*.

Palæoniscus.

The genus *Palæoniscus* has been made to include an immense number of species, which are, indeed, referable to more than one generic type, some of them actually not being Palæoniscidæ at all. Authors have, in point of fact, been only too apt to refer nearly every small rhombic-scaled fusiform-shaped ganoid fish from Upper Palæozoic rocks to *Palæoniscus*, without inquiring too narrowly into how far its structure agrees with that of the original type of the genus, and have even sometimes overlooked distinctions of more than generic importance.

The species of *Palæoniscus* enumerated and described by Agassiz in the 'Poissons Fossiles' are referable to at least seven different types.

I. Type of *Palæoniscus Freieslebeni*, Ag. (Genus *Palæoniscus* restricted). The body is elegantly fusiform; the scales moderate, sculptured; the fins of comparatively small size; the dorsal situated opposite the interval between the ventrals and the anal; the rays of the pectoral are articulated; the fin-fulcra are small but easily recognizable. The suspensorium is very oblique, the operculum and interoperculum broad; the mandible is slender. The teeth are small, conical, sharp, and of different sizes, the smaller ones being more externally placed, but without specially prominent laniaries. The species here included are *Palæoniscus Freieslebeni*, *magnus*, *macropomus*, *elegans*, *comptus*, *longissimus*, and *macrophthalmus*. *Palæoniscus*, if limited to the species just enumerated, becomes intelligible as a genus; otherwise it seems to me, as already stated in the preliminary part of this paper, that the conception of a *Palæoniscus* becomes so vague that no tangible ground of distinction can be found between it and *Amblypterus* and many other genera of the family. It is most closely allied to *Elonichthys*; but from that genus it is distinguished by the small size of the fins, and by the dentition, in which the differentiation of "laniaries" has not proceeded so far. The teeth, however, are not "en brosse," as described by Agassiz, though their small size sufficiently accounts for his use of the term; probably, also, they were not very perfectly exhibited in the specimens then at his disposal; indeed in those from the German Kupferschiefer they are rarely seen at all. Agassiz's description of them as being "en brosse," and also "si excessivement petites qu'il est très-rare de pouvoir les distinguer"*, has been rather severely criticized by Messrs. Hancock and Atthey; it must, however, be borne in mind that the species (*Egertoni*) in which they correctly described the teeth as being "disposed in two distinct rows, one within the other, much in the same fashion as in *Megalichthys* and *Rhizodopsis*, but still much more like that which obtains in *Pygopterus*, in which the teeth are likewise arranged in two rows—one being of large laniary teeth, the other of small external ones," is not a true *Palæoniscus*, but is more properly referable to *Elonichthys*. The passage referred to was also written by Agassiz in special reference to the species occurring in Continental Permian strata, and before he became acquainted with those Carboniferous forms with conspicuous laniaries which he somewhat incorrectly referred to the same genus.

As above restricted, the genus *Palæoniscus* must meanwhile be considered as limited to the Permian formation, though it has hitherto been looked upon as common also to the subjacent Carboniferous rocks. It will presently be seen that the so-called

* Poissons Fossiles, vol. ii. pt. 1.

Carboniferous *Palæonisci* all belong to types essentially distinct from that of *P. Freieslebeni*.

II. Type of *Palæoniscus Duvernoyi*, Ag. (Genus *Amblypterus*, Ag.). This includes fishes with mostly rather deep bodies arcuated in front of the dorsal fin, which is situated rather further back than in the true *Palæonisci*; the median fins are large; the tail large and powerful; the scales usually smooth; the suspensorium only slightly oblique; the teeth probably very minute. There must be included (besides the Agassizian species *P. Duvernoyi*, *wratislaviensis*, and *lepidurus*), the *P. dimidiatus*, *elongatus*, *tenuicauda*, *gibbus*, and *opisthopterus* of Troschel, the *P. Gelberti* of Goldfuss, the *P. decorus*, *arcuatus*, and *Beaumonti* of Egerton, and, I think, also the *P. Rohanni*, *caudatus*, *obliquus*, *Reussii*, and *luridus* of Heckel. *P. minutus*, *angustus*, *Voltzii*, and *Blainvillei* of Agassiz seem to be allied forms, though the latter especially may possibly be the type of still another genus.

Between these species and the smooth-scaled *Amblypteri* of Saarbrücken and Lebach I can, as already stated, see no tangible grounds of generic distinction, though in some (e. g. *P. decorus*) the fins are rather smaller and their fulcra more prominent. But the slight obliquity of the suspensorium, the general form of the body, the position of the fins, and the aspect of the squamation are similar in all. As regards the scales, they are mostly smooth, or show only slight concentric lines; in some, however (e. g. *P. Gelberti*, *P. Beaumonti*), those of the front of the flank display a certain amount of ornamentation. They are certainly not *Palæonisci* in the strict sense of the term: and until at least their cranial structure and dentition are more fully elucidated, they are better classed with *Amblypterus* than with any other genus. Giebel had, indeed, previously proposed to transfer *P. Duvernoyi* to *Amblypterus*, but, unfortunately, on the untenable ground that the fulcra were absent in it except on the upper lobe of the tail.

All these species are from strata similar in age to the beds at Saarbrücken &c., in which the typical *Amblypteri* occur, and which are now referred by continental geologists to the Lower Permian (*unteres Rothliegendes*). Even the fish-bearing schists of Autun, characterized by *Palæoniscus Blainvillei*, have ceased to be reckoned as appertaining to the 'Terrain houiller.'

III. Type of *P. striolatus*, Ag. (Genus *Elonichthys*, Giebel). Here are included *P. striolatus*, *Robisoni*, and *Egertoni*, fishes with large median fins, sculptured scales, powerful tail, very oblique suspensorium, and, as regards the dentition, possessed of a row of distinct conical laniaries internal to a series of smaller teeth. It is difficult to conceive why Agassiz placed these species in the genus *Palæoniscus*, while at the same time he described, as has been already shown, certain closely allied forms from the Wardie shales as *Amblypteri*. They are all, in my opinion, referable to the genus *Elonichthys* of Giebel. (See also under type of *Amblypterus nemopterus*, p. 553.)

IV. Type of *Palæoniscus ornatissimus*, Ag. (Genus *Rhadinichthys*, Traquair). I had long suspected that a very beautiful species from Burdiehouse was identical with the *P. ornatissimus*, Agassiz; and a few days ago I obtained two of the original specimens of that species, and found that one of them, at least, certainly confirmed my opinion. It is the type of a group including *P. carinatus*, Ag., a species described from a very imperfect specimen from the Wardie shales now in the museum of the Royal Society of Edinburgh. Examples in a much better state of preservation, however, have subsequently turned up in the same locality. The body is slender, elegantly shaped; the scales are rather large, especially on the flank; the median fins are large in proportion to the size of the fish; the dorsal is situated nearly opposite the anal; the caudal body-prolongation is delicate. I have had no satisfactory view of the dentition or of the structure of the pectoral fin in this species; but its general aspect leads me to class it along with the *Palæoniscus ornatissimus*, Ag., and *Palæoniscus Wardii*, of Prof. Young, recently briefly described by Mr. Ward, of Longton *, as constituting a new genus, *Rhadinichthys*. The characters of generic importance displayed by the two last named species are as follows:—The body is comparatively slender; the suspensorium is very oblique; the jaws are armed with a row of incurved conical laniaries, outside which there is a series of smaller teeth; the principal rays of the pectoral fin are, as in *Pygopterus* and *Oxygnathus*, unarticulated till towards their terminations; the dorsal is situated rather far back, nearly opposite the anal; the caudal body-prolongation is comparatively delicate. There are, besides these, several other new species from British Carboniferous strata referable to this type, the description of which I hope soon to be able to overtake; in some of these the scales are nearly smooth, as in *R. carinatus*, in others elaborately ornamented.

Palæoniscus Albertii, of Jackson, seems to me to be allied to *R. carinatus*; but more especially so, judging from the drawings, is his *P. Cairnsii*, and some of the other small Palæoniscidæ from the Coal Measures of New Brunswick, figured, but not described, by the same author †. All the species which I propose to include under *Rhadinichthys* are from Carboniferous strata.

The three remaining types included by Agassiz in *Palæoniscus* must be altogether excluded from the family Palæoniscidæ.

V. Type of *Palæoniscus fultus*, Ag. (Genus *Ischypterus*, Egerton). This Triassic species, in which the caudal body-prolongation is considerably more reduced than in the Palæoniscidæ, the tail consequently showing the first approach to the semiheterocercal form, and whose general structure, including the osteology of the head, betrays a strong affinity to *Semionotus*, has been already separated by Sir Philip Grey-Egerton under the name of *Ischypterus* ‡. Besides *Ischypterus fultus*, Ag., sp., there are here included *I. Agassizii*, *I. macropterus*, *I. latus* (= *Eurynotus tenuiceps*, Ag.), and

* North Staffordshire Naturalists' Field Club, Addresses and Papers (Hanley, 1875), pp. 239–240.

† Report on the Albert Coal Mine, New Brunswick.

‡ Quart. Journ. Geol. Soc. iii. 1847, p. 279; ibid. vi. 1850, p. 8.

I. ovatus of W. C. Redfield, species originally referred by that author also to *Palæoniscus*, though he was not unaware of their essential differences from that genus, and of the likelihood of their being eventually separated. For in alluding to the stout character of the fins and their insertions, whence the specific name *fultus*, given by Agassiz, he says that "this character is also found to pertain in a greater or less degree to all the American species of the genus, and would perhaps warrant their separation from the *Palæonisci*" *. He notices, further, the great strength of the fulcra, their comparatively small number, and unequal length and inclination, and, as regards the tail, that the scales of the body are prolonged into the upper lobe, "but to a more limited extent than in the European species of the genus." The small extent of the gape has also been mentioned by Sir Philip Grey-Egerton.

Ischypterus was classed by Sir Philip Grey-Egerton among the Ganoidei Heterocerci (= Lepidoidei Heterocerci, Ag.) along with *Palæoniscus* and *Amblypterus*; more recently, however, it has been, by Prof. J. V. Carus, disassociated from the Palæoniscidæ and placed among the Sauroidei as remodelled by Dr. Andreas Wagner. But as I have hitherto seen no detailed account of its structure, I may here give a few particulars concerning *I. latus*, which will clearly show how widely this genus deviates, not only from *Palæoniscus*, but from the entire group of Palæoniscidæ.

In *Ischypterus* the body is rather deep, and strongly arcuated in front of the dorsal fin; the scales are rhomboidal and smooth; but along the middle line of the back, from the occiput to the dorsal fin, there extends a row of peculiarly shaped median scales, like those in *Semionotus Bergeri*, Ag., and *Lepidotus minor*, Ag., these being somewhat spur-shaped, with posteriorly directed points, and imbricating over each other from before backwards. They were pointed out by Mr. W. C. Redfield, who says of them that they were "sometimes mistaken for an anterior comblike dorsal." The caudal fin is comparatively short and small; it is hardly cleft, being only somewhat concave behind, and is, moreover, nearly symmetrical in external form, the upper projecting point only passing a little further back than the lower. The prolongation of the body-scales along the upper margin of the fin is very narrow and rapidly attenuating, and, although it reaches nearly to the extremity of what may be called the upper lobe, is very short, owing to the shortness of the fin itself. The rays are comparatively few in number, those of the upper lobe gradually diminishing in length towards its extremity; and the fulcra, which run along the margin of the lower lobe, are nearly as strong as the V scales, usually also called fulcra, which border the upper one above. Though this form of tail cannot be called "homocercal," inasmuch as a scaled prolongation of the body does extend nearly to the point of the upper lobe, yet, from the shortness, feebleness, and attenuation of this prolongation, along with the striking reduction of the number of

* Am. J. Sc. xli. 1841, p. 25.

the fin-rays of that upper lobe, it is not heterocercal to the same extent as in *Palæoniscus* or *Acipenser*. It seems, indeed, to furnish us with the first step in the transition from the typically heterocercal tail to such semiheterocercal forms as in *Lepidotus*, *Dapedius*, *Pholidophorus*, &c., in which the body-prolongation is proportionally shorter still, and the rays of the upper division of the fin extend considerably beyond it. In the other fins the rays are distant compared with those of *Palæoniscus*, and unarticulated for the greater part of their length; the fulcra of their anterior margins are enormously large, and correspondingly few in number, being totally unlike any thing we find in the Palæoniscidæ, though much reminding us of those in some species of *Semionotus* and *Lepidotus*. Though the notochord was probably persistent, there are obvious remains of strongly developed spinous processes, interspinous bones, and ribs, the latter being apparently totally absent in the Palæoniscidæ. The bones of the head are, unfortunately, very badly preserved in all the specimens of *Ischypterus* which I have had the opportunity of examining; they display, however, enough to render certain the following essential points of structure. The line of the top of the head slopes very rapidly from the occiput downwards and forwards to the snout, which, in profile, appears rather sharp, and does not form the peculiar nasal prominence over the mouth seen in *Palæoniscus* and its allies. The opercular bones are conformed quite according to the type characteristic of the Mesozoic Ganoids and modern Teleostei. The operculum and suboperculum are rather narrow; the præoperculum, passing first downwards, curves then gently forwards, carrying the articulation of the mandible to a point in front of the upper attachment of the suspensorium; the interoperculum is also distinctly visible as a small triangular plate with anteriorly directed apex, and placed in front of the lower part of the suboperculum and below the anterior extremity of the præoperculum. The gape is small; the configuration of the maxilla I have not been able to determine; but the mandible is stout and short and has its dentary margin set with a row of equal-sized, small and rather bluntly conical teeth. In one specimen I have seen similar teeth, apparently in more than one row, in the upper part of the mouth; but, from defective preservation, it is hardly possible to tell on what bone they are situated. The orbit has not the remarkably anterior position characteristic of the Palæoniscidæ, but is situated nearly right above the articulation of the lower jaw. Beyond pretty distinct indications of frontals and parietals, and of a powerfully developed parasphenoid, no further details of the osteology of the head are revealed by such specimens of *Ischypterus* as I have had at my disposal.

The few details given above render it, however, perfectly evident that the affinities of *Ischypterus* are not with *Palæoniscus*, but that it must, on the other hand, be looked upon as the most heterocercal of that great series of Lepidosteoid Ganoids especially characteristic of Mesozoic times, and of which *Lepidotus*, *Semionotus*, *Dapedius*, *Pholidophorus*, &c. are prominent examples. To two of those, already referred to, its resemblances are especially striking, viz. to *Semionotus Bergeri*, Ag. *, of the German Keuper, and *Lepidotus minor* of the English Purbeck.

Fishes of this genus occur in the Triassic strata of North America; it is also said to have been found in the Lower Permian schists of Autun, in France †.

VI. Type of *Palæoniscus glaphyrus*, Ag. (? Genus *Acentrophorus*, Traquair). I have not seen the type specimen of this rare species from the English Marl Slate; but, to judge from the figures given in the 'Poissons Fossiles' ‡ and in King's 'Permian Fossils' §, the conclusion seems unavoidable that it is neither a *Palæoniscus* nor a member of the family of Palæoniscidæ. Certain suspicious details occur in Agassiz's description—for instance, that the mouth is "très-petite," also that the fulcra "diffèrent de ceux des autres espèces en ce qu'il sont plus allongés et moins serrés contre le bord des nageoires." This latter condition is very distinctly represented in the figure of the species, in which we also miss the prominent heterocercy characteristic of the Palæoniscidæ: in fact the entire aspect of the fish, as there delineated, is eminently suggestive of its affinity to the three little species from Fulwell Hill, Durham, described by Mr. Kirkby as *Palæoniscus varians*, *Abbsii*, and *altus* ||, but whose reference to that genus is certainly erroneous. Until, however, the type specimen is reexamined, it would be unsafe to pronounce as to the generic identity of *P. glaphyrus* with these last-mentioned forms: at least one marked distinction is found in the denticulation of the scales in the former, a difference which may possibly be only of specific importance.

But as regards the non-palæoniscoid nature of the Fulwell-Hill fishes there cannot be the smallest doubt: and although these species are not Agassizian, it may not be altogether out of place here to devote a little more attention to them than a mere passing reference. That they are not *Palæonisci* has been already pointed out by Dr. Lütken, of Copenhagen, in the following terms, "But already in the Dyas we find, alongside of a preponderating number of heterocercal forms, a few half-homocercal ones." And in a foot-note appended to the same passage he says, "as, for example, *Palæoniscus Abbsii*, *varians*, and *altus* from the English Permian formation, which should be expelled from the genus *Palæoniscus* (like the North-American Triassic species, also previously referred to *Palæoniscus*, which are now called *Ischypterus*, *Catopterus*,

* Poissons Fossiles, vol. ii. pt. 1, p. 224-227. Strüver in Zeitschr. der deutschen geol. Gesellsch. xvi. 1864, pp. 303–330, pl. xiii.

† The statement that "at Autun, in France, we find the genus *Ischypterus* accompanying the true *Palæonisci*" is made by Sir Charles Lyell (Quart. Journ. Geol. Soc. iii. 1847, p. 278); but Sir Philip Grey-Egerton, three years later, states that he is not cognizant of any species of the genus being found there (ibid. vi. 1850, p. 8).

‡ Atlas, vol. ii. tab. 10 *c*. figs. 1 and 2.

§ Pl. xxii. fig. 3.

|| Ann. & Mag. Nat. Hist. (3) ix. 1862, pp. 267–269, also in Quart. Journ. Geol. Soc. xxi. 1865, pp. 345–358.

Dictyopyge, &c.), as they do not show a complete heterocercy, but only an indication or approximation to it" *.

A glance at the beautiful plate by Mr. Dinkel, with which Mr. Kirkby's paper in the 'Quarterly Journal' is illustrated, is in itself quite sufficient to raise in one's mind the gravest doubts as to the accuracy of the position assigned by that author to the little fishes in question. However, having been, by the kindness and liberality of the Earl of Enniskillen, furnished with the loan of a beautiful series of specimens, and having also examined those in the British Museum and in the museum of the Royal Dublin Society, I am now in a position to go into the question more in detail, and with the result of finding the decision so briefly expressed by Dr. Lütken most fully substantiated.

The three species described by Mr. Kirkby are very like each other, save in the general contour of the body; so that the following observations, though principally made on specimens of *Palæoniscus varians*, will apply also to the other two as far as essential points of structure are concerned.

The caudal fin of *P. varians* so closely resembles that of *Ischypterus* that it would, indeed, be impossible to draw any generic distinction between them from that part alone. It is, compared with that of *Palæoniscus*, short and feeble, few-rayed, nearly symmetrical in external outline, and hardly cleft; the rays of the upper lobe gradually diminish in length towards its extremity. The caudal body-prolongation is, as in *Ischypterus*, much reduced, becoming very rapidly narrow and delicate, though its scales may be traced nearly to the extremity of the short upper lobe of the fin. The caudal fin, however, is not the only one which shows a marked deviation from the *Palæoniscus* type. It at once strikes the eye that the fulcra in front of the dorsal and anal fins are fewer in number, set at lower angles, and very much larger and stronger than in any of the Palæoniscidæ—that they are, in fact, proportionally nearly as powerfully developed as in *Ischypterus*, though they diminish in size more gradually, from the origin to the apex of the fin, than in the latter genus. Behind the margin of strong fulcra only about ten rays are counted in the dorsal, and eight in the anal; these are rather distant save just in front, and for a considerable distance show no transverse articulations. The paired fins are very small and few-rayed; and in like manner the fulcra along their margins are strong beyond any thing met with in the Palæoniscidæ.

The osteology of the head shows a still more marked deviation from the type of structure in the Palæoniscidæ. The opercular bones are very distinctly seen in most specimens, and totally differ in form and arrangement from those in *Palæoniscus*, though closely resembling the corresponding bones in *Lepidotus* and other Mesozoic genera. The entire opercular apparatus has an evenly rounded posterior margin; the operculum and suboperculum are large, and of nearly equal area, being divided by a line running obliquely

* "Ueber die Begrenzung und Eintheilung der Ganoiden," Palæontographica, vol. xxii. 1873, p. 26.

upwards and backwards. In front of the lower end of the sub-operculum, a small but very distinct interoperculum is seen, of a triangular shape, with anteriorly directed apex. The præoperculum, which does not cover any portion of the cheek, shows a distinct upper and lower limb, the upper being nearly perpendicular, and curving round below into the lower, which, passing forwards, carries the articulation of the lower jaw considerably in front of the upper extremity of the suspensorium. The jaws are comparatively feeble, and the mouth very small. The mandible has quite a different shape from that in *Palæoniscus*, being, of course, considerably shorter, and seems to form the immediate margin of the mouth only towards its extremity, which is bent a little downwards. The maxilla is especially feeble, extending only to about half the length of the mandible, and is absolutely unlike that in any of the Palæoniscidæ, as it stops short just before the orbit, and ends with a rounded spatulate extremity, which overlaps the mandible considerably in front of the quadrate articulation of the latter. Mr. Kirkby makes no mention of teeth; nor have I discovered any; nevertheless it would be hardly safe to conclude that the jaws were edentulous. The branchiostegal rays are few in number, about seven on each side; the posterior ones are rather long, narrow, and gently curved; but they become rapidly shorter in front. In one specimen, compressed upon its back, a space is seen just behind the symphysis of the mandible, and in front of the branchiostegal rays of each side, which was probably occupied by a large median "jugular" as in *Dapedius*, *Eugnathus*, &c., and in the recent *Amia*. The bones of the cranium proper are not well seen, owing to their delicacy, and to the crushing which they have undergone; the ethmoidal region is usually wanting or undecipherable as to its component parts. The frontals are almost always distinct as two well-marked roof-bones, broader behind than before, their outer margins being excavated in front for the orbits. Two shorter parietals succeed the frontals behind; and there are evident traces of a squamosal plate on the outer side of each parietal, above the suspensorial articulation, though the operculum is usually crushed down over this region of the skull. There are faint traces of small plates completely surrounding the orbit, which was placed nearly right over the articulation of the lower jaw instead of being considerably in front of it as in *Palæoniscus*. Traces also of the palatoquadrate arch are seen in many specimens; but it is hardly possible to make out its constituent bones; a well-marked quadrate, however, is distinct enough. The direction of the suspensorium is undoubtedly considerably forwards as well as downwards.

Of the elements of the shoulder-girdle, the posttemporal and supraclavicular are so generally covered and obscured by the opercular bones that a description of them is hardly possible. The clavicle, however, is usually well seen, and differs greatly from that in the Palæoniscidæ. It is a comparatively slender bone, bent forwards at a very obtuse angle about its middle; the lower extremity is pointed and comes in contact with its fellow of the opposite side; there is no trace of any infraclavicular, so constant and prominent an element in the shoulder-girdle of all the Palæoniscidæ.

The scales of the body are smooth; and those of the flank remind us, in their form, more of the scales of *Pholidophorus* than of *Palæoniscus*.

These details render it sufficiently evident that the fishes entitled, by Mr. Kirkby, *Palæoniscus varians*, *Abbsii*, and *altus* belong neither to the genus *Palæoniscus*, nor even to the family of Palæoniscidæ. The differences of structure between them and all the other genera which may be included in the last-named family are, indeed, so strong that I am a little surprised to find him comparing *Palæoniscus varians* with such forms as *P. Voltzii*, *angustus*, and *wratislaviensis*—species which, if they cannot be included in the genus *Palæoniscus* as now restricted, most obviously belong to the Palæoniscidæ. *Palæoniscus fultus* and *P. glaphyrus* are also mentioned as allied, especially the latter; and here I am able most fully to agree with the author; for *P. glaphyrus* seems, indeed, to be closely related to, if not generically identical with, the little fishes in question. But if that be the case, then it also, as already mentioned, must cease to be regarded as having even family relations with *Palæoniscus*. But, as regards *Palæoniscus fultus*, Mr. Kirkby seems to have overlooked the fact that as far back as 1847 it was transferred by Sir Philip Grey-Egerton to a new genus, namely *Ischypterus*; and I have above shown how widely this genus differs from the Palæoniscidæ in most essential points of structure. It is, in fact, not the type of *Palæoniscus*, but that of *Lepidotus* and its allies, which rises before the mind on the contemplation of the structural details of these fishes along with their entire aspect. And it is precisely with this American genus *Ischypterus* that Mr. Kirkby's fishes display the greatest possible affinity—in the structure of the tail, of the fins, and in the osteology of the head, so far as that can be made out in the genus just named. A difference of decided generic value, however, is to be found in the absence, in the Fulwell-Hill fishes, of the median row of spur-shaped scales along the back, so prominent in *Ischypterus*; and in reference to this distinction, I propose the new generic term *Acentrophorus* for the *Palæoniscus varians*, *Abbsii*, and *altus* of Kirkby. Whether or not *Palæoniscus glaphyrus* of Agassiz is also inclusible in this genus, can only, as aforesaid, be accurately determined by a reexamination of the type specimen; but that it also is not related to the *Palæonisci* is meanwhile pretty clear to my mind.

VII. Type of *Palæoniscus catopterus*, Ag. (? Genus *Dictyopyge*, Egerton). This little species, from the Triassic Red Sandstone of Rhone Hill, co. Tyrone, was originally named by Agassiz, but was not described by him. Sir Charles Lyell, however, in referring to it in connexion with certain American Triassic forms, says concerning it:—"The Irish *Palæoniscus catopterus* of Roan or Rhone Hill, referred by Col. Portlock to the Trias, is a true *Palæoniscus*, and not allied generically either to the *Ischypterus* of Egerton or the

Catopterus of Redfield" *. And in Sir Philip Grey-Egerton's brief description of the species† occurs the following passage:—"The dorsal fin is placed much nearer the tail than in any other species; in this respect, but in no other, *Palæoniscus catopterus* resembles the genus *Catopterus* of Mr. Redfield. The tail is decidedly heterocerque." The eye is also said to be placed forwards, the mouth to appear small, the operculum to be nearly semicircular.

The smallness of the mouth would in itself be considerable presumptive evidence against the affinity of this species with *Palæoniscus*, in which the gape is enormously extensive, as it is also, more or less, in the entire family; it displays, however, another peculiarity which conclusively shows that the position hitherto assigned to it is incorrect.

However, the specimens usually seen in collections are almost always in so bad a state of preservation, from their very friable nature, that it is not astonishing that such eminent naturalists as Agassiz, Lyell, and Grey-Egerton should have fallen into error as regards its affinities; indeed they are ordinarily so rubbed and abraded that in many cases it is barely possible to determine that they are the remains of small ganoid fishes. But in the Museum of Practical Geology, Jermyn Street, there is one rather good specimen, and in the collection of the Geological Survey of Ireland there are several others, on examining which I was not a little surprised to find that the tail is not that of *Palæoniscus*. The fin-rays are, as in the Palæoniscidæ, closely set and articulated throughout, their fulcra being small and numerous; and the tail is deeply cleft and somewhat inequilobate. But the body-scales stop short in a little rounded "sinus," which projects only a very short distance up into the base of the upper lobe of the caudal fin, and is then followed by rays which are just as elongated as those of the lower lobe. The tail is therefore much less heterocercal than in *Ischypterus* or *Acentrophorus*, in fact not more so than in *Lepidotus*; so that the retention of this little fish in the family Palæoniscidæ is no longer possible.

Are we, however, to consider it as the type of a new genus, or can it be received into any previously known? This question can only be answered to complete satisfaction when fresh specimens are discovered from which the structure of the head can be more fully made out; and, unfortunately, since the first "find," none have come to light either in the original or in any other locality. Meanwhile, if we turn to the figure of *Dictyopyge macrura* (*Catopterus macrurus*, W. C. Redf.), from the Virginian Triassic strata, given in the previously quoted memoir by Sir Charles Lyell, we shall find that there is a very obvious correspondence between it and the Rhone-Hill fish in the form of the tail, and in the structure and position of the fins—so much so that the probability of their belonging to the same genus seems to me very great. Still greater is the resemblance which it bears to the *Dictyopyge socialis* of

* Quart. Journ. Geol. Soc. iii. (1847), p. 278.
† Quart. Journ. Geol. Soc. vi. (1850), p. 4.

Strüver, from the Keuper Sandstones of Coburg *, for an opportunity of examining actual specimens of which I am indebted to the kindness of Prof. von Seebach, of Göttingen. Until therefore the cranial osteology and the dentition of these forms is better known, I would propose that the *Palæoniscus catopterus* of Agassiz be included in the genus *Dictyopyge* of Sir Philip Grey-Egerton. Of the closeness of the alliance there can be hardly a doubt; so that the relationship of this little fish to the American Triassic genus *Catopterus* is not so distant as has been supposed †.

Gyrolepis.

In the "Tableau synoptique des genres et des espèces," given at the beginning of the second volume of the 'Poissons Fossiles,' this genus is referred to in the following terms:—

"Le genre *Gyrolepis*, Agass., n'étant établi que sur quelques écailles, est encore douteux. Ce qui le distingue, c'est que les stries d'accroissement forment des saillies concentriques à leur surface." Three Triassic species are here included, viz. *G. maximus*, Ag., *G. tenuistriatus*, Ag., and *G. Albertii*, Ag., along with one from the Kupferschiefer, *G. asper*, Ag. Further on in the same volume (p. 172), in a more special description of the genus, Agassiz again owns that, having found only detached fragments, non-coherent scales, and even these rarely entire, the special characters of the genus are not satisfactorily established. Meanwhile, he says "l'aspect de ces écailles est tel, qu'il serait impossible de les rapprocher d'aucun des genres que j'ai déja décrits. La surface extérieure des écailles est ornée de grosses rides, tantôt concentriques et parallèles aux lames d'accroissement, tantôt obliques et irrégulièrement ramifiées. J'ai cru pendant quelque temps que ces rides étaient toujours concentriques; mais plus tard je me suis assuré qu'elles étaient souvent aussi disposées en peignes irrégulières." Certain dentigerous fragments found along with the scales are also, with some doubt, referred to the same genus; the teeth on them are described as being small and "en forme de cônes obtus dont l'extrémité est arrondie, et qui sont disposées comme dans la famille des *Pycnodontes*

* Zeitschr. der deutschen geol. Gesellsch. xvi. 1864, pp. 303–330, pl. xiii.

† The genus *Dictyopyge* was separated from *Catopterus* of J. H. Redfield by Sir Philip Grey-Egerton on account of the supposed heterocercal nature of the tail in the latter. I hope, however, that I shall not be deemed wanting in respect to the high authority of our greatest English writer on fossil ichthyology in pointing out that not only is the semiheterocercal nature of the tail in *Catopterus* distinctly asserted in Mr. J. H. Redfield's original description and borne out by his figure (Ann. Lyc. Nat. Hist. N. York, iv. 1848, pp. 35–40, pl. i.), but also reaffirmed by Mr. W. C. Redfield, who therefore proposed to cancel *Dictyopyge*, recalling *D. macrura* as a *Catopterus* (Proc. Am. Assoc. Albany, 1856, pp. 180-188). But, as in the typical *Catopterus gracilis*, J. H. Redf., the dorsal fin is situated still further back than in the species *macrurus*, W. C. Redf., *socialis*, Strüver, or in the little *catopterus* of Agassiz, the genus *Dictyopyge* may, I think, be advantageously retained for these last-named forms.

sur toute la surface des os qui les portent." *G. asper* (*Palæoniscus Dunkeri*, Germar) is now referred to the genus *Acrolepis*; but another species, *G. giganteus*, is added from the Old Red Sandstone of Scotland. Finally, in the general list of Ganoids from the various formations published in 1843, and appended to the beginning of the second volume, *G. Rankinei*, from the Coal-measures of Leeds, is named though not described, and *G. giganteus* is transferred to the genus *Holoptychius*. The latter is described in the 'Poissons fossiles du vieux Grès Rouge' (1844), p. 73.

Another species of *Gyrolepis*, from the German Muschelkalk, was described by Münster under the name of *G. biplicatus*, characterized by the possession of two strong parallel ridges on the outer surface of the scale.

But in 1848 Giebel announced that he had discovered the scales known as *Gyrolepis Albertii*, Ag., and *G. biplicatus*, Münst., in great numbers, and on the same slabs with dentigerous and other cephalic bones referable to *Colobodus*, a genus instituted by Agassiz for certain tooth-bearing fragments (*C. Hogardii*, Ag.) from the Muschelkalk, and referred by him to the family of Pycnodonts. *Gyrolepis tenuistriatus*, Ag., on the other hand, was referred by Giebel to *Amblypterus*. He therefore proposed the total abolition of the genus *Gyrolepis*, uniting and renaming the species *G. Albertii* and *biplicatus* as *Colobodus varians*, Giebel *, and in like manner the species *G. tenuistriatus* and *maximus* as *Amblypterus decipiens*, Giebel †, and in each case apparently without the smallest regard to priority of specific nomenclature. The accuracy of Giebel's reference of the two former species to *Colobodus* was questioned by Eck ‡.

Quenstedt, in his 'Handbuch der Petrefactenkunde,' agrees with Giebel as to the reference of *G. Albertii* and *G. maximus* to *Colobodus*; *Tholodus*, v. Meyer, he also considers as belonging to the same type, but is inclined to consider these forms as related, not to the Pycnodonts nor to the heterocercal Ganoids, but to *Lepidotus* §. In the same work he expresses himself in a rather guarded manner regarding the reference of *G. tenuistriatus* to *Amblypterus* ||.

The doubtful nature of the characters of *Gyrolepis* is thus referred to by Sir Philip Grey-Egerton in his paper on the "Ganoidei Heterocerci:"—"The scattered and fragmentary condition in which the remains of this genus have always been found has proved hitherto an insurmountable obstacle, not only to a definition of its generic characters, but to a determination of the family in which it ought to be placed. It is not even known whether the tail was homocerque or heterocerque—a point of some importance as bearing upon the value of this character as a criterion of the age of strata,

* Fauna der Vorwelt, i. 3, pp. 181, 182.

† Ibid. p. 255.

‡ 'Ueber die Fauna des bunten Sandsteins and des Muschelkalks in Oberschlesien,' p. 67. I have not myself seen this work, which I therefore quote on the authority of Dr. Martin.

§ Handbuch der Petrefactenkunde, 2nd ed. (1867), pp. 248–250.

|| Ibid. p. 268, 269.

since some of the species are confined to the Triassic period" *. Subsequently, however, Sir Philip expressed an opinion that in *Gyrolepis* "we have probably a heterocerque fish" †.

More recently Dr. Karl Martin has advocated the view that the Triassic scales known as *Gyrolepis* belong to *Saurichthys*, "because the strongly marked sculpture of their surface (like the condition of the teeth of *Saurichthys*) reminds us of that of the scales of *Acrolepis*, and because hitherto neither teeth have been found which could correspond to these scales of *Gyrolepis*, nor other scales which could be ascribed to the teeth of *Saurichthys*." *Saurichthys* itself is referred by Martin to the family Palæoniscidæ on account of the resemblance which the teeth and a fragment of a maxilla figured by him bear to those of *Acrolepis asper* ‡.

Finally, as I have already mentioned (p. 550), Prof. Victor Carus has not only reunited *Rhabdolepis*, Troschel, to *Amblypterus*, Ag., but has added, as synonyms of the latter, *Gyrolepis*, *Colobodus*, and *Tholodus*. I need not again point out how inconsistent it is with the prevailing ideas of the limits of a genus to reckon as congeneric with such a fish as *Amblypterus latus* scales like those known as *Gyrolepis*, or teeth like those of *Colobodus* or *Tholodus*.

From the preceding sketch of its history it is abundantly clear that at present all definition of *Gyrolepis* as a genus is impossible; and under the circumstances it does seem to me better to follow the example of Giebel in cancelling the term altogether. As regards the Triassic species which have been so named, I must necessarily leave the final determination of their position to continental palæontologists. But, as to the use of the name *Gyrolepis* in catalogues of British Carboniferous fossils, there can, I think, be no doubt as to the propriety of its entire abolition; for, unless the Triassic scales to which the name was originally given are really referable to *Acrolepis*, there is no Carboniferous fish of which we have the smallest evidence that it belongs to the same genus with them. What, then, is the real nature of the one Carboniferous species which has been definitely named *Gyrolepis*, but which has hitherto remained undescribed?

The name *Gyrolepis Rankinei* occurs in Agassiz's general list of fossil Ganoids, the formation and locality quoted being the Coal-measures of Leeds. Neither description nor figure is given; and the original specimen seems now, unfortunately, to be lost or unknown. But in Morris's 'Catalogue of British Fossils' (p. 273) Lanarkshire is given as an additional locality for this species; and on inquiring of Dr. Rankin, of Carluke, and Mr. Grossart, of Salsburgh, in that county, I learn that Agassiz, when in Scotland, also designated as *G. Rankinei* a specimen in Dr. Rankin's collection. To these gentlemen I am indebted for the opportunity of examining portions of the original Lanarkshire specimen, along with others

* Quart. Journ. Geol. Soc. vol. vi. 1850, pp. 8, 9.

† Dec. Geol. Survey, viii. 1855, text accompanying pl. ix. p. 3.

‡ Zeitschrift der deutschen geol. Gesellsch. xxv. (1873).

referable to the same species—and to Dr. Hunter, of Braidwood, for the loan of a magnificent slab covered with its scales, bones, and fin-rays from the shale underlying the "Main Limestone" (Lower Limestone series) of that locality. All the specimens which have as yet been found have been fragmentary, consisting only of detached scales and bones, or of masses of scales either confused or adhering together to some extent in their original rows. Dr. Hunter's slab measures 20 inches in length by 11 in breadth. It displays, in the first place, a number of bones the forms of such of which as are determinable stamp the fish at once as a member of the family Palæoniscidæ. Among these may be recognized the median supereth-moidal, which in this family forms the anterior projection of the snout over the mouth; and lying near it is the impression of a bone, 4 inches in length, which displays the characteristic form of the Palæoniscid maxillary. No impressions of teeth are seen; it is therefore unfortunate that the counterpart of the specimen could not be found, as the bony substance of the maxilla has evidently remained on it, the teeth not having been exposed. The lower portions of both clavicles are also seen; and the dimensions of these are such as to lead one to suppose that the length of each, when entire, could not have been less than five or six inches. The external ornamentation of all these bones is of a tubercular nature, the tubercles sometimes finer, sometimes coarser, occasionally showing a tendency towards a linear arrangement or to coalesce into short ridges.

Besides the numerous scattered scales which occur in the slab, there are two large patches in which the scales still cohere together in rows. One of these patches evidently represents a portion of the skin of the front of the flank, the position of the other being further back towards the caudal region. These flank-scales are large; one of the largest of them is $\frac{5}{8}$ inch in breadth; its exposed and ganoid area is nearly equilateral, measuring about $\frac{7}{16}$ inch in breadth and in height; this area is rhomboidal, but not acutely so, and is obliquely traversed by strong subparallel ridges, which proceed in a direction from above, downwards and backwards, occasionally branching and anastomosing, or, where two diverge, another being intercalated between, there being, on an average, five such ridges in the space of $\frac{1}{8}$ inch. The anterior covered area overlapped by the scale in front is extensive, being $\frac{3}{16}$ inch in breadth; its lower margin is more oblique than that of the sculptured portion, with which it consequently forms an obtuse angle; above it is produced into a prominent pointed process, where it coalesces with the narrower covered area of the upper margin, overlapped by the scale next above. From the middle of the upper margin there projects, in addition, the proper articular peg of the scale, stout and triangular in form. Near these scales are scattered others which were evidently situated towards the ventral aspect of the fore part of the fish. These display a similar sculpture of the exposed area; but their form is lower, narrower, and more oblique; the articular peg of the upper margin has disappeared: but the anterior superior production of the covered areas is proportionally longer and more acute. The scales of the other coherent patch are smaller in size, and more obliquely rhomboidal in form, as regards the exposed surface; they are further distinguished by the absence of the articular peg of the upper margin, and by the much greater narrowness of the covered areas, which are not specially produced upwards and forwards. Their thickness is also very considerable, being no less than $\frac{1}{8}$ inch in one of these scales entirely detached from the matrix, and measuring about $\frac{1}{2}$ inch in breadth. A difference is also observable in the sculpture of these posterior scales, viz. a tendency of the ridges to coalesce in a reticulating manner towards the posterior, superior, and interior-inferior obtuse angles of the scale, so as to interrupt the intervening furrows in these two regions, converting them more or less into pits.

The specimen also exhibits, as already mentioned, many detached and broken-up, transversely jointed fin-rays, some of which attain a breadth of $\frac{1}{8}$ inch; the length of their joints is somewhat less, but varies in different rays. These rays are all seen only from their internal non-ganoid surfaces.

As already stated, it is quite evident that the fish to which these remains belonged is a member of the family Palæoniscidæ; and the form and thickness of the scales, with their very large anterior covered area, and the nature of their sculpture, along with the peculiar tubercular ornamentation of the cephalic and shoulder-bones, point out, as it seems to me, that *Acrolepis* is the genus to which it should be referred. The scales of the Permian *A. Sedgwickii* are quite similar in shape, though proportionally smaller and with fewer ridges. The tendency to reticulation of the ridges on certain parts of the posterior scales of the Lanarkshire fish reminds us also of the peculiar sculpture which is characteristic of the entire scale and over the whole body of *A. exsculptus*. The narrow ventral scales are, indeed, undistinguishable from the one from the Carboniferous Limestone of Derbyshire contained in the Cambridge Museum, and figured by M^cCoy as *Acrolepis Hopkinsii* *; but if that be the same, as I believe it to be, with a fish from the Millstone Grit of Hebden Bridge, of which several beautiful fragments are in the collection of Mr. John Aitken of Bacup, it is a distinct species, and differs from *A. Rankinei* in other respects.

In conclusion, if all definition of *Gyrolepis* as a genus is at present impossible, if the diagonal ridged scale-ornament, supposed to be characteristic of it, is also characteristic of the scales of many species belonging to various other genera, such as *Acrolepis*, *Elonichthys*, *Rhabdolepis*, *Cosmoptychius*, &c., and if the "*Gyrolepis*" *Rankinei* of Agassiz be referable to *Acrolepis*, then there is, as I have maintained above, no longer any justification for the retention of the name "*Gyrolepis*" in our lists of British Carboniferous fossils.

* 'British Palæozoic Rocks and Fossils,' p. 609, pl. 3 *g*. fig. 10.

PYGOPTERUS.

The definition of *Pygopterus* given by Agassiz in the "Tableau Synoptique" is as follows:—

"A. très-allongée; D. opposée à l'intervalle entre l'A. et les V. La mâchoire supérieure déborde l'inférieure. De petits rayons le long des rayons extérieurs des nageoires."

Further on in the volume the characters of the genus are indicated more in detail. The large size of the fins, especially of the heterocercal and deeply cleft caudal, is noticed, the paired fins being less developed; also the pointed conical teeth, the comparatively small size of the rhomboidal scales, and the well-developed internal skeleton. But it is on the form of the anal fin that the greatest stress is laid:—"Mais ce qui caractérise plus particulièrement les *Pygopterus*, c'est qu'à cette caudale inéquilobe se joint une anale fort longue qui garnit le bord inférieur du corps sur une grande étendue." The dorsal is still stated to be placed opposite the interspace between the ventrals and the anal, but "de manière à être plus rapprochée de cette dernière." In his description of *P. mandibularis*, however, Agassiz states that in it the anal is more directly opposed to the dorsal than in *P. Humboldtii*.

The restored outline of *Pygopterus* given in the Atlas to the 'Poissons Fossiles' (vol. i. tab. B. fig. 3) displays, however, the same faults as the accompanying restorations of *Palæoniscus*, *Amblypterus*, &c., viz. a want of acquaintance with the structure of the head, besides considerable inaccuracies as to the general form of the body and fins. Had Agassiz been acquainted with the cranial osteology of the Palæoniscidæ, it is, indeed, impossible to conceive that on the sole ground of the possession of large laniary teeth, he could have separated *Pygopterus* and *Acrolepis*, as "Sauroïdes," from their natural allies *Palæoniscus* and *Amblypterus*, a precisely similar dentition existing, as has been subsequently shown, in several of the species which he referred to the two latter genera.

By Quenstedt a peculiarity of *Pygopterus*, certainly of generic value, is noticed, which seems to have escaped the attention of Agassiz, viz. the non-articulation of the principal rays of the pectoral fin. As he says:—"Die grossen ungegliederten Strahlen der Brustflossen errinern an *Pachycormus*." The position of the dorsal fin is also more correctly indicated by Quenstedt, according to whom it stands, "weit hinter der Bauchflosse über der vordern Hälfte der langen Afterflosse," though he might also have mentioned that it commences in front of the latter. He also gives a figure of some of the bones of the head (operculum, maxilla, mandible, branchiostegal rays), in which the essential agreement of these in form and arrangement with the corresponding bones in *Palæoniscus* is clearly shown *.

The peculiar form of the anal fin is also emphasized by Germar, by whom the position of the dorsal fin is correctly stated in the following words:—"Man erkennt diesen Fisch sehr leicht an den

* 'Handbuch der Petrefactenkunde,' 2nd ed. (1867). p. 269, pl. 21. fig. 4.

deutlich erkennbaren Wirbelsäule, an seiner, wenn auch in verminderter Höhe sich fast bis zur Schwanzflosse fortziehenden Afterflosse, wesshalb man ihm auch die Benennung *Afterflossenfisch* geben kann, und an der, der Afterflosse fast gerade gegenüberstehenden Rückenflosse." Again he remarks:—" Die Afterflosse beginnt bei zwei Drittheil Länge des Bauches, dehnt sich anfangs stark in die Höhe aus, wird dann aber schnell wieder niedrig, und setzt sich nachher mit allmählig verminderter Höhe bis in die Nähe der untern Schwanzflosse fort. Die Rückenflosse steht der Afterflosse ziemlich gerade gegenüber, doch noch weiter nach vorn gerückt, so dass etwa ihre Mitte dem Anfange der Afterflosse sich gegenüber befindet, sie steigt auch anfangs schnell und hoch empor und endigt nach hinten durch eine sichel- oder halbmondförmige Ausbüchtung"*.

The definition of *Pygopterus* given by M^cCoy is as follows:—

" Body large, elongate ovate; fins very large, with fulcral scales, anal fin of moderate depth and very long, dorsal of moderate length, nearly opposite or a little in front of the anal fin; ventrals small, slightly in front of the middle of the body; pectorals moderately small, falcate caudal very large, deeply notched; upper jaw a little longer than the lower; endoskeleton strong, vertebræ usually wider than long; scales proportionally rather small, rhomboidal, smooth, and minutely punctured or diagonally striated, extending over the pedicles of the fins, and particularly over the thick upper lobe of the tail to the extremity, having a moderately wide articular margin, sometimes prolonged at the upper angle, and having a medial internal articular ridge which forms a prolongation from the middle of the upper margin"†.

What, therefore, the salient generic characters of *Pygopterus* are, is perfectly clear from the foregoing extracts, which all refer to the Permian species *P. Humboldtii* and *P. mandibularis*; for even Agassiz, though he enumerated several other species from the Carboniferous formation, made only the briefest possible reference to their distinctive characters, deferring that description to a future opportunity, which, unfortunately for fossil ichthyology, never arrived. These two species, which, indeed, resemble each other exceedingly closely, must therefore be taken as typical of the genus. It now remains for us to inquire whether the others named by Agassiz sufficiently agree with them in structure to warrant their retention under the same generic title.

The species of "*Pygopterus*" enumerated by Agassiz, in his general list of Ganoids, are the following:—

From the "Coal-formation."	From the Permian (Zechstein).
1. *P. Bonnardi*, Muse, near Autun.	6. *P. Humboldtii*.
2. *P. Bucklandi*, Burdiehouse.	7. *P. mandibularis*.
3. *P. lucius*, Saarbrücken.	8. *P. sculptus*.
4. *P. Jamesoni*, Burdiehouse.	
5. *P. Greenockii*, Newhaven.	

* 'Die Versteinerungen des Mansfelder Kupferschiefers' (Halle, 1840), pp. 22–24.

† 'Palæozoic Fossils.'

Of these one must be deleted before proceeding further, viz. *P. lucius*, from Saarbrücken, which subsequently turned out to be a head of *Archegosaurus* *. Of two others I can give no account, viz.:—*P. Bonnardi*, from the Autun fish-beds (now referred to the Lower Permian), which I have never seen, nor am I aware of its having ever been described; and *P. Jamesonii*, from Burdiehouse, of which also no description has ever appeared; and as the specimen, a detached jaw, appears to be lost, the name must be cancelled, like too many others given by Agassiz to fish-remains to whose identification we have no longer any clue. The others fall into the three following generic types.

I. Type of *P. Humboldtii* (genus *Pygopterus*, Agassiz, restricted).—The general form is elongated; the head is rather large, the suspensorium very oblique; the jaws long, powerful, and armed with large conical laniaries, outside which is a series of smaller teeth; the operculum and interoperculum are rather small, the branchiostegal rays numerous; both the cranial and facial bones are striated. The scales of the body are small in proportion to the size of the fish, nearly equilateral over the greater part of the body, but rather higher than broad on the front of the flank; their form is rhomboidal, their anterior marginal covered area is moderate, and at the anterior superior angle of the scale is produced upwards into a prominent point; the proper articular spine of the upper margin is well marked. The pectoral fin is of considerable but not excessive size; its principal rays are, like those of *Oxygnathus* and *Rhadinichthys*, unarticulated till towards their terminations; the ventral is rather small. The anal commences rather remote from the caudal; it is high and acuminate in front; but behind the apex its contour falls rapidly away, so that posteriorly it extends in a fringe-like manner for some distance along the lower margin of the body. The dorsal commences slightly in front of the anal, and has a much shorter base, the middle of which is opposite the commencement of the last-named fin; it is acuminate and high in front, the posterior margin being concavely cut out. The caudal is of enormous size, powerfully heterocercal, deeply cleft, but not very inequilobate. The fin-rays do not seem to me to have been ganoid externally, but to have been covered with a delicate skin, as in the recent *Polyodon*; the fulcra are well marked. The internal skeleton is well developed, the vertebral arches, spinous processes, and interspinous bones usually showing prominently through the external scaly covering; but it seems to me very doubtful that the vertebral bodies had got beyond the stage of "Halbwirbel:" nor have I seen any trace of ribs, though these are mentioned by Germar. The snout projects over the front of the mouth, as in other Palæoniscidæ; hence, probably, the expression used by Agassiz:—"La mâchoire supérieure déborde l'inférieure."

* Dr. G. Jäger, "Ueber die Uebereinstimmung des *Pygopterus lucius*, Ag., mit dem *Archegosaurus Dechenii*, Goldf.," Abh. der k.-bayerisch. Ak. der Wiss. v. pp. 877–886. See also a notice by Prof. Ferd. Römer, in Verh. preuss. Rheinl. u. Westphal. 1850, pp. 155–157.

To this type, which has as yet occurred only in rocks of Permian age, the term *Pygopterus* ought in future to be strictly limited. Here are embraced *P. Humboldtii*, Ag., *P. mandibularis*, Ag., and *P. latus*, Egerton,—*P. sculptus*, Ag., being pretty certainly, as suggested by Sir Philip Grey-Egerton, only a synonym of *P. mandibularis* *, Agassiz not having been aware that the anterior scales of this species were sculptured with diagonal striæ. The nearest approach to *Pygopterus* in general form is made by some of the much smaller Carboniferous fishes which I include in the genus *Rhadinichthys*; but in all of these the scales are proportionally larger and thicker, the caudal body-prolongation is not so powerfully developed, and the anal fin, though considerably " échancrée," is not prolonged backwards in the same manner. In the structure of the pectoral fin it also resembles *Oxygnathus* and *Thrissonotus*, as well as *Rhadinichthys*: in *Thrissonotus*, also, the anal fin has apparently a somewhat similar form†.

II. Type of *P. Bucklandi*, Ag. (genus *Elonichthys*, Giebel). This species has never been described; and the original type, stated by Agassiz to be in the Museum of the Royal Society of Edinburgh ‡, cannot now be found. A figure of it, however, is given by Hibbert, in his celebrated memoir on the Burdiehouse Limestone §, from which figure, along with the very brief notice of this species in the ' Poissons Fossiles,' I feel pretty confident in referring to it a number of mostly fragmentary remains of a large Palæoniscoid fish from Burdiehouse, contained in the Edinburgh Museum of Science and Art. All that Agassiz says of it is as follows:—

" *Pygopterus Bucklandi*, Agassiz. Espèce caractérisé par la petitesse et la forme allongée de ses écailles, et par son anale très-rapprochée de la caudale. Elle est à peu près de la taille du *P. mandibularis* et provient du calcaire de Burdiehouse en Ecosse "‖.

Hibbert's figure represents only the posterior half of the fish, with the dorsal, anal, and caudal fins; and the two former strike one at the first glance as having the position and shape, not of those in *Pygopterus* but in *Elonichthys*. In fact, the approximation of the anal to the caudal, mentioned by Agassiz as a specific mark, is in reality a generic one; moreover, not being prolonged backwards, the anal resembles the dorsal in size and shape, while the latter is placed relatively further forwards. A comparison of this figure with the actual specimens to which I have referred, shows that we have here to deal with a fish which is certainly not a *Pygopterus*, but a species closely allied to those from the North-Staffordshire Coal-field, which I have recently described as *Elonichthys semistriatus*, *E. caudalis*, and *E. oblongus*, as well as to the *E. striolatus*, which

* In King's ' Permian Fossils,' p. 233.

† Dec. Geol. Surv. ix. 1858, pl. 2.

‡ It is possible that this is a mistake, and that the specimen may have been in the private collection of Dr. Hibbert, as all the other type specimens mentioned by Agassiz as belonging to the Royal Society of Edinburgh are in their places.

§ Trans. Roy. Soc. Edinb. vol. xiii. pl. 7. fig. 2.

‖ ' Poissons Fossiles,' vol. ii. pt. 2, p. 77.

is associated with it in the same beds *. The only entire specimen I have seen is $11\frac{1}{2}$ inches in length; it is most unfortunately crushed on its back. It displays, however, the right pectoral and ventral fins; and the former, unlike the pectoral of *Pygopterus*, has its principal rays articulated throughout; the ventral is of moderate size. The median fins are large; the dorsal is not shown in any of the specimens belonging to the Edinburgh Museum; but in Dr. Hibbert's figure it is seen to resemble the anal, and is evidently placed nearly opposite the interval between that fin and the ventrals, though the latter are not shown in the figure. The anal, however, is well shown in one specimen; it is large, triangular, and acuminate, and is closely followed by the caudal, which is very powerful. The fin-rays are externally ganoid and finely striated; their transverse articulations are very close; the fulcra are closely set, and minute for the size of the fish. The scales of the body are proportionally small. Those of the front part of the body are apparently nearly equilateral; but posteriorly, and more especially towards the ventral margin, their form is low and narrow. Their anterior covered area is very narrow; the posterior margin is very finely denticulated; the exposed area is covered with a delicate yet sharply defined ornamentation, consisting of fine subparallel ridges, which pass from before backwards across the scale, in a gently sigmoid direction, tending to become intermixed with punctures posteriorly, especially above the diagonal between the two acute angles of the scale. Towards the tail the ridges become less marked on the posterior part of the scale, giving way to the thickly dotted punctures, till on the caudal body-prolongation the former, after lingering at the anterior margin, altogether disappear, and punctures alone remain.

Very little can be made out concerning the bones of the head; however, in the above-mentioned entire specimen the lower jaw is seen to be very stout, and ornamented externally with fine, sharp, closely set, wavy, branching, anastomosing, and interrupted ridges, running in a longitudinal direction. The laniary teeth are very strong, incurved and smooth, with apical enamel-cap; similar teeth are seen on the maxilla, the dental margin of which is finely tuberculated.

Imperfect as the above-described specimens are, the affinities of the fish which they represent are clear and unmistakable, and forbid its being retained any longer as a "*Pygopterus*." On the other hand, though attaining a larger size, the resemblances which it bears to *Elonichthys striolatus*, in the form, structure, and position of the fins, and in the nature of the scale-ornament, are so great that it is impossible to include them in different genera, though specifically they are at once distinguishable.

I have already stated that the original of "*Pygopterus*" *Jamesoni* seems to be lost, and that, as no figure or description of it exists,

* These species are described in the first part of my monograph on the British Carboniferous Ganoids, in the Memoirs of the Palæontographical Society for 1877, plates 3–7.

the name must consequently drop. The only statement made regarding it by Agassiz, is as follows :—

"*Pygopterus Jamesoni*, Agass. Sous ce nom j'ai distingué une seconde espèce de Burdiehouse, dont je ne connais encore que la mâchoire inférieure qui diffère de celle du *P. mandibularis*, en ce qu'elle est proportionnellement plus courte "*. As he does not, however, state how this jaw (the only relic found) differs from that of *P.* (*Elonichthys*) *Bucklandi*, I cannot help strongly suspecting that it belonged to the same fish.

The scale figured by Mr. T. P. Barkas †, from the Northumberland coal-field, as belonging to a species of "*Pygopterus*" evidently appertains to the same fish as that from North Staffordshire, described by myself as *Elonichthys semistriatus*, as is also most probably the case with the mandible represented by him on the same plate ‡.

III. Type of *Pygopterus Greenockii*, Agass. (genus *Nematoptychius*, Traquair).—Concerning "*Pygopterus*" *Greenockii* the following brief statement was made by Agassiz :—

"Espèce très-distincte sous le rapport spécifique, mais douteuse sous le rapport générique. Les fragmens connus ne sont guère que des têtes avec la partie antérieure du tronc. Les écailles qui recouvrent cette partie du corps sont plus hautes que longues, et diffèrent par-là de celles de tous les autres *Pygopterus.* Du terrain houiller de Newhaven. Il en existe plusieurs exemplaires dans la collection de Lord Greenock, qui sont tous contenus dans des géodes de fer hydraté carbonaté " §.

Although the original examples of this species, collected by Lord Greenock, and now in the Museum of the Royal Society of Edinburgh, were thus imperfect, there is hardly any Carboniferous fish concerning whose structure I have been able to acquire more complete information, my own collection being especially rich in its remains, and many other specimens being in the Edinburgh Museum of Science and Art. These specimens, some of them entire, confirm the doubts which Agassiz himself entertained regarding its generic position ; and accordingly in 1875 || I proposed for its reception the new genus *Nematoptychius.* The configuration of the scales is alone sufficient to demand its separation from *Pygopterus.* Those of the flanks are much higher than broad ; their anterior covered margin is very narrow ; the exposed surface is rhomboidal ; but the acute angles are the anterior-inferior and posterior-superior ; the articular spine is broad and triangular, and arises from the whole, or nearly the whole, of the narrow upper margin. The scales alter their form on the ventral aspect, where they become low and very small ; their external ornament consists of fine, wavy, thread-like ridges. The pectorals are of moderate size, and have their principal

* 'Poissons Fossiles,' vol. ii. pt. 2, p. 78.
† 'Manual of Coal-measure Palæontology,' pl. 4. fig. 130.
‡ Ibid. fig. 131.
§ 'Poissons Fossiles,' vol. ii. pt. 2, p. 78.
|| Ann. & Mag. Nat. Hist. (4) vol. xv. pp. 258–262.

rays unarticulated only for about $\frac{1}{3}$ of their length; the dorsal and anal fins are large and triangular, the dorsal being placed far back and nearly opposite the anal. The latter is slightly larger than the dorsal, but is similar to it in shape, and is not prolonged backwards in the fringe-like manner characteristic of *Pygopterus*.

For further details regarding the structure of this genus I must refer to my previous papers on the subject *. A second species, which I have named *N. gracilis*, has also recently turned up in the black-band ironstone (Carboniferous Limestone series) of Gilmerton, near Edinburgh †.

It thus follows that there is no Carboniferous species of *Pygopterus* as yet known, and that it must consequently be regarded as strictly a Permian genus, though in this case, as in others, negative evidence may be at any time overturned. I have also, in the preceding pages, endeavoured to show that a better understanding of the Carboniferous species hitherto ascribed to *Amblypterus*, *Palæoniscus*, and *Gyrolepis* excludes these genera also from the Carboniferous list, as far as our present knowledge goes. This is especially important with regard to the questions still pending as to the respective limits of the Carboniferous and Permian formations, both in England ‡ and in Bohemia §; for it cannot be denied that an accurate determination of genera, as well as of species, of imbedded fish-remains is essential to all safe generalization as to the aspect or distinctions of particular faunas, whether they be "Carboniferous" or "Permian," and that such generalization has been seriously impeded by the vague ideas hitherto prevalent regarding the genera discussed in the present paper. I may therefore express a hope that the observations here recorded may not be without their value, in spite of the inevitable shortcomings which the nature of the subject, and the limited opportunities of any one observer, forbid them being without.

* Trans. Royal Soc. Edin. vol. xiv. 1867, pp. 701–713. Also paper in Ann. & Mag. Nat. Hist., quoted already.

† Proc. Roy. Soc. Edin. 1876–77, pp. 262–265.

‡ "On the Relation of the Upper Carboniferous Strata of Shropshire and Denbighshire to Beds usually described as Permian," by D. C. Davies, F.G.S. (Quart. Journ. Geol. Soc. vol. xxxiii. 1877, pp. 10–28).

§ "A Permian Flora associated with a Carboniferous Flora in the uppermost portion of the Coal-formation of Bohemia," by Dr. O. Feistmantel (Geol. Mag. (2) vol. iv. 1877, pp. 105–120).

31. *The* Bone-caves *of* Creswell Crags.—3rd Paper. By the Rev. J. Magens Mello, M.A., F.G.S., &c. (Read April 11, 1877.)

Contents.

Introduction.

It will be remembered that on two previous occasions the history of the Creswell-Caves Exploration has been brought before the Society, on the latter of which the results of the work were given up to the close of 1875.

During the early part of last summer the exploration has been carried on under the auspices of a Committee, consisting of Sir J. Lubbock, M.P., F.R.S., as President, Prof. W. Boyd Dawkins, F.R.S. (Secretary), F. Longdon (Treasurer), Prof. G. Busk, F.R.S., W. Bragge, F.G.S., R. D. Darbishire, B.A., F.G.S., J. Evans, F.R.S., A. W. Franks, F.R.S., Rooke Pennington, LL.B., F.G.S., Prof. Prestwich, F.R.S., and the Rev. J. M. Mello, M.A., F.G.S. (Director and Reporter), Prof. W. Boyd Dawkins and T. Heath, F.R.H.S., being Superintendents.

It will hardly be necessary to do more by way of recapitulation than just allude to the first papers read, which have established the fact that we have at Creswell a series of highly important caves, illustrating by their contents two periods of human occupation during the Palæolithic age in Britain, when man was contemporary in Derbyshire and the adjoining district with the characteristic Pleistocene fauna. The remains of animals belonging to this fauna, in great abundance and representing a remarkably large number of species, have been found in these caves, in conjunction with quartzite and flint implements of two different types:—the one ruder than the other and underlying it, corresponding in character to the rude implements of the Lower Breccia of Kent's Hole and of the river-gravels; the upper series of implements being of a somewhat more finished type, and in general form agreeing with those assigned by M. Mortillet to the age of Solutré, and which have been found in this country in the cave-earth of Kent's Hole and in Wookey Hole*.

It was thought advisable to carry on the exploration of the two

* *Vide* Quart. Journ. Geol. Soc. vol. xxxii. p. 255.

principal caverns simultaneously: these are the Robin-Hood Cave, and another, on the opposite side of the ravine, called the Church Hole.

A. *The Robin-Hood Cave.*

At the beginning of the year a very considerable portion of the Robin-Hood Cave remained, as will be seen in the ground-plan, unexplored; thoroughly and carefully to clear this out formed a large part of our work. Great care has been taken to keep the contents of the different beds separate, each bed having been worked out, as far as possible, independently, and the earth riddled as it was removed to the mouth of the cave; the various objects found each day were separately packed and labelled. We trusted that by exercising this care we should be able to obtain as conclusive evidence as might be possible as to the occupation of the caves by man during the two stages of the Palæolithic period already alluded to.

1. *The Talus.*—The work was commenced, on June 19th, by cutting a trench through the talus outside the entrance of the cavern (fig. 1.). At a depth of 3 feet, the unproductive white calcareous sand with limestone blocks forming the lowest bed in the interior was met with; above this was a deposit of cave-earth, 1 foot thick, in which, near the mouth of the cavern, were a few flint chips, a fragment or two of worked flakes, and a few teeth and a portion of the jaw of *Cervus megaceros*, together with two or three teeth of Hyæna and *Rhinoceros tichorhinus*. Over the cave-earth was an old floor full of bits of charcoal, with pieces of coarse Roman earthenware in the lower part, and with more modern remains at the top. In this floor a few small fragments of human bones and some teeth occurred, as well as teeth of Sheep, Celtic Shorthorn, Hare, and Water-vole, together with some small bird-bones. The talus generally proved of very little interest; and it was resolved to proceed at once to the resumption of work in the interior.

The distribution and order of the various beds as they occur in this cavern will be best understood by comparing the sections taken at different points in the cave (figs. 2–7). Where all the beds are present they are at least five or six in number; but it will be seen that the whole series seldom, if ever, occurs at one spot.

2. *The Surface-soil.*—Below the numerous blocks of limestone which were plentifully spread over the floor, a thin surface-soil (1), seldom exceeding six inches in thickness, extended over the greater part of the cave. Just within a small square-cut entrance into Chamber C (fig. 8), which is known as Robin Hood's Parlour, the surface-soil was reddish with thin films of stalagmite enclosed in it (fig. 3); usually this soil was of a dark drab colour. In this uppermost bed in Chamber C an enamelled bronze fibula was found, very similar in shape and condition to one from the Victoria Cave figured by Prof. W. Boyd Dawkins in 'Cave-Hunting.' A small bronze graving-tool, double-pointed at one end, was obtained from the same bed; also a rudely carved bone ornament with a triangular

iron socket in its under side; this may have been the boss of a sword or dagger. In other parts of the cavern nothing of any importance was discovered in the surface-soil; here and there we met with broken fragments of Roman and later pottery; and we have heard that a coin of Faustina has since been picked up outside; but we were disappointed in finding so few traces of Roman or Romano-British occupation.

3. *The Breccia.*—A great quantity of breccia (2) remained on the left-hand side of Chamber A, blocking up the entrance to Robin Hood's Parlour (C); this had to be removed by frequent blasting, before the cave-earth below could be reached. The breccia, which near the entrance of the cave had proved very rich in its fossil contents, yielding numerous bones and flint implements, contained very little further in, owing probably to its having accumulated in close proximity to the roof, to which at several points it was united by thick masses of stalactite and stalagmite. Above the breccia in this part of the cave the stalagmite was as much as 2 feet thick (fig. 2).

Amongst the stalagmitic breccia, some very beautiful crystallizations of calcite occurred, with most delicate acicular and botryoidal forms. Towards the back of Chamber C the breccia thinned out, as well as towards the right-hand side of the cave, where it was absent, except at the mouth of the small side fissure (Chamber G). The few remains found in the breccia consisted, as before, of bones of the Hare, a few teeth of the larger Pleistocene Mammalia (*R. tichorhinus*, Hyæna, Bear, and Horse), together with fragmentary flint implements and a small piece of ruddle.

4. *The Cave-Earth.*—The succeeding deposit, that of cave-earth (3), was very uniformly distributed throughout the cavern, although varying very considerably in thickness in different parts. Near to the entrance, as has been observed in a previous paper, it was very thin where the breccia attained its greatest development; but in the inner parts of the cave it increased considerably in amount, being as much as 4 feet 6 inches thick at the extremity of Chamber F (fig. 5).

Under the breccia between the square doorway and the mouth of the cave, the bed of waterworn pebbles mentioned in the second paper on these caves became a thickish red conglomerate, the pebbles being firmly cemented together by iron and lime. The deposit was of very limited extent, but apparently denoted the presence of a stream of water running across this part of the cavern during a short period. As there was no trace of a continuance of the pebble-bed towards the entrance of the cave, it was perhaps thrown down in a hollow of the floor during some flooding.

From the cave-earth the most important remains, both of the Pleistocene Mammalia and of Man, have been obtained; in it bones and teeth in great abundance of all the species that have already been catalogued as occurring in this cavern continued to be found in all the chambers. Horse's teeth were particularly numerous. In Chamber G several large bones (Mammoth) were found lying together. Flint chips and some fine flakes were found pretty generally distributed in the cave-earth; but they were far outnumbered by the rudely fashioned implements of quartzite. There were so many of these in all stages of wear as almost to suggest a manufactory of them. The most interesting, however, of the implements found here were two of clay ironstone. It will be remembered that last year an oval tool of this material was also discovered in this same cave-earth. The two implements now found are somewhat more leaf-shaped, one being a singularly perfect specimen, similar in form to many of the well-known river-gravel types: this was got from the Passage B; the other was found in Chamber G.

The most important of all our discoveries in the Robin Hood's Cave have yet to be recorded. In the cave-earth, about the middle of Chamber F, a small fragment of a bone (the rib of some animal) was observed by the writer to have marks of engraving upon it. These, on being brought to the light, we examined carefully; and Mr. Tiddeman, who was present at the time with Prof. Dawkins, at once noticed the rude picture of the fore part of a horse exactly similar to the Palæolithic figures that have been found in some of the continental caves. The value of this discovery, the first of its kind made in this country, need scarcely be insisted upon. But we have yet to record another discovery of as great, if not greater, importance. At the far end of Chamber F, in the same cave-earth, at a depth of about 1 foot, Prof. Dawkins had the good fortune to see extracted, by a workman, a canine of *Machairodus latidens*, an animal whose remains, as all will be aware, have only twice before been found in England—the Rev. J. M'Enery having obtained from Kent's Hole, many years ago, five canines and two incisors of that formidable animal, and a third incisor having been found as lately as 1872 in the same cavern. The discovery, therefore, of the *Machairodus* at Creswell in the undisturbed cave-earth is one of the greatest interest, which will be dwelt upon, in conjunction with all the details relating to the various remains found in these caves, in the accompanying paper by Prof. W. Boyd Dawkins.

5. *The Mottled Bed.*—Below the cave-earth in the front part of Chamber F, and also in chamber G, was a bed of earth (No. 4) mottled with numerous small angular fragments of limestone (fig. 4). Its thickness ranged from 1 to 2 feet; and it occupied only a limited part of the cavern, thinning out rapidly towards the back of Chamber F, where it was absent (fig. 5), and dying out in a similar way in Chamber G. The remains found in this bed were similar in character to those of the cave-earth, teeth and bones of the Pleistocene animals and quartzite implements being numerous.

6. *The Red Sand.*—The lowest bone-bearing bed in the Creswell caverns is one of red sandy earth (No. 5). In the Robin-Hood Cave this was found uniformly distributed over the whole floor, its average thickness being about 3 feet. In the large entrance (Chamber A), and under the breccia in the front part of Robin Hood's Parlour, there was a good deal of tough laminated red clay mingled with it. giving the bed in some places quite an argillaceous character.

Possibly this clay may have been connected with the same flow of water which afterwards deposited the gravel and conglomerate in the same chambers. Bones were very abundant in this red sand-bed, together with teeth of most of the Mammalia occurring in the upper beds; in the argillaceous portion of it, under the breccia, on the left-hand side of Chamber A, where the cave-earth was very thin, a nearly perfect skull of the Hyæna was found, and also one of the Fox, and the posterior part of a Wolf's skull, together with fragments of the lower jaw of the Horse, and other remains. In the red sand of Chamber A, up to the close of 1875, we had obtained no evidence of human occupation during the period of its deposition; but further in, especially in Chambers G and F, a considerable number of worked quartzite pebbles were found in this bed.

7. *Original Floor.*—The original floor of the Robin-Hood Cave was immediately below the red sand, and consisted of a greater or less thickness of decomposed limestone rock forming a whitish sand containing angular fragments of the limestone. In this no remains of any sort were found.

8. *Chamber* C.—It will be observed that comparatively few bones were discovered in Chamber C, large as is this portion of the cave. The rock floor in it was generally nearer to the roof than in the other chambers, and the deposits of cave-earth and sand were, on the whole, less thick; at the extreme left a considerable stalagmitic deposit is to be seen coating the rock. The comparative absence of bones in this chamber may perhaps be attributed to the presence of a stream of water running for some time through this branch of the cavern.

9. *Chambers* D *and* E.—The little side chamber, D, was formed by a protruding mass of rock; it consisted of a hollow in the rocky floor, and was consequently filled up with a greater thickness of beds than C. This was also the case with Chamber E; the narrow passage leading into it was bare of any deposits, the limestone floor rising to the surface from beneath the cave-earth of the adjoining chamber. In both chambers, D and E, we found at least 8 feet of cave-earth and red sand (fig. 7) containing bones and teeth; the surface-soil, which had been previously examined, had yielded some traces of occupation by man in Roman and post-Roman times.

10. *Chamber* G.—The small opening G, on the right-hand side of the cave, was filled up to within a few inches of the roof. The breccia at its mouth was 16 inches thick and contained bones; further in it decreased to about 2 inches; it was followed by the complete sequence of beds, viz. cave-earth, mottled bed, and red sand; the mottled bed died out at about 10 feet from the entrance of the aperture (fig. 6). A considerable number of bones and teeth were found in this chamber, amongst them a lower jaw of *C. megaceros*, a pelvis of the Woolly Rhinoceros, many teeth of the same animal and of the Hyæna and others, some large bones of the Mammoth, and also many quartzite implements, as well as the second of the clay-ironstone ones already mentioned.

11. *Terminal Fissure.*—At the extremity of Chamber F (fig. 5),

which we had taken to be the end of the Cave in that direction, we found, on digging to the base of the Red-Sand bed, about 6 feet below the level of the floor, that there was an extension of the cave at a lower level (fig. 8, Sect. A); this was nearly, but not quite, filled to the roof with an independent deposit of red sand dipping down into the fissure from the main cave; its upper surface was very smooth and fine, as well as perfectly clean; it appeared as though freshly thrown down by water, and was decidedly bedded. It was dug into to a depth of 3 feet 7 inches, and followed up for about 10 feet, where it was found to be in contact with the roof. As no bones were found here, it was not thought worth while to pursue it any further. Low down in the red sand of Chamber F, at the mouth of this fissure, a fragment of Mammoth bone was obtained; but no other remains were met with here. We consider that the Robin-Hood Cave is now practically worked out, very little having been left in it that has not been carefully searched.

B. *The Church Hole.*

We must now turn to the second cave to be described, viz. the Church Hole. This is situated on the opposite side of the ravine, and faces the north; its mouth is 14 feet above the present water-level, and 60 feet from the summit of the crags above it, the entrance to the cave being in a crag 40 feet in height. The Church Hole is mainly a long straight fissure (fig. 9), averaging about 4 or 5 feet in width, and running horizontally for the greater part of its length in nearly a due N. and S. direction, for a distance of 155 feet. At that point it rises at a considerable angle for another 41 feet, where it ends in a mere blocked-up crack, the extremity of which, we believe, is apparent in a fissure on the hill-top close to an old quarry. This long passage was covered with angular and partially worn fragments of limestone, mostly small and flat; there were also a good number of quartzite pebbles, and many recent bones brought in by foxes. The roof of the fissure was very low in several places, not more than one foot above the floor at one point; but at intervals there were some lofty cracks and chimneys, one of which apparently opens into a passage overhead. Besides this principal portion of the cave, there is a small chamber (B) on the right-hand side near to its mouth, and having a secondary entrance from the face of the cliff through a narrow fissure. The front part of the Church Hole, which is tolerably wide, appeared to have been used at a recent period as a stable or kind of barn; and for about 20 feet from the doorway we had fixed near the entrance the floor had been partially disturbed and dug into, in the centre, to a depth of some 3 or 4 feet; but its fossil contents had been, at any rate for the greater part, unnoticed and unremoved*. Last year, whilst the digging was going on in the

* N.B.—Since the exploration of these caverns commenced, we have heard that, on several occasions, a few teeth and bones had been found here by individuals, by Mr. Tebbet amongst others; but no attention was called to these discoveries at the time.

Robin-Hood Cave, the upper beds of the fore part of the Church Hole were also examined, and the main passage (A), up to a wall built across the narrow part of the fissure 25 feet from our door, was dug up, as well as part of Chamber B. A large number of bones and teeth of the Woolly Rhinoceros, the Mammoth, the Horse, the Reindeer, the Bison, the Brown Bear, and the Hyæna were obtained, the teeth of the Horse being particularly abundant; and no fewer than 27 tibiæ and 18 femora, as well as other parts of the skeleton of the Rhinoceros, were found here. Amongst these bones there were also a perfect ulna of a bear, and several milk-teeth of the Mammoth, besides one large fourth molar which Mr. Heath was fortunate enough to find near the old wall: this measured 11 inches in length by 9 inches in height.

1. *The Talus.*—When we resumed work this year we began, as we had done at the Robin-Hood Cave, by making an examination of the talus at its mouth (fig. 10). This consisted of surface-soil a few inches in thickness; in this, on the left-hand side, close to the extreme edge of the entrance, a very fine and perfect bronze fibula was found; this was the only trace of Roman civilization found outside the cave. Under the surface-soil was a bed of reddish earth or sand, 1 foot 7 inches thick, with blocks of limestone in it. This bed contained a few teeth and bones of the Rhinoceros, Bear, Hyæna, Badger, Horse, Reindeer, and *Cervus megaceros*, and also some fragments of the lower jaw of a large Wolf. Below the red bed was one of white calcareous sand containing a black layer, probably of oxide of manganese; in this we found no bones.

2. *Deposits in Interior.*—Our first work in the interior of the cave was to clear out all the front part as far as the wall already mentioned, so as to get a good road for the barrows, and also to make a complete section of the various beds. Beneath the previously examined material, undisturbed red sand was found, containing various bones and teeth, but nothing of great importance. Close to the wall in the long passage (A) the total thickness of the floor-deposits was about 9 feet, gradually narrowing downwards, the bottom of the cave being a mere fissure about 1 foot wide. A very complete section was obtained at this point, all the beds of this cave being well developed here (fig. 11). It will be noticed that they are almost identical in general character and arrangement with those already described in the Robin-Hood Cave, and were doubtless deposited at the same period and under similar circumstances.

3. *The Breccia.*—We have first a stalagmitic breccia (1), averaging 1 foot in thickness. At one or two places in Chamber A this breccia was as much as 5 feet thick; but it only attained that thickness close to the side of the cave, and it was then mostly of a very open character, having numerous cavities in it filled with stalactites (figs. 12, 13). There was evidently at some former time a considerable amount of breccia in the front part of the cavern, although now nothing remains of it but masses of stalagmite projecting here and there from the sides. At about 31 feet from the door, where Section II. (fig. 11) was taken, the upper part of the breccia was

composed of dark-brown earth with blocks of limestone in it, firmly cemented together by stalagmite; the lower portion was of a softer texture, and passed gradually into the next bed.

The breccia contained a good many fragments of charcoal, together with worked flints and teeth of Hyæna &c., with numerous bones of the Hare and of some other animals.

4. *The Cave-Earth.*—The cave-earth of this cavern, where developed to its fullest extent, was found to consist of three divisions, the uppermost, 1 foot thick, being a reddish loamy earth (No. 2) with fragments of charcoal, and in one place a layer of the same, flint implements, a fragment of ruddle, and bones &c. of the Hare, Reindeer, and Hyæna. This dark bed was only found for a short distance; at 42 feet from the door it had disappeared; and here also the breccia was absent, except at the sides of the cave. A thin crust of stalagmite formed the surface.

A bed of lighter earth (No. 3) succeeded the red bed, and was present everywhere in the cave, varying in thickness from 1 foot to 2 feet. The usual bones and teeth of the Pleistocene Mammalia, including the Bear, Wolf, Woolly Rhinoceros, and Reindeer, were found in the cave-earth. In one place, 6 inches below the stalagmitic crust, a ramus of the lower jaw of the Hyæna, with its condyle and coronoid process intact, occurred; and near to it, under a large block of stone, were found part of the lower jaw of *Cervus megaceros* and a fine quartzite flake; fragments of charcoal were in contact with all these specimens.

The cave-earth here was only 1 foot thick. Somewhat further in the cavern, beneath 2 inches of breccia, a small circular bronze brooch was found; and not far from this point a small ivory counter or ornament, presumably of Roman or Romano-British workmanship, was dug up close to the surface.

5. *The Mottled Bed.*—The next bed we come to is a mottled one, very similar to that which has been described in connexion with the Robin-Hood Cave,—a bed of reddish cave-earth remarkably mottled with small angular fragments of very friable cream-coloured limestone, which at once suggested to us visions of almond-cake on a large scale. At about 50 feet from the door this bed was subdivided (fig. 13)—an upper layer with a brown matrix (No. 4 *a*), 9 inches thick, resting on the red bed (No. 4 *b*), which here was 3 feet in thickness. We found this to continue for a short distance only, when the mottled bed resumed its normal character (fig. 14). Bones, teeth, and implements, especially those of quartzite, were numerous in this mottled bed; amongst them were the pelvis of *Rhinoceros tichorhinus*, the scapula of the Mammoth, and teeth of Hyæna, Wolf, Bear, Rhinoceros, Horse, and Hare. In it also two or three fine bone implements were found, a perfect bone needle, some awls, and a kind of gouge—the awls being made from Hare-bones, the gouge from Reindeer-antler. The majority of the implements of stone were quartzite flakes and hammers; but there were also found with these some flint flakes and chips. The mottled bed was absent at the far end of Chamber A, at 120 feet from the door,

where the upper cave-earth (No. 3) was immediately succeeded by a bed of red sandy earth (fig. 15).

6. *The Red Sand.*—This red sand (No. 5) was present everywhere in the cavern, below the previously described beds: it averaged from 3 feet to 4 feet in thickness, and contained many bones and teeth of various animals, amongst them those of the Hyæna, Wolf, Bear, *R. tichorhinus*, Mammoth, Horse, Bison, Reindeer, &c. One fragment of Rhinoceros-jaw consisted of the anterior portion of both rami, with two premolars *in situ* on either side; there was also a nearly perfect lower jaw of the Hyæna, one incisor alone being absent. A few quartzite implements were found in the red sand, and also a fragment of a bone which has some scratches, apparently made by a flint.

This bed, at a depth of about 8 feet from the surface, was not above one foot wide, the cave at that depth being contracted to a mere fissure, the lowermost stratum consisting merely of the decomposed limestone rock, forming a non-fossiliferous bed of white sand similar to the corresponding bed in the Robin-Hood Cave.

At about 120 feet from the door a small fissure was found opening out of Chamber A to the right, below the original level of the floor. As in the case of the fissure at the extremity of Chamber F in the Robin-Hood Cave, this was filled with red sand nearly but not quite in contact with the roof. The surface of the sand was also dry and powdery, and it was destitute of fossil contents. The digging has not been carried on beyond this point in Chamber A, the few remaining feet giving little promise of having any thing of sufficient value to repay the work of exploration.

7. *Chamber* B.—Turning to Chamber B, which opens out from the main chamber of the cavern near the entrance, a few words will suffice to describe its contents. The greater portion of it was examined in 1875, and similar remains of the Mammalia obtained from this floor to those found in the main passage. At the back of Chamber B a fissure was found, running parallel to Chamber A; the entrance to this was blocked up by a mass of stalagmitic breccia, 5 feet thick, containing bones and teeth of *R. tichorhinus* and of other animals (fig. 16). Below this we found a bed of red sand, filling a narrow but deep pothole-like fissure, running apparently in two directions, viz. S. and W. This fissure was not above 1 foot wide, but was at least 11 feet deep from the top of the breccia. The sand contained the bones and teeth of Mammoth, Horse, Bison, Rhinoceros, &c. Very few bones, however, were found in its lower portion; and it was not thought worth while to dig it out completely.

Conclusion.

The Church Hole, as well as the Robin-Hood Cave, may now be considered to have been worked out sufficiently for all practical purposes. A detailed account of the valuable remains found in them will be given, as has been stated, in the accompanying paper by

Prof. W. Boyd Dawkins; so that they need not be dwelt upon at any greater length here.

It will be seen that the exploration of the three principal caves of Creswell Crags has made it manifest:—that during the Pleistocene period Derbyshire and the adjoining counties were inhabited by a very numerous and diversified fauna; that in the vast forests and pastures which we may picture to ourselves as extending in one unbroken line far to the east and south of the present shores of England, the Mammoth and the Woolly Rhinoceros, the Hippopotamus (which has been found in Yorkshire), the great Irish Elk, the Reindeer, the Bison, and the Horse found a congenial home; that here also the savage Hyæna, the crafty Glutton, the Bear, the Lion, the Wolf, and the Fox, together with the great sabre-toothed Feline, sought their prey; and that, with these and others not named, man lived and hunted, and waged a more or less precarious struggle for existence, finding a shelter, amidst the vicissitudes of a varying climate, in the numerous caves of the district, already the haunts of the Hyæna and its companions.

(*For the Discussion on this paper, see p.* 611.)

Figs. 10–16.—*Sections, Church-Hole Cave.*

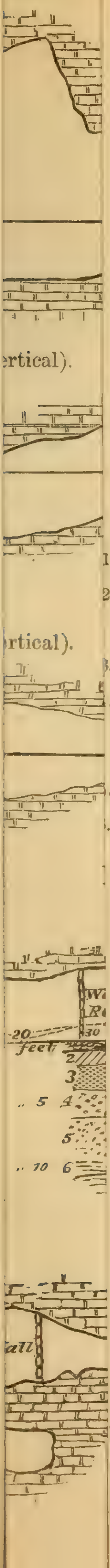
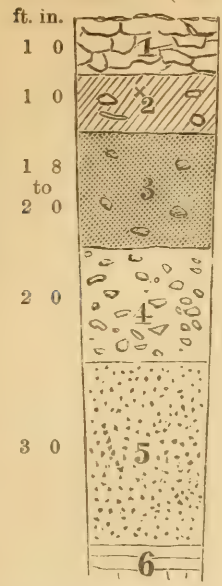


Fig. 11.

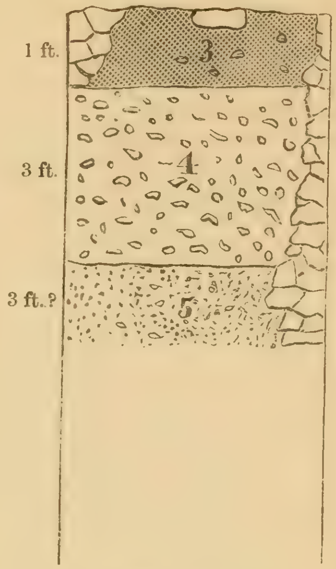
31 ft. from Gate (June 22).



1. Stalagmitic breccia, with charcoal, worked flints, and bones.
2. Reddish cave-earth, with charcoal fragments, layer of ditto, flint implements, bones, and blocks of limestone.
3. Lighter cave-earth, with similar remains.
Mottled cave-earth, more sandy and mottled, with small angular fragments of friable limestone; quartzite and flint-implements, and bones.
Light-reddish sandy earth; bones, but no implements.
White calcareous sand and rock.

Fig. 12.

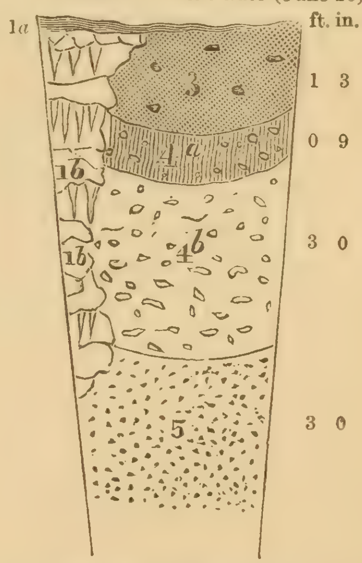
About 42 ft. from Gate (June 24.)



1. Nearly absent.
3. Cave-earth, with loose breccia lining right side of cave; charcoal, bones, and implements.
4. Mottled bed; bones, and implements of stone, flint, and bone.
5. Red sand; bones &c.

Fig. 13.

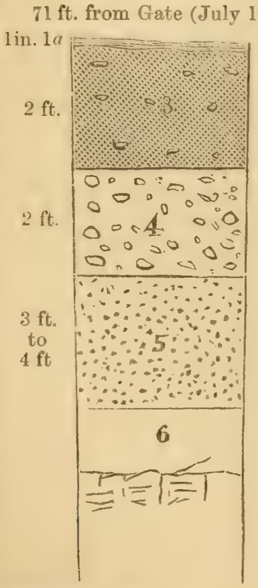
About 50 ft. from Gate (June 26).



1*a*. Surface-soil and stalagmite, 2-3 in.
1*b*. Open breccia, with stalactites, lining left side of cave.
3. Cave-earth.
4*a*. Brown mottled bed.
4*b*. Red mottled bed.
5. Red sand.

Fig. 14.

71 ft. from Gate (July 13).

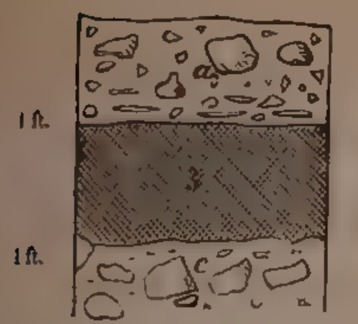


Stalagmitic film.
Cave-earth; few bones.
Mottled bed; few bones, a bone implement.
Red sand; bones numerous.
White calcareous sand and rock; no bones.

Figs. 1-7.—*Sections, Robin Hood's Cave.*

Fig. 1.

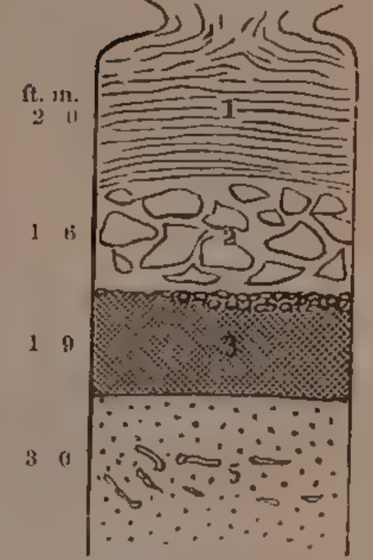
Talus outside Cave.



a. Modern and Roman layer; old floor, charcoal, and pottery.
b. Cave-earth; flint-implements, Pleistocene remains.
c. White calcareous sand, with limestone blocks.

Fig. 2.

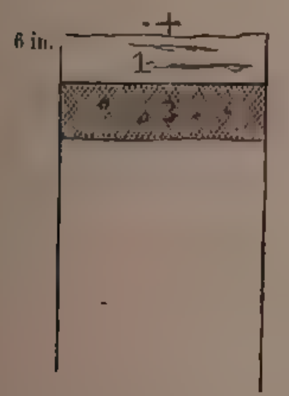
Chambers A & C.



1. Stalagmite attached to roof.
2. Breccia, a few bones and flint-implements; at one point a bed of conglomerate of waterworn pebbles at base.
3. Cave-earth; bones and implements.
5. Red clayey sand; bones.

Fig. 3.

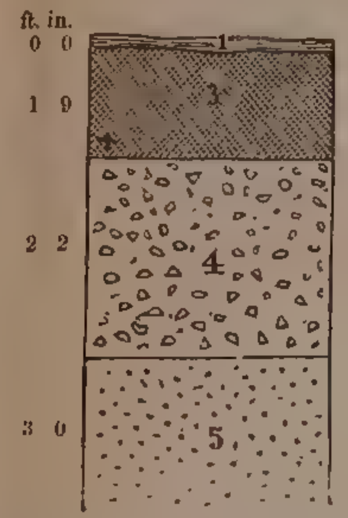
Entrance to C.



1. Reddish surface-soil, with stalagmite.
3. Cave-earth.

Fig. 4.

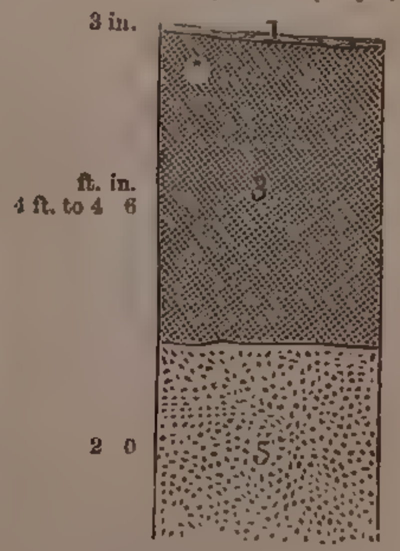
Chamber F (June 30).



1. Surface-soil.
3. Cave-earth; bones and implements.
†. Engraved bone.
4. Mottled bed, light brownish matrix; bones and implements.
5. Red sand; bones and quartzite implements.

Fig. 5.

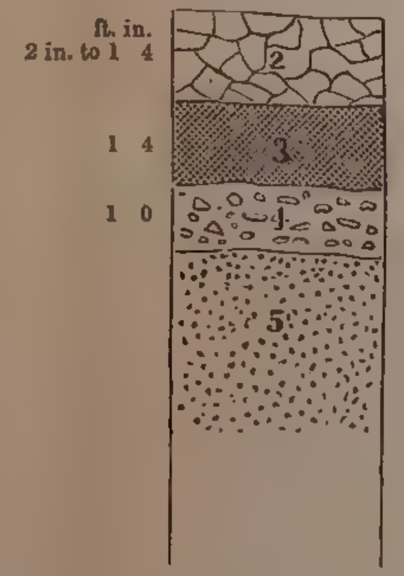
Chamber F, far end (July 3).



1. Surface-soil. 3. Cave-earth.
*. Tooth of *Machairodus*.
5. Red sand; few remains.

Fig. 6.

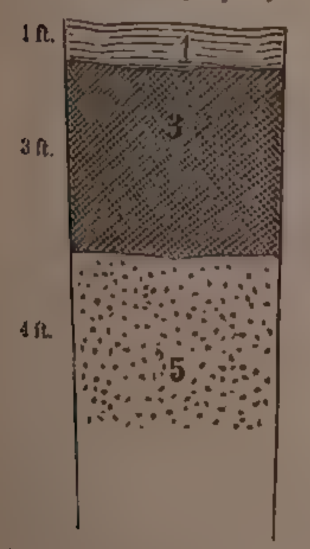
Chamber G (July 5).



2. Breccia. 3. Cave-earth.
4. Mottled bed; bones and implements.
5. Red sand; bones, and implement of quartzite.

Fig. 7.

Chambers D, E (July 21).



1. Surface-soil.
3. Cave-earth; bones.
5. Red sand; few remains.

Fig. 8.—*Ground-plan and Sections of Robin Hood's Cave.*

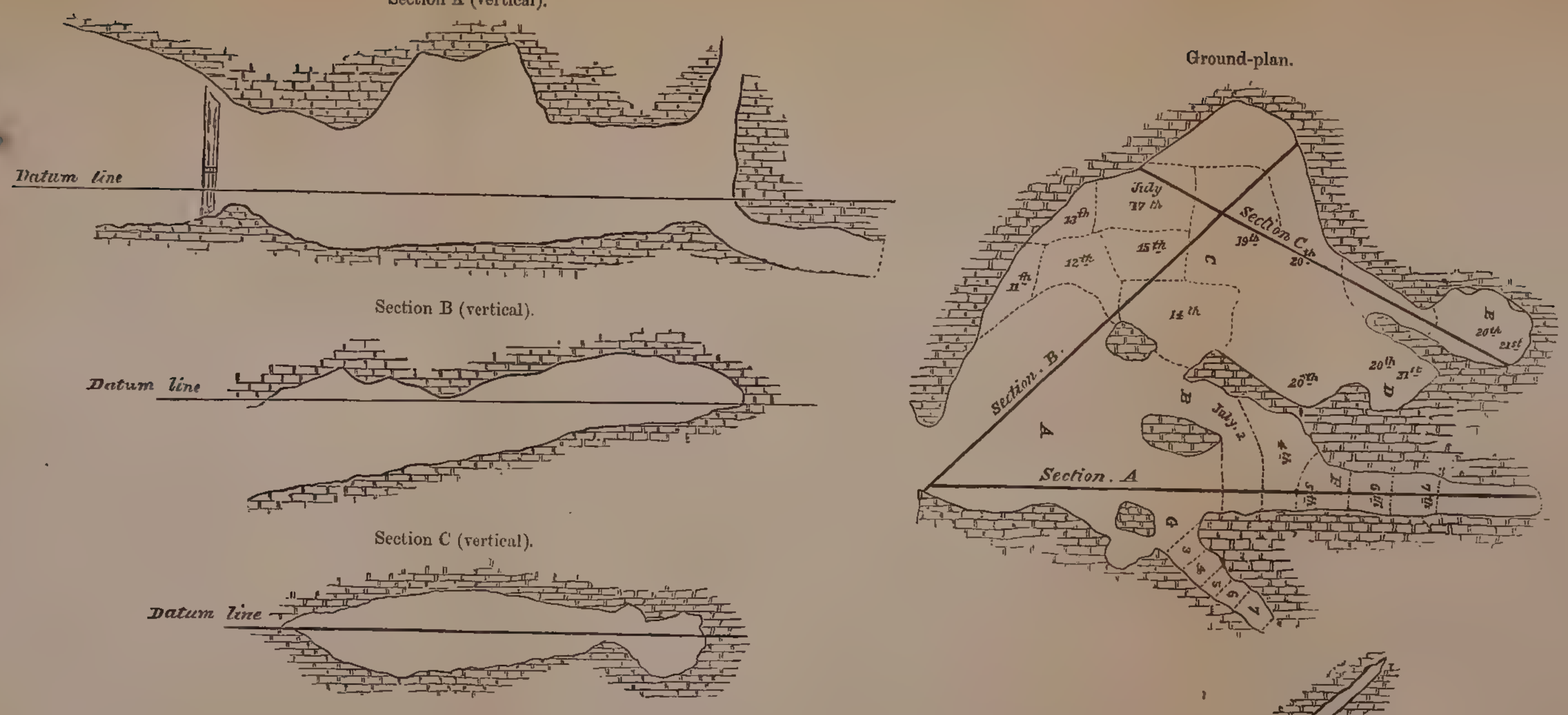
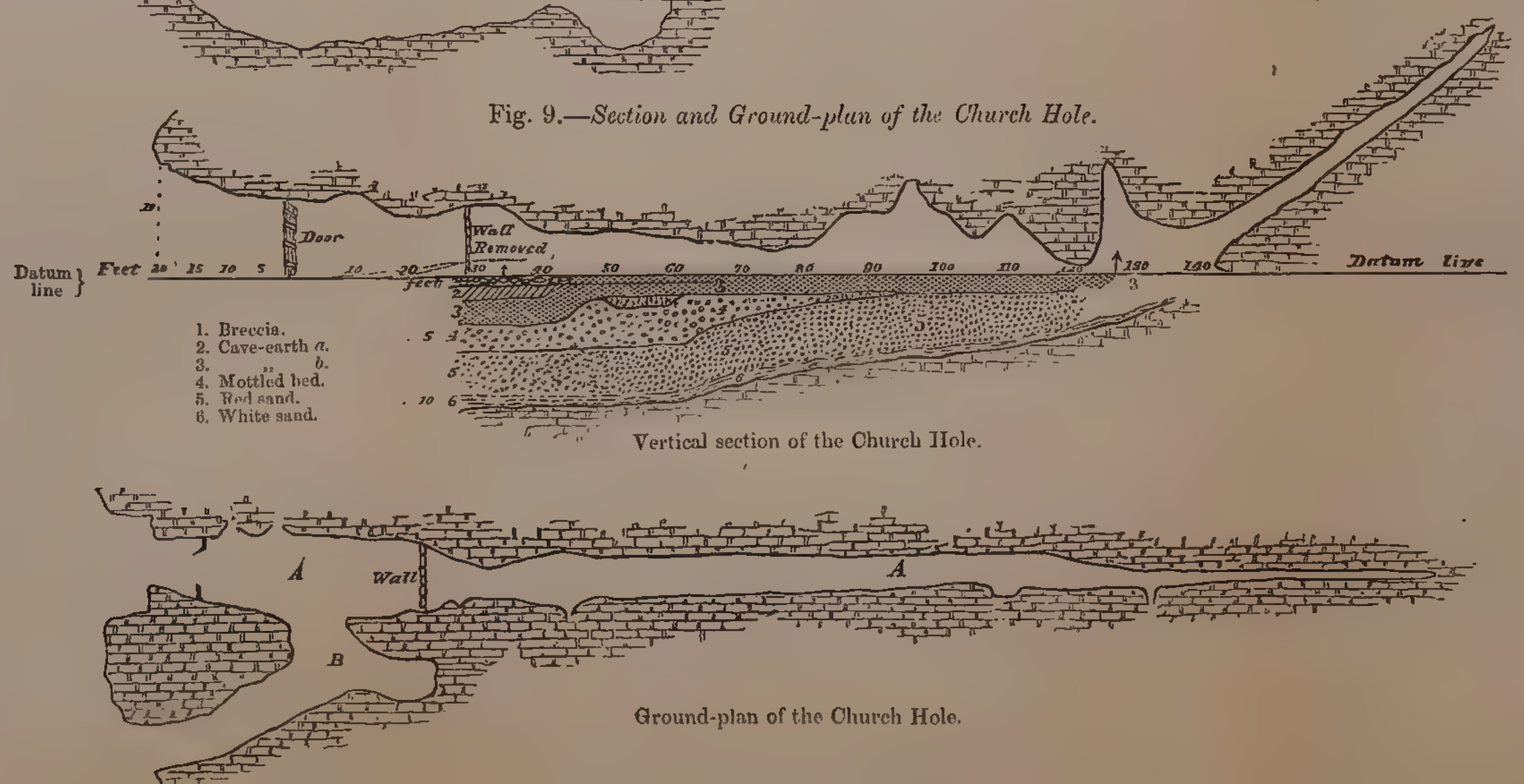


Fig. 9.—*Section and Ground-plan of the Church Hole.*



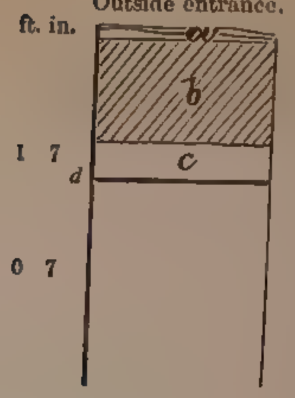
Vertical section of the Church Hole.

Ground-plan of the Church Hole.

Figs. 10-16.—*Sections, Church-Hole Cave.*

Fig. 10.

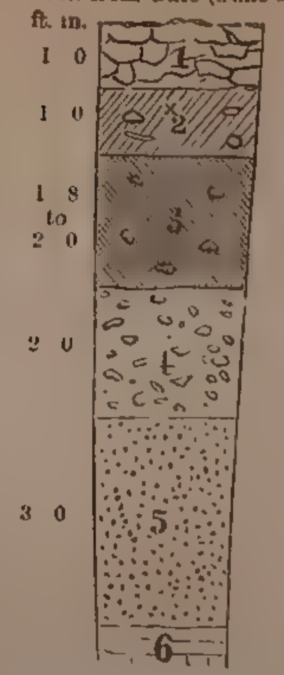
Outside entrance.



a. Surface-soil Brit-Welsh; variable.
b. Reddish cave-earth or sand; pleistocene remains.
c. Whitish sand.
d. Black band (manganese?).

Fig. 11.

31 ft. from Gate (June 22).



1. Stalagmitic breccia, with charcoal, worked flints, and bones.
2. Reddish cave-earth, with charcoal fragments, layer of ditto, flint implements, bones, and blocks of limestone.
3. Lighter cave-earth, with similar remains.
4. Mottled cave-earth, more sandy and mottled, with small angular fragments of friable limestone; quartzite and flint-implements, and bones.
5. Light-reddish sandy earth; bones, but no implements.
6. White calcareous sand and rock.

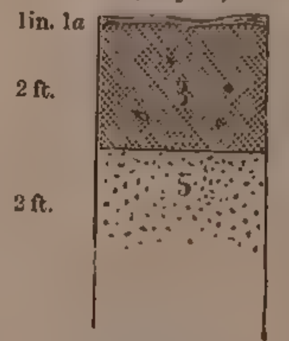
Fig. 12.

About 12 ft. from Gate (June 24.)

1. Nearly absent.
3. Cave-earth, with loose breccia lining right side of cave; charcoal, bones, and implements.
4. Mottled bed; bones, and implements of stone, flint, and bone.
5. Red sand; bones &c.

Fig. 15.

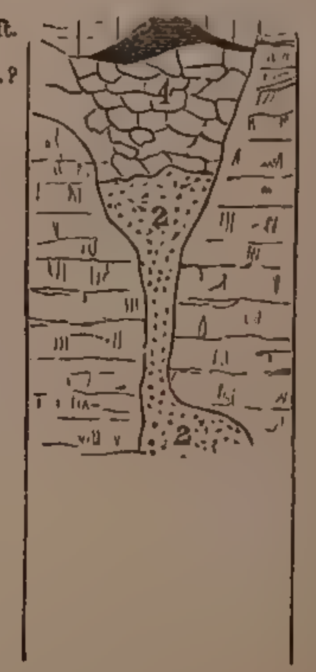
120 ft. from Gate (July 21).



1a. Stalagmitic film.
3. Cave-earth; few bones.
5. Red sand; few bones.

Fig. 16.

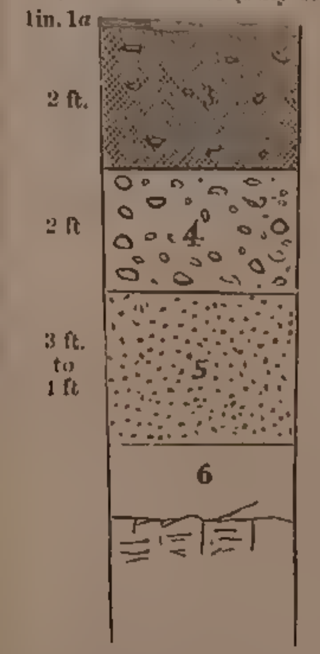
Pot-hole, Chamber B.



1. Breccia; bones.
2. Red sand; bones.

Fig. 14.

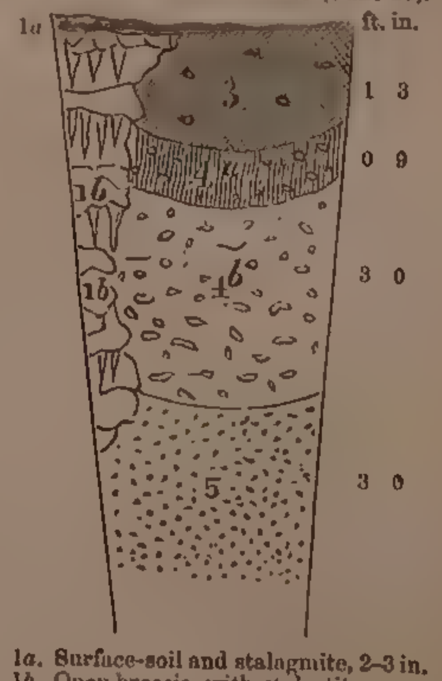
71 ft. from Gate (July 13).



1a. Stalagmitic film.
3. Cave-earth; few bones.
4. Mottled bed; few bones, a bone implement.
5. Red sand; bones numerous.
6. White calcareous sand and rock; no bones.

Fig. 13.

About 50 ft. from Gate (June 26).



1a. Surface-soil and stalagmite, 2-3 in.
1b. Open breccia, with stalactites, lining left side of cave.
3. Cave-earth.
4a. Brown mottled bed.
4b. Red mottled bed.
5. Red sand.

32. *On the* Mammal-fauna *of the* Caves *of* Creswell Crags. By Prof. W. Boyd Dawkins, Esq., M.A., F.R.S., F.G.S., F.S.A., Professor of Geology and Palæontology in the Owens College. (Read April 11, 1877.)

Contents.

I. Introduction.

The exploration of the caves of Creswell Crags carried on by the Rev. J. M. Mello, F.G.S., in 1875, and brought before the Society in that and the following year, was finally concluded last summer; and the results have been handed over to me, by the Committee, for description—a task of no little difficulty, from the vast numbers of the fossil remains which have been discovered *. The results are of considerable importance, not merely because they confirm the conclusions which were arrived at from the previous explorations, but because they add new facts to the history of palæolithic man in Britain. In dealing with these the Robin-Hood Cave will be taken first; and then I shall check the evidence which it offers by that furnished by the cavern on the other side of the ravine of Creswell Crags known as the Church Hole. It must, however be remarked that the history of both these caverns is rendered imperfect from the promiscuous diggings carried on by unauthorized persons, the results of which have not been brought before the Committee.

* Our method of work was to put up into calico bags, properly labelled, the results of the labours of each day; and these were, from time to time, sent off in hampers to Owens College, where they were spread out, cleaned, gelatinized, and arranged, each date, corresponding with the day's work, being marked on the plan. This was continued until, in six weeks, the caves were worked out as far as we cared to pursue them.

II. The Robin-Hood Cave.

A. *Distribution of Species in the Lower and Middle Strata.*

In the description of the remains from the Robin-Hood Cave in this Journal (August 1876, p. 245), attention was drawn to the fact that the cave was inhabited by hyænas during the time of the deposition of the red sand below, the cave-earth, and the breccia above, and that no traces of man were found below the cave-earth. The late exploration confirms the hyæna-occupation ; but it proves also that man was living in the neighbourhood at the time when the red sands and clays were being deposited on the unfossiliferous grey sand which covered the rocky floor (see preceding sections).

The breccia of the previous exploration turned out to be a mere local deposit, which was represented in other parts of the cave by the upper strata of cave-earth. Consequently, in the following list of the vertical range of the animals in the cave, I have classified it with the cave-earth, with which also is included the mottled stratum noted in Mr. Mello's sections, which does not seem to me to differ in any important degree from the cave-earth. The specimens from the superficial deposits above the stalagmite will be reserved for separate treatment.

The following Table shows the distribution of the animals in the Pleistocene strata.

Pleistocene Fauna of Robin-Hood Cave, 1876.

	Total from both deposits.	Grey sand.	Red sand and clay.					Breccia and cave-earth.				
			Jaws.	Teeth.	Bones, antlers.	Tools.	Total.	Jaws.	Teeth.	Bones, antlers.	Tools.	Total.
1. Man (*Homo*)	1040	...	...	...	...	8	8	...	...	...	1032	1032
2. *Machairodus latidens*	1	...	...	...	...	...	...	...	1	...	...	1
3. Lion (var. *Felis spelæa*)	10	...	...	...	...	...	...	...	2	8	...	10
4. Wild Cat (*F. catus*)	3	...	...	...	...	...	...	3	...	...	...	3
5. Leopard (*F. pardus*)	1	...	...	...	...	...	...	...	...	1	...	1
6. Spotted Hyæna (var. *H. spelæa*)	928	...	4	32	4	...	40	49	780	59	...	888
7. Fox (*Canis vulpes*)	121	...	9	4	...	...	13	30	27	51	...	108
8. Wolf (*C. lupus*)	61	...	...	...	...	...	...	1	28	32	...	61
9. Bear	78	...	...	...	...	...	...	2	39	37	...	78
10. Reindeer (*C. tarandus*)	473	...	...	20	12	...	32	1	180	260	...	441
11. Irish Elk (*C. megaceros*)	18	...	1	3	1	...	5	6	7	...	...	13
12. Bison (var. *Bison priscus*)	20	...	...	1	...	...	1	...	10	9	...	19
13. Horse (*Equus caballus*)	550	...	2	22	25	...	49	1	490	10	...	501
14. Woolly Rhinoceros (*R. tichorhinus*)	357	...	...	3	...	...	3	...	250	104	...	354
15. Mammoth (*Elephas primigenius*)	53	...	...	2	2	...	4	...	46	3	...	49
16. Hare (*Lepus timidus*)	52	...	...	...	1	...	1	...	...	51	...	51
Totals	3766	...	...	...	...	...	156	...	...	...	...	3610

From this Table it is evident that the animals were, on the whole, more rare during the deposit of the red sand below than during the time of the accumulation above it, the proportion of remains in each being as 156 : 3610.

The remains of the animals were also, on the whole, more perfect in the red sand than in the cave-earth, and not so much gnawed by the hyænas.

We may also observe that here, as in Wookey Hole, hyænas, rhinoceroses, horses, and reindeer are most abundant among the lower animals; while the traces of man, represented mainly by flint and quartzite implements, being practically indestructible, stand at the head of the list.

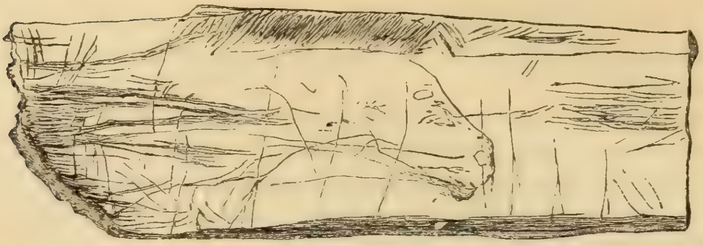
B. *Palæolithic Man.*

The implements and ornaments left behind by palæolithic man amount to a number of no less than 1040, all of which, with the exception of a few of the trimmed flakes and the incised figure of a horse engraved on a fragment of rib, are of the simplest forms, and of the types which I have already described in my former paper. The conclusion thus arrived at, that the rude implements of quartzite were used by the hunters before the more carefully finished implements of flint, is thoroughly borne out by this exploration; for although the absence of the breccia in which most of the more finely worked implements were met with in 1875 rendered the definition of the horizon of flint from that of the quartzite less distinct than before, we observed that, on the whole, the flints were found in the upper part of the cave-earth, while the quartzite implements were mainly found in the lower portion. The latter also ranged downwards, as may be seen from the following Table, into the lower red sand and clay, while the former did not.

Distribution of Traces of Palæolithic Man in Robin-Hood Cave, 1876.

	Lower red sand and clay.	Breccia and cave-earth.
Incised figure of Horse (fig. 1) ..	....	1
Bone awl	....	1
Pointed antler-tips............	....	43
Incised bone	....	1
Flint flakes, simple	....	143
Simple scrapers	....	6
Double scraper	....	1
Lanceolate trimmed flakes......	....	3
Oval trimmed flakes	....	4
Flakes worn to bevelled edge (see Q.J.G.S. 1876, figs. 9, 10, p. 253)	....	8
Chipping-block	....	1
Splinters....................	....	296
Oval ironstone implement (fig. 2).	....	2
Ironstone fragments	....	2
Quartzite round stones	5	48
,, choppers.............	....	8
,, hammer stones	....	19
,, scrapers	....	3
,, chips	3	442
Total	8	1032

Fig. 1.—*Incised figure of Horse*, $\frac{1}{1}$.



The most important discovery of the handiwork of man is the head and fore quarters of a horse (fig. 1) incised on a smoothed and rounded fragment of rib, cut short off at one end and broken at the other. On the flat side the head is represented with the nostrils and mouth and neck carefully drawn. A series of fine oblique lines show that the animal was hog-maned. They stop at the bend of the back, which is very correctly drawn. Indeed the whole is very well done and is evidently a sketch from the life. As is usually the case, the feet are not represented.

On comparing this engraving with those of horses from the caves of Périgord * and from the recently described cave of the Kesslerloch †, near Thayingen, in Switzerland, the identity of style renders the conclusion tolerably certain that the palæolithic hunters who occupied the Creswell cave during the accumulation of the upper part of the cave-earth were the same as those who hunted the Reindeer and Horse in Switzerland and the south of France.

A bone awl was also found, composed of the metacarpal of a Reindeer, and carefully rounded and smoothed ; it had been broken into three pieces before it was thrown away. By a fortunate chance I found two out of the three fragments.

The pointed antlers may have been used by man ; but they may also be the result of the action of carbonic acid in wearing away the bruised surfaces, as we shall presently see.

Of the flint implements it is only necessary to say that they are all of the types which I have described, with two exceptions, the one being an oval trimmed flake, and the other a double scraper of the
The quartzite implements are of the forms already described ; and
same form as those of the caves of Southern France and of the Kesslerloch.
of those made of clay iron-stone, only one demands special notice. It is a small oval implement of the St.-Acheul and Moustier type, blunt at the base and tapering to a rounded point (fig. 2).

The numerous split quartzite pebbles are of the same sort as those recently described by Captain Jones, U. S. A., as being in use among the American Indians of Wyoming. He writes, " Certain articles of a very rude character are still in use to some extent among our western Indians, and even in the case of such tribes as have now

* Reliquiæ Aquitanicæ.

† See 'Excavations at the Kesslerloch Cave, near Thayingen.' By Conrad Merk. Translated by J. E. Lee. Longmans, 1876.

Fig. 2.—*Ironstone implement, Robin Hood Cave, 1/1.*

entirely discarded the implements of stone and bone, relics of such materials are not uncommonly found in graves which cannot be regarded as ancient. The Shoshones, though mostly provided with tools of iron and steel of approved patterns, are still to be seen employing as a scraper in the dressing of skins a mere 'teshoa,' consisting of a small worn boulder, thinner at one end, split through the middle in such a manner as to furnish a rough cutting-edge at one side. There seems to be a considerable advantage in this over any form of knife or other tool which has yet reached them from without; and it is probable that it will be retained so long as their present method of preparing hides is in vogue"*. Probably those of the Robin-Hood Cave were put to the same use.

A fragment of "red raddle" from the cave-earth had probably been used for painting.

The large number of splinters in the cave proves that it was used by the hunters as a place of resort for a considerable time, and that they brought the raw material along with them, and made their cutting-tools as they were wanted, on the spot. The numerous broken bones prove that they were in the habit of breaking bones for the sake of the marrow, after the fashion of many savage tribes

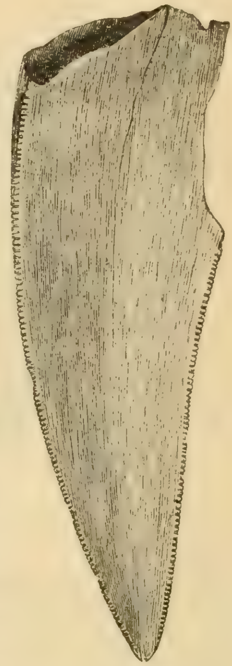
* 'Reconnaissance of North-western Wyoming,' by W. A. Jones, p. 261.

at the present day*. The obtusely pointed quartzite choppers would be admirably adapted for that purpose. Fragments of charcoal and calcined bone show also that the game was roasted inside the cave.

C. *Order Carnivora.*

Machairodus.—The discovery of the incised drawing of a palæolithic Horse is rivalled in value by that of the rare animal *Machairodus* (fig. 3) in the same stratum at a short distance away. On July 3, while I happened to be superintending the work, one of our men dug out, before my eyes, the crown of a fine upper canine quite perfect. It lay about one foot below the stalagmite in the cave-earth; and in association with it were a fine flint flake and remains of Bear, Woolly Rhinoceros, Reindeer, Horse, and Mammoth.

Fig. 3.



Upper canine of *Machairodus*, Robin-Hood Cave, $\frac{1}{1}$.

The length of the crown measures 2·6 inches as compared with specimens of the same tooth from other localities; and it is of the same broad form as those from Kent's Hole and that which I examined in 1873 in the Museum of Lyons, which was discovered at Chagny, near Dijon, in association with the Horse, Beaver, *Mastodon arvernensis*, *Ursus etruscus*, *Hyæna antiqua* (?), and three species of *Cervus*. The base of the crown measures 1·25, while the tape measurement from the base of the fang to the much-worn stump of the crown, is 4·2 inches. This specimen is of peculiar value, because it proves that the *Machairodus latidens* is a variety or species that lived in France in the Pliocene age †. Taken in connexion with similar discoveries in Kent's Hole, the Creswell example implies that the *Machairodus* was a survival from the Pliocene into the Pleistocene age, like the *Rhinoceros hemitœchus*, the Horse, and the *Elephas antiquus*, and into that later stage which is marked by the presence of large herds of Reindeer in this country. The tooth was probably introduced into the cave by the hand of man, since it is broken short off by a sharp blow, and is without marks of the teeth of hyænas; a few scratches at its base may have been made by a flint flake. Its singular shape and sharp, serrated cutting-edges would certainly strike the fancy of any rude huntsman who might be fortunate enough to meet with the carcass or skeleton of

* Dr. Schweinfurt remarks that, on his journey to the Niam-Niam, "the halting-places of a former caravan were covered by heaps of broken bones."—Vol. i.

† I take this opportunity of thanking Dr. Lortet, the Director of the Geological Museum in the Palais des Beaux Arts, at Lyons, for giving me every facility for working in 1873 at the fossil mammals under his care.

its possessor, or who might have had the rare luck to kill so formidable an animal. Indeed, that this tooth attracted attention in ancient times, we have evidence in a specimen in the Museum at Florence, found in an Etruscan tomb, and which may be fairly taken to be the earliest example of fossil-collecting within the historic period. It was derived from the Pliocene of the Val d'Arno. Whether, however, the Creswell tooth was collected or not, its mineral condition agreeing with that of the other associated teeth forbids the supposition that it was obtained from the Forest-bed, or from any Pliocene strata on the Continent, in which the remains, so far as I have yet seen, are in a totally different state of preservation and of a different colour. As the evidence stands, it is in favour of the animal having been a contemporary of man in the neighbourhood.

The Lion (Felis spelæa).—A canine, a lower true molar, a gnawed tibia, and 8 bones of the feet, belong to the Lion. The following measurements of metatarsal bones compared with those given by Mr. Sanford and myself in the monograph on *Felis spelæa* (Palæont. Soc. part 1, p. 25) imply that the animal was intermediate, in point of size, between the large variety of the caves and the smaller form now prevailing in Africa and India.

Comparative Measurements of Metatarsal 3 of Lion.

	Robin-Hood.	Fossil, Taunton Museum.	Fossil, Taunton Museum.	Recent, College of Surgeons.	Recent, W. A. Sanford.
1. Maximum length	5·0	5·94	5·40	4·08	4·66
2. Minimum circumference	1·95	2·55	2·20	1·45	1·72
3 Transverse measurement of proximal articulation	0·98	1·27	1·05	0·56	0·63
4. Vertical " " "	1·3	...	1·37	0·78	1·00
5. Transverse measurement of distal articulation ...	0·8	0.86	0·9	0·65	0·85
6. Vertical " " " ...	1·3	1·80	1·8	1·37	1·6

The Leopard (F. pardus).—One ectocuneiform from the cave-earth is undistinguishable from that of a Leopard. It is far too large to be identified with any of the smaller Pleistocene felines, and too small to match with that of any of the fossil or recent Lions, as may be seen by comparing the measurements below with those in part 1, p. 18, of 'British Pleistocene Mammalia' (Palæont. Soc.).

	inch.
Antero-posterior length	0·42
Circumference	1·5
Transverse measurement of proximal articulation	0·48
Vertical " " "	0·65
Vertical measurement of distal articulation	0·6

The Wild Cat (Felis catus ferus). Three lower jaws from the Cave-earth and one from the stratum above the stalagmite belong to the Wild Cat. One is remarkable for its massive character and large size, in which points it far surpasses any of the recent Wild Cat's with which I have had the opportunity of comparing it. The thickening of the inner alveolar border, and the implantation of the molar series in the outer edge, prove that this feline does not belong to the *Felis caffer* described by Mr. Sanford and myself in the Palæontographical Society's Memoirs (" British Pleistocene Mammalia," part iv. p. 121). The rest are also larger than the recent Wild Cat's, as may be seen by the following Table of measurements (in inches) :—

	Felis catus. Cave-earth, Robin-Hood.	*F. catus.* Cave-earth, Robin-Hood.	*F. catus.* Above stalagmite.	*F. catus* (recent). Owens College.	*F. catus.* Scotland. College of Surgeons.	*F. catus.* Germany. British Museum (Pal. Soc.).
Length of jaw	2·86	...	...	2·22		
Transverse measurement of proximal articulation	0·65	...	...	0·52		
Height of coronary process	1·3	...	...	0·98		
Length of molar series	0·97	0·82	0·95	0·78	0·82	0·74
M. 1. Length	0·38	0·3	0·35	0·3	0·32	0·29
,, Posterior transverse diameter	0·15	0·15	0·16	0·12	0·14	0·11
,, Anterior transverse diameter	0·14	0·14	0·15	0·11	0·13	0·10
,, Height	0·25	0·225	0·23	0·18		
Pm. 4. Length	0·35	0·28	0·33	0·27	0·28	0·26
,, Transverse diameter	0·15	0·125	0·15	0·11		
,, Height	0·2	0·2	0·21	0·18		
Pm. 3. Length	0·25	0·24	0·25	0·22	0·20	0·20
,, Transverse diameter	0·1	0·12	0·14	0·1	0·10	0·10
,, Height	0·18	0·18	0·18	0·15	0·18	0·15
Depth of jaw at $\overline{\text{M. 1}}$, internal	0·56	...	0·49	0·4	0.40	0·39
Thickness	0·25	...	0·24	0·2	0·25	0·22
Depth at $\overline{\text{Pm. 4}}$	0·55	...	·49	0·4		
Circumference at diastema	1·35	...	...	0·9		

The Spotted Hyæna (H. crocuta).—The remains of the Spotted Hyænas consist principally of jaws and teeth of all ages ; and those from the Cave-earth are, for the most part, in fragments.

Two skulls, a scapula, and a cervical vertebra were obtained from the Red Sand. On a comparison of the two skulls with those of the recent *H. crocuta* in the College of Surgeons, which belonged to the collection made by Captain Gordon Cumming in S. Africa, I am unable to detect any points of specific value. If any thing, the larger of the two fossil skulls, possessing the sutures and teeth of the adult, is smaller than the larger of the two recent, as may be seen from the following measurements (in inches) :—

	Red Sand, Robin-Hood Cave.	447 *a*, College of Surgeons.	447, College of Surgeons.
Length of basisphenoid	1·07	1·25	1·28
Width „ „	0·65	0·8	0·8
Length of presphenoid	1·0	1·0	1·1
Maxillaries in temporal width	3·28	3·42	3·4
Postorbital width	1·55	1·8	1·7
Length of parietals	3·0	4·0	
Length of frontals	2·56	3·32	3·2
Postorbital width of palatines	3·65	3·65	3·5
Width of posterior nares......	1·0	1·1	0·98

Both these fossil skulls have been gnawed by Hyænas; and the smaller is so mutilated that it offers no measurements of value.

The large number of teeth and jaws from the caves of Creswell, amounting altogether to 1096 and 99 respectively (Robin-Hood 812 and 53; Church Hole 284 and 46), offers a wide basis of induction for the determination of the amount of variation in the teeth of the fossil Hyæna of the caves. So far as relates to their form, I have nothing to add to the essay on the dentition published in the 'Natural-History Review,' in 1865, which was founded mainly on the large stores of remains furnished by the cavern of Wookey Hole. The extremes of size, however, are greater, as may be seen from the comparison of the following measurements (in inches) with those of the above essay.

Upper Molar Series.

	Hyæna spælea.		*H. crocuta.*	
	Pm. 1.			
	Max.	Min.	Max.*	Min.
1. Antero-posterior length	0·33	0·26	0·3	
2. Transverse breadth..................	0·32	0·25	0·25	
3. Height	0·26	0·25	0·26	
	Pm. 2.			
1. Antero-posterior length	0·62	0·58	0·58	
2. Transverse breadth..................	0·48	0·48	0·48	
3. Height	0·46	0·51	0·52	
	Pm. 3.			
1. Antero-posterior length	1·08	0·9	0·9	0·71
2. Transverse breadth	0·72	0·65	0·68	0·60
3. Height	1·0	0·9	0·96†	
	Pm. 4.			
1. Antero-posterior length	1·8	1·42	1·5	1·30
2. Transverse breadth	0·94	0·75	0·78	0·75
3. Height	0·86	...	0·82	

* 4447, College of Surgeons. The socket of the true molar proves the latter to have been bifanged. It is monofanged in 4447 A. This tooth is therefore variable in character in the living *H. crocuta*.

† Caged specimen.—*Busk.*

Lower Molar Series.

	Hyæna spelæa. Creswell.		*H. crocuta.*	
	Pm. 2.			
	Max.	Min.	Max.	Min.
1. Antero-posterior length	0·7	0·58	0·58	0·5
2. Transverse breadth	0·5	0·4	0·38	0·35
3. Height	0·42	0·39	0·42	
	Pm. 3.			
1. Antero-posterior length	0·95	0·78	0·82	0·70
2. Transverse breadth	0·66	0·5	0·55	0·5
3. Height	...	0.8	0·72+	
	Pm. 4.			
1. Antero-posterior length	1·0	0·75	0·9	0·70
2. Transverse breadth	0·53	0·50	0·5	0·50
3. Height	0·525	0·52	0·68+	
	M. 1.			
1. Antero-posterior length	1·35	1·2	1·19	1·00
2. Transverse breadth	0·58	0·45	0·48	0·4
3. Height	0·7+	0·7	0·61	

The spelæan teeth, as may be observed from the figures given above, are, on the whole, larger than those of the Spotted Hyæna which are in our museums; but the minimum measurements of the former fall within the maximum measurements of the latter. I am unable to detect any differences of form between the two which are constant. They are related to each other in the same manner as those of the spelæan are related to those of the living Lions.

The articulation of the scapula measures $2 \times 2{\cdot}5$; and the circumference of the neck is 4·5 inches.

In reviewing the whole evidence at my command as to the relation of the Cave-hyæna to the living Spotted Hyæna (*H. crocuta*), I am unable to recognize any constant differences, and therefore believe them to be specifically identical.

Fox (Canis vulpes), *Wolf* (Canis lupus).—The remains of the Fox and Wolf offer no points worthy of special notice.

Bear (Ursus ferox? U. arctos?).—The remains of Bear, consisting of two jaws, 39 teeth, and 32 bones, belong to young adults and very old individuals. Some of the teeth agree with those of the Grizzly Bear as defined by Prof. Busk (Trans. Royal Soc. 1872, p. 532 *et seq.*), while others agree closely in size and form with those of the *Ursus arctos*. I am unable to lay hold of characters by which these closely allied forms, both recent and fossil, are distinguished, so far as relates to their dentition; and I feel inclined to hold the view, lately taken by Mr. J. A. Allen *, that the two living

* Bulletin of the United-States Geological and Geographical Survey of the Territories, vol. ii. pt. iv. pp. 334 *et seq.*

forms (*U. arctos* and *U. ferox*) in North America are merely varieties "or subspecies" of one species.

D. *Orders Artiodactyla, Perissodactyla, Proboscidea, and Rodentia.*

The remains of the Reindeer, Bison, and Irish Elk merit no special attention. It may, however, be remarked that of the teeth of the first of these, amounting to 200, eleven are milk-molars, two being *deciduous molar* 2. We may also observe the absence of the Stag, which is, as a rule, very rare in the Pleistocene caves of this country, while in the prehistoric deposits it is very abundant. In the early Pleistocene, as, for example, in the Lower Brickearths of the Thames Valley, the animal abounded in Britain. It retreated before the advance of the Reindeer as the temperature became lowered, and it did not again appear in force till after the close of the Pleistocene age.

Woolly Rhinoceros.—The adult Woolly Rhinoceros is represented by 145 teeth, the young by 108. All these but three were discovered near the cave-earth.

Horse.—Most of the teeth of Horses belong to adults; but 29 milk-teeth prove that the colts were also present.

On comparing the limb-bones with those of a Shetland pony and the racehorse "Orlando" in the College of Surgeons, it is evident that the animal to which they belonged was about the size of a stout cob-horse, being considerably larger than the former, and falling short of the stature of the latter. The horse, however, of the Pleistocene age varied considerably in size. In the museum at Lyons a skeleton, set up from the remains found at Solutré, is not taller than that of a middle-sized pony; and the remains found in the cave at Shandon are considered by Prof. Leith Adams, F.R.S., to belong to animals about 14 hands high.

	Humerus.				Radius.				Metacarpal.			
	Robin-Hood.		Shetland Pony.	Racehorse.	Robin-Hood.		Shetland Pony.	Racehorse.	Robin-Hood.		Shetland Pony.	Racehorse.
1. Maximum length.........	...	...	8·4	13·0	13·8	13·5	9·8	1·45	9·2	9·2	7·0	9·9
2. Minimum circumference	5·6	5·5	3·75	8·4	5·25	5·5	3·4	5·6	4·5	4·25	2·95	4·2
3. Transverse measurement of proximal articulation	3·0	...	2·25	3·4	3·3	3·25	2·3	3·5	2·2	2·1	1·6	2·3
4. Vertical measurement of proximal articulation ...	4·4	...	...	3·3	1·5	1·25	...	...	1·25	1·4		
5. Transverse measurement of distal articulation ...	3·3	3·25	2·25	3·4	2·75	2·8	2·0	3·0	2·1	2·1	1·55	2·2
6. Vertical measurement of distal articulation	3·9	3·9	...	...	1·25	1·25	...	...	2·3	2·4		

The spelæan bones measured (in inches) belong to the limbs of two individuals which fell a prey to the Hyænas, and by a rare chance were not destroyed by their teeth. They were found in the Red Sand.

Mammoth.—The Woolly Elephant is represented by 8 teeth and fragments belonging to adults, and by 38 teeth and fragments belonging to the young. The three oldest and largest teeth are first true molars.

The remains of the Hare and the Water-vole demand no special notice, excepting that the numerous broken bones of the former show that it was an important article of food with the palæolithic inhabitants of the cave during the accumulation of the upper Cave-earth and the breccia.

E. *Remains of Historic and Prehistoric* (?) *Age.*

The superficial layer in the cave, which in some places rested on the stalagmite and in others on the upper Cave-earth, and was nowhere more than a few inches in thickness, contained the same group of objects as that from the upper strata in the Victoria Cave.

They consist of the following :—

1. A harp-shaped Romano-British brooch, adorned with blue diamonds of enamel, flanked by red triangles, of the exact size and form of that figured in my work on 'Cave-hunting' from the Victoria Cave (coloured plate, fig. 1). The two are so alike that I have no doubt that they were turned out of the same workshop.

2. A flat lamina of bronze pierced at one end for suspension, and at the other prolonged into two points which may have been used as fixed compasses. It is an implement of the same kind as that figured in 'Cave-hunting' from the Victoria Cave (coloured plate, fig. 2).

3. The boss of the hilt of a sword or dagger carved out of the head of the femur of Horse or Ox, and ornamented with concentric circles which may have been made with number 2.

4. A fragment of Samian ware, and many fragments of grey lathe-turned pottery of the usual Romano-British type, such as that found in abundance at the Romano-British cemeteries of Hardham * and Seaford † in Sussex.

5. A whetstone. Numerous broken bones of animals which had been used for food.

6. A few human teeth, human vertebræ, a fragment of a femur, of an ulna, and a few bones of the extremites were also met with.

7. The remains of the animals imply a mixture of wild and domestic species, as may be seen in the following Table :—

* Dawkins, "Romano-British Cemetery and Roman Camp at Hardham," Sussex Archæol. Coll. 1863.

† Price, Journ. Anthrop. Inst. vol. vi. p. 300.

Prehistoric (?) and Historic Fauna of Robin-Hood Cave, 1876.

	Jaws.	Teeth.	Bones. Antlers.	Total.
Wild Cat (*Felis catus ferus*)	2	...	...	2
Dog (*Canis familiaris*)...................	...	...	2	2
Fox (*C. vulpes*)............................	3	...	15	18
Marten (*Mustela martes*)	1	...	...	1
Stoat (*M. erminea*)	1	...	...	1
Badger (*Meles taxus*)	...	...	4	4
Stag (*Cervus elaphus*)	2	5	...	7
Roe (*C. capreolus*)	...	...	2	2
Shorthorn (*Bos longifrons*)	1	2	17	20
Sheep or Goat?	13	10	87	110
Pig (*Sus scrofa*)	2	2	15	19
Hare (*Lepus timidus*) .... } Rabbit (*L. cuniculus*) .... }	5	...	51	56

To these may be added a few birds' bones.

We may remark that the condition of the remains of the Dog show that it was used for food as well as for the chase.

This group of remains belongs to the historic period, as established by the Romano-British pottery and enamelled brooch.

Three small fragments of pottery, black in colour, and with little fragments of limestone imbedded in its paste, are of the same sort as that generally found in Neolithic deposits, and are unlike any Romano-British pottery which I have seen. They may imply that the cave was used as a shelter by Neolithic tribes as well as by Palæolithic hunters and Romano-British refugees.

A flint strike-a-light, triangular in form, and of uncertain date, was also obtained, as well as two leaden pistol-bullets and an iron ring, which it is unnecessary to notice.

The remains of the following Mollusca have been specifically identified by Mr. Thomas Kelsall, of the Manchester Museum:—

1. *Helix nemoralis.*
2. —— *lapicida.*
3. —— *rotundata.*
4. *Helix pulchella.*
5. *Achatina acicula.*
6. *Unio pictorum.*

The general conclusions relating to the fauna of the Robin-Hood Cave will be deferred until that of the Church Hole has been brought before the Society.

III. The Fauna of the Church-Hole Cave.

A. *Distribution of Species in Pleistocene Strata.*

In dealing with the distribution of the fossil remains in the Church Hole, I have adopted the same divisions as in the Robin-Hood Cave, those from the Red Sand being classified together, while those from the strata above, as far as the stalagmite, are ranked under a second head. The most important deduction to be made from the following Table is, that while the association of remains is similar to that in the Robin-Hood Cave, the remains in the Red Sand are more abundant and, it may be added, in a more fragmentary state. The Hyænas were present in greater force during the earlier stage in the history of this than in that of the above-mentioned cave.

Pleistocene Fauna of Church-Hole Cave, 1876.

	Totals from both deposits.	Red Sand.					Stalagmitic Breccias and Cave-earth.					Expl. 1875.
		Jaws.	Teeth.	Bones and Antlers.	Tools.	Total.	Jaws.	Teeth.	Bones and Antlers.	Tools.	Total.	
Man (*Homo*)	234	...	...	...	23	23	...	...	...	211	211	
Lion (var. *Felis spelæa*)	2	...	...	...	...	...	...	...	2	...	2	
Polecat (*M. putorius*)	1	1	...	...	...	1	...	...	...	...	...	
Spotted Hyæna (var. *H. spelæa*)	410	13	140	32	...	185	33	144	48	...	225	10
Fox (*Canis vulpes*)	19	...	2	...	...	2	10	1	6	...	17	
Wolf (*C. lupus*)	19	4	3	...	...	7	3	2	7	...	12	
Bear (*U. ferox*?, *U. arctos*?)	55	...	10	12	...	22	...	10	23	...	33	1
Reindeer (*Cervus tarandus*)	412	37	...	101	...	138	8	55	211	...	274	4+
Irish Elk (*C. megaceros*)	14	2	4	3	...	9	1	2	2	...	5	
Bison (var. *B. priscus*)	45	...	...	11	...	11	3	6	25	...	34	5
Horse (*Equus caballus*)	310	...	90	30	...	120	1	170	19	...	190	77
Woolly Rhinoceros (*R. tichorhinus*)	250	...	31	70	...	101	2	51	96	...	149	103+
Mammoth (*E. primigenius*)	57	...	10	8	...	18	...	33	6	...	39	11
Hare (*Lepus timidus*)	10	...	2	...	...	2	...	...	8	...	8	8
Totals	1838	57	292	267	23	639	61	474	453	211	1199	219

The last column in the above Table represents the species found by Mr. Mello in 1875.

B. *Palæolithic Man.*

Human implements of various sorts were met with in intimate association with the fossil animals in all the deposits under the stalagmite; and large quantities of broken bones testified to the presence of Man, just as the gnawed bones proved that of the Hyænas in the cave. In the strata above the Red Sand there were fragments of charcoal and of calcined bone.

As may be seen from the following Table of distribution of works of Man, there is the same distinction to be observed here as in the Robin-Hood Cave between the implements of the upper and lower strata. From the former were obtained all the implements of bone, antler, and flint; while in the latter we only discovered a few implements of the rudest kind, made of quartzite.

Articles of Bone and Antler.—The articles made of bone are as follows:—

1. A well-shaped needle (fig. 4), absolutely perfect, made out of a metacarpal or tarsal bone of a ruminant, and larger than any of those figured from the palæolithic caves of France, Belgium, or Switzerland.

Fig. 4.—*Bone Needle, Church-Hole Cave*, $\frac{1}{1}$.

Fig. 5.—*Bone Awl, Church-Hole Cave*, $\frac{1}{1}$.

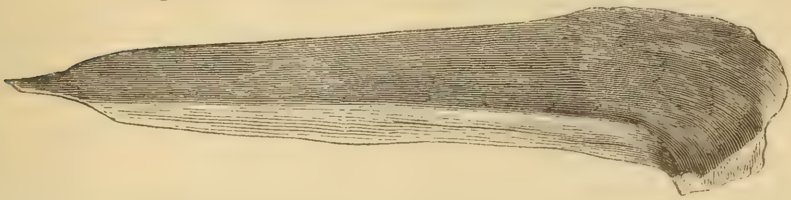
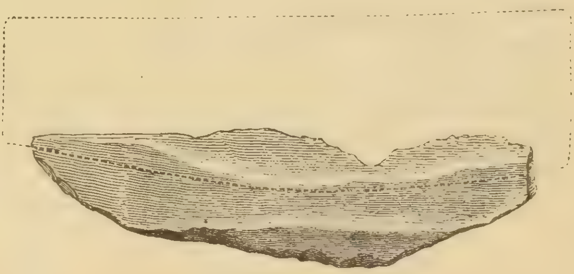


Fig. 7.—*Rod of Reindeer Antler, Church-Hole Cave*, $\frac{1}{1}$.

Fig. 6.—*Notched Bone, Church-Hole Cave*, $\frac{1}{1}$.

Fig. 8.—*Flake worn on one side, Church-Hole Cave.*



2. Two bone awls (fig. 5) fashioned out of the tibiæ of a Hare, and polished by long-continued use.

3. A broad spatulate fragment (fig. 6) of the distal portion of the transverse process of one of the lumbar vertebræ either of a Horse or large ruminant, rounded at the end and with its edges notched. It closely resembles the "bone knife-like implement notched and scored" from the Grotte de la Gorge d'Enfer, figured in the 'Reliquiæ Aquitanicæ' (B, pl. xxv. fig. 2, pp. 183 *et seq.*). In our specimen, however, the notches are deeper and wider apart.

4. Two carefully rounded rods made of antler, with one of their extremities traversed by a deep lateral groove (fig. 7), and the other broken short off, may have been spear-heads, in which case the groove would be for the reception of the tapering end of the shaft. They are of the same form as the basal portions of those from the cave of the Kesslerloch, considered by Dr. Merk to be spear-heads (*op. cit.* figs. 16, 20, 26). A third cylinder of antler, rounded like the above, resembles the one from Cro-Magnon, figured in the 'Reliquiæ Aquitanicæ' (B, pl. xii.).

3. *Articles of Flint and Quartzite.*—Among the stone implements the only two forms worthy of notice are those presented by three flakes, two of which have one of their edges straight, sharp, and unworn, while the other is worn to a curve (fig. 8). This is doubtless due, as Mr. Evans has suggested in his 'Ancient Stone Implements,' to the sharp edge having been imbedded in a handle of some perishable material, either wood, like some of the flakes from the neolithic pile-dwellings of Switzerland, or horn, which would speedily be destroyed (see dotted outline in fig. 8). The second form is that of an awl, consisting of a flake with the end chipped to a point and well worn by friction.

The following list represents the distribution of the palæolithic implements in the cave:—

Distribution of Traces of Palæolithic Man in Church-Hole Cave, 1876.

	Red Sand.	Cave-earth.
Bone needle (fig. 4)	..	1
Bone awl (fig. 5)	..	2
Notched lamina of bone (fig. 6)	..	1
Rounded spear-head?	..	2
Rod of antler (fig. 7)	..	1
Flint flakes	..	70
Flint awls	..	2
Simple scraper	..	1
Flakes worn to bevelled edge	..	2
Splinters	..	62
Quartzite round stones	20	53
,, choppers	1	4
,, flakes	..	3
,, chips	3	9
	24	213

The group of implements from the upper strata is, on the whole, of the same general type as that of the Robin-Hood Cave, although no fragments of the elaborately chipped "lance-heads" of the "type de Solutré" were discovered, nor any implements of the St.-Acheul or Moustier forms.

The remains of the associated animals, as compared with those of the Robin-Hood Cave, present no points of difference which are worthy of special notice.

C. *Remains of Historic Age.*

The works of art and the remains of the animals in the superficial stratum at the entrance, and above the stalagmite in the cave, are of the same general order as those which have been mentioned from the Robin-Hood Cave ; bnt no fragments of prehistoric pottery were met with. They consist of the following :—

1. A large, plain, harp-shaped fibula of bronze, quite perfect, found at the entrance.

2. A bone awl.

3. A square polished bone, like a die cut in half, ornamented with circles on all sides but one.

4. Numerous fragments of grey lathe-turned Romano-British ware.

5. A fragment of a whetstone.

6. A black flint strike-a-light.

7. A calcaneum of an adult, and three vertebræ of a child. The first of these was found outside the entrance, associated with the bronze brooch above mentioned and a fragment of coarse pottery. Close by were burnt stones and charcoal, and fragments of broken and cut bones, which proved the position of the hearths during the time of the Romano-British occupation of the cave.

A fragment of glazed mediæval (?) ware and a silver coin, which Mr. Evans has been kind enough to identify as probably of Henry 1st, demand no further notice.

The following animals occurred in the superficial deposit above the stalagmite :—

	Jaws.	Teeth.	Bones.	Total.
Wild Cat (*F. catus*)	...	...	1	1
Marten (*Mustela martes*)	1			
Meles taxus	2	...	2	4
Dog (*Canis familiaris*)	1	...	3	4
Fox (*Canis vulpes*)	3	...	2	5
Stag (*Cervus elaphus*)	1	...	3	4
Shorthorn (*Bos longifrons*)	...	3	14	17
Sheep or Goat	6	...	50	56
Horse (*Equus caballus*)	...	3	1	4
Hog	2	3	3	8
Hare and Rabbit	20+	...	100+	120+

D. *Robin-Hood and Church-Hole Caves occupied by Brit-Welsh Refugees.*

This group of prehistoric and historic animals is identical with that which has been met with in the caves of Dowkerbottom, Kelko, and Victoria in Yorkshire, of Kirkhead in North Lancashire, of Poole's Cave, near Buxton, and of Thor's Cave, near Ashbourne, in Staffordshire; and in all these it is associated with the same set of human implements and ornaments, which are proved by the coins to belong to the period which lies between the departure of the Roman legions from Britain and the conquest by the English. All these caves, as may be seen by a reference to my work on 'Cave-hunting,' have been used as places of shelter by Brit-Welsh refugees flying from their homes before the face of the English invaders. They complete and round off the story of the conquest revealed by the lament of Gildas, and by the blackened ruins of the Roman towns and villages, and they testify to the truth of the views as to the nature of the English conquest held by the eminent historians Messrs. Green and E. A. Freeman.

The date of the occupation of these caves by the Brit-Welsh probably falls within the fifth or sixth centuries, and is not later than the time when that district fell into the power of the Mercian or Northumbrian Angles, an event which certainly took place when the kingdom of Elmet (district of Leeds and Bradford) was conquered at the close of the sixth century. The same group of remains may reasonably be looked for in all the caves which lie within the area fought over so long in this country, by the Brit-Welsh fragments of the Roman empire on the one hand, and the ruthless, exterminating English on the other, who won it with their own good swords, and whose descendants are now founding other Englands beyond seas by similar though less violent methods.

IV. Condition of Fossil Remains in the Creswell Caves.

The bones, antlers, and teeth in these two caverns are divisible into three distinct groups, so far as relates to their condition:—(1) those which are gnawed by the Hyænas; (2) those which have been broken up and, in some cases, burnt by Man; (3) those which have been attacked by the carbonic acid in the rainwater which has percolated through the cave-earth and red sand.

By this last active agent they have sometimes been reduced to very fantastic forms. In some cases the enamel of the tooth is worn away, in others the dentine; many of the antler-tips have been so sharpened by it that they may readily be mistaken for human implements. That, for example, figured in my last paper (fig. 1) I now consider not to be of proved human workmanship. Wherever also the surface of the bone or antler has been crushed the chemical action has been intensified, and a hollow cavity is the result. In working out this point I am indebted to my colleague Prof. Schorlemmer, F.R.S., for proving it by experiment in his laboratory.

I have never observed the results of this chemical action so marked in the contents of any other cavern, which may be explained by these being nearer the surface of the ground above, and therefore more exposed to the attack of the acid-laden water than the great majority of caverns.

It may be added that the same results may be produced by chemical action intensified by pressure, as pointed out by Mr. Sorby's experiments.

V. General Conclusions as to Pleistocene Fauna of Creswell Caves.

It remains now to sum up the results of these explorations of the Creswell Caves. The associated species of the Robin-Hood Cave are the same as those of the Church Hole; and there can be no doubt that the caves were inhabited at the same time. The fauna of the Red Sand and of the Cave-earth is alike in both. The palæolithic hunter who first appeared used ruder implements than those who succeeded him.

The animals belong to groups which spread over Central Europe, from the Pyrenees as far north as the Elbe, and swung to and fro according to the season. They would naturally find their way from the low grazing-lands now occupied by the German Ocean up the line of the Trent to Creswell, as may be seen by the accompanying map (fig. 9).

In the absence of physical evidence it is useless to speculate on their relation in this district to the Glacial period, because they lived in Europe in Preglacial, Glacial (= Interglacial), and Post-glacial times.

A. *No Cave-fauna proved to be Pre- or Interglacial.*

Nor, may it be added, is there satisfactory evidence offered by any cave in this country which enables us to fix the relation to the Glacial age of any cave-fauna in particular. In the Victoria Cave, for example, quoted by Mr. Tiddeman, Mr. James Geikie, and others, as decisive of the Pre- or Interglacial age of the cave-fauna below the clay, the whole question turns on the age of the clay above the bone-bearing strata at and within the entrance. And this is not proved to be "boulder-clay" ('Ice Age,' p. 510), because there are no boulders in it; nor is it proved to be Glacial ('Nature,' 1876, p. 505), because clay of that kind is now being deposited in that very cave. That it has ultimately been derived from the wreck of the Boulder-clay at a higher level, which was formerly spread over the country, and has been washed in by the rains, is very probable. Nor do the piles of travelled blocks which occur in the talus outside the entrance throw any light on the point, because they are *remaniés* and not *in situ*. They may have tumbled from the cliffs above during the accumulation of the talus, and long after the glaciers had retired from Yorkshire. These doubts as to the pre- or interglacial age of the fauna below the clay which grew up in my mind while intrusted with the conduct of the exploration, and have

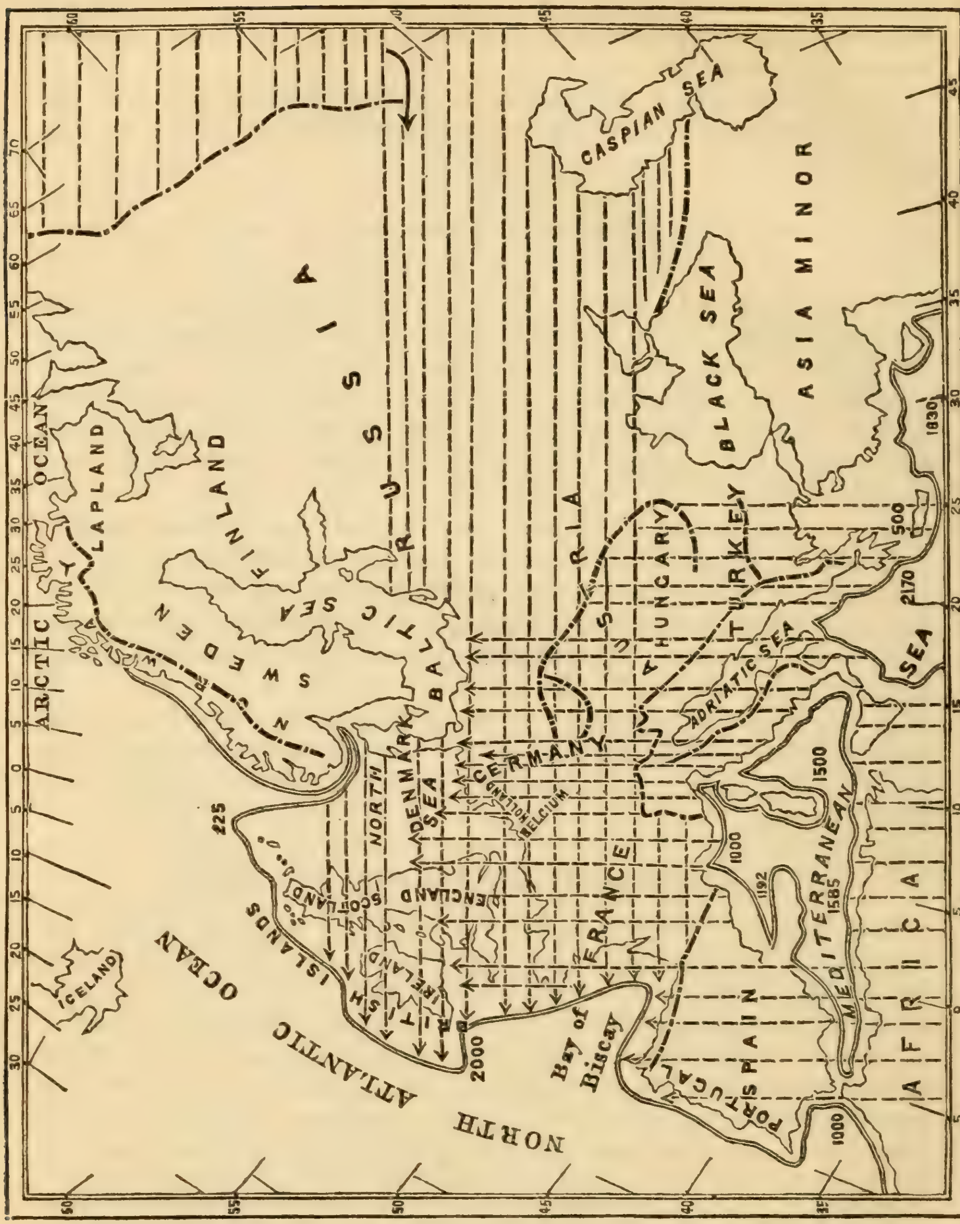


Fig. 9.—Map of the Pleistocene Geography of Europe.

The double line represents the probable outline of the Pleistocene land. The vertical broken lines show the range of the southern Mammalia, and the horizontal ones that of the northern forms.

been confirmed since by repeated visits, are shared by Prof. Hughes, whose opinions on a matter of this kind are entitled to the greatest weight. At present he holds that it is postglacial.

The second reputed case of the discovery of Pleistocene mammalia in Glacial or Interglacial deposits is offered by those in the caves of Cefn explored and described by Dr. Falconer, Mrs. William Wynn, Prof. Hughes, the Rev. D. R. Thomas, and myself, and lately correlated (Quart. Journ. Geol. Soc. xxxii. p. 94) by Mr. Mackintosh with the Glacial strata of the surrounding district. Here, again, the value of the evidence turns on the point as to whether the strata inside the caves are Glacial deposits *in situ* or have been derived from their denudation. Both Prof. Hughes and myself agree in holding the latter view. This may have happened at any period in the Pleistocene age subsequent to their deposition, by the waves of the sea. It seems therefore to me altogether premature to build up any hypothesis on the foundations offered by the discoveries made hitherto in these two sets of caves as to the relation of their contents to the Glacial period. The open caves were undoubtedly inhabited by the wild animals before the Glacial age; but I do not know of any one cave in any part of Europe which has been proved to contain Preglacial or Interglacial mammalia.

B. *No proof of Pre- or Interglacial Cave-Man in Britain.*

The question naturally arises, When did Man first appear the cave-fauna? Messrs. Tiddeman and James Geikie* find an answer in the discovery of "a human bone or fibula," which "was certainly found beneath Glacial clay in the Victoria Cave." That this clay is Glacial is, as I have shown above, a matter of opinion; nor am I by any means satisfied that the fragment of shaft without articulations of so variable a bone is really beyond all doubt human. When first discovered it seemed to me too equivocal a specimen to be identified with absolute certainty; and therefore it was omitted from my report to the British Association in 1873. Prof. Busk (Anthropological Journ. iii. p. 392) also, to whom it was submitted, considered it equivocal, then "was induced to think that it might be elephantine," and ultimately concluded, from its correspondence with an abnormal and unique recent human fibula, that it is human. Since this identification the numerous Bear's fibulæ from Windy Knoll which I have examined seem to me to throw additional light on the fragment, and to render it very probable that it is ursine. I am not prepared to say that I can identify it with any one ursine fibula; but, taking into account the great difference in size and form in that bone, and the fact that one fossil Bear's fibula differs from another as much as or more than this one does, it may probably be referred to one or another of the fossil Bears *U. spelæus* or *U. ferox*, of which the remains found in the Victoria Cave are of gigantic size. On this point I would remark that a fragment of ursine fibula, from the cavern of Lozère, in the British Museum very nearly comes up to that of Victoria in size, measuring in circumference 2·0 inches as compared with 2·2 of the latter. The Victoria fibula differs far

* Tiddeman, 'Nature,' 1876, p. 505; see also Brit. Assoc. Rep. 1875, p. 173:—"In the opinion of your reporter, the Craven savage, who lived before the Great Ice-sheet and *before the Great Submergence*, may form another of the many strong ties which bind together the sciences of Geology and Anthropology." Geikie, 'Ice-Age,' 1st edit. p. 510:—"The interest of this discovery (*i. e.* of the fibula) consists in the fact that the deposit from which the bone was obtained is overlaid, as Mr. Tiddeman has shown, 'by a bed of stiff Glacial clay containing ice-scratched boulders.' Here then is direct proof that Man lived in England *prior to the last Interglacial period*."

more from the series of normal human fibulæ than from the series of those of Bears. At all events the obscure fragment in question seems to me altogether insufficient to base any theory as to "Pre-" or "Interglacial Man," both in itself and in the conditions of its discovery. Prof. Busk, whose absence through indisposition this evening I regret, has requested me to say on his part that he "should not himself be inclined to rest or to base the existence of Preglacial Man on a fragment of bone like that, about which it is impossible that some doubt should not exist."

Nor am I aware of any other cave which offers proof of the presence of Man in this country before or during the Glacial period. Fixing my eyes upon the Pleistocene fauna only, I find that that portion of it to which Man belongs (the Arctic division) arrived in Britain before the deposit of the Boulder-clays, and lived here afterwards, and that therefore there are *a priori* grounds for the belief that Man also arrived at the same time. Proof of this, however, is wanting, unless the Lower Brick-earths of the Thames valley with *Rhinoceros megarhinus* be taken to be Preglacial, in which the discovery of a flint flake by the Rev. O. Fisher (Proceed. West Lond. Scient. Assoc. Sept. 1876) and myself in 1872 has been recently confirmed by that of a second by Mr. R. W. Cheadle.

In all probability, while the Pleistocene climate was being lowered to such a degree as to allow of the invasion of Europe by the Arctic animals Man came in; and as the climate became so severe as to allow of large tracts of ground in the north being covered with an ice-sheet, and the higher grounds of Central and Southern Europe with glaciers, Man and the animals were pushed down further to the south. When the climate, after various oscillations, grew warmer, they found their way again northwards and over the glaciated areas. On this view Man would be Preglacial, Glacial, and Postglacial in Europe, and it would be impossible to arrive at the age of any given accumulation of his remains either in the caves or river-valleys, apart from physical evidence in each case,—such evidence, for example, as that recorded by Lyell, Prestwich, Evans, Wyatt, and others regarding the fluviatile strata with Palæolithic implements at Bedford, Hoxne, and in the valley of the Thames, which are proved to be newer than the Boulder-clay of their respective districts, and to be therefore "Postglacial" in the sense of being after the minimum temperature was reached, of which that Boulder-clay is the sign*. I am unable to see that we gain any thing by the term "Interglacial," which Mr. James Geikie proposes not merely for these Palæolithic gravels but for all those in France as far south as the Pyrenees, without proving that any one of them is covered by a Glacial deposit.

C. *The Palæolithic Man of Creswell of late Pleistocene Age.*

It seems to me that glaciers and icebergs and their work, however

* The Palæolithic gravels of Hoxne, Bedford, and Teddington are considered by Mr. Evans later than *the Upper Boulder-clay* of Searles Wood (Presidential Address, Quart. Journ. Geol. Soc. 1875, p. lxxiv).

valuable instruments they may be for classifying the Pleistocene strata in glaciated areas, cannot be used successfully in non-glaciated areas for the arrangement of the European Pleistocenes, which must be treated in the same way as other geological deposits by an appeal to the animal remains which they contain. The glacial series of events * is one thing, and the zoological † altogether another thing. The Pleistocene fauna is not divided from that which went before and that which followed after by a barrier of ice.

The Palæolithic hunters of the Creswell Caves, judged by the zoological standard, belong to the late Pleistocene age, since the numerous remains of Reindeer prove that the Arctic mammalia were then in possession of the land. Whether they be Pre- Inter-, or Postglacial is altogether doubtful.

Discussion.

Prof. Rütimeyer dwelt on the insufficiency of stratigraphical data for the determination of the age of glacial deposits in caves, but referred to two beds of lignites on the shores of the Lake of Zürich, which are undoubtedly of interglacial age, seeing that they are underlain and overlain by glacial deposits. In these lignites there had been found remains of *Cervus elaphus*, *C. alces*, *Ursus spelæus*, and of *Rhinoceros hemitœchus* and *Elephas antiquus*, the last two determined by the late Dr. Falconer. He remarked that traces of man's existence have been found along with such remains, and in Italy a human skull occurred in strata containing *Elephas meridionalis*. In the lignite of Wetzikon thin wooden stakes have been met with, sharpened at one end, and bound round with what seemed to be strips of bark, which, however, had proved to be small segments of similar sticks split radially in the direction of the medullary rays. Prof. Rütimeyer added that traces of man have been thus discovered in true Pliocene deposits on both sides of the Alps.

Mr. Evans, from the form of the needle and scrapers, was inclined to refer them to a later age than that usually assigned to Solutré. He inquired whether the ruddle mentioned by Prof. Dawkins consisted of scraped hæmatite like that found in French caves; for if so it showed an interesting similarity of habit in people so widely separated. He noticed the resemblance of the quartzite implements to those of the neighbourhood of Toulouse. With regard to the earliest appearance of man in this country, Mr. Evans remarked that, if there was evidence of his presence in glacial or preglacial times, he must have existed previously somewhere else under a milder climate. This, he thought, was probable; but he had not yet met with any conclusive evidence of the fact, and he was glad to find that the determination of the supposed human fibula from the Victoria Cave was so doubtful that it may safely be rejected. With regard to the alleged discovery of traces of preglacial man in Suffolk and Norfolk, he

* Geikie, 'Ice-Age.'

† Boyd Dawkins, "Classification of Pleistocene Strata by Mammalia" Quart. Journ. Geol. Soc. 1872, and 'Cave-hunting.'

thought it was founded on a complete misunderstanding of the nature of the beds, which were really *remaniés*.

Dr. Murie said that the whole matter resolved itself into a very small point. With regard to the supposed human fibula from Victoria Cave, he stated that, his attention having been called to the bone by Prof. Busk, he had made a careful examination and comparison of it in the Museum of the Royal College of Surgeons, and come to the conclusion that it might be the bone of almost any animal; all ideas of the habits of the cave-dwellers founded upon it were therefore mere fictions.

Prof. Ramsay thought that the evidence went to prove the existence of these caves before the Glacial period. They must have been excavated by the action of water charged with carbonic acid; and glacial bones may easily have got into them. He was much gratified by Prof. Rütimeyer's confirmation of the occurrence in Switzerland of interglacial beds containing evidence of the existence of man; and if man went up to Glacial beds, he must have previously lived somewhere outside them. He thought that the evidence for the existence of man in the Victoria Cave before the Glacial period was stronger than that against it.

Mr. Callard remarked that the Victoria-Cave fibula was found just at the entrance to and not inside the cave; and as there was a doubt about its being human, it should be left out of consideration. The lamination of the clays that cover the bone might, he thought, have resulted from their being slowly dropped from above at a subsequent period.

Prof. Prestwich said that geologists could not found any argument upon this bone. He differed from Prof. Dawkins with regard to the age of the deposits in the Victoria Cave, which he thought might be Preglacial, but agreed with him that in this country we have no evidence of the presence of man before the Glacial age. The Lower Thames gravels are of Postglacial age, as the *Gryphæa incurva* has been found in them, and this would tend to fix their date as subsequent to the Boulder-clay, from which that fossil is most likely derived.

The President noticed the interesting association of the Woolly Rhinoceros, Mammoth, and Reindeer, and commented on the alleged difficulty of separating the Grizzly and Brown Bears by their comparative anatomy, which, dealing as it does here with the skeletons alone, and leaving out of consideration the habits of the animals and all zoological data, seems to show an identity of two animals which in nature are very distinct. He asked Prof. Boyd Dawkins whether the impression which prevailed in some quarters that there had been a want of care in the excavation of the Victoria Cave was well-founded.

Prof. W. Boyd Dawkins said that, with respect to the Victoria Cave, he could not say whether it was preglacial or glacial, nor even define its relation to the Glacial period. The age of the clays was a matter of opinion. At present the Victoria Cave is being very carefully worked. In this country, he thought, we have no evidence of Preglacial man, unless the Lower Brick-earths be Preglacial.

33. *On the* Upper Limit *of the* essentially Marine Beds *of the* Carboniferous Group *of the* British Isles *and adjoining* Continental Districts; *with* Suggestions *for a* fresh Classification *of the* Carboniferous Series. By Professor Edward Hull, M.A., F.R.S., F.G.S., Director of the Geological Survey of Ireland. (Read April 25, 1877.)

Contents.

Part I.

Introductory.—It is only recently that the materials have been obtained for a complete comparison between the different members of the Carboniferous group as they occur in Ireland and Great Britain. Much misconception has, for example, prevailed in some quarters regarding the true position in the series of those beds which, in the south of Ireland, immediately overlie the Carboniferous Limestone; and by some means or other, which I have not fully been able to ascertain, the term "Coal-measures" has come to be applied to all the beds from the top of the Limestone up to the coal-bearing measures of the Leinster Coal-field and of the corresponding beds of Kerry, Limerick, and Clare. The consequence is that it has sometimes been supposed that the coal-bearing districts of the south of Ireland are much more extensive than is actually the case. As far as the maps of the Geological Survey are concerned, we are now taking steps to give to the public a truer idea of the actual limits of the coal-bearing strata, and also to correlate with the British series the strata between them and the Limestone. Mr. Hardman has nearly completed a resurvey of the coal-districts of Carlow, Kilkenny, and Tipperary, resulting in a more accurate and detailed representation of the different divisions; and I hope a similar revision will ultimately be extended to that large area in the south-west occupied by similar beds, with very little true Coal-measures at all, but which has been described only recently as "one of the largest coal-fields in the British Islands."

Notwithstanding that the term "Coal-measures" has been applied to all the beds above alluded to in the publications of the Geological Survey as well as of amateur geologists, the late Director of the Irish Survey, Professor Jukes, has left on record his opinion that the lower portion of them, including the shales and flags immediately over the Limestone, are in reality the representatives of the Millstone-Grit series of England. Thus, in the Explanatory Memoir to sheet 137 of the maps of the Geological Survey, he says:—"Doubtless the whole of the Coal-measure series of Central Ireland is contemporaneous with the lower part only of that of Central England, including the Millstone Grit in that lower part."*

I have reason to believe, from a conversation I have had with the father of Irish geology himself, Sir R. Griffith, that he shares the same opinion; and if there had been room for doubt on the subject on other grounds, this doubt must have been dispelled upon the identification in the Leinster Coal-field of that peculiar and important member of the Carboniferous series, namely the "Lower Coal-measures" or "Gannister Beds,"† which, in the north of England, overlies the Millstone Grit, and contains the expiring representatives of the marine fauna of the Lower Carboniferous series as hitherto constituted.

The additions which are now being made to the maps of the Geological Survey of the Leinster and Munster coal-fields will be at once understood when it is stated that instead of one formation, represented by one shade of dark colour, and included under the general term of "Coal-measures," we are tracing out and distinguishing representatives of four divisions, viz.:—1. Yoredale Beds; 2. Millstone Grit; 3. Gannister Beds; and 4. the Middle Coal-measures of the British series. The changes thus effected will have, at

* *L.c.* p. 11, foot-note.

† In the succeeding pages I shall call this member of the series by the designation of "Gannister Beds," in order, amongst other reasons which will appear further on, to avoid confusion.

least, one important value—that they will strictly define the limits of the coal-bearing tracts.

I propose in this paper to show to what extent the British Carboniferous rocks have their representatives in Ireland; after which I will endeavour to point out the significance, as bearing on the question of classification, of that remarkable series of beds already referred to, known as the "Gannister Beds" of the late Professor Phillips; and lastly I shall state the conclusions which seem to me to arise from the above considerations, and which seem to render desirable a fresh mode of classifying the Carboniferous beds, with a view to the introduction of a "Middle Carboniferous series" to include all the strata lying between the Mountain Limestone and the Middle Coal-measures, and including the Yoredale Beds, Millstone Grit, and Gannister Beds.

Arrangement of the Subject.—In considering the subject of the Carboniferous beds of Ireland, it will be desirable to divide it into three portions, taking:—I. The Southern Coal-districts; II. The Northern Coal-districts; and III. The Ballycastle Coal-district in Co. Antrim, which differs from both. But before doing so it will be desirable, for the sake of comparison, to state the succession of the strata in the British Carboniferous districts, as now very generally recognized*; and for the purpose of easy reference I have arranged them into stages.

The British Carboniferous Series.

Beds in descending Order, with Localities.

	Name of Formation.	Localities.
Essentially Freshwater and Estuarine Beds.	STAGE G. *Upper Coal-measures.*—Reddish and grey sandstones, breccias, and clays, with thin coal-seams and limestones. FOSSILS (freshwater or estuarine).—Fish (migratory); Crustacea, *Cythere inflata*; Annelids, *Spirorbis carbonarius*.	Manchester, Stoke-on-Trent, Newcastle-under-Lyne, S. part of Dudley Coal-field; Banks of the Dee near Ruabon; Hamilton and Ayrshire in Scotland.
	STAGE F. *Middle Coal-measures.*—Yellowish sandstones, clays, and shales, with thick coals. FOSSILS (freshwater or estuarine)†.—Fish (migratory); Molluscs, *Anthracosia*, *Anthracomya*; Crustacea, *Beyrichia*, *Estheria*; Annelids, *Spirorbis*. Marine species, rare.	Central portions of all the coal-fields of England and Wales; Upper Coal-measures of Scotland.

* 'Coal-fields of Great Britain,' 3rd edit. p. 80. Index-sheet of formations of the Geological Survey (1871).

† Though the fossils of the Middle Coal-measures consist of those bivalves above named, and of whose habitat there is some doubt, true marine bands are occasionally found, as at Ashton-under-Lyne, with *Discites*, *Aviculopecten*, &c. See "Geology of the Country around Oldham," Mem. Geol. Survey, p. 64.

	Name of Formation.	Localities.
Essentially Marine.	STAGE E. *Gannister Beds* (Phillips), or *Lower Coal-measures.* — Flagstones, shales, and thin coals, with hard siliceous floors (Gannister). FOSSILS (marine).—Fish, similar to those above (migratory); Molluscs, *Goniatites, Discites, Orthoceras, Posidonia, Monotis, Aviculopecten, Anthracosia, Lingula*, &c.	South Lancashire, N. Staffordshire, N. Wales and S. Wales.
	STAGE D. *Millstone-Grit Series.*—Coarse grits, flagstones, and shales, with a few thin coal-seams. FOSSILS (marine).—Similar to those of the Lower Coal-measures.	Uplands of Yorkshire, Lancashire, and Derbyshire; N. Staffordshire and N. and S. Wales, &c.
	STAGE C. *Yoredale Series.*—Shales and grits, passing downwards into dark shales and earthy limestones. FOSSILS (marine).—Including *Goniatites, Aviculopecten, Ctenodonta, Chonetes, Discina, Posidonomya, Productus*, &c.	Uplands and valleys of Lancashire, Yorkshire, Derbyshire, N. Staffordshire, Wales, &c.
Essentially Marine (except Stage A in Scotland).	STAGE B. *Carboniferous Limestone.*—Massive limestone, passing northwards into several beds, with intervening shales and grits. FOSSILS.—Fish, Crustacea, Molluscs, Crinoids, Corals, &c.; all marine species.	Wales, N. & S., Derbyshire, Yorkshire, Cumberland; in Scotland, the Lower or Main Limestone.
	STAGE A. *Lower Limestone Shale and Calciferous Sandstone.*—Dark shales in some places; grits, conglomerates, and red sandstones and shales in the northern districts. FOSSILS (marine).—*Spirifera cuspidata, Rhynchonella pleurodon*, &c.	South Wales, Northumberland, and Durham; in Scotland "Calciferous Sandstone Series."
Freshwater Beds.	BASIS. *Upper Old Red Sandstone.*—Yellow sandstones and conglomerates. FOSSILS (freshwater?).—Not well represented in England.	S. Wales, Northumberland; Scotland (Dura Den); Ireland (Kiltorcan).

Thus, taking the lacustrine formation of the Upper Old Red Sandstone as the basis for the succeeding Carboniferous system, we ascend through a vast series of essentially marine strata with oceanic beds, until we reach the top of the Gannister stage, where a change occurs in the character of the fossil forms, and the marine molluscs give place to those of freshwater or estuarine characters. I hope to be able to show that this change is coextensive with the British Isles and at least the neighbouring European Carboniferous districts.

PART II.

IRISH CARBONIFEROUS DISTRICTS.

A. *Southern Coal-districts.*

We now come to the consideration of the Carboniferous series of Ireland, taking the districts in the order indicated above.

These include the coal-fields of Castlecomer and Killenaule, with the surrounding districts occupying portions of the counties of Carlow, Queen's County, Kilkenny, and Tipperary, those of Mill-street in co. Cork, and a few patches in the counties of Kerry, Limerick, and Clare. The succession of the beds above the Carboniferous Limestone in these districts is remarkably uniform, and has been illustrated in the memoirs of Griffith, Kane, Meadows, and of the officers of the Geological Survey; so that all that remains for me to do is to describe the series in one district as a type of the whole, and refer the different beds to their representatives in England and Wales. For this purpose I shall take the section which may be made out in crossing the country from east to west through Carlow and the centre of the coal-basin of Castlecomer, referring to the accompanying section (fig. 1) in illustration of the subject.

It will be seen from this section that the Castlecomer Coal-field forms a basin, in the centre of which are the highest beds, surrounded by a zone of "Gannister Beds" (stage E) supported by flagstones, and these latter by shales and flaggy beds, which in their turn rest on the Carboniferous Limestone. This order of succession may be observed in many places on all sides of the coal-field; and the strata may be arranged as follows in descending order, the stages (A, B, C, &c.) affixed to each division corresponding with those of the British series (see Table, pp. 615, 616):—

*Descending Series of the Castlecomer and Killenaule Coal-fields**.

STAGE G. *Upper Coal-measures.*—Absent (probably owing to denudation).

Fresh-water or Estuarine.
- STAGE F. *Middle Coal-measures* (Jarrow series).—Sandstones, shales &c., with several coal-seams from the "Jarrow Coal" upwards.
- FOSSILS.—*Anthracosia* (*Unio*), *Myalina*; Crustacea, Reptilia, &c.

Marine Series.
- STAGE E. "*Gannister Beds.*"—Grits, shales, and two or three thin seams of coal, with roofs containing marine shells.
- FOSSILS.—*Phillipsia, Bellinurus regina* (Baily), *Goniatites, Bellerophon, Aviculopecten,* and many others stated below, recently discovered (p. 621).
- STAGE D. *Flagstone Series* (representing Millstone Grit Series).—Beds of rippled micaceous flagstones and shales.
- FOSSILS.—Chiefly tracks of marine Annelids or of Molluscs †.
- STAGE C. *Shale Series* (representing the Yoredale Beds).—Grey sandy shales, passing downwards into dark shales, with earthy limestones.
- FOSSILS.—*Goniatites sphæricus, Bellerophon, Euomphalus, Aviculopecten papyraceus, Posidonomya Becheri, P. membranacea,* &c.
- STAGE B. *Carboniferous Limestone.*—(*a*) Upper Limestone (with beds of chert); Coralline; (*b*) Middle Limestone or "Calp" beds; Carbonaceous shales and earthy limestones; (*c*) Lower Limestone, compact limestone, often dolomitic.

Total thickness 1700 ft.

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* Explanation of sheets 136 and 137 of the maps of the Geological Survey of Ireland.

† W. H. Baily, Explan. of sheet 128 of the maps of the Geol. Survey, p. 15.

Fig. 1.—*Section across the Leinster Coal-field.*

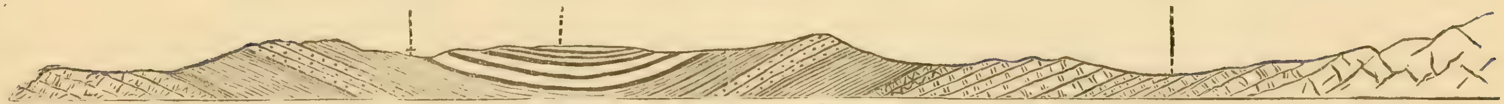

Fig. 2.—*Section across the Tyrone Coal-field.*

Stage F. Middle Coal-measures, with principal coal-seams.
,, E. Gannister Beds (or Lower Coal-measures) with thin coal-seams.
,, D. Carlow Flags and Millstone Grit.
,, C. "Yoredale" shales &c.
,, B. Carboniferous Limestone: top beds cherty.

Gr. Granite of Leinster. N.R.S. New Red Sandstone &c.

The Lower Limestone here rests on the granite of Leinster, so that Stage A is not represented here.

It will be unnecessary for me to give a detailed description of the range, and order of succession, of the Carboniferous beds in this district, after the numerous publications already in existence treating of this, the most important coal-field in the south of Ireland *; and I shall therefore confine my observations to those points which concern my argument, namely the upper limit of the truly marine fauna, and its representative horizon amongst the British series.

The shales overlying the Carboniferous Limestone are admitted by all observers to be essentially marine, the large number of fossils which have been collected both by Griffith and the officers of the Geological Survey having placed this beyond question; of these *Posidonomya Becheri* is perhaps the most characteristic form. We have only to compare the lists of forms obtained from these beds in the south of Ireland with those from the Yoredale Shales of the north of England to see that the fossils of the one are representative of, if not identical with, those of the other, and that both are of marine origin †. Here we find *Goniatites, Bellerophon, Euomphalus, Aviculopecten*, and *Posidonomya*, the successors of the forms which flourished more vigorously in the sea of the preceding period.

Physical break between the Limestone and Yoredale Shales.—The line of demarcation between the Carboniferous Limestone and overlying shales is more than usually decisive around the Leinster Coal-field. Mr. Hardman, of the Geological Survey, assures me that there is not only an abrupt change in the mineral character of the beds, but that this is accompanied by a physical break or discordance. This abrupt change is general over the southern districts of Ireland ‡.

In fact the upper beds of the limestone have in this region undergone a species of pseudomorphism, and are largely converted into chert; and my colleague, Mr. Hardman, agrees with me that this process has taken place before the deposition of the Yoredale Shales, and is a consequence of certain physical changes which took place over the bed of the sea. To this subject I hope to return on another occasion; but I wish here to observe that the Yoredale Beds of Ireland are more intimately associated with the Millstone Grit and Gannister Beds than with the Carboniferous Limestone—which

* The following are the principal:—'Report upon the Leinster Coal-district,' by Sir R. Griffith (1814), accompanied by an engraved map and sections; Explanations of the sheets 128 and 142 of the maps of the Geological Survey of Ireland, by Messrs. Jukes, Kinahan, and O'Kelly (1859); "The Leinster Coal-field," by J. M'C. Meadows, Journ. Roy. Geol. Soc. of Ireland, vol. iv. part i. (1873–4); 'The Coal-fields of Great Britain,' 3rd edit. p. 300 *et seq.* (1873).

† For instance, compare the list given by Jukes and Geikie, 'Manual of Geology,' 3rd edit. p. 592, with those of the late Mr. Salter from the corresponding series in Lancashire, "Geology of the Country around Oldham," Mem. Geol. Survey, Appendix, p. 59; and "Geology of Stockport, Macclesfield, &c.," *ibid.* p. 92.

‡ See Explanation to sheet 163 &c. of the Geological-Survey Maps, p. 14; also Expl. to sheet 46, N.W. p. 20.

is an additional reason why these formations should be grouped together in one division as here proposed*.

Ascending into the overlying flagstones the molluscous forms disappear, either owing to migration or because the strata were not favourable to their preservation; but instead of these we find those remarkable tracks both of annelids and molluscs which are described and figured by Mr. Baily in the publications of the Survey †. That these flagstones and associated grits and shales are the exact equivalents in time of the Millstone-Grit series of England there can, I think, now be no question since the identification of the succeeding beds with the "Gannister Beds," of the north of England, which are immediately superimposed on the Millstone-Grit series of that district ‡.

Gannister Beds.—The beds overlying "the Flag series" consist of hard grits, shales, dark mudstones, and two or three thin but workable beds of coal, which have been traced around the entire coal-field, and worked at several places, such as at Modubeagh, Wolfhill, Rushes, Tollerton, Rossmore, and Skehana. The Bilboa coal, with *Bellinurus regina*, lies above these seams, and is included by Mr. Hardman in the Lower Coal-measures. Like the Gannister coal the second of these seams has a hard floor, "compact and quartzose," while the shale roof of the Wolfhill seam contains shells of the genera *Aviculopecten*, *Goniatites*, and *Bellerophon* §; along with these are other species, presently to be mentioned, occurring near Castlecomer. Thus in every respect these beds resemble "the Gannister Beds" of England, and, like them, are characterized by a marine fauna.

The list of fossils above given has recently been considerably amplified by the discovery of a slightly calcareous band in the Lower Coal-measures of Castlecomer, just below the rock of the second coal, containing a remarkable assemblage of marine forms. The existence of this band was brought to the notice of Mr. Hardman, of the Geological Survey, about two years since, by Mr. Aher, of Castlecomer, who states that it was laid open in a quarry in beds associated with the Skehana coal ‖. The fossils, which are usually small in size, consisting both of those discovered by Mr. Aher and subsequently collected by the officers of the Survey, have been named by Mr. Baily, Acting Palæontologist to the Survey, as follows:—

* In the S.W. of Ireland (Kerry &c.) the Yoredale Shales apparently overlap the Upper Limestones and rest on the Lower; the change of beds is clear and decisive.

† 'Explanation" to sheet 128 of the Geological-Survey Maps, p. 14.

‡ That the whole series from the top of the Limestone into the upper measures of the coal-field represents the "Millstone Grit and Yoredale Series" of England has been suggested by the late Professor Jukes himself. (See Jukes and Geikie's 'Manual of Geology,' p. 591, as well as in other places.)

§ Jukes and Kinahan, Explan. sheet 128, p. 13.

‖ The position of the band from which *Phillipsia* has been taken is (according to Mr. Hardman) twenty yards above the second or "Skehana Coal." The beds consist of dark bluish shales, underlying a massive and coarse sandstone well known throughout the district.

Fossils from the Lower Coal-measures of Castlecomer.

CRUSTACEA	Phillipsia pustulata (*Schloth.*, sp.). Leperditia Okeni ? (*Münst.*, sp.).
CEPHALOPODS	Goniatites fasciculatus (*M'Coy*). —— crenistria (*Phil.*). Nautilus (like cyclostomus, *Phil.*). Orthoceras Steinhaueri (*Sow.*).
GASTEROPODS	Euomphalus (sp. inc.).
LAMELLIBRANCHS	Aviculopecten (Lima) alternatus (*M'Coy*). —— granosus ?. Axinus (sp. inc.). Edmondia (small sp.). Pullastra bistriata (*Portl.*). —— scalaris (*M'Coy*).
BRACHIOPODS	Athyris planosculata (*Phil.*). Orthis resupinata (*Mart.*). Productus semireticulatus (*Mart.*). Rhynchonella pleurodon (*Phil.*). Spirifer pinguis (*Sow.*), *or* trigonalis.
CRINOIDS..................	Actinocrinus (joints of, abundant).

The above list of 16 genera and 19 species shows the essentially marine character of the fauna of this stage, and its close connection with the Lower Carboniferous group. The most remarkable, perhaps, of the whole series heads the list. Several portions of individuals of this trilobite were discovered ; and this is probably the first time its presence in the British Islands has been recorded in beds higher than the Yoredale shales, in which it is found in other parts of Ireland. In Morris's ' Catalogue of British Fossils ' it is placed in the Carboniferous Limestone both of England and Ireland ; and its survival into the stage of the Lower Coal-measures is another connecting link between the two formations. Further on, it will be shown that it has been recognized by Prof. Römer in beds of this stage in Silesia (p. 638). The Middle Coal-measures contain *Anthracosia* (*Unio*), which has been observed by Mr. Hardman above the " Old Three-foot " coal.

Slieveardagh Coal-field, Co. Tipperary.

The general section of this coal-basin resembles that of Kilkenny and Carlow. The beds lie along a sharp synclinal fold the axis of which ranges in a N.E. direction, in the centre of which the highest coal-seams occur. The district has been described by the officers of the Geological Survey, Messrs. F. J. Foot and J. O'Kelly, and the fossils by Mr. Baily. The shales overlying the lower coal (called " Upper and Lower Glengoole " seams) contain *Aviculopecten*, *Mya-*

cites, and *Myalina*, and a large number of plants*; and we can recognize in the upper seams the representatives of the Coal-measures stage F, which has a very restricted area in this district.

Limerick, Clare, &c.—From the observations of Messrs. Kinahan and Foot it is known that the section of the Carboniferous beds of the south-west of Ireland is similar to that of the south-east †. The following is the general section as given by these authors, with the stages to which the beds are referable.

General Section, in descending order ‡.

			ft.	in.
GANNISTER BEDS...	Shales principally. Thickness not determinable.			
	"Money-Point Flag" series	about	150	0
	Shales principally	,,	100	0
	III. coal		1	6
STAGE E	Intermediate beds	about	600	0
	II. coal		2	6
	Intermediate beds	about	700	0
	I. coal		0	6
STAGE D	Grits and shales	about	930	0
	Lower Flagstone series	,,	70	0
STAGE C	Shale series, with *Posidonomya vetusta* and *P. Becheri*, *Goniatites crenistria*, &c.		500	0
STAGE B	Carboniferous Limestone.			

The stage E probably includes all the beds to the top of the series of that district. At Knockabooly Colliery, Mr. Kinahan found in the shales overlying No. II. coal *Posidonomya*, and a number of minute univalves figured and described by Mr. Baily under the name of *Loxonema minutissima*, a marine form. In other places over the same coal Goniatites have been found§.

Over coal No. III. the shells are similar to those from the shales over the "Bilboa coal," co. Carlow, namely *Goniatites* and *Aviculopecten*. Bivalves ("allied to *Unio*") are found in about the same position ||.

I have every hope that on the completion of a fresh survey of this district the extent and thickness of these successive stages will be clearly made out. It is sufficient for our present purpose to be certain, from the investigations of the officers of the Survey, that the general succession of the beds is similar to that in Tipperary, Kilkenny, and Carlow, and that, like these, they show the prevalence of marine conditions throughout this stage.

* Explanation to sheet 142 of the Geological Survey maps.

† Ibid. p. 9.

‡ Explanation to sheet 146, pp. 11 and 21.

§ Ibid. p. 37.

|| The proper identification of these bivalves is very difficult, and their relations are somewhat problematical.

B. *The Northern Coal-district.*

This includes the Leitrim and the Tyrone coal-fields, of which a short description will suffice, as several accounts with very full details are already in existence, my only object being to show how the successive stages which can be recognized in the south are also here fully represented.

1. *The Leitrim Coal-fields.*—These have been described by Sir R. Griffith*, Sir R. Kane†, the late Mr. Du Noyer ‡, and Mr. Readwin. They are now being surveyed by Mr. Cruise, of the Geological Survey ; and some of the maps are already published §. They occur in the form of several detached tablelands on both sides of Lough Allen, from 1000 to 1377 feet above the sea. The Yoredale shales are, as is well known, rich in beds of ironstone, which were formerly smelted at the Arigna Ironworks, built on the western shore of the lough. The beds of coal, three in number, occur partly in the Millstone Grit, which rises in terraced escarpments above the slopes, and in Cuilcagh reaches an elevation of 2188 feet, giving rise to scenery resembling that of the Yorkshire and Derbyshire uplands. The succession of the beds from this mountain to Enniskillen is given by Phillips in his 'Geology of Yorkshire'‖. It requires some modification, but is in the main correct. The general series of Lough-Allen beds is as follows, in descending order¶ :—

Section at Kilronan, Co. Leitrim.

STAGE E. *Gannister Beds.*	1. Flaggy grits and shales	180	0
	2. Dark shales with thin flagstones, and numerous marine fossils—*Goniatites crenistria, Orthoceras Steinhaueri, Posidonomya Becheri*	170	0
	Top coal	2	6
STAGE D. *Millstone Grit**.*	Hard massive grit	40 to 60	0
	Dark-blue shales with ironstones	40	0
	Second coal	1	6
	Hard grit	5	0
	Shales with a thin coal and marine shells††	10	0
	Massive hard grit, fine-grained, with numerous stems of *Lepidodendron, Sigillaria,* &c.	80	0

* "On the Connaught Coal-fields," Rep. to Royal Dublin Society, 1818.

† 'Industrial Resources of Ireland,' 2nd edit.

‡ "On the Bituminous Coal of the Arigna District," Geol. Mag. March 1863.

§ Mr. R. J. Cruise, who has surveyed this district, has also made analyses of the coal, which approaches "steam-coal" in quality.

‖ 'Geology of Yorkshire,' part ii. p. 11 (1836). The name is there spelt "Kulkeagh."

¶ 'Coal-fields of Great Britain,' 3rd edit. p. 308. In my description of this district I have given a section founded on that by the late Mr. Du Noyer.

** The divisional line between stages D and E is rather uncertain. Possibly the beds above the lowest Millstone Grit may probably be placed in stage E.

†† The following species, determined by Mr. Baily :—*Aviculopecten, Rhynchonella pleurodon, Posidonomya Becheri, P. B.,* var. *membranacea, Goniatites crenistria, Lunulocardium Footi* (Baily). Also a species of *Palæoniscus.*

STAGE C. *Yoredale Series.*	Grey and dark shales, with bands of flagstone, clay-ironstone, and cement-stones. Fossils abundant, *Goniatites*, *Posidonomya Becheri*, &c.	600	0
STAGE B............	*Carboniferous Limestone.*		

In the above series we have, in stage E, clearly the representatives of the Gannister Beds with their characteristically marine fauna, in addition to the Millstone Grit. It is somewhat doubtful where the line between these two divisions should be drawn; but this is of little moment so long as we can be certain that they are both there. The representatives of the [Middle] Coal-measures (stage F) have been entirely removed by denudation.

2. *The Tyrone Coal-field.*—This is the most important coal-field in Ireland, as in it the Coal-measures (stage F) are developed to an extent nowhere else equalled, and contain numerous beds of bituminous coal (see Section, fig. 2, p. 618). The Lower, or Gannister beds are very largely developed, while on the other hand the Millstone Grit and Yoredale beds are comparatively unimportant as regards their vertical thickness.

An admirable Report on the structure of this coal-field was drawn up in 1829 by Sir R. Griffith for the Royal Dublin Society; and since then the Geological Survey of the district has nearly been completed, and a memoir thereon by Mr. Hardman will shortly be issued. The coal-field itself forms a triangular area, bounded along the north by a large upcast fault, bringing to the surface the Carboniferous Limestone, along the east by the Triassic formation (below which the Carboniferous beds extend), and along the south by the natural outcrop of the strata. At Drumglas Colliery the lowest seam has been worked, its position being near the base of the Lower Coal-measures (stage E). A synopsis of the Carboniferous series by Mr. E. T. Hardman is published in the Trans. of the British Association for 1874, from which the following section is condensed *.

Section of the Tyrone Coal-field near Dungannon (fig. 2).

		Feet.
STAGE F. *Coal-measures.*—Sandstones, shales, and clays, with eight or ten coal-seams. Fossils: fish, *Anthracosia*, *Lingula squamosa*, &c. (Coal island), plants, ferns, &c.	about	930
STAGE E. *Gannister Beds.*—Sandstones, shales, &c., and two or three workable coals (Crenagh and Drumglas). Fossils: fish-remains, *Orthoceras*, *Goniatites*, *Productus*, and *Lingula* †	about	1000
STAGE D.—*Millstone Grit.*—Coarse grits below the Drumglas Coal	,,	200
STAGE C. *Yoredale Beds.*—Black shales with bands of limestone, sandstone, and clay-ironstone nodules		600
STAGE B. *Carboniferous Limestone* (Dungannon).		

* "On the Structure of the Tyrone Coal-field," Rep. B. A. Trans. Sect. p. 77 (1874).

† *Lingula squamosa* occurs in shales over the "Crenagh Coal," which is high up in the Lower Coal-measures (see Geological-Survey maps, 6-inch scale, No. 47, co. Tyrone); also above the Yard and Belteboy seams in stage F.

The Gannister Beds are of unusual but unknown thickness; they occupy a considerable tract between Drumglas Colliery and Coal island, and, though only partially explored, have been proved to contain some of the marine Mollusca characteristic of stage E. Thus over the Crenagh coal *Lingula squamosa* occurs in considerable numbers associated with *Orthoceras*, *Bellerophon*, and *Productus*. Just above "the Drumglas coal" *Lingula* occurs abundantly, and in beds 200 yards higher up *Goniatites* *.

3. *The Ballycastle Coal-field, Co. Antrim* (Lower Carboniferous).—This is the last of the Irish coal-fields requiring our attention; and it stands alone in geological position, for there can be little doubt that it is the representative of the "Lower Coal-fields" of Scotland, and, like them, of the age of the Yoredale Beds and Carboniferous Limestone. It has been the subject of several memoirs by Berger†, Bryce‡, and Griffith §, the last of whom gives a very elaborate account of the remarkable features of this district. While making, in 1869, a rapid survey of this coal-field in order to arrive at some approximate estimate of its resources for the Royal Coal-Commission, I was so struck by the general resemblance of the beds to those which form the Lower Coal-field of the Clyde basin, that I came to the conclusion that they also were of Lower-Carboniferous age, a conclusion confirmed by the evidence of the fossils ||.

General Section.

The general section seems to be divisible into two, possibly three, stages, corresponding to stages A, B, and possibly C of the classification here adopted, and is as follows ¶:—

UPPER BEDS. Stage C.—Reddish and grey sandstones, shales with seams of coal, clay-band and black-band ironstone. *Lingula squamiformis* (Phil.), *Sagenaria imbricata, Sigillaria*, &c.

MIDDLE BEDS. Stage B.—Compact argillaceous limestone in two thin beds with shales. Fish, *Orthoceras Steinhaueri, Bellerophon Urii, Murchisonia angulata, Leda attenuata, Rhynchonella pleurodon, Productus giganteus*, &c.

LOWER BEDS. Stage A.—Red and yellow sandstones, sometimes coarse, with shales and black-band ironstone; conglomerate at base (Murloch Bay).

(The entire thickness exceeds 1200 feet).

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* Information supplied by Mr. Hardman.

† Trans. Geol. Soc. Lond. ser. 1, vol. iii.

‡ *Ibid.* ser. 2, vol. v.

§ 'Geological and Mining Survey,' Dublin, 1829.

|| The fossils have been determined by Mr. W. H. Baily, and are given in my paper "On the Geological Age of the Ballycastle Coal-field," Journ. Geol. Soc. Ireland, vol. i. New Series, 1871.

¶ 'Coal-fields of Great Britain,' p. 314 (1873).

On a former occasion I have endeavoured to explain the origin of the phenomena presented in this coal-district *. Here we find the Carboniferous Limestone represented by only a few feet of that material, its place being taken by sedimentary, or mechanical, deposits. It is exactly a parallel case with that which occurs in North Britain. In the Clyde basin, as is well known, the Carboniferous Limestone (as such) is represented by only a few thin bands, which, however, swell out as we proceed southwards, until in Derbyshire the formation is a solid mass of limestone at least 5000 feet in thickness †. The changes which took place in Britain during the period of the Carboniferous Limestone and subsequently, had also their counterpart in Ireland. Thus we find, in proceeding northwards from the central plain, the beds of limestone, which there attain a thickness of 2500 feet, begin to change their characters. In Fermanagh, Tyrone, and Armagh the "Calp," or Middle Limestone, has passed into massive sandstones and beds of shale with very thin coal-seams; and the Lower Limestone is largely mixed with similar beds. Still further north the limestone diminishes in thickness, till on the shores of Antrim and in Derry the calcareous beds seem on the point of disappearing.

Part III.

English Carboniferous Districts.

Having now completed our survey of the Irish Carboniferous districts, I propose briefly to extend it over the British area, in order to point out the equivalent stages. A brief description of a few typical sections will probably be considered sufficient—as so much has been written on the subject already.

Adopting the lettering of the successive stages, as already given in the Table (pp. 615, 616) of the British Carboniferous Series, I shall commence with South Lancashire, which may be taken as the typical district, owing to the magnificent development of all the stages from the Mountain Limestone upwards.

(1) *South-Lancashire District.*

Our knowledge of the succession of the beds in this district is largely owing to the labours of Mr. E. W. Binney, F.R.S.; and the mode of clasification adopted by the Geological Survey differs but slightly from his. It is as follows:—

* "On the Geological Age of the Ballycastle Coal-field," *supra cit.* The details of the above are treated in the author's paper "On the Relative Distribution of the Calcareous and Sedimentary Strata of the Carboniferous Period," Quart. Journ. Geol. Soc. vol. xviii. p. 127.

† Some recent authors have placed the thickness of the Derbyshire limestone at only half this amount; but the measured sections published by the Geological Survey place the thickness, as here stated, almost beyond doubt.

	Maximum thickness. feet.
STAGE G. *Upper Coal-measures.*—Shales, sandstones, and limestones of Ardwick, with *Spirorbis*, *Cythere*, and fish. A bed of black-band ironstone, with *Anthracosia Phillipsii*. Below these red sandstones, shales, and thin coal-seams*	1680 to 2000
STAGE F. [*Middle*] *Coal-measures.*—Sandstones, shales, clays, and thick coal-seams, from the "Worsley Four-feet coal" to the flags below the Arley mine. *Anthracosia*, *Anthracomya*, &c.	3000 to 4000
STAGE E. *Gannister Beds.*—Flagstones, shales, and thin coal-seams, one of which has a hard siliceous floor (Gannister). *Goniatites Listeri*, *Nautilus*, *Aviculopecten papyraceus*, *Lingula squamiformis*, *Anthracosia*, *Spirorbis*, fish, &c.	1400 to 2000
STAGE D. *Millstone Grit.*—Coarse grits, flags, and shales, with a few thin coals. Marine shells: *Aviculopecten*, *Posidonomya Gibsoni*, *Goniatites reticulatus*, *Orthoceras*, &c.	3500 to 5000
STAGE C. *Yoredale Beds.*—Shales principally, with thick beds of grit in the centre (Yoredale grit). *Goniatites excavatus* and several other species, *Modiola*, *Myalina*, *Discina nitida*, *Productus*	2000 to 4000
STAGE B.—*Carboniferous Limestone*, &c.	

(2) *Yorkshire and Derbyshire Districts.*

	feet.
STAGE G. *Upper Coal-measures.*—Reddish sandstones, with plants (Ackworth rock), and "red rock of Rotherham" resting unconformably on Stage F†	54
STAGE F. *Middle Coal-measures.*—Sandstones, shales, clays, with ironstones and coal-seams. *Anthracosia* &c.; fish	2500
STAGE E. *Lower* (*or Gannister*) *Beds.*—Flagstones and shales, with thin coals, and Gannister-floor. *Aviculopecten papyraceus*, *Goniatites*, *Posidonomya*, *Orthoceras Steinhaueri*, *Nautilus Rawsoni*	1000
STAGE D. *Millstone Grit.*—Coarse grits, flags and shales	2000
STAGE C. *Yoredale Beds*—Principally shales, with grit in centre. Marine fossils	2000
STAGE B.—*Carboniferous Limestone* about	5000
Base not seen.	

(3) *North-Staffordshire District.*

	feet.
STAGE G. *Upper Coal-measures.*—Brown and reddish sandstones, red and mottled clays, and shales, thin coals and ironstones down to the "red mine"-band. A bed of limestone at Fenton, with *Spirorbis carbonarius*, and *Anthracomya Phillipsii* (Shelton)	1500

* Marine shells occur in a band in this position at Ashton-under-Lyne—*Aviculopecten fibrillosus* (Salter), *Ctenodonta*, *Goniatites*, *Nautilus præcox* (Salter), *Discites rotifer* (Salter). These were discovered by my colleague, Prof. A. H. Green; see 'Geology of Oldham,' Mem. Geol. Survey.

† Assuming that the "Ackworth rock" is the "red rock of Rotherham," which Mr. Aveline describes as unconformable to the Coal-measures underneath. The plants are *Lepidodendron aculeatum*, *L. obovatum* ?, *Calamites Suckovii*, and *Sigillaria*, as determined by the late Mr. Salter, "Geology of Parts of Notts, York, and Derby," by W. T. Aveline, F.G.S., Mem. Geol. Survey (1861).

	feet.
Stage F. *Coal-measures.*—Sandstones, clays, and shales, with numerous beds of ironstone and coal. Fish-remains abundant, also *Anthracosia*, *Anthracomya*, and *Anthracoptera*. One or two marine bands occur over the "Ten-foot Coal of Hanley" *	3500
Stage E. *Gannister Beds.*—Black shales and flags, with a few thin coals and red ironstone. *Orthoceras*, *Goniatites Listeri*, *Lingula*, *Aviculopecten papyraceus*, *Anthracomya*	1000
Stage D. *Millstone Grit.*—Coarse grit, shales, and flags	1000
Stage C. *Yoredale Beds.*—Dark shales and yellow grits, with marine shells †,—*Goniatites excavatus* (Phil.), *G. obtusus* (Phil.), *G. reticulatus* (Phil.), *G. truncatus* (Phil.), *Macrocheilus*, *Aviculopecten papyraceus*, *A. alternatus*, *Inoceramus*, *Ctenodonta gibbosa*, *Myalina*, *Discina nitida*, *Productus longispinus*, &c.	3100
Stage B. *Carboniferous Limestone.* (Base not visible).	

The very complete lists drawn up by the late Mr. Salter ‡, prove that the great mass of the central measures were either estuarine or freshwater—the Mollusca being represented by *Anthracosia* and its congeners,—while those of the Lower Coal-measures are distinctively marine. Mr. Ward, F.G.S., of Longton, however, has discovered two bands of marine shells amongst the Middle Coal-measures. One of these, in the black shale, overlying the "Bay Coal" contains shells of the genera *Nautilus*, *Goniatites*, *Aviculopecten*, *Melania*, *Productus*, *Discina*, and *Lingula*; and Mr. Ward informs me that he has lately discovered another band with similar fossils above the "Ginmine" coal, near the bottom of the Middle Measures §.

(4) *Flintshire and Denbighshire.*

	feet.
Stage G. *Upper Coal-measures.*—Red and grey sandstones, red clays, shales, and a few thin coals. A band of limestone with *Spirorbis carbonarius*	1000
Stage F. [*Middle*] *Coal-measures.*—Sandstones, shales, &c., with coal-seams and ironstones, fish-remains ‖ and *Anthracosia*, &c.	800
Stage F. *Gannister Beds.*—Grits, flags, and shales, with thin coals. *Goniatites*, *Aviculopecten*, &c.¶	1000
Stage D. *Millstone Grit.*—Massive grit, coarse and fine, with shales	800
Stage C.—Shales (series thin here)	100
Stage B.—Carboniferous Limestone	1000 to 1500
Stage A.—Shales, thin or absent	0 to 30

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* Salter, 'Iron-ores of Great Britain,' part ii. Appendix. Mr. Salter has given very complete lists of the beds in descending order. With two exceptions, the truly marine genera are confined to the Lower Measures.

† Determined by Mr. Salter and Mr. Etheridge, "Geology of Stockport, &c.," Mem. Geol. Survey, 1866.

‡ *Loc. supra cit.*

§ Letter, dated Aug. 4, 1876.

‖ *Rhizodus*, *Cœlacanthus*, *Platysomus*, and *Palæoniscus*, according to Sir P. Egerton.

¶ Determined by Mr. Binney, F.R.S., and communicated to the writer, 'Coal-fields of Great Britain,' 3rd ed. p. 149.

The thinness of Stage A is accounted for by the supposition of the proximity of land at this period. The Old Red Sandstone is but sparingly represented.

(5) *Coalbrook-Dale Coal-field.*

The observations of Prof. Prestwich, followed more recently by those of Mr. Marcus W. T. Scott*, Mr. Randall†, and Mr. D. Jones‡, show that, after the Lower and Middle Measures (Stages E and F) had been deposited, a considerable amount of denudation took place along the centre of the field, and that in the hollow thus formed the Upper Measures (Stage G) were deposited. There is therefore a considerable break between Stage G and those below it.

General Section.

	Thickness—feet.
STAGE G. *Upper Coal-measures.*—Mottled clays and greenish grits; calcareous breccia with band of compact limestone. *Spirorbis carbonarius*	300
STAGE F. *Coal-measures.*—Yellow sandstones, shales, and clays, with ironstones and coal-seams. Fish-remains, *Anthracosia*	1000 (Stages F and E together)
STAGE E §. *Gannister Beds* (or *Pennystone Series*).—Sandstones, shales, with coal and ironstone (Pennystone- and Crowshaw-bands ‖). Crustacea, *Limulus*; Mollusca, *Nautilus, Orthoceras, Bellerophon, Conularia, Spirifer bisulcatus, Productus scabriculus, Aviculopecten, Lingula, Rhynchonella*	

Stages D, C, & B are but poorly represented, and Stage A not at all. This is owing to the proximity to the marginal land and the existence of terrestrial conditions during the early portion of the Carboniferous period ¶. Having dealt with this subject on former occasions, I do not consider it necessary to enter upon the physical geology of the Carboniferous beds in this district at the present time, further than to observe that in the "Chance Pennystone" (which occurs probably in Stage F, but of which there is some uncertainty) we have an accidental marine band with *Productus scabriculus*, as described by Prof. Prestwich, lying 200 feet above the "Pennystone" bed.

* Quart. Journ. Geol. Soc. vol. xvii. p. 457.

† Letters in the Mining Journ. 1871. ‡ Geol. Mag. vol. viii. p. 200.

§ The fossils have been enumerated in detail by Prof. Prestwich in his original paper, Geol. Trans. 2nd ser. vol. v. 1840. Amongst them the genus "*Unio*" is mentioned; but there can be little doubt that the bivalves included under this head are really not *Uniones*; their association with the marine genera makes it highly improbable. In this view Mr. Baily concurs.

‖ The position of the "Pennystone" ironstone is (according to Mr. D. Jones) just above "the stinking" coal in the lower part of the measures.

¶ This subject is explained at some length in the Memoir "On the Triassic and Permian Rocks of the Central Counties," Mem. Geol. Surv. p. 109, and in 'The Coal-fields of Great Britain,' 3rd edit. p. 462. It is owing to the same cause that Stages A, B, C, D are absent in South Staffordshire.

(6) *South-Staffordshire Coal-field.*

	Thickness—feet.
STAGE G. *Upper Coal-measures.*—Red and mottled clays, red and grey sandstones, and gravel beds	800
STAGE F. *Coal-measures.*—Shales, sandstones, clays, with coal-seams and ironstones above the New-mine ironstone. Fish-remains, *Anthracosia* (*Unio*)	200
STAGE E. *Lower* (or *Gannister*) *Beds.*—Shales, sandstones, with coals and ironstone ("New mine" and "Pennystone"), with marine fossils—*Productus scabriculus, Aviculopecten scalaris, Lingula mytiloides, Conularia quadrisulcata,* &c.	200

As these beds rest directly on the Upper Silurian rocks, Stages A, B, C, and D are not represented.

The marine fossils from the "New- (or "White-") Mine" and "Pennystone" ironstones are similar to those from the ironstone of the same name in the Coalbrook-Dale Coal-field; both are near the bottom of the Coal-measures, and mark a definite marine horizon. Along with the truly marine genera, bivalves of the genus *Anthracosia* (?) are sometimes found; but the late Mr. Salter states that "it appeared that generally where undoubtedly marine shells were present these so-called *Uniones* were absent"*. The commingling of these shells is not confined to this district, but has been observed in Lancashire, and probably indicates the alternation of marine and estuarine conditions in certain localities.

(7) *Leicestershire Coal-field.*

All the stages are here represented, though in diminished dimensions as compared with the coal-districts to the north.

	Thickness—feet.
STAGE G. *Upper Coal-Measures.*—Coarse grits of Moira and Newall, with *Sternbergia,* resting unconformably on Middle Coal-measures†	20 to 50
STAGE F. *Middle Coal-measures.*—Sandstones, shales, and clays, with several coal-seams. Plants; *Anthracosia* (*Unio*)‡, *Cythere* or *Cypris*	1500
STAGE E. *Lower Coal-measures.*—Shales and sandstones &c., with a few thin seams of coal below the "Heath-end" coal§. Shells of marine genera have recently been discovered	1000
STAGE D. *Millstone Grit.*—Coarse grits, &c.	50
STAGE C. *Yoredale Beds.*—Shales, &c.	25
STAGE B. *Carboniferous Limestone.*	

* Jukes, 'South-Staffordshire Coal-field,' 2nd edit. p. 58.

† The late Rev. W. H. Coleman, 'The Geology of the Leicestershire Coal-field' (Mem. Geol. Survey), p. 56.

‡ Mammatt, 'Geological Facts,' &c.

§ These beds are chiefly known from boring records.

(8) *Warwickshire Coal-field.*

	feet.
Stage G.—Sandstones and shales, with a band of limestone near the base, with *Spirorbis carbonarius* *	50
Stage F.—Sandstones, shales, coals, &c.	1400
Stage E.—Sandstones, shales, &c., with sheets of intrusive basalt	1500
Stage D. *Millstone Grit.*—Converted into quartzite by sheets of intrusive trap	500

Lower Stages C, B, & A not represented.

The above concludes all that is necessary in order to show the relations of the beds in the northern group of coal-fields of England and Wales. With regard to the southern group, it will probably be sufficient if we notice the Sections of Somersetshire and South Wales.

(9) *The Somersetshire (or Bristol) Coal-field.*

It is very doubtful whether any representatives of the Stage G occur either here or in South Wales. It is true that there is a local subdivision of the Coal-measures into three stages in both districts, of which the "Pennant Grit" forms the central member. This arrangement is convenient for local purposes; but the Pennant grit can only be considered as an exceptionally thick group of sandstones interposed amongst the Middle Coal-measures (Stage F), and not as forming a central group corresponding to Stage F in other districts. As regards the Lower Coal-measures (Stage E), although this stage is remarkably well represented by its numerous marine fossils around the rim of the South-Wales basin, it is less so in Somersetshire, partly owing to its dislocated or inverted condition along the northern flanks of the Mendips, and also to the fact that it rarely crops out to the surface, the beds being concealed by Triassic or newer strata. The general section will therefore be somewhat as follows:—

Section of the Bristol or Somersetshire Coal-field.

	feet.
Stage G.—Imperfectly represented. Possibly the upper part of the Radstock series	?
Stage F. *Middle Coal-measures.*—Shales, grits, and coals of the Farrington, Pennant, and Bedminster series. Fossils: plants, fish, and *Anthracosia*	4700
Stage E. *Lower Coal-measures.*—Sandstones, shales, and numerous coals of the Holcombe series (in part)	2000
Stage D.—*Millstone Grit* (Bristol)	950
Stage C.—*Yoredale Shales* (thin)	100
Stage B.—*Carboniferous Limestone*	2330
Stage A.—*Lower Limestone Shale*	100
Old Red Sandstone.	

* Mr. Howell, "The Geology of the Warwickshire Coal-field," Mem. Geol. Survey (1859).

(10) *South-Wales Coal-basin.*

Notwithstanding the great thickness which the coal-measures of this district attain, amounting to 11,650 feet, still higher beds have once been superimposed on those now remaining, which must have constituted Stage G, either in whole or in part. It is impossible to say whether the uppermost known beds of Glamorganshire—those above the "Mynydd Isslwyn" coal—are in part the representatives of this stage, as there are no peculiarities by which to distinguish those beds from Stage F; the probabilities are, however, in favour of this supposition. As in the case, also, of the Somersetshire coal-field, the Pennant grit must be considered as a member of the Middle Coal-measures.

The Lower Coal-measures, especially along the southern borders of the field, form a well marked zone, very rich in coal and ironstone, and distinguished by a remarkable group of fossil shells of marine genera, as in the case of the same beds in the northern counties*. The higher beds are only characterized by shells of the genus *Anthracosia* and its allies; and whatever may have been the conditions under which this genus of molluscs lived, the vertical extent of its range, as compared with that of the marine species in the Lower Coal-measures, seems to point to some marked physical difference in the conditions under which the Lower and Middle stages were deposited†.

Section in Glamorganshire.

	feet.
Stage G? *Upper Coal-measures.*—Sandstones and shales down to the Mynydd Isslwyn Coal (?)	1000
Stage F. *Coal-measures.*—Sandstones, shales, and coal-seams, in the lower part of which is the Pennant Grit series, 3246 feet near Swansea. Plants, fish, *Anthracosia, Anthracomya, Phillipsia, Estheria*, and *Leaia*	5646
Stage E. *Gannister Beds.*—Principally shales rich in ironstones and coal-seams with Gannister floors. Fish, *Anthracomya, Athyris planosculata, Spirifer, Productus, Orthis Michelini, O. resupinata, Chonetes, Nautilus falcatus, &c.*	800 to 1000
Stage D.—*Millstone Grit*, including the "Gower Series"	200 to 350
Stage C.—*Yoredale Shales* (unimportant)	100 to 200
Stage B.—*Carboniferous Limestone*	800 to 900
Stage A.—*Lower Limestone Shale*	100

Old Red Sandstone.

The shales of the "Rosser vein" are especially rich in marine shells, consisting of 24 genera, of which a full list, with plates, is given by the late Mr. Salter. Some of the species are found in the "Pennystone" beds of Coalbrook Dale, and are undoubtedly on, or

* Determined by the late Mr. Salter from the collection of Dr. Bevan. 'Iron-ores of Great Britain,' Part iii.

† Coal-fields of Great Britain, 3rd edit. p. 92.

about, the same horizon; those above the "Bottom" vein have only yielded remains of placoid and ganoid fishes.

From a review of the fauna of the South-Wales Coal-field, Mr. Salter drew the following amongst other inferences:—

"1st. That there is a real distinction between the different beds of ironstone in regard to their fossil contents, and that we may hereafter use these fossils for the purposes of identification.

"2nd. That the lower beds of the Coal-measures in South Wales, Lancashire, and Shropshire contain a set of marine fossils, some of which are Mountain-Limestone species, and the rest peculiar to the Coal-measures.

"4th. That the decidedly marine species diminish as we ascend in the section; and that their place is occupied by other (bivalve) shells, *Anthracomya*, *Modiola*, *Myalina*?, which must have been inhabitants of salt, or at least highly brackish water, and that, as the *Anthracosiæ* (the common "*Unio* or mussel bands") are always in company with these, they also must be marine (or brackish?), and not freshwater as commonly supposed. They were mud-burrowing shells with wrinkled epidermis, like the *Myadæ*"*.

This eminent palæontologist did not live to complete the palæontological examination of the British Coal-fields which he had so well begun in South Wales, Staffordshire, and Lancashire. It yet remains to be determined whether special horizons amongst the Middle Coal-measures can be identified in different districts on fossil evidence.

Part IV.

Scottish Carboniferous Districts.

Having now passed in review as many sections in England and Wales as seem necessary for my purpose, I proceed to examine the Scottish series with a view to correlation with those in South Britain; and after a good deal of consideration I have come to the conclusion that the following is a correct representation of the corresponding series in both countries:—

General Section of the Scottish Carboniferous Beds
(Central Valley of Scotland).

Stage G. *Upper Coal-measures*, 200 feet.—Red Sandstones and Clays of Bothwell without coal-seams. This series in Ayrshire contains a seam of limestone with *Spirorbis*, and rests unconformably on the beds underneath.

Stage F.—"Upper or Flat Coal-measures" of Scotland. Sandstones, shales, and clays, with coal-seams and ironstones. Fish-remains, *Anthracosia*, *Anthracomya*, and *Anthracoptera*. A marine band occurs at Drumpeller about 60 feet above the "Ell coal"†.

* Iron-ores of Great Britain, Part III. p. 234.

† Described by Mr. Whyte Skipsey. The following occur—*Productus scabriculus*, *Discina nitida*, *Conularia*, *Bellerophon Urii*. This band may be on the horizon of the Chance Pennystone of Salop.

STAGE E. *Gannister Beds.*—Shales &c. with the "Slaty-band" ironstone with marine shells; *Lingula mytiloides, Discina nitida, Axinus deltoides, Murchisonia, Conularia quadrisulcata, Nautilus**.

STAGE D. 340 to 400 feet.—"Moorstone-Rock" series (Roslin sandstones) with accompanying beds down to the Garnkirk Limestone. Fossils marine.

STAGE C (?). *Yoredale Beds.*—(*b*) "Upper Limestone Series" of Scottish geologists, including the *Garnkirk-limestone.* (Marine and Estuarine beds.) 290 feet thick.

(*a*) "Lower Coal and Ironstone Series." Shales, coals, and black-band ironstones with fish, Entomostraca (*Carbonia*), &c. (Estuarine and freshwater.) 160 feet.

STAGE B.—"Lower Limestone Series," including the Roman Camp and Gilmerton Limestones (marine), 522 feet.

STAGE A.—"Calciferous Sandstone Series" in two groups, the upper (*b*) variable in thickness and extent, consisting of white and grey sandstones, bituminous shales and limestones with cyprids, fish, &c. (Burdie-house limestone near Edinburgh); the lower (*a*) of dull reddish sandstones, shales, conglomerates, and beds of "Cornstone" (Plants &c.).

Mr. J. Young, of the Hunterian Museum, is of opinion that the lower division of Stage C is of freshwater origin. Marine shells are absent, while Entomostraca of the genus *Carbonia* are abundant in the shales; of these, ten species have been determined by Messrs. Rupert Jones and Kirkby.

In the above section of the Scottish strata it will be observed that I have ventured to insert two groups not hitherto recognized—namely, Stages E and C, representing the "Gannister Beds" and "Yoredale Series" of England respectively. I have never been able clearly to understand why these two groups have failed to be admitted into the classification of the North-British Carboniferous series, as it was difficult to conceive that groups which in North Lancashire and Yorkshire attain considerable proportions (about 2000 and 3000 feet respectively) should have altogether thinned away, or disappeared north of the Border Land.

During the debate, however, which took place upon the reading of my paper at Glasgow, Mr. John Young, F.G.S., suggested that if representatives of the Gannister-beds were to be found in Scotland at all, it would be in the horizon of "the Slaty black-band ironstone" series, which is rich in marine forms, and lies immediately above the "Millstone-Grit series." The fossils which are above enumerated have been collected by Dr. W. Grossart, in the parish of Shotts: and

* Determined by Dr. W. Grossart, and communicated to the author by Mr. John Young, F.G.S., of the Hunterian Museum, Glasgow.

The following are the fossil forms from the Slaty-band Ironstone given in the Memoirs of the Geol. Survey of Scotland from Lanarkshire—*Lingula mytiloides, L. squamiformis, Anthracosia subconstricta, A. acuta, A. aquilina.* (Explanation of Sheet 23, p. 89–90.)

Those from the Millstone Grit are—*Lingula mytiloides, L. squamiformis, Orthis resupinata, Streptorhynchus crenistria, Naticopsis*, sp. inc. (Ibid. p. 89.)

the same strata have yielded similar forms elsewhere. With such good evidence before us we can have little hesitation in placing the "Slaty-band" beds on the horizon of Stage E.

As regards Stage C, perhaps the evidence is not so conclusive as in the former case. Nevertheless there are strong grounds for the course I have adopted. It will be recollected that as we proceed northwards from the borders of Lancashire a marine band of limestone makes its appearance, which ultimately assumes important proportions. In the Clitheroe and Pendle district the Yoredale series is of extraordinary thickness (from 3500 to 4000 feet); and it is really almost incredible that such a mass of strata should be unrepresented in Scotland, which is not (after all) so many miles distant. On the other hand, the Carboniferous Limestone of Derbyshire itself is represented in the North of England only by the "Scaur-limestone" series of Prof. Phillips, as Mr. Lebour has very clearly shown *. On reading Mr. Lebour's paper, it occurred to me that the explanation of the Scottish series was to be found in an arrangement such as that given below; and in consulting with my colleague, Prof. Geikie, and Mr. Lebour, I am glad to find that they regard my suggestion as not improbable, either on stratigraphical or palæontological grounds †. If we place the Scottish and the North-of-England series side by side we obtain the following results:—

Supposed Representative Stages.

	North of England.		*Central Scotland.*
Stages E.	Gannister beds.	(E.)	Slaty-black-band series.
" D.	Millstone Grit.	(D.)	Moorstone-rock series.
" C.	{ "Great limestone." { Flagstones and shales.	(C.)	{ Upper Limestone series. { Lower Coal-and-Ironstone series.
B.	"Scaur-Limestone series."	(B.)	Lower Limestone series.
A.	(Sometimes absent.) ("Tuedian.")	(A.)	Calciferous Sandstone series.

In corroboration of this view of the arrangement, Mr. Lebour states that "on comparing a list of 130 species of fossils from the 'Great Limestone' (the most marked Yoredale bed) with Scotch lists ‡, I find that 32 species are not known in Scotland, that about 60 run through the three Scotch divisions, that 28 are found in the Scotch upper and middle series only, and 10 are only found in the lower series." Now, making allowance for the difference in geographical position, and recollecting that during the earlier Carboniferous periods the Scotch and English marine areas were to some extent separated by the barrier of Silurian land, it must be admitted

* "On the Larger Divisions of the Carboniferous System in Northumberland," Proc. North-of-England Institute of Mining Engineers, vol. xxv.

† Letter dated 17th Nov. 1876.—Mr. Lebour has adopted the name "Bernician beds" to include Stages B and C in Northumberland.

‡ As the excellent "Catalogue of the Western-Scottish Fossils," by Messrs. Armstrong, Young, and Robertson (Glasgow, 1876).

that the community of 28 species is a fact which strongly corroborates the views here suggested*.

It should be recollected also that, over the north of England and the borders of Scotland, land and shallow-sea conditions prevailed during the earlier Carboniferous stages. This accounts for those changes in the limestone series that have been pointed out by Phillips and Murchison, and more recently by Mr. Lebour. Such changes would necessarily be accompanied by the disappearance of various forms which flourished in the deeper seas of Central England, and the appearance of others more adapted to shallow water.

Part V.

Continental Equivalents.

A. *Stage* E—*Lower Coal-measures.*

That the great mass of the Coal-measures of Belgium, France, Rhenish Prussia, and North Germany are characterized by shells of recognized freshwater or lacustrine habitats is well known from the writings of continental geologists. Thus, we learn from the authors of 'Die Steinkohlen Deutschlands' that the Coal-measures of Saxony and Westphalia are characterized by the prevalence of such forms as *Unio*, *Anodonta*, *Cyrena*, *Cyclas*, *Dreissena*, *Cardinia* (*Anthracosia*), and *Planorbis*†. At the same time one or two bands of marine shells occur amongst this great mass of lacustrine or estuarine strata, in a manner similar to that which I have described above as being present in North Staffordshire and at Ashton-under-Lyne. Thus, Herr R. Ludwig has recognized *Goniatites* and *Aviculopecten* in the Coal-formation of Westphalia both near the base of the formation and at a higher horizon‡. It cannot be doubted that the former position is that of the "Gannister Beds" (Stage E).

The occurrence of a marine band at the base of the Coal-formation, and in the position of the Gannister Beds of England is now fully established by the labours of several observers, particularly Prof. F. Römer, of Breslau§, and M. Charles Barrois, of Lille||, and of Prof.

* On communicating to my colleague, Professor Geikie, Director of the Geological Survey of Scotland, the views above expressed regarding the representative beds on each side of the border below the Millstone Grit, he replies (in letter dated 24th Nov. 1876) that the correlation is a natural and probable one, and that for several years the Scottish Surveyors have always believed the so-called "Carboniferous-Limestone series" to represent generally all the English series between the Millstone Grit and the base of the Scaur Limestone. At the same time the survey of the border districts had not sufficiently far advanced to warrant the adoption of the English names of subdivisions.

† Herren Geinitz, Fleck, and Hartig. Band I. pp. 107–8 and 109.

‡ Von Meyer and Dunker, 'Palæontographica,' viii. pp. 31–38.

§ "Ueber eine marine Conchylien-Fauna im produktiven Steinkohlengebirge Oberschlesiens," Zeitschr. d. deuts. geolog. Gesellsch. 1863.

|| "Sur la faune marine du terrain houiller, &c.," Bulletin de la Soc. Géolog. de France, 3e sér. t. ii. p. 223.

de Koninck, of Liége*. We shall take a brief survey of their observations:—

(1) *Belgium.*—The lower marine zone of the Coal-formation has been recognized by Prof. de Koninck†. At Chokier-on-the-Meuse a band of limestone is associated with alum-shales containing small Goniatites. From these beds M. de Koninck enumerates 25 species of marine shells also found in the Carboniferous Limestone of Belgium, including *Aviculopecten papyraceus*, *Chonetes*, *Lingula*, *Orthoceras* (4 species), *Nautilus*, *Goniatites* (including *G. Listeri*), *Productus*, and fishes of the genera *Palæoniscus* and *Campodus* Ten species of *Cardinia* (*Anthracosia*) are mentioned from the "système houiller" of Liége; but these are probably from the beds above the marine zone. Of the species several are characteristic of Stage E of the Coal-measures of England; and both Dr. Römer and M. C. Barrois agree in referring these beds to this stage‡. This marine zone at the base of the productive Coal-measures of Belgium has been noticed in several places, so as to leave no doubt of its general occurrence. It corresponds to the "second niveau fossilifère" of MM. Cornet and Briart, containing *Productus carbonarius*, *Goniatites*, *Avicula*, *Chonetes Laguessiana*, &c. The remaining five *niveaux fossilifères* are characterized by the presence of *Anthracosia* (*Cardinia*) and, rarely, *Posidonomya* and *Mytilus*, showing the occurrence of estuarine conditions amongst a great mass (of about 1500 metres) of freshwater beds§.

(2) *North of France.*—M. Charles Barrois|| has recently published an account of the discovery which he, in company with M. Gosselet, has made of marine shells at the base of the Coal-measures of the north of France, in a position corresponding to that of the Belgian marine band of Chokier. These fossils have been found at Auchy-au-Bois, Lens, and Carvin—those at the last-named locality being, however, on a higher *niveau* than those of Auchy, and probably representing the stage of the "Chance Pennystone" of England in Stage F.

The following have been determined—*Cypridina concentrica* (De Kon.), *Orthoceras Goldfussianum* (De Kon.), *Nautilus subsulcatus* (Phil.), *Schizodus sulcatus* (Bronn.), *Leda attenuata* (Flem.), *Arca Lacordairiana* (De Kon.), *A. arguta* (Phill.), *A. elegans* (De Kon.), *Avicula papyracea* (Sow.), *Anthracosia* (sp.), *Spirifer glaber* (Mart.), *S. mesogonius* (M'Coy), *S. trigonalis* (Mart.), *Productus semireticulatus* (Mart.), *P. carbonarius* (De Kon.), *P. marginalis* (De Kon.), *Streptorhynchus crenistria* (Phil.), *Poteriocrinus* (sp.). Of these about one half ascend from the Carboniferous Limestone, the remainder being only known in later beds. Another band at Carvin, with

* Description des animaux fossiles qui se trouvent dans le terrain Carbonifère de Belgique.

† Ibid. p. 627 (*Tableau Résumé*).

‡ Bull. de l'Acad. roy. de Belgique, 2e sér. tom. xxxiii. (1872).

§ Bulletin de la Société Géologique de France, 3e sér. tom. ii.

|| That of the "Pennystone" of Coalbrook Dale. These fossils have also been studied by MM. Dumont, Dewalque, Cornet, and Briart.

Anthracosia, *Productus carbonarius*, *P. semireticulatus*, and *Streptorhynchus crenistria*, is considered to be the representative of the Chance Pennystone of Coalbrookdale, and is included in the Middle Coal-measures.

Notwithstanding the freshwater conditions that appear to have prevailed throughout the great mass of the Coal-measures of France and Belgium, brackish-water or estuarine conditions, consequent on slight depressions below the sea-level of the period, occurred at several intervals, so that out of twelve fossiliferous stages described by MM. Cornet and Briart five contain *Cardinia* and *Posidonomya*. In the 12th stage marine fossils occur which M. Charles Barrois assigns to the zone of "the Chance Pennystone" of Coalbrookdale*. The same observer has discovered *Productus carbonarius* in "*le grès des Plaines*" in the Boulonnais at the base of the Coal-formation, which he considers as probably representing the Millstone Grit of England.

(3) *Germany. Silesia.*—In August of 1862 the attention of Prof. Ferd. Römer was called to the existence of marine shells at two collieries in Upper Silesia, in strata of shale lying near the base of the productive Coal-measures of that district. The beds containing these fossils consist of dark shales about 100 feet in thickness, and upon further examination yielded a large number of forms, described and figured in Dr. Römer's paper†. They are as follows—*Phillipsia* (sp. inc.), *Orthoceras undatum*, *O. dilatatum*, *O. telescopiolum* (n. sp.), *Nautilus subsulcatus*, *Nautilus concavus*, *N. nodoso-carinatus* (n. sp.), *Goniatites diadema*, *G. Listeri*, *Bellerophon Urii*, *Littorina obscura*, *Anthracosia* ? (n. sp.), *Schizodus sulcatus*, *Leda attenuata*, *Nucula gibbosa*, *Arca Lacordairiana*, *Pecten* (sp. inc.), *P. interstitialis*, *Productus longispinus*, *P. semireticulatus*, *P. pustulosus*, *Orthis resupinata*, *O. crenistria*, *Lingula mytiloides*, *Discina nitida*, *Poteriocrinus*, and plants—*Nœggerathia*, *Calamites*, *Trigonocarpum*. Dr. Römer very aptly points out the resemblance of this fauna to that of the *Pennystone beds* of Coalbrook Dale, described by Professor Prestwich, and to that of the Gannister beds of Yorkshire, described by the late Professor Phillips. There can, in fact, be no doubt whatever that the beds in which they occur are the representatives of those just named. Out of the species above enumerated there are no less than 9 which are known as occurring in the Gannister-beds in the British Isles, viz. *Phillipsia* (genus), *Nautilus concavus*, *N. subsulcatus*, *Goniatites Listeri*‡, *Littorina obscura*, *Schizodus sulcatus*, *Productus semireticulatus*, *Orthis resupinata*, *Lingula mytiloides*, and *Discina nitida*. Here again we find representatives of the genus *Anthracosia* associated with marine forms.

(4) *Westphalia.*—The marine zone at the base of the productive

* *Loc. supra cit.* pp. 225, 226.

† *Supra cit.*

‡ This may be considered the characteristic shell of Stage E in Lancashire, Yorkshire, and Derbyshire. The species of *Phillipsia* is probably *pustulata*, which occurs (as we have seen) in the beds of this stage at Castlecomer in Ireland.

Coal-measures has been recognized in Westphalia. In the district of Werden, on the Ruhr, the dark shales of the Coal-formation have yielded to Herren von Dechen and Lottner *Goniatites carbonarius* and *Aviculopecten papyraceus* *. Lottner divides the Coal-formation of Westphalia into three stages (a lower, middle, and upper), possibly corresponding to Stages E, F, and G of the British classification; and he shows that all the marine fossils belong to the beds lying at the verge of the Lower and Middle Stages. Along with the marine shells are associated *Anthracosiæ*, which in the middle Stage occur in considerable numbers. Sections of the Lower series are laid open on the banks of the river Mulde.

B. *Continental Equivalents of Stages* A, B, C, *and* D.

It will be quite unnecessary for me to describe at any length the representatives of the divisions on the Continent subordinate to the Lower Marine zone (Stage E) of the productive Coal-measures. The reader will find an admirable summary of the views of continental geologists in Murchison's 'Siluria'† or Professor Renevier's Tables; and it is therefore only necessary for me to observe that they can be recognized in various districts, though they are occasionally impersistent. In the beds of sandstone (Flötzleerer Sandstein) of the Rhenish provinces which underlie the productive Coal-measures geologists are unanimous in recognizing the Millstone Grit of England‡, in which may probably be included the Yoredale beds (Stage C). This latter division, however, does not appear to occupy a well-recognized position amongst the continental Carboniferous beds. The Carboniferous Limestone of Belgium, which has been so admirably illustrated palæontologically by M. de Koninck, is stated by Murchison to rest directly on the Devonian rocks; but it would appear that the "schistes de Tournai" intervene, at least locally.

Towards the banks of the Rhine this great formation gradually changes its characters, and gives place to dark schists and bands of limestone, with *Posidonomya Becheri*. In this form it is represented generally in Westphalia; but in Silesia, Bohemia, &c. limestone reappears.

The lowest stage, A, is represented (according to Murchison) in the Rhenish provinces by the "Kiesel-Schiefer" of the Prussian geologists, which occasionally expands into a deposit of considerable dimensions. In Belgium the "schistes de Tournai" appear to be the representatives of this stage.

The following Table is intended to show the representative continental beds, as far as our means of determination extend (Table I.).

* 'Geognostische Skizze des westphälischen Steinkohlengebirges' (1859), quoted by Dr. Römer, *loc. supra cit.*

† 4th edit. p. 401 *et seq.*

‡ Geinitz, Fleck, and Hartig state that this formation occupies an intermediate position between the productive Coal-measures and the Carboniferous Limestone in Westphalia and Rheinland, 'Steinkohlen-Formation Deutschlands.'

Table I.—Continental Equivalents of British Carboniferous Divisions.

Divisions.	Stages.	British Equivalents.	France.	Belgium *.	Rhenish Provinces &c.	Silesia &c.
Upper Carboniferous (essentially estuarine and lacustrine).	G.	Upper Coal-measures.	....	Belgian Coal-field.	Saarbrück, Dortmund, and Westphalian Coal-fields.	Coal-measures. "Étage hangende" (Lottner)?
	F.	Middle Coal-measures.	Alais, St. Etienne.	Lille and Hainaut (Bassin de Namur).		Coal-measures. "Étage mittlere" (Lottner).
Middle Carboniferous (essentially marine).	E.	Gannister beds, &c.	Schistes de Lens, Auchy-au-Bois.	Schistes alunifères de Chokier, de camp de Casteau près Mons.	Dark shales with marine shells (Westphalia) Lower stage (Lottner).	Black shales (schwartze Schieferthon) with marine shells. "Étage liegende" (Lottner).
	D.	Millstone-Grit series.	Not recognized.	Schistes des Ampélites?	Flötzleerer Sandstein of Rhenish Prussia.	Lower Sandstones of the Hartz &c. (Murchison).
	C.	"Yoredale series" of the Geol. Survey.	....	Calcaire de Visé†.	Not recognized.	Not recognized.
Lower Carboniferous (essentially marine, sometimes lacustrine at base).	B.	Carboniferous Limestone.	Calcaire de Lille, Sablé, &c.	Calcaire de Dinant, Tournai, Namur, &c.	Dark limestones and schists with *Posidonomya Becheri*.	Beds of Limestone, (often absent).
	A.	Lower shales, slates, calciferous sandstones, and conglomerates.	....	Schistes de Tournai.	"Kieselschiefer."	Replaced by older rocks.

* To stage E in the Belgian series the second "niveau fossilifère" of MM. Briart and Cornet is referable, with *Productus carbonarius*, *Chonetes Laguessiana*, a *Cardinia*, and *Avicula*; to which Prof. Dewalque has added *Orthis crenistria*, *Posidonomya vetusta*?, *Goniatites*, *Pecten*, and *Terebratula* (Bull. de l'Acad. Roy. de Belgique, 2e sér. t. 33, no. 1, 1872).

† Mr. G. A. Lebour, F.G.S. (to whom my acknowledgments are due for much assistance in reference to several parts of my subject) states that out of the three divisions into which Dumont divided the Carboniferous Limestone, viz. (3) Calcaire de Visé (highest), (2) Calc. de Dinant, and (1) Calc. de Tournai, the uppermost of these is undoubtedly referable to Stage C (Yoredale Beds). It is uncertain whether the series of Ampelites belong to this stage or the succeeding one of the Millstone Grit (Stage D).

[*America.*—I am unwilling to lengthen this paper by reference to the succession of beds on the American continent, but think it proper to observe that, as Dr. Ferd. Römer has pointed out, the marine stage, E, is fairly represented at the base of the Coal-measures in the United States*. In the lower beds of the productive Coal-measures in the western portion of the State of Kentucky occurs a small *Lingula* (*L. umbonata*, Cox), which Dr. Römer considers to be in all probability identical with *L. mytiloides* of Phillips; and about 100 feet higher in the series, at Nolin Iron-works, several genera of Cephalopods also are found. Amongst these is *Nautilus ferratus*, Cox, which approaches very closely to, if it be not identical with, *N. bilobatus*, Sow., from the Carboniferous Limestone of Coalbrookdale.

In the State of Iowa, a band of marine limestone occurs about 20 feet above the "Concretionary Limestone" which marks the upper limit of the Carboniferous Limestone proper. It is separated from this latter by shales, sandstones, and a bed of coal 15 inches thick. In this limestone are found several species of *Productus*, a small *Spirifer*, a *Nautilus*, and the tail of a Trilobite†. Similar marine bands are found in the districts lying at the base of the productive Coal-measures, and may be regarded as referable to the horizon of the Lower Coal-measures of the British Isles.

Even if America afforded no analogy as regards the succession of beds with that of Britain, it ought not to be considered as invalidating the views here expressed. The British and continental areas are sufficiently large to form the basis for a classification of beds.]

Part VI.

(a) *Conclusions regarding the Conditions of Deposition of Carboniferous Strata drawn from the Characters of the Fossil Fauna.*

Amongst the varieties of remains of animals which have been found in various Carboniferous strata there are none upon which we can rely with so much confidence for information regarding the conditions of deposition as the Mollusca. Of those which lived in the Carboniferous period many of the genera, or their modifications, descend down to the present day; so that we may determine their habits by actual observation, and, by inference, those of their predecessors.

It is not so with the fishes. The placoids and ganoids of the Coal-period were, in all probability, like the sturgeon and other inhabitants of the Black Sea and the Caspian, migratory, and capable of living either in the open ocean, or of navigating the streams and plant-choked estuaries of the period; so that they throw no light upon the conditions of deposition of the strata in which their remains are found.

* *Loc. supra cit.* p. 604. Quoting MM. E. T. Cox and Leo Lesquereux, 'Geological Report of Kentucky,' vol. iii. pp. 515, 516 (1857).

† 'Report on the Geological Survey of the State of Iowa,' by J. Hall and J. D. Whitney, vol. i. p. 233 (1858).

The remains of reptiles are too scarce and vague for such a purpose; and the like may be affirmed of the Crustacea, with the exception of the Trilobites, whose presence in vast numbers amongst the marine beds of the Silurian period places the nature of their habits beyond question. We therefore fall back upon those orders and genera of molluscs whose habits can be determined either by actual observation, or association with other forms, as guides to classification of strata.

The lacustrine conditions of the Old Red Sandstone with *Anodonta Jukesii* in Ireland gradually give place to marine conditions in the period of the Lower Carboniferous Slate, which in other districts (except in Scotland, where the beds are marginal) extended over the remainder of the British Isles as far as they were submerged. Throughout the period of the Carboniferous Limestone deep-sea conditions generally prevailed, and the molluscan fauna flourished to an extent greater than at any subsequent stage of the Carboniferous period.

With the close of the period represented by the Carboniferous Limestone the seas became shallower, and muddy sediment pervaded the heretofore clear waters. The marine fauna became dwarfed, or carried on a lingering existence, and in numerous instances died out altogether. Those forms which survived sometimes became modified through the succeeding periods; but, as may be seen from the list of species (Table II.), a goodly number reached the stage of the Gannister beds; and probably, were we fully acquainted with the entire fauna of the Carboniferous Limestone seas, we should find that all the forms in Stage E have descended from the earlier period.

Amongst the known and prevalent marine forms in the Gannister beds are a few of those bivalves to which Professor King has given the name of "*Anthracosia*." Their presence probably indicates the recurrence of estuarine conditions from time to time at this stage; but subsequently they assumed a high importance as the representatives of molluscan life during the periods of the Middle and Upper Coal-measures, amongst the beds of which formations they occur at intervals throughout. That these shells were sometimes estuarine, sometimes lacustrine, appears to be borne out by the evidence before us, especially their rare association in the same stratum with truly marine forms of the succeeding stages.

(b) *Census of Marine Forms (British Islands).*

This decided change in the fauna of Stage E (Gannister beds), as compared with that of Stages F and G, will be recognized upon reference to the Tables of Species, which have been drawn up, with the assistance of Mr. Baily, F.G.S., from available sources. From these we find:—

1. That Stage E (Gannister beds) has yielded 36 genera with about 70 species, of truly marine forms.

ls" (Stage E).

Localities &c.
tage E).
taffordshire; Lancashire in Stage E. Exceptional in
E); Yorkshire (Stage B).
(Bullion coal).
ordshire (Bay-coal bass).
tone).
k Dale.
tone).
e E).
tone).
annister and Feather-edge coals).
stone)

TABLE II.—Showing the Vertical Range of the known Marine Genera and Species of the "Gannister Beds" (Stage E).

Names.	STAGE B. Carboniferous Limestone.	STAGE C. Yoredale Beds.	STAGE D. Millstone Grit.	STAGE E. Gannister Beds (or Lower Coal-measures).	STAGE F. Coal-measures.	STAGE G. Upper Coal-measures.	Localities &c.
Phillipsia pustulata (*Schl.*)	*	*	*	*	......	Stage G characterized by *Spirorbis carbonarius* and *Anthracosia* only. No marine shells.	Ireland, Castlecomer (Stage E).
Goniatites Listeri (*Mart.*)	*	*	*	*	* (Bay coal, Staffordsh.)		South Wales; North Staffordshire; Lancashire in Stage E. Exceptional in Stage F.
—— fasciculatus (*M'Coy*)	*	*	*	*	......		Ireland, Castlecomer.
—— crenistria (*Phil.*)	*	*	*	*	......		Ireland (Stages B and E); Yorkshire (Stage B).
—— reticulatus (*Phil.*)	......	......	......	*	......		Lancashire.
—— Gibsoni (*Phil.*)	......	......	......	*	......		Lancashire, Bolton.
—— paucilobus (*Phil.*)	*	*	*	*	......		Yorkshire; Lancashire (Bullion coal).
—— Looneyi (*Phil.*)	*	*	*	*	* (Bay coal, Staffordsh.)		Yorkshire; North Staffordshire (Bay-coal bass).
Nautilus armatus (*Sow.*)	......	......	......	*	......		Coalbrook Dale (Pennystone).
—— concavus (*Sow.*)	......	......	......	*	......		South Wales; Coalbrook Dale.
—— clitellarius	......	......	......	*	......		Coalbrook Dale (Pennystone).
—— (like cyclostomus, *Phil.*)	......	......	......	*	......		Ireland, Kilkenny (Stage E).
—— falcatus (*Sow.*)	......	......	......	*	......		South Wales.
—— subsulcatus	......	......	......	*	......		Coalbrook Dale (Pennystone).
Orthoceras, sp. inc.	......	......	*	*	......		Lancashire (above the Gannister and Feather-edge coals).
—— scalpratum (*Prestw.*)	......	... ..	......	*	......		Coalbrook Dale (Pennystone).
—— Steinhaueri (*Sow.*)	*	*	*	*	......		Yorkshire (Stage B); Ireland, Stage E (Leitrim) and Castlecomer.
Bellerophon apertus (*Sow.*)	*	*	*	*	......		South Wales.
—— decussatus (*Flem.*)	*	*	*	*	......		Ireland and South Wales.
—— hiulcus (*Sow.*)	*	*	*	*	......		South Wales; Derbyshire; Coalbrook Dale (Pennystone).
—— navicula (*Sow.*)	......	......	......	*	......		Coalbrook Dale.
Conularia quadrisulcata (*Sow.*)	*	*	*	*	* (Scotland)		South Wales; Coalbrook Dale; South Staffordshire (Pennystone); Scotland (C. L.).
Euomphalus, sp. inc.	?	?	?	*			South of Ireland, Castlecomer (Stage E).
Littorina (?) obscura (*Sow.*)	......	......	......	*	......		South Wales and Coalbrook Dale.
Macrocheilus fusiformis (*Sow.*)	......	......	......	*	......		Coalbrook Dale; South Wales (minute specimen).
Pleurotomaria limbata (*Phil.*)	*	*	*	*	......		South Wales (Stage E); Yorkshire (Stage C).
Arca (striate species)	......	......	......	*	......		South Wales (Rhymney).
Aviculopecten scalaris (*Sow.*)	......	......	*	*	......		Coalbrook Dale, South Wales, and South Staffordshire.
—— gentilis (*Sow.*)	......	......	......	*	......		Ditto, ditto.
—— papyraceus (*Goldf.*)	*	*	*	*	* (Bay coal)		North of England; Ireland (Stages A to E); Liége. Exceptional in Stage F.
—— (Lima) alternatus (*M'Coy*)	*	*	*	*	......		Ireland, Castlecomer; England, Congleton.
—— variabilis (*M'Coy*)	*	*	*	*	......		Ireland (Calp, Stage B), Leitrim (Stage E).
Avicula quadrata (*M'Coy*)	*	*	*	*	......		South Staffordshire (in Stage E, above the Pennystone).
—— modiolaris	......	......	......	*	......		Coalbrook Dale.
Axinus, sp. inc.	......	......	......	*	......		Ireland, Castlecomer.
—— (Donax) sulcatus (*Sow.*)	......	......	......	*	......		Coalbrook Dale (Pennystone).
Ctenodonta undulata (*Phil.*)	*	*	*	*	......		South Wales and Yorkshire.
—— gibbosa (*Flem.*)	*	*	*	*	......		South Wales, England, and Ireland (Stage B).
—— æqualis (*Sow.*)	......	......	......	*	......		South Wales and Coalbrook Dale.
Edmondia unioniformis (*Phil.*)	*	*	*	*	......		South Wales, &c.
Myacites sulcatus (*Flem.*)	*	*	*	*	......		South Wales (Stage E); Coalbrook Dale (Stage E); Yorkshire (Stage B).
Myalina triangularis (*Sow.*)	......	......	......	*	......		Coalbrook Dale (Crawstone band).
Pullastra bistriata (*Portl.*)	......	.. ...	......	*	......		Ireland, Castlecomer.
Monotis lævis (*Brown*)	......	.....	......	*	......		Lancashire (Stage E).
Posidonia (Posidonomya) Gibsoni (*Brown*)	......	.....	.... .	*	......		Lancashire (Oldham district).
—— lævigata (*Brown*)	......	.....	*	*	......		Lancashire.
Posidonomya Becheri (*Goldf.*)	*	*	.....	*	......		Ireland (Stage C), Leitrim (Stage E).
Schizodus sulcatus (*Sow.*)	......	......	*	*	......		South Wales and Coalbrook Dale.
—— carbonarius (*Portl.*)	......	......	......	*	......		Ditto, ditto.
Athyris planosulcata (*Phil.*)	*	*	......	*	......		Ireland, Kilkenny.
Chonetes Hardrensis (*Phil.*)	*	*	*	*	......		South Wales (Stage E); Co. Clare (Stage C); Cork (Stage A).
Discina nitida (*Phil.*)	*	*	*	*	......		South Wales and South Staffordshire.
Edmondia (small sp. ind.)	*	*	*	*	* (Scotland)		Kilkenny in Stage E.
Lingula mytiloides (*Sow.*)	*	*	*	*	......		South Wales; Dudley; North Staffordshire (Stage E).
Orthis resupinata (*Mart.*)	*	*	*	*	......		North of England; Ireland (Stage E), Castlecomer.
Productus semireticulatus (*Mart.*)	*	*	*	*	......		North of England; South Wales (Stage E); Ireland, Castlecomer.
—— concinnus (*Sow.*)	*	*	*	*	......		Coalbrook Dale (Pennystone).
—— hemisphærica (*Sow.*)	*	*	*	*	......		*Passim* Stage B; South Wales (Stage E).
—— scabriculus (*Mart.*)	*	*	*	*	......		South Staffordshire; Coalbrook Dale, Stage E (New-mine and Pennystone beds).
Rhynchonella pleurodon (*Phil.*)	*	*	*	*	* (Scotland)		England and Continent (Stages B and E); Ireland (Stages C and E).
Pullastra scalaria (*M'Coy*)	......	...	*	*	......		Ireland, Castlecomer (Stage E).
Spirifera Urii (*Flem.*)	*	*	......	*	......		South Wales (Stage E).
—— glabra (*Sow.*)	*	*	*	*	......		From Upper Devonian; South Wales (Stage E).
—— bisulcata (*Sow.*)	*	*	*	*	......		Coalbrook Dale; Cratloe, co. Limerick.
—— pinguis (*Sow.*)	*	*	*	*	......		Ireland, Kilkenny.
—— semicircularis (*Phil.*)	*	*	*	*	......		Coalbrook Dale (Pennystone; Stage E).
Actinocrinus	*	*	*	*	......		Ireland, Castlecomer (Stage E).
Archæocidaris?	......	......	*	*	......		Oldbury (Pennystone). Species too imperfect for identification.
Cyathocrinites quinquangularis (*Miller*)	......	... .	......	*	.. ...		Coalbrook Dale (Pennystone).

Note.- When a species is known to occur in Stages B and E, it is considered to belong to the intermediate Stages C and D, and is marked accordingly.

2. That all the genera, and about 40 species, ascend upwards from the Carboniferous Limestone into Stage E.

3. That only 6 species pass up into Stages F and G.

4. That about 18 species are peculiar to Stage E.

5. And that 5 are peculiar to Stages F and G. (Table IV.)

The number of genera and species in Stage E is probably greater than is here stated; for it is exclusive of some forms of bivalves from the Pennystone of Coalbrook Dale, figured by Professor Prestwich in his well-known memoir on that coal-field, and classed under the head of the genus *Unio* *. But it seems more probable that they belong to the marine genus *Myacites*, or some similar form, as it is in the last degree improbable that shells of a freshwater genus should be associated in the same bed with such forms as *Productus*, *Spirifer*, *Orthoceras* and *Nautilus*. These bivalves (the *Anthracosiæ* of King) are the bane of palæontologists; and after a long consideration of their relationship to other fossils in Carboniferous strata, and their ever-varying forms, I have come to the conclusion that either they were capable of inhabiting both lakes and estuaries on the one hand and the open sea on the other, or else that the marine and freshwater forms are so similar in appearance that they can only be identified by reference to those which may occur along with them in the same bed. Thus, when (as in Coalbrook Dale and Lancashire) we find them associated with undoubted marine forms we can only conclude that they themselves were inhabitants of the sea; but if they happen to occur unaccompanied by such well-recognized forms, then we may assume that they represent lacustrine or estuarine conditions, the probability being that, had the strata been formed under the sea, marine shells would have been preserved along with those of this genus.

The most striking fact brought to light in the above census is the essentially marine character of the fauna in Stage E, which is clearly representative of that of the Carboniferous-Limestone period. In this it is distinguished from that of Stages F and G, in which, with the exception of two or three marine bands occurring throughout a series of (in some districts) 5000 to 6000 feet of strata, the beds are destitute of recognized marine forms. If any one will carefully peruse the list of species drawn up by the late Mr. Salter from the Upper and Middle Coal-measures of North Staffordshire †, and compare it with that from the Gannister beds of the same coal-field, or of the Pennystone bands of Coalbrook Dale ‡, he cannot fail to be struck with the change in the character of the fauna—*the contrast bearing comparison with that between the faunas of the Portland Oolite and the Purbeck beds of the south of England.*

* Trans. Geol. Soc. 2nd ser. vol. v. p. 413, and pl. xxxix.
† 'Iron-ores of Great Britain,' part iv.
‡ Prestwich, *loc. cit.*

(c) *Occasional Marine Beds in Stage* F.

That the ocean-waters were not far distant from the British and European areas during the formation of the Middle and Upper Coal-measures is proved by the appearance at rare intervals of bands of truly marine shells. Such are those which occur above the "Bay Coal" and the "Gin-mine Coal" in North Staffordshire*, that in the banks of the river Tame at Ashton-under-Lyne†, and that of the "Chance Pennystone" of Coalbrook Dale. But it should be observed that the species in these bands are sometimes different from those in the Gannister beds, most of which have descended from the Carboniferous Limestone. Thus, out of about 29 species determined by Salter from the Lower Coal-measures (Stage E) of South Wales‡, all but five, viz. *Aviculopecten gentilis* (Sow.), *A. scalaris* (Sow.), *Myalina triangularis* (Sow.), *Discites falcatus* (Sow.), and *Nautilus concavus* (Sow.), have been recognized in the Carboniferous Limestone. The species from the same stage in Coalbrook Dale and South Staffordshire are similarly related to those of the Mountain Limestone; the exceptions to identity are probably owing to insufficient knowledge of the Lower-Carboniferous fauna.

On the other hand, if we compare the species from the accidental marine bands which occur in the Middle Measures (Stage F) we find them to be mostly peculiar to that horizon. Thus, out of about ten species from the marine band at Ashton-under-Lyne only one was considered by Salter to be identical with a form from the Gannister beds. Of this remarkable group Mr. Salter has observed:—"A special notice should be given of this marine band, containing as it does a small peculiar fauna, comparable with that of the Lower Coal-measures of Shropshire, but yet wholly distinct. It is true the common marine shell, *Aviculopecten papyraceus*, occurs in this remarkable band; but even this is dwarfed, and, except this species, the fossil contents are wholly different from those of the Gannister beds and those of the beds among which they occur"§. These species, nevertheless, may be regarded as the representatives of the fauna living in the adjoining seas during the deposition of the strata of the Middle and Upper Coal-measures, and as such differing to some extent from that of Stage E. It is only thus by accident (as it were) that we obtain a view of the characters of the marine fauna during the long stage of the great coal-growth.

(d) *Present Mode of Classification Objectionable.*

With such palæontological evidence before us, it has long seemed to me that the generally received system of classification, by which the whole Carboniferous series is divided into only two great divisions, does not express the real relations of the different members to each other. The stages above the Mountain Limestone, including

* Discovered by Mr. John Ward, of Longton.

† Discovered by Prof. A. H. Green.

‡ Rosser vein, a seam above the true Millstone Grit, 'Iron-ores of Great Britain,' part iii. p. 221.

§ 'Geology of Oldham, &c.' (Mem. Geol. Survey), p. 64.

the Yoredale-beds, Millstone Grit, and Gannister beds, are (as we have seen) palæontologically connected with the Mountain Limestone, while in composition and mineral character they are more nearly related to the Upper Carboniferous beds. It was in view of their mineral character exclusively that they were originally grouped with the Coal-measures into an Upper Carboniferous series; for it is only recently that their palæontological and stratigraphical relations to the Middle Coal-measures have been made out. The small development of coal in these earlier stages, as compared with the later, and certain minor differences in the arrangement of the strata, serve to distinguish the two sets of beds mineralogically. To this may be added evidence of a break in the continuity of the strata at the base of the Middle Coal-measures in Lancashire *, thus affording proof that the change of the fauna was coincident with, and was due to, changes in the physical conditions of land and water.

It is true, however, that tripartite classifications have in several instances been proposed; but they are open to similar objections as in the case of the binary divisions. Sir R. I. Murchison arranges the Carboniferous series of the British Isles and Europe into three stages, the lower of which only includes the Lower Limestone Shale and Calciferous Sandstone, while the middle includes all the strata up to the Millstone Grit; the Lower, Middle, and Upper Coal-measures are grouped in the upper division †.

Mr. H. B. Woodward, in his 'Geology of England and Wales' (1876), adopts a binary classification, placing all the beds below the Millstone Grit in the "Lower Carboniferous," and all above in the "Upper Carboniferous." The objection to this arrangement is that it unites beds which are palæontologically different, and separates those which are palæontologically similar.

Sir C. Lyell, in his 'Student's Manual,' has also adopted a binary division, placing all the beds above the Carboniferous Limestone in the upper, and those below this horizon in the lower division.

Professor Geikie, in his edition of Jukes's 'Manual of Geology,' judiciously avoids the difficulty of the subject by omitting to make any classification at all; yet, for general purposes of correspondence or description, some classification appears highly desirable.

Mr. Lebour also adopts a binary classification, placing the beds below the Millstone Grit, including "the Bernician" and "Tuedian" groups, in the lower division, all above this in the upper.

Prof. E. Renevier, in his 'Tableau des Terrains sédimentaires' ‡, gives the following classification:—

Ages=Etages.			English equivalents.
Carbonifère	supérieure:	Houiller	Coal-measures.
,,	moyen:	Culm	Millstone Grit.
,,	inférieur:	Condrusien	Mountain Limestone.
,,	,,	Ursien	(Lower) Limestone Shale, Carboniferous Slate, &c.

* The section showing the break occurs near Bury, and is figured and described by myself in the memoir on the Geology of the Country around Bolton-le-Moors, p. 6 (1862).

† 'Siluria,' 4th edit. p. 404.

‡ Lausanne, 1874.

Table III.—Representat

	Stages.	England and Wales.		I
		North.	South.	North.
Upper.	G.	Upper Coal-measures of Manchester, &c., Staffordshire, Denbighshire.	Generally absent (through denudation).	Absent (through den dation).
	F.	Middle Coal-measures with thick coal-seams &c., Lancashire, Yorkshire, Derbyshire, &c.	Middle Coal-measures of South Wales and Somersetshire, &c.	Coal-Island Coal-fiel co. Tyrone.
Middle.	E.	"Gannister Beds," or Lower Coal-measures.	Lower Coal-measures, with ironstones and thin coals.	Lower Coal-measures Drumglas (Tyron coal-fields of Lou Allen (co. Leitrim).
	D.	Millstone Grit series, Lancashire, Yorkshire, Derbyshire, &c.	Millstone Grit, or "Farewell Rock."	Millstone Grit of Fe managh, Sligo, & (Cuilcagh).
	C.	Yoredale series, or Upper Limestone shale. "Upper Bernician beds" (Lebour).	Upper Limestone shale (thin).	Ironstone shales Lough Allen, also Drumglas (co.Tyron
Lower.	B.	"Mountain Limestone" of Derbyshire, "Scaur or Scar" Limestone (Sedgwick).	Carboniferous Limestone of Cheddar, the Wye, Avon, and S. Wales, &c.	Carboniferous Limesto in three divisior Ballycastle Coal-fiel co. Antrim (in part)
	A.	"Tuedian Group" (Tate), often absent in N. Lancashire &c.	Lower Limestone shale (thin).	Calciferous Sandsto series or Lower Ca boniferous Grits.

oniferous Formations.

ND.	Scotland.	Continental.	Conditions of Deposition.
South.	Central.	Belgium and Germany.	
bsent (through denudation).	Upper red sandstones of Bothwell &c. Ayrshire beds with Spirorbis Limestone.	Possibly present in the Belgian and Saarbrück Coal-fields.	Essentially estuarine and lacustrine, with intrusions of the sea at long intervals.
einster Coal-field, from "the Jarrow Coal" upwards.	"Flat-coal" series or "Upper Coal series" of Scotland with thick coals.	Main Coal-measures of Belgium, Saarbrück, Westphalia, Saxony, and Silesia, &c.	
ower Coal-measures of Leinster, Modubeagh, Tollerton, Skehana and Slieveardagh, &c.	Beds on the horizon of "the Slaty-band" ironstone ?	Schistes de Lens, Auchy-au-Bois, Chokier. Bottom shales of the Coal-measures of Silesia, &c.	
lagstone series of Carlow, Kilkenny, Clare, &c.	"Moorstone rock" and Roslin sandstone.	Generally absent in Belgium. Flötzleerer Sandstein of Germany.	Essentially marine, rarely estuarine. (Sea shallower than in Stage B.)
Shale series" of Carlow, Kilkenny, Clare, &c.	"Upper Limestone series" resting on "Lower coal and ironstone series" ?	Calcaire de Visé. Bruchberg crinoidal sandstone (Harz) ?	
'arboniferous Limestone, in three divisions.	"Lower Limestone series" of Gilmerton, Roman camp, &c.	Carboniferous Limestone of Belgium (Calc. de Dinant, Calc. de Tournai), France, Germany, Russia, &c.	Essentially marine, and deep-sea beds (except occasionally in Scotland, where lacustrine or estuarine beds occur).
ower Carboniferous slate (in part) with Coomhola grits.	Calciferous Sandstone series in two groups.	Psammites du Condroz, "Schistes de Tournai," and "Kiesel - Schiefer," &c. "Jüngere Grauwacke" of the Vosges and of the Schwarzwald.	

TABLE III.—Representative Carboniferous Formations.

	Stages.	England and Wales.		Ireland.		Scotland.	Continental.	Conditions of Deposition.
		North.	South.	North.	South.	Central.	Belgium and Germany.	
Upper.	G.	Upper Coal-measures of Manchester, &c., Staffordshire, Denbighshire.	Generally absent (through denudation).	Absent (through denudation).	Absent (through denudation).	Upper red sandstones of Bothwell &c. Ayrshire beds with Spirorbis Limestone.	Possibly present in the Belgian and Saarbrück Coal-fields.	
	F.	Middle Coal-measures with thick coal-seams &c., Lancashire, Yorkshire, Derbyshire, &c.	Middle Coal-measures of South Wales and Somersetshire, &c.	Coal-Island Coal-field, co. Tyrone.	Leinster Coal-field, from "the Jarrow Coal" upwards.	"Flat-coal" series or "Upper Coal series" of Scotland with thick coals.	Main Coal-measures of Belgium, Saarbrück, Westphalia, Saxony, and Silesia, &c.	Essentially estuarine and lacustrine, with intrusions of the sea at long intervals.
Middle.	E.	"Gannister Beds," or Lower Coal-measures.	Lower Coal-measures, with ironstones and thin coals.	Lower Coal-measures of Drumglas (Tyrone), coal-fields of Lough Allen (co. Leitrim).	Lower Coal-measures of Leinster, Modubeagh, Tollerton, Skehana and Slieveardagh, &c.	Beds on the horizon of "the Slaty-band" ironstone?	Schistes de Lens, Auchy-au-Bois, Chokier. Bottom shales of the Coal-measures of Silesia, &c.	
	D.	Millstone Grit series, Lancashire, Yorkshire, Derbyshire, &c.	Millstone Grit, or "Farewell Rock."	Millstone Grit of Fermanagh, Sligo, &c. (Cuilcagh).	Flagstone series of Carlow, Kilkenny, Clare, &c.	"Moorstone rock" and Roslin sandstone.	Generally absent in Belgium. Flötz-leerer Sandstein of Germany.	Essentially marine, rarely estuarine. (Sea shallower than in Stage B.)
	C.	Yoredale series, or Upper Limestone shale. "Upper Bernician beds" (Lebour).	Upper Limestone shale (thin).	Ironstone shales of Lough Allen, also of Drumglas (co. Tyrone).	"Shale series" of Carlow, Kilkenny, Clare, &c.	"Upper Limestone series" resting on "Lower coal and ironstone series"?	Calcaire de Visé. Bruchberg crinoidal sandstone (Harz)?	
Lower.	B.	"Mountain Limestone" of Derbyshire, "Scaur or Scar" Limestone (Sedgwick).	Carboniferous Limestone of Cheddar, the Wye, Avon, and S. Wales, &c.	Carboniferous Limestone in three divisions. Ballycastle Coal-field, co. Antrim (in part).	Carboniferous Limestone, in three divisions.	"Lower Limestone series" of Gilmerton, Roman camp, &c.	Carboniferous Limestone of Belgium (Calc. de Dinant, Calc. de Tournai), France, Germany, Russia, &c.	
	A.	"Tuedian Group" (Tate), often absent in N. Lancashire &c.	Lower Limestone shale (thin).	Calciferous Sandstone series or Lower Carboniferous Grits.	Lower Carboniferous slate (in part) with Coomhola grits.	Calciferous Sandstone series in two groups.	Psammites du Condroz, "Schistes de Tournai," and "Kiesel-Schiefer," &c. "Jüngere Grauwacke" of the Vosges and of the Schwarzwald.	Essentially marine, and deep-sea beds (except occasionally in Scotland, where lacustrine or estuarine beds occur).

TABLE IV.—Showing the Vertical Range of the known Marine Genera and Species of Stage F (Middle Coal-measures).

	Stage A.	Stage B.	Stage C.	Stage D.	Stage E.	Stage F.	Stage G.	Localities.
Discites rotifer (*Salter*)	......	......	......	......	......	*	......	Ashton-under-Lyne.
—— (sp. in.)	......	......	......	......	......	*	......	Ditto.
Goniatites Looneyi (*Phil.*)	......	*	*	*	*	*	......	Stage F. Bay-Coal bass, N. Staffordshire.
Nautilus præcox (*Salter*)	......	......	......	......	......	*	......	Ashton-under-Lyne.
Bellerophon Urii (*Flem.*)	......	*	*	*	*	*	......	Stage F. Scotland.
Conularia quadrisulcata (*Sow.*)	......	*	*	*	*	*	......	Stage F. Scotland. "Chance Pennystone" of Coalbrookdale.
Aviculopecten papyraceus (*Goldf.*)	?	*	*	*	*	*	......	Stage E. Bay-Coal bass, N. Staffordshire.
—— fibrillosus (*Salter*)	......	......	......	......	......	*	......	Stage F. Ashton-under-Lyne.
Ctenodonta (sp. nov.)	......	......	......	......	......	*	......	Ashton-under-Lyne, Bay-Coal bass.
Discina nitida (*Phil.*)	......	*	*	*	*	*	......	Stage F. Scotland.
Productus scabriculus (*Mart.*)	......	*	*	*	*	*	......	Stage F. Scotland. Chance Pennystone of Coalbrookdale.
Total	?	6	6	6	6	11		

Along with the above known marine forms are numerous species of bivalves of the genus called by different authors "*Unio*," "*Myacites*," "*Cardinia*," and "*Anthracosia*," which, according to the views stated in this paper, are considered to be either lacustrine or estuarine.

It will be seen from the above Table that out of eleven species of marine forms known in Stage F, only six occur in Stage E, the other five being specifically distinct and peculiar to the Middle Coal-measures alone.

This classification rather closely approaches the one here suggested.

In the 3rd edition of the 'Coal-fields of Great Britain,' having recognized, though not so fully as at present, the palæontological connexion between the Gannister Beds (Stage E) and the Mountain Limestone, I placed all the beds from this formation downwards inclusive in the "Lower Carboniferous" division. Though this arrangement is, from my point of view, preferable to that which places all the beds above the Limestone in the Upper Carboniferous division, it is open to the objection of not sufficiently recognizing petrological characters and affinities.

The conflicting views amongst authors above noticed is to be attributed to the want of some clear principle upon which to determine the relationships of the various members of the Carboniferous series to each other. The palæontological differences between the Gannister Beds and the Coal-measures seem to offer a good basis for drawing a divisional line at this horizon; while the petrological differences between the Carboniferous Limestone and the succeeding stages, together with the great destruction of coralline, crinoidal, and molluscan life at the close of the former stage, afford sufficient grounds for drawing another line of division at this lower horizon,—thus constituting a middle Carboniferous group, the beds of which are closely related in mineral and palæontological characters.

(*e*) *Proposed Classification.*

In order, therefore, to give the affinities and differences in the Carboniferous beds due recognition, it seems desirable to adopt a threefold arrangement, constituting a middle group differing from the lower in mineral characters, and from the upper in the characters of the prevalent molluscan fauna; and with this object the arrangement shown in Table I. p. 640, seems to me the most natural that can be adopted.

In speaking of the main divisions as "essentially marine," "essentially lacustrine," &c., I wish those terms to be understood as representing the prevalent conditions, which admit of exceptions, as in the case of the Lower Carboniferous group, which, though essentially marine, contains in Scotland marginal representatives of the period which are estuarine and lacustrine in character.

(*f*) *Summary of Conclusions.*

From the above considerations it is to be inferred that the Gannister Beds (Stage E) should be dissociated from the main mass of the coal-measures above, and grouped with the formations below:—

First. Because Stage E is essentially of marine origin, while Stages F and G are essentially estuarine and lacustrine. (See Table III.).

Secondly. Because the few marine species found in Stages F and G are for the most part specifically different from those in Stage E. (See Table IV.)

Thirdly. Because of local breaks in stratification between Stages E and F, concurrent with the palæontological break*.

* An illustration of Professor Ramsay's views, as expressed in his Presidential

On the other hand, Stages E, D, and C form one natural group, somewhat similar in mineral composition, and palæontologically connected throughout by marine molluscan forms. Their association under the term "Middle Carboniferous," seems to be a proper way in which to recognize this relationship.

Lastly, it is proposed to retain Stages A and B in the Lower Carboniferous group as generally accepted—representing the predominance of marine conditions, and of mineral characters generally differing from those of the overlying beds.

Discussion.

Prof. Ramsay, after referring to the exceptional opportunities which Prof. Hull had enjoyed of becoming intimately acquainted with the Carboniferous rocks of these islands, remarked that in the present paper he had correlated these beds with singular ability, but added that, for his own part, he was averse to drawing hard and fast lines without any distinctly evident unconformity. There was, however, evidence of great up-and-down physical changes, slowly substituting estuarine for marine conditions, and *vice versâ*; and these were associated with small palæontological breaks. He did not feel sure that the Scaur Limestone of the north-east is the entire representative of the Lower Carboniferous Limestone of Derbyshire. He thought that the only philosophical way of mapping the Carboniferous deposits of England was upon lithological principles, colouring the sandstones, limestones, &c. separately, and, when coal-beds occur, indicating the underclays &c. In this way a good physical map of the whole series would be obtained. Prof. Ramsay also stated that he had been informed by a Russian gentleman that the Scotch Coal-measures are identical with those of Southern Russia.

Prof. W. Boyd Dawkins, referring to the break which Prof. Hull had put at the top of the Gannister series, stated that he was unable to recognize any decided physical or palæontological break at this point. Taking Lancashire and the north, the Coal series appears to be continuous. From the presence of remains of sharks he inferred that the upper deposits were not exclusively estuarine or freshwater, but at least partly marine.

Prof. Hughes objected to the assumption of a sharp line of demarcation at the top of the Mountain Limestone. He doubted the identification of the so-called Irish Yoredale beds with those of Yoredale, and stated that the latter in the typical locality thin out from 2200 to 609 feet within a short distance. In the Carboniferous series we have local alternations of marine and freshwater conditions; and such a correlation as had been attempted by the author, implying synchronism in England, Scotland, and Ireland, did not seem to him to be useful.

Prof. Prestwich did not doubt the correctness of Prof. Hull's

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Addresses to the Geological Society of London, Quart. Journ. Geol. Soc. vols. xix. and xx.

classification as a whole, but thought that such hard separate groups as appeared to be indicated could not be sustained. In Shropshire we have at the top of the Coal-measures the *Spirorbis* Limestone, then beds with various marine fossils, and below these deposits with *Anthracosiæ*. In Belgium the Coal-measures are also associated with beds containing *Bellerophon* and other marine forms. He considered the character of the Carboniferous series to be dependent on conditions of depth in the different areas.

Mr. Etheridge thought that previous speakers had been rather hard on Prof. Hull, seeing that the sharp lines objected to are precisely those which we have been long working on, and the author had merely attempted to correlate certain beds. The author's lists of fossils seemed to him to be of great use as evidence of very significant changes. Mr. Etheridge maintained that in the correlation of these, as of other deposits, palæontological as well as physical evidence must be taken into consideration. It was difficult to understand how such a flora as that of the Coal-measures came to be associated with a marine fauna. Mr. Hull's groups were not new; but the grouping was important, and Mr. Etheridge was disposed to agree with him in his correlations.

Mr. Warington W. Smyth referred to the work done in connexion with these questions more than thirty years ago by Mr. Binney, and expressed a hope that due credit was given to that gentleman in the paper. It seemed to him that the author had set out by establishing the homotaxis in this country, but that he had then jumped to a conclusion about the deposits in Scotland. He inquired if there was evidence of the Gannister beds between those generally so called in England and those in Scotland, as, for example, in Durham.

Prof. Morris agreed with Prof. Dawkins as to the difficulty of recognizing a break at the Gannister beds, the distribution of which was very interesting; but they differ in their characters somewhat in their E. and W. range to Wales, as compared with their trend from S. to N. towards Scotland. Some of the marine forms in these rocks are species continued from the old Carboniferous sea. He said that *Anthracosia* was certainly not a *Unio*. In Shropshire there are intercalated marine beds, and with these the same *Anthracosia*. In Scotland the horizons are not so distinct.

The Author, in reply, said that some of the points raised by the speakers were already met in his paper. He stated that he had on principle rejected both fish and plants as furnishing data for classification: the fish were Ganoids, and therefore probably migratory. Hence we are compelled to fall back on the Mollusca. Throughout the investigation *Anthracosia* had been his bane, since it occurs sometimes with marine and sometimes with freshwater companions. As regards the term "Yoredale series," he used it in this paper in the sense adopted by the Geological Survey in the districts of Derbyshire, Lancashire, and Yorkshire. It seemed to him that sufficient importance had not been given by the speakers to the palæontological break above the Gannister beds; out of 75 species of marine genera below this line not more than 6 pass upwards.

34. *On a new* Area *of* Upper Cambrian Rocks *in* South Shropshire, *with a* Description *of a new* Fauna.

By Charles Callaway, Esq., M.A., B.Sc. Lond., F.G.S. (Read March 21st, 1877.)

[Plate XXIV.]

Introduction.

In March 1874 I communicated to this Society a paper entitled, "On a Tremadoc area near the Wrekin in South Shropshire, with description of a new Fauna," which was published in abstract in the Society's Journal, vol. xxx. p. 196.

In that paper I described certain shales, commonly supposed to be Caradoc, which I had examined at Shineton, two miles S.S.W. of the Wrekin. In these shales I had found *Conocoryphe*, *Lingulella*, and other fossils of a Cambrian* type; and from this and other evidence I had concluded the beds were of Tremadoc age. My views, however, were not accepted by the Fellows present at the reading of my paper, on account of the alleged imperfection of the fossil evidence; and, as I was at the time absent in America, I had no opportunity of defending my position. Since my return home I have collected more abundant and satisfactory evidence, both geological and palæontological, which I venture to think will establish my original conclusions. I have also made out some additional points of interest in the geology of the neighbourhood of the Wrekin.

Previous Information.

Sir R. Murchison has described the area under examination, from the Wrekin on the north-east to the May-Hill Sandstone at Kenley on the south-west, as composed of strata of Caradoc age, the Wrekin itself being an igneous outburst altering the Caradoc sandstone on its flanks into quartzite.

The Geological Survey has followed Murchison, but has included, under the name of "quartzite," certain sandstones in which I have detected fossils in abundance.

In the Journal of this Society (vol. x. p. 62), Messrs. Aveline and Salter describe this area as Caradoc, and Salter gives a list of fossils from (so-called) Lower Caradoc shales at Harnage and Shineton, mixing up Cambrian forms, such as *Olenus*, from Shineton, with Cambro-Silurian genera, such as *Trinucleus*, from Harnage, the shales at Shineton and at Harnage evidently being considered identical.

* I adopt Mr. Hicks's classification of the Cambrian rocks, and the name "Cambro-Silurian" for the groups from the Arenig to the Lower Llandovery inclusive.

Salter, in the 'Geological Magazine' for 1867, refers to the shales at Shineton, which he there regards as "the top of the Llandeilo Flags proper." The same writer seems, in after years, to have been struck with the incongruous association of Cambrian and Cambro-Silurian forms; for, in 'A Catalogue of the Collection of Cambrian and Silurian fossils contained in the Geological Museum of the University of Cambridge,' published in 1873, while describing what he supposes to be a *Triarthrus* from Shineton, he suggests, "it is possible that the locality may include some *Tremadoc* beds." With this exception, geologists have regarded the rocks of the area under consideration as of Caradoc age.

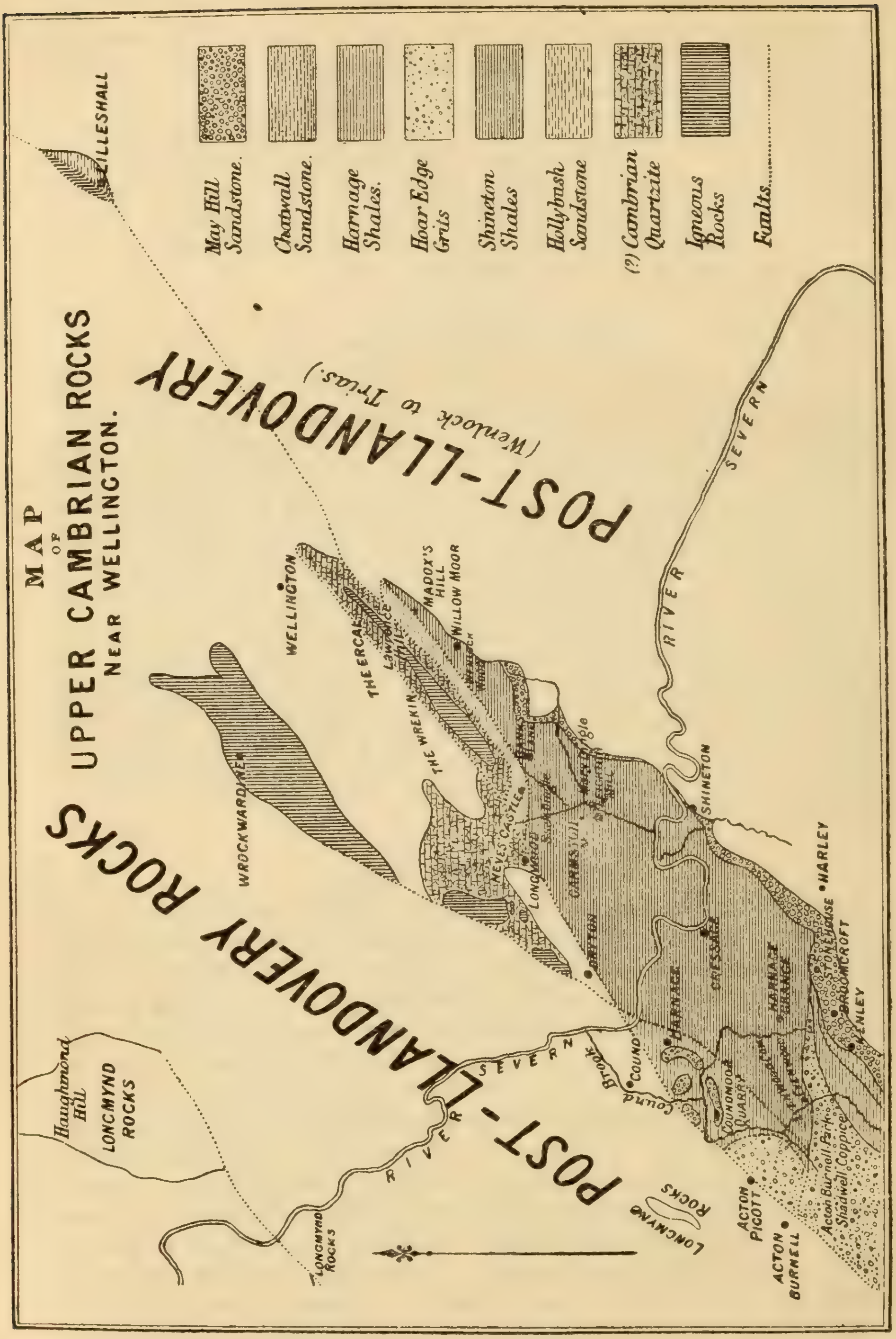
Object of the Paper.

I propose to describe the Lower Palæozoic rocks ranging from near Wellington on the north-east to the May-Hill Sandstone, at Kenley, on the south-west (see map, p. 654). This area is nine miles in length, and two and a quarter miles in its greatest breadth. My description will include an inlier of ancient rocks at Lilleshall, five miles to the north-east of Wellington. I shall pay no attention to rocks newer than the Caradoc, except so far as is necessary for the elucidation of my subject. I shall endeavour to prove that the shales at Shineton are of Tremadoc age, and that a part of the so-called "quartzite" between the shales and the Wrekin represents the Hollybush Sandstone of Malvern. I have also satisfied myself that the so-called "greenstone" of the Wrekin and neighbouring areas is largely composed of bedded rocks; but I defer discussion on this point, and on the quartzites overlying the Wrekin rocks, till I have made further observations.

Lower Caradoc Rocks.

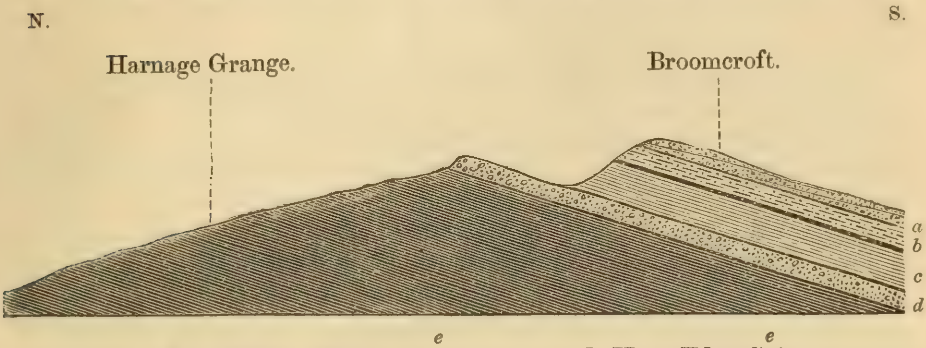
Mr. Salter noticed at Harnage and on Cound Brook certain shales containing *Trinucleus concentricus*, Eaton, *Beyrichia complicata*, Salt., *Diplograpsus pristis*, His., *Orthis testudinaria*, Dalm., and other Cambro-Silurian fossils; and as these shales are very similar in lithological characters to the shales at Shineton, and have the same general strike, both shales were lumped together by him as Lower Caradoc.

After extensive collections of fossils from all parts of the area under consideration, I arrived at the conclusion that in no case were the Shineton and Harnage faunæ intermixed. I also observed that there was a distinct lithological difference between the two shales, the Shineton shales being more fissile, the Harnage shales more conchoidal, in their fracture. I was greatly puzzled, however, at noticing that, in the Cound-Brook and Harnage area, the shales with a Cambro-Silurian fauna were overlain by utterly unconformable Caradoc Sandstone, the unconformability in some cases approaching a right angle. At the same time the shales with the older fauna dipped with apparent conformability under Caradoc sandstone. At last I discovered the following section (fig.1), which cleared


MAP OF UPPER CAMBRIAN ROCKS NEAR WELLINGTON.
May Hill Sandstone.
Chatwall Sandstone.
Harnage Shales.
Hoar Edge Grits
Shineton Shales
Hollybush Sandstone
(?) Cambrian Quartzite
Igneous Rocks
Faults
POST-LLANDOVERY (Wenlock to Trias.)
POST-LLANDOVERY ROCKS
LILLESHALL
WELLINGTON
WROCKWARDINE
THE ERCAL
LAWRENCE HILL
THE WREKIN
MADOX'S HILL
WILLOW MOOR
NEVES CASTLE
LONGWOOD
CRESSAGE
HARNAGE
HARNAGE GRANGE
SHINETON
HARLEY
STONEHOUSE
BROOMCROFT
KENLEY
COUND
Cound Brook
COUNDMOOR QUARRY
ACTON PICOTT
ACTON BURNELL
Acton Burnell Park
Shadwell Coppice
LONGMYND ROCKS
Haughmond Hill
RIVER SEVERN

up the difficulty and revealed the true succession. The formations represented are:—the Shineton Shales; the Caradoc, consisting of the Hoar-Edge Grits, the Harnage Shales, and the Chatwall Sandstone; and the May-Hill Sandstone, or Upper Llandovery of Murchison.

Fig. 1.—*Section through Harnage Grange and Broomcroft.*



a. May-Hill Sandstone.
b. Chatwall Sandstone.
c. Harnage Shales.
d. Hoar-Edge Grits.
e. Shineton Shale.

In this section the Shineton Shales and the Caradoc are apparently conformable, and dip at an angle of about 15°. The May-Hill overlies the Caradoc unconformably at a lower angle.

In the road $\frac{3}{4}$ mile to the west of Harley (see map p. 654) the May-Hill Sandstone rests immediately upon fossiliferous Shineton Shales, both dipping at a very low angle. Half a mile to the west of this locality, a few feet of sandstone with characteristic Caradoc fossils intervene between the shales and the May-Hill; and half a mile to the west of the last locality the section is as above described. Still further to the west and south-west the Caradoc subformations thicken out rapidly. The Hoar-Edge Grits especially, which, in the above section, are represented by sandstone rendered subcalcareous by fossils, acquire great thickness, and form in some parts massive beds of grit. They constitute a ridge ranging from above Harnage Grange, west-south-west, to Shadewell Coppice, where they present a conspicuous feature in the landscape, the increased elevation appearing to correspond with the thickening-out of the beds. To the south-west these beds form the sharp ridge of Hoar Edge. The dip is about 15° in the above section, but becomes steeper to the south-west. The strike is east and west in the ridge above Harnage Grange; but to the south-west it acquires a south-westerly trend. The Hoar-Edge Grits are characterized by *Strophomena expansa*, Sow., *Orthis vespertilio*, Sow., and *O. flabellulum*, Sow.

The grits are succeeded by the Harnage Shales, which are hollowed out into a valley parallel to the ridge made by the grits. The most abundant fossils of these shales, collected near Broomcroft and in the Harnage and Cound-Brook area, are *Trinucleus concentricus*, Eaton, *Beyrichia complicata*, Salt., *Primitia bicornis*, R.

Jones, *Orthis testudinaria*, Dalm., *Theca*, several species of Lamellibranchs, *Diplograpsus pristis*, His., and *Favosites fibrosus*, Goldf. Overlying the Harnage Shales, and forming a ridge parallel to the ridge of the Hoar-Edge Grits, is the Chatwall Sandstone with *Orthis alternata*, Sow.

The May-Hill Sandstone laps round the whole of the older formations from the Shineton Shales to the Chatwall Sandstones, and is clearly unconformable to all, the dip being in every case I have observed lower than the dip of the beds on which it rests.

It will be seen from the above facts that the Hoar-Edge Grits, the Harnage Shales, and the Chatwall Sandstone, all thin out very near together in the area between Stonehouse and Broomcroft, the three subformations succeeding each other in regular order without disturbance beyond their elevation at an angle.

Lower Caradoc Rocks in the Cound-Harnage district.—North of the Shadewell-Coppice ridge, the Hoar-Edge Grits and the Harnage Shales assume characters which are stratigraphically discordant with their relations in the area just described. This discordance is apparently caused by the well-known fault which runs from the Wrekin many miles to the south-west, and in the Harnage district brings the Carboniferous, Permian, and Triassic rocks down against the Caradoc. These lower Caradoc strata cover an area of nearly three miles, from the river Severn on the north-east to Acton-Burnell Park below Shadewell Coppice on the south-west, and $\frac{3}{4}$ mile in their greatest breadth. They are well exposed on Cound Brook where it runs through Evenwood Common, and on the same stream and its easterly branch in the picturesque dells to the south-west of Harnage. The strike of the Harnage Shale is, roughly, north-east, sometimes ranging round to east-north-east. The beds are sometimes nearly vertical; but more frequently they dip at a high angle to the south-east or to the north-west, the north-westerly dips in some cases being as low as 45°. These shales are often very fossiliferous, containing the fauna above described. They are moderately fissile, but less so than the Shineton Shales, of a blue colour, changing to olive near the surface, and often marked with iron-stains, these changes being obviously due to peroxidation of the ferrous oxide.

With the Harnage Shales are associated the Hoar-Edge Grits, which, as in the undisturbed areas, consist of coarse sandstones, sometimes forming conglomerates, and containing a bastard limestone arising from the abundance of fossils. It is not necessary to my present purpose that I should describe these rocks in detail; suffice it to say that, in the dells near Harnage, the Lower Caradoc strata form hills consisting of outliers of low-dipping or horizontal Hoar-Edge Grit resting upon the upturned edges of the Harnage Shales, the older lying unconformably upon the younger. At Acton Pigott, to the south-west, the sandstone constitutes an outlier nearly a mile in length. A portion of this outlier forms a cornice overhanging Cound Brook at Evenwood Common, the lower portion of the banks of the stream consisting of the nearly vertical Harnage Shales. The extraordinary relations of these subformations at first suggested that the sandstone of Acton Pigott might be Carboniferous. But the discovery in it of *Orthis vespertilio* and *Favosites fibrosus* clearly established its Cambro-Silurian age; and further evidence convinced me that it, as well as the sandstones near Harnage, represented the Hoar-Edge Grits.

This branch of my subject I leave for the present, the chief purpose of my paper being the description of the older rocks of the neighbourhood.

The Shineton Shales.

The locality where I first observed these shales is the spot near Shineton marked on the Geological-Survey Map with an arrow dipping to the south-east at 50°. The rocks are there exposed in two good sections on the left bank of the stream. It is from these sections that most of the characteristic fossils have been obtained; and I have therefore named the formation from this locality.

1. *Area.*—These shales cover an area extending from near Evenwood, on the south-west, to within a mile of Wellington, on the north-east, a distance of eight miles. Their greatest breadth, from Shineton to Dryton, is about two miles; but where they range towards Wellington it is contracted almost to a point. The area is roughly triangular in shape, the apex of the triangle pointing to the north-east. Its north-west side is bounded by a fault or faults for probably its entire length, various formations from the Hollybush Sandstone to the Trias abutting against the shales. On the south-east side, the triangle is covered in by intrusive basaltic rocks for one third of its distance from the apex, and the remainder by the May-Hill Sandstone. The base of the triangular area is limited by the Hoar-Edge Grits. It is not improbable that the Shales will also be found under the Hoar-Edge Grits to the south-west*.

2. *Lithological Characters.*—The Shineton Shales are dark blue, weathering to olive and yellow, the colouring iron-oxide sometimes separating as a stain or film. They are micaceous, thin-bedded, soft, and rather fissile. On the Severn, near Cressage, and at Leighton Mill, my friend the Rev. C. Croft, of Newtown, has detected calcareous nodules; and we have collected similar specimens near the base of the series in a stream below the road $\frac{1}{4}$ mile east of Bank's Lane. At the top of the series, where it passes under Caradoc rocks, the shales become more arenaceous and thicker-bedded, and present the characters of a shore-deposit.

3. *Relations to surrounding Formations.*—Commencing at the apex of our triangular area on the south-east side, the shales are overlain for a distance of nearly two miles by basaltic rocks intruded into the Carboniferous series. For the next five miles to the south-west they are succeeded unconformably by the May-Hill Sandstone. At the base of our triangle they dip with apparent conformity under the Hoar-Edge Grits. The north-west side is probably entirely limited by faults, the formations being brought against the shales

* There is little doubt that the valley between the Lawley hill and Hoar Edge is hollowed out of Shineton Shale.

in the following order, commencing on the south-west:—Harnage Shales, Coal-measures, Quartzite, Hollybush Sandstone, and Millstone Grit. Mr. Croft and myself have detected the Shineton Shales within the disturbed area of the Harnage Shales. In a section of about 100 yards, on Cound Brook, just above Cound-Moor Quarry, we have the following perplexing succession:—

(1). Shineton Shales, dip easterly at 55°.
(2). Harnage Shales, dip N.N.W. at 55°.
(3). Conglomerate, dip unknown.
(4). Shineton Shales, dip unknown.

The beds are so dislocated in this area that I can make out no definite relations between the Shineton Shales and the newer rocks; and I have not attempted to map these fragments of the older series.

4. *Dip and Strike.*—The general strike of the shales is about south-west, agreeing with the direction of the great fault and of the so-called igneous elevations of the district; but towards the south-west end of the area it bends round to the west, corresponding with the strike of the overlying Caradoc. The mean dip of the greater part of the shales is about 30° to the south-east; but in the lower part of the series, where they approach the fault, it becomes higher, then vertical, then dips steeply to the north-west, the evidence pointing towards the existence of an anticlinal. To the south-west, where the beds incline to the south below the Caradoc, the dips are below 30°, averaging 15° to 20°. A few examples will illustrate my statements. At Bull-Hill Cottage, near Evenwood, where an upper branch of Cound Brook cuts through the escarpment of the Hoar-Edge Grits, the grits dipping at 25° rest upon the shales inclined at about the same angle. One mile to the east, above Harnage Grange*, Caradoc at 15° is underlain by shale at 12°. One mile to the east of the last locality, where May-Hill Sandstone lies on the Shineton Shale, both dip at an angle of not more than 6°. Two miles to the north-east, at Shineton, the shales dip at 45° and the May Hill at 10°. Most of these dips and strikes were first taken by the Rev. C. Croft, to whom I am indebted for many valuable suggestions and much effectual assistance, and on whose judgment I can entirely rely; but in the great majority of cases I have confirmed his results by my own observations. A few dips in different parts of the area are discordant with the general strikes, but they are probably due to slight local disturbances. I estimate the thickness of the Shineton Shales at not less than 1500 feet.

5. *Stratigraphical Position.*—The Shineton Shales underlie the May-Hill Sandstone unconformably; they are therefore older than that formation by an interval. They underlie the Caradoc, and are, of course, of greater antiquity. There is no formation which they clearly overlie; they may therefore be of any age anterior to the Caradoc. I shall endeavour to show that they are of Tremadoc age.

* This locality must not be confounded with the village of Harnage, one mile and a half to the north.

(*a*). *Evidence from fossils.*—Most of the Shineton forms are new specifically, and several new generically. The species which are of geological value are the following:—

Conocoryphe monile, Salter.

This species closely resembles *C. striata*, Emmr., which is one of the forms characteristic of Barrande's "Primordial zone," and is truly typical of the genus. *Conocoryphe* proper is common in the Lower Cambrian of St. David's and in the Potsdam Sandstone of North America, but is not characteristic in newer formations in Britain. It is one of the most ancient known forms of life.

Olenus Salteri, Callaway, and *O. triarthrus*, n. sp.

This genus has not hitherto, so far as I am aware, been found above or below the horizon of the Lingula-flags. These two species are not typical *Oleni*, but are allied to some of Angelin's subgenera, possessing characters found in *Leptoplastus, Eurycare*, and *Sphærophthalmus*; but they cannot be located with either. Angelin's subgenera are characteristic of his *Regio A*, which, whatever be the exact position to which it is finally assigned, is certainly very low down in the earlier rocks. It is probably representative of our Lingula-flags.

Agnostus dux, n. sp.

A form closely allied to certain Menevian forms of St. David's.

Lingulella Nicholsoni, Call.

Resembling *L. lepis*, Salt., of the Lower and Upper Tremadoc of Portmadoc.

Obolella sabrinæ, Call.

Closely allied to *O. sagittalis*, Salt., of the Menevian of St. David's.

The above fauna has a very ancient facies, and, taken by itself, would suggest an age anterior to the Tremadoc.

Species of *Theca* and *Bellerophon* occur in the shales, and, though not of decisive value, are forms which we should expect to find in Cambrian rocks.

Asaphus (*Asaphellus*) *Homfrayi*, Salt.

An Asaphid with unforked labrum, common in the Upper Tremadoc of Portmadoc, and the only form in the Shineton Shales (except perhaps a hydrozoan or two) which is not new to science.

Asaphus (*Platypeltis*) *Croftii*, Call.

An asaphoid form with entire labrum, but of a different type from *A. Homfrayi*. The typical Asaphids are Cambro-Silurian; but the entire labra connect these two species with the older forms of the family, such as *Niobe*.

The majority of the above species have an older facies than the Tremadoc; but the abundant occurrence of an Upper-Tremadoc form and of another Asaphid points in an opposite direction; and I submit that the facts of the case, so far as the fossils are concerned, will be best satisfied by referring the beds to the age of the Lower Tremadoc.

(*b*). *Evidence from Correlation with rocks in other localities.*

Dictyonema-beds at Pedwardine.—About 25 miles to the south-west of Shineton, there is a small exposure of shales at Pedwardine, near Brampton Bryan. These have been noticed by Sir Roderick Murchison and other authors, and have been commonly placed in either the Lingula or the Tremadoc series. They occur in the same line of strike as the Shineton Shales, and are close to the same great south-west fault on the same (the south-east) side. They dip at a high angle (about 45°) to the west or west south-west, and are overlain by nearly horizontal May-Hill Sandstone, the relation of the two formations being similar to their relation at Shineton. In lithological character, the Pedwardine beds are undistinguishable from the Shineton Shales; and they contain in abundance a common Shineton fossil, *Lingulella Nicholsoni*. It can scarcely be doubted that the two shales are identical; but, before offering further comment, I will call attention to another locality.

Upper Cambrian of Malvern.—The succession of Cambrian rocks near White-leaved Oak, south of Malvern, in descending order, is as follows:—

1. Light-coloured shales with *Dictyonema sociale*, Salt.
2. Black shales with numerous Olenids.
3. Hollybush Sandstone.

The uppermost group, the *Dictyonema*-shales, has been generally considered the equivalent of the shales at Pedwardine, since it is lithologically identical, and contains abundance of the same *Dictyonema.* I have examined certain specimens from these shales which are in the museum at Malvern College, and in Dr. Grindrod's collection; and I had the satisfaction of identifying them as *Platypeltis Croftii* and *Conophrys salopiensis*, two Trilobites characteristic of the Shineton Shales. These shales are also lithologically identical with those of Shineton, and hold the same relation to the overlying May-Hill Sandstone. They hold a similar relation to the Hollybush Sandstone. I have recently discovered between the Shineton Shales and the Wrekin a band of Hollybush Sandstone, which I shall describe further on. This sandstone occurs below the *Dictyonema*-shales at Malvern with the interposition of the black *Olenus*-shales. The juxtaposition of this sandstone to the shales at Shineton and at Malvern is a strong corroboration of the evidence I have adduced for the identity of the two shales.

A comparison of the three formations at Shineton, Pedwardine, and Malvern is very interesting. The Shineton beds are connected with the Pedwardine shales by lithological resemblance, stratigraphical position, and the occurrence of *Lingulella Nicholsoni.* The Pedwardine rocks are correlated with the Malvern *Dictyonema*-shales by lithological resemblance, stratigraphical position, and the link of *Dictyonema sociale.* The Shineton Shales are *directly* connected with the Malvern beds by lithological resemblance, stratigraphical position, and the occurrence of two species of Trilobites in common—and *indirectly* through their correlation with the Pedwardine shales. I think I may fairly conclude that the *Dictyonema* beds at Pedwardine and Malvern are representatives of the Shineton Shales.

The occurrence of *Dictyonema sociale* in the Shineton Shales at Pedwardine and Malvern furnishes another link in the chain of palæontological evidence. This species is common at the base of the Lower Tremadoc of North Wales, and helps to connect that formation with the Shineton Shales. Taken by itself, the occurrence of a single species may not be decisive; but when other lines of evidence converge to the same point, this fact is of value.

I have stated that all the species of the Shineton Shales are new but two, *Asaphellus Homfrayi* and *Dictyonema sociale*, and perhaps a hydrozoan. It is strange that the fauna should be thus so nearly unique, if beds of the same age and of similar lithological characters (slates being simply altered shales) had been deposited in the same sea; and that there was a water connexion between the Shineton and Tremadoc areas is evident from the occurrence of two species in common. I would therefore suggest the probability of the Shineton Shales forming beds of passage between the Lingula-flags and the Lower Tremadoc—a probability which is strengthened by the fact that *Dictyonema sociale* occurs in passage-beds in the Tremadoc area.

6. *Distribution of the Fauna.*—The bulk of the fossils have been found high up in the series at Shineton; but *Lingulella Nicholsoni* and *Obolella sabrinæ* occur almost wherever the shales are fossiliferous, ranging down to the base of the series near Dryton, where the rocks begin to assume a north-westerly dip. Graptolites are common north of the Severn, their chief habitat being Mary Dingle, near Garmston, but have not yet been found south of that river on any horizon. Trilobites have rarely been found away from the Shineton section, the exceptions being a single specimen of *Platypeltis Croftii* in Mary Dingle, an undeterminable Trinucleoid form from the same locality, *Conophrys salopiensis* in the arenaceous beds near the top of the series west of Harley, and both *P. Croftii* and *C. salopiensis* from Malvern. *Macrocystella* (a new Cystid) has been detected only at Shineton and on Cound Brook.

7. *Relation to the black Olenus-shales at Malvern.*—In the Shineton area the shales are lithologically homogeneous from top to bottom (except that they grow more arenaceous towards the top), and never put on the aspect of the black shales. The fossils also show no signs of transition into another formation, *Lingulella Nicholsoni* and *Obolella sabrinæ* characterizing the series throughout its entire vertical extent; and none of the forms are found in the black shales, the three Shineton species, *Dictyonema sociale, Conophrys salopiensis*, and *Platypeltis Croftii* being found at Malvern only in the light-coloured upper shales. I am therefore disposed to conclude that the Shineton Shales represent only the *Dictyonema*-shales of Malvern, though they have a much greater thickness. There are signs of great unconformity between the Shineton Shales and the Hollybush Sandstone of the Wrekin. In Wenlock Wood, near the Wrekin, the shales dip away in the same direction as the sandstone; but to the south-west, near Bank's Lane, they dip towards the sandstone to the north-west; and to the north-east, under Madox's Hill and near Willow Moor, the sandstone dips away from the shale. It therefore appears probable that the shales are faulted against the sandstone; and if the black shales ever existed in the area, they must

either be thrown down out of sight, or the anticlinal to which I have alluded has not brought them to the surface.

The Hollybush Sandstone.

Forming a continuous band between the Shineton Shales and the quartzite which rests upon the Wrekin, is a series of thin-bedded, micaceous, green sandstones, holding the same geographical relation to the Shineton Shales as the Hollybush Sandstone of Malvern holds to the black *Olenus*-shales. The identification of this rock with the Hollybush Sandstone is placed beyond doubt by the further evidence of *Kutorgina cingulata*, Bill., which occurs in abundance and in good preservation at Neves Castle, at the south-west end of the Wrekin, and has also been detected by me near Lawrence Hill, one of the lower elevations of the Wrekin range, where the sandstone has been excavated for the purpose of erecting an ancient tumulus. At this locality I also found the impression of the thorax of a Trilobite, but too imperfect for even generic identification. The sandstone covers an area three and a half miles in length by half a mile in its greatest breadth, its length running parallel to the axis of the Wrekin. The dips are very various. At the north-east end of the area several exposures give a dip averaging 50° to the west-south-west. Near the road ascending from the Wrekin to the Hatch Kiln the dip is 75° to the north-west. One third of a mile to the south-west of this locality, the sandstones dip south-30°-east at an angle of 55°, apparently resting conformably upon the quartzite which immediately underlies them. In a quarry 250 yards from this, the dip is west-30°-south, at 35°. At the south-west end of the sandstone area, near Neves Castle, are two exposures, one on the north of the road dipping south-south-east at 50°, and one to the south of the road with a dip of 50° to the south-5°-west. This last locality is the quarry in which *Kutorgina cingulata* plentifully occurs. The same dip as the last is seen in a quarry to the south of the road from Neves Castle to Long Wood. The sandstone and the shales are found in almost immediate contact in Back Dingle, to the south-west of Neves Castle; and, south of the road from Neves Castle to Bank's Lane, a stream-section shows the Shineton Shales plunging at an angle of 65° towards the sandstone. I have already (p. 661) given reasons for concluding that the Shineton and the Hollybush are separated by a fault. The irregularity of the dips which I have just described shows also a want of conformity between the sandstone and the quartzites, which dip regularly away from the Wrekin to the south-east. I am obliged to infer that the Hollybush Sandstone in this locality is bounded by faults on both sides.

This sandstone is also found at Lilleshall, five miles to the north-east of the Wrekin, where it constitutes an inlier a mile long by ¼ mile wide. It is micaceous, thinly laminated, and of a blackish green colour. It is well exposed in the road through the village, dipping evenly to east-30°-south at 30°. On the south-east it is bounded by the Carboniferous Limestone and the Millstone Grit, on the north-west by a fault which divides it from rocks similar to those of the Wrekin. The quartzite, which in the Wrekin district intervenes between the sandstone and the central rocks of the axis, is here absent. I have not detected fossils in this area.

Physical Features of the Shineton Area.

The Shineton Shales, as may be imagined from their uniform softness, present few striking inequalities in the landscape; but to the north of the Severn, where small streams have cut deeply into them, the narrow and picturesque ravines called respectively Back Dingle and Mary Dingle are formed. To the south-west of the Wrekin, the Hollybush Sandstone constitutes high ground sloping down towards the shales; but to the north-east of the area, where the Wrekin chain rises into a lower elevation called the Ercal, the sandstone forms a distinct wooded ridge parallel to the axial elevation of the district, and during the north-easterly part of its course is accompanied by a second parallel ridge, caused, I believe, by a repetition by a fault. In the disturbed region on Cound Brook, the outliers of Caradoc sandstone give great variety to the scenery, forming the cappings of low but steep hills separated by narrow gorges excavated in the soft Harnage Shales. The Hoar-Edge Grits also constitute the low ridge on which Acton Pigott is situated. The same sandstone, with the upper arenaceous beds of the Shineton Shales underlying, forms the ridge which limits the area of the Shineton Shales to the south-west, and rises to a bold elevation at Shadewell Coppice, overhanging Acton-Burnell Park. In this same locality the Chatwall Sandstone, partly covered in by the May-Hill Sandstone, makes a ridge running roughly parallel to the Hoar-Edge Grits, the intermediate Harnage Shales being hollowed out into a deep valley.

DESCRIPTION OF THE FAUNA.

Asaphus, *Brongn.*

Asaphellus, nov. subgen.

Asaphus (Asaphellus) Homfrayi, Salter. (Plate XXIV. fig. 1.)

Our Shineton form is undistinguishable from Salter's species. I reproduce part of his description (Mon. Sil. Tril. p. 165, pl. xxiv. figs. 6–12):—

"The head is more than a third of the whole length, and longer than the thorax, which in its turn is longer than the caudal shield. The head is semioval, rather pointed in front, and has very short posterior spines; it is broadly depressed round the margin. The glabellar portion is scarcely marked out; the eyes are placed nearly halfway up the head; they are small (two lines long), the facial sutures curving out boldly beneath them, and cutting the posterior margin more than halfway out from the axis. Above the eye they form a narrow ogive, and nearly follow the front margin. On the underside of the head the vertical furrow on the epistome shows distinctly through the cast. The labrum is imperfect, but exhibits a strong marginal groove and two small lateral furrows.

"The body-rings have the axis as broad as the sides, and moderately convex. The pleuræ are flat as far as the fulcrum, truncate at their ends, and have but a slight groove, which reaches only two thirds of the length. The fulcrum is at one third in front, and less than halfway out in the middle rings.

"The caudal axis extends three fourths down the smooth tail, very indistinctly marked above, but in some specimens crossed by several faint rings, and is always prominent at the tip.

"This has the characteristic facial suture of *Isotelus*; but if its labrum be like that of *A. affinis* (*i. e.* entire), a point which is not yet known, it may belong to quite a distinct subgenus."

To this account, which very well suits our Shineton forms, I have to add a description of the labrum.

Labrum as broad as long, rounded on all sides, slightly indented in front; centre rather convex, with a strong furrow on each side converging to nearly the front indentation; just below the centre a tubercle on each side, margined by a short deep furrow behind.

The labrum (Pl. XXIV. fig. 1), as Salter inferred from the imperfect material at his command, is not forked, a character which clearly distinguishes this species from typical *Asaphi*; and I propose for it the subgeneric name of *Asaphellus*. Fragments indicate a size of three inches by two. This makes the breadth greater than in Salter's description, "three inches long and one and a half broad;" but the specimens from Portmadoc are so greatly cleaved as to render the measurement of proportions exceedingly difficult.

From the Shineton Shales at Shineton. Very common.

PLATYPELTIS, subgen. nov., *Callaway*.

Platypeltis, Callaway, Quart. Journ. Geol. Soc. vol. xxx. p. 196, 1874.

Oval, moderately convex; axial furrows tapering gradually backwards from where they meet the facial suture in front of the eye to two thirds the length of the tail; head and thorax about equal in length, tail shorter.

Head with short cheek-spines, length two thirds the width; eyes placed near the margin, one third the length of the head, facets small as in typical *Asaphi*; facial suture forming three curves of about equal length, cutting the front margin in front of the eye, and the hinder margin at more than halfway from the axis; glabella one third of the width of the head behind, lobeless, axial furrows well marked; labrum (Pl. XXIV. fig. 2 *a*) entire, broadly rounded in front, closely resembling the labrum of *Asaphellus*, but seemingly destitute of the two furrows which converge from the side tubercles towards the front.

Thorax with well-marked axis equal in breadth to the pleuræ; pleuræ rounded at the ends, faceted, grooved to less than half their length in front, to two thirds behind, with fulcrum at about one third from the axis.

Tail smooth; axis extending to two thirds the length, faintly marked with transverse furrows; caudal fascia broad, well striated.

This subgenus is distinguished by its large eyes and unforked labrum. The central shield of the head is often found alone; and its peculiar shape is very distinctive. It is worth noting that both the Asaphids of these ancient rocks have the labrum entire.

Asaphus (Platypeltis) Croftii, *Call.* (Plate XXIV. fig. 2.)

Asaphus (*Platypeltis*) *Croftii*, Call. Quart. Journ. Geol. Soc. vol. xxx. p. 196, 1874.

The characters of the genus will suffice for the one species.

From the Shineton Shales at Shineton, where it is common; Mary Dingle, near Garmston; Dictyonema-shales at Malvern (Dr. Grindrod's collection).

Agnostus, *Brongn.*

Agnostus dux, n. sp. (Plate XXIV. fig. 3.)

Head: length and breadth equal, with a narrow margin; glabella half the length of the head, sometimes longer, as broad as the side cheeks behind, narrowing towards the front, with a transverse sulcus one third from the front.

Thorax: axis wide, each of its rings trilobed, the central lobe much wider than the others; pleuræ not much longer than the side lobes of the axis.

Tail same size as the head, with small side angles; axis one half to two thirds the length of the tail, with a large tubercle at each side in front, and a transverse sulcus about halfway down, the triangular space thus enclosed rising into a tubercle.

This species resembles *A. Maccoyi*, Salt., but differs from it in the glabella, which in *A. Maccoyi* has its front division lunate, whereas *A. dux* has the glabella divided transversely by a straight line, in this respect resembling *A. scutalis*, Salt., and some other Menevian forms. The largest specimen I have seen is a little over half an inch.

From the Shineton Shales at Shineton. Not very rare.

Conocoryphe, *Corda.*

Conocoryphe monile, *Salt.* (Plate XXIV. figs. 4, 4 *a*, 4 *b*.)

Conocoryphe monile, Salt. Cat. Cambr. & Sil. Foss. Univ. Cambr. 1873, p. 32. "Glabella lobed and front marginal furrow dotted."

I add a fuller description of this interesting little species:—

Oval, convex, surface finely granuliferous, length about $\frac{1}{2}$ inch.

Head semicircular; front marginal furrow dotted; cheek-spines long; glabella strongly lobed, almost as in *Calymene*, three fifths the length of the head; facial suture cutting the front margin a little inside the eye and the hinder margin a little inside the head-spines: eye large, placed near the side margin, ocular ridges well marked.

Thorax of 13 rings; axis about $\frac{1}{4}$ the width of the body, each ring rising into a nodule at the sides; pleuræ, fulcrum nearly half-way out, grooved almost to the ends, which are rounded.

Tail small, entire, axis reaching nearly to the margin.

This species closely resembles *C. striata*, Emmr., of Barrande's "Primordial Zone."

From the Shineton Shales at Shineton. Common.

OLENUS, *Dalm.*

OLENUS SALTERI, *Call.* (Plate XXIV. fig. 5.)

(*Conocoryphe*) Quart. Journ. Geol. Soc. vol. xxx. p. 196.

Head wider than body, transversely oval, with short curved spines at two thirds from the front, margined by a narrow furrow; glabella ovate, wider than fixed cheeks, nearly reaching the front margin, with two pairs of lateral furrows; facial suture as far out behind as the ends of the pleuræ, but in front cutting the margin a little outside of the anterior prolongation of the sides of the glabella; eyes forward, submedian, roundish oval, prominent, distinctly showing the facets; occipital ring with a spine or tubercle.

Thorax of 11 (or more) rings, each ring with a tubercle; axis as wide as pleuræ; pleuræ strongly grooved and bent sharply backward into points.

Pygidium small, axis of two or three rings, nearly reaching the margin, which is rounded.

I originally described this as a *Conocoryphe*, from imperfect material.

From the Shineton Shales at Shineton. Common.

OLENUS TRIARTHRUS, n. sp. (Plate XXIV. fig. 6.)

Head wider than body, transversely oval, with curved spines at two thirds from the front reaching back as far as the tail, margined by a deep dotted furrow; glabella much wider than the fixed cheek, subquadrate, shorter than in *O. Salteri*, with two pairs of lateral furrows, the hinder pair nearly meeting; facial suture nearly as far out as the ends of the pleuræ behind, in front cutting the margin some distance outside the forward prolongation of the sides of the glabella; eyes forward, near the glabella; occipital ring with a tubercle.

Thorax of 15 (or more) rings; axis not so wide as the pleuræ, each ring with a tubercle; pleuræ grooved to the ends, bent back to a point.

Pygidium short, rounded; axis of 2 or 3 rings, reaching nearly to the margin.

This species is easily separated from *O. Salteri* by its squarish glabella, its long cheek-spines, its narrow axis, and its more numerous segments. In its long spines it resembles *Eurycare*, Ang.; but the eyes are not lateral as in that genus. In some points it suggests *Triarthrus*, and is, perhaps, the form which Salter doubtfully assigned to that genus.

From the Shineton Shales at Shineton. Common. I am indebted to my friend, Mr. C. Bird, B.A., of Bradford, for the loan of specimens of this and other species.

These two species are distinguished from *Olenus* proper by their wide, rounded side cheeks, with spines proceeding from the middle, and they are more nearly allied to some of Angelin's subgenera. *O. Salteri* resembles *Leptoplastus*, Ang., in its short head-spines, and *Sphærophthalmus* in its convex, nearly circular eye; while *O. triarthrus* has the long cheek-spines of *Eurycare*, Ang. I am not, however, prepared to suggest a new generic name for Trilobites which are essentially *Oleni*.

CONOPHRYS, *Call.*

Conophrys, Call. Quart. Journ. Geol. Soc. vol. xxx. p. 196.

Very small, not more than $\frac{1}{4}$ inch long, oval, convex.

Head subquadrate, front rounded; glabella three fourths the length of the head, behind as wide as the side cheeks, its sides parallel for two thirds of its length, with two very small lobes on each side deeply separated from the cheeks, abruptly expanding in front into two side nodules, its anterior margin hardly distinguished from the front portion of the head; neck and side cheeks with deep marginal furrow behind; no trace of eyes or facial suture.

Thorax a little longer than the head, of six rings; axis a little wider than the pleuræ in front, rather less than the pleuræ behind, rings nodular at the sides; pleuræ bent down sharply at half their length, for three fourths of their anterior breadth raised above the hinder margin, and separated from it by a narrow sulcus.

Tail about half the length of the thorax, semicircular behind and slightly indented, with a narrow raised margin; axis nearly reaching the margin, of four rings; sides consisting of three rings raised in front; margin, axial rings, and side rings all covered with small tubercles.

This curious little genus is easily distinguished by its peculiar glabella. Its small size at first suggested that it was embryonic; but upwards of 20 specimens in my collection, with others that I have seen, show no signs of transition into any thing different, the characters being remarkably permanent. I am unable with certainty to refer it to any known family.

CONOPHRYS SALOPIENSIS, *Call.* (Plate XXIV. fig. 7.)

Same reference as genus.

From the Shineton Shales at Shineton, arenaceous beds west of Harley, Dictyonema-shales at Malvern (Dr. Grindrod's Museum).

LICHAPYGE, *Call.*

Lichapyge, Call. Quart. Journ. Geol. Soc. vol. xxx. p. 196.

Pygidium minute, semicircular in front, a little longer than broad; axis of three or more rings, convex, sharply defined, rather rapidly tapering behind, at half the length of the tail contracting to a tip, and continuing as a narrow rib to the extremity; side ribs not sharply separated; front side ribs curved backwards and ending in free points which are parallel to the axis, grooved down the centre almost to the ends; second ribs similar, but bent more abruptly backwards; third ribs united on the rib-like prolongation of the axis into a broad ensiform limb, the anterior half of which is embraced by the other ribs, and is marked by similar grooves parallel to its sides, while the hinder half projects in a broad point, the sides of which form an angle of about 60°.

Length $\frac{1}{8}$ inch.

This tail bears some resemblance to *Paradoxides*, but is more like *Lichas*, yet can hardly be classed with either. The specimen is unique; but I have thought it of sufficient interest for description.

Lichapyge cuspidata, *Call.* (Plate XXIV. fig. 8.)

Same reference.

From the Shineton Shales at Shineton.

Primitia, *R. Jones & Holl.*

I have collected more than one species of this genus at Shineton; but Prof. Rupert Jones, who has been kind enough to examine them for me, is unable to identify them with any known species, and the material at my command is not sufficient for satisfactory description. Messrs. Rupert Jones and Holl figure two *Primitiæ* from Shineton in Ann. Nat. Hist. ser. 4, vol. iii. p. 221, stating that their specimens, which they observed in the Woodwardian Museum, did "not exhibit sufficiently definite characteristics for exact determination."

Theca, *Sow.*

Theca lineata, *Call.* (Plate XXIV. fig. 9.)

Same reference.

Biconvex, length four times the breadth, aperture straight, longitudinally striated, about 25 striæ in its greatest width.

Length about $\frac{3}{8}$ inch.

Shineton Shales at Shineton. Not rare.

Bellerophon, *Montfort.*

Bellerophon shinetonensis, n. sp. (Plate XXIV. fig. 10.)

Rapidly expanding, aperture large, striated transversely, about 5 striæ to the line.

Greatest diameter 7 lines.

Shineton Shales at Shineton. Rare.

Lingulella, *Salter.*

Lingulella Nicholsoni, *Call.* (Plate XXIV. figs. 11, 11 *a*, 11 *b*.)

Same reference.

Ovate, depressed, widest about the middle, two thirds as broad as long, front and sides rounded, beak moderately acuminate, area of ventral valve striated, the striæ parallel to the external slope of the valve, pedicel-groove divided by a narrow ridge down the middle, visceral surface pitted, exterior surface marked by fine concentric lines of growth.

Length 5 lines, width $3\frac{1}{2}$.

This is a larger shell than *L. ferruginea*, Salt.; and its sides are not so parallel. It closely resembles *L. lepis*; but *L. lepis* is wider towards the front, according to Mr. Davidson's figures.

The Shineton Shales at Shineton, Mary Dingle, Dryton, Cressage, Bull-Hill Cottage, west of Harley, under Cound-Moor quarry, and Pedwardine. Common.

Obolella, *Billings*.

Obolella sabrinæ, *Call.* (Plate XXIV. fig. 12.)

Same reference.

Small, not exceeding two lines in length, transversely oval, striated concentrically, posterior margin straight; dorsal valve nearly flat, with a narrow area; ventral valve high, conical, pointed, the beak overhanging the hinder margin, with a distinct false area.

In the interior, the dorsal valve is furnished with a pair of large oval muscular scars near the posterior margin, a pair of smaller near the middle, and a large elevated mesial ridge extending nearly three fourths the length of the valve.

This species bears a close resemblance to *O. sagittalis*, Salt., of the Menevian rocks, but is broader, and has the ventral valve more conical, the median ridge is larger and longer, and the valves are furnished with areas.

I originally described this form, from incomplete materials, under the name of *Metoptoma sabrinæ*, the conical ventral valve closely resembling a patelloid Gasteropod.

The Shineton Shales at Shineton, Mary Dingle, Dryton, Cressage, one mile west of Cressage, west of Harley, under Cound-Moor quarry. Common.

Macrocystella, n. gen.

Calyx subcylindrical, nearly twice as long as its greatest breadth, widest in the middle; composed of about four rows of hexagonal plates, two plates occupying the width, those at the ends smaller than the central ones, each compartment of the hexagon being separated from the others by a strong ridge, and containing smaller radiating ridges.

The calyx is surmounted by a ring of small jointed pinnulæ about one fourth the length of the calyx.

Stem very long, nearly as wide as the base of the calyx at the top, tapering rapidly at first, continued in a long, slender, slightly tapering column which consists of longer rings than the wider end.

The shales have not preserved this peculiar form in sufficient perfection for satisfactory determination. It is very crinoid-like in its long, slender stem, and its circle of arms, which, however, appear to be only simple pinnulæ.

MACROCYSTELLA MARIÆ, n. sp. (Plate XXIV. fig. 13.)

Some of the best specimens were collected by Mr. Bird.

The Shineton Shales at Shineton, and under Cound-Moor quarry. Not rare.

DENDROGRAPTUS, *Hall.*

DENDROGRAPTUS, sp.

I am not prepared to assign the Shineton specimens to any known species, or to give them a new name; and several graptolithologists to whom I have submitted them differ from each other in their determinations. All are found in Mary Dingle, associated with *Obolella*, *Lingulella*, and *Platypeltis*, on a lower horizon than the bulk of the Shineton fauna.

DICTYONEMA, *Hall.*

DICTYONEMA SOCIALE, *Salter.*

Good specimens of this common North-Wales species are found in abundance in the Shineton Shales at Pedwardine and south of Malvern.

KUTORGINA, *Billings.*

KUTORGINA CINGULATA, *Bill.*

Kutorgina cingulata, Bill. Geol. Surv. Canada, Pal. Foss. vol. i. pp. 8–10.

This form is found in the Potsdam Sandstone of North America, the probable equivalent of our Lingula-flags, or of a still lower group. The *Obolella Phillipsii*, Hall, of the Hollybush Sandstone of Malvern, is identified by Mr. Davidson with Billings's species. I have collected it in abundance in the Hollybush Sandstone at Neves Castle, at the south-west end of the Wrekin, and have also detected it near Lawrence Hill. The specimens collected will throw some light upon the characters of this comparatively unknown genus; but I defer further discussion until I have obtained more satisfactory material.

SUMMARY OF THE FAUNA.

CRUSTACEA.

Asaphus (Asaphellus) Homfrayi, *Salt.* Shineton Shales.
Asaphus (Platypeltis) Croftii, *Call.*, gen. et sp. Shineton Shales.
Agnostus dux, n. sp. Shineton Shales.
Conocoryphe monile, *Salt.* Shineton Shales.
Olenus Salteri, *Call.* Shineton Shales.
—— triarthrus, n. sp. Shineton Shales.
Conophrys salopiensis, *Call.*, gen. et sp. Shineton Shales.
Lichapyge cuspidata, *Call.*, gen. et sp. Shineton Shales.
Primitia, sp. (more than one). Shineton Shales.

PTEROPODA.

Theca lineata, *Call.* Shineton Shales.

HETEROPODA.

Bellerophon shinetonensis, n. sp. Shineton Shales.

BRACHIOPODA.

Lingulella Nicholsoni, *Call.* Shineton Shales.
Obolella sabrinæ, *Call.* Shineton Shales.
Kutorgina cingulata, *Bill.* Hollybush Sandstone.

ECHINODERMATA.

Macrocystella Mariæ, n. gen. et sp. Shineton Shales.

HYDROZOA.

Dictyonema sociale, *Salt.* Shineton Shales.
Dendrograptus. Shineton Shales.

EXPLANATION OF PLATE XXIV.

Fig. 1. Labrum of *Asaphus* (*Asaphellus*) *Homfrayi*, Salter, App. Ramsay, Geol. N. Wales, Mem. Geol. Surv. vol. iii. p. 311, pl. viii. figs. 11–14, 1866: enlarged.

2. *Asaphus* (*Platypeltis*) *Croftii*, Call.: enlarged. A young specimen, showing seven thoracic segments only. Some specimens have as few as two segments. 2 *a*. Labrum of ditto, enlarged.

3. *Agnostus dux*, n. sp.: enlarged.

4. *Conocoryphe monile*, Salter, Cat. Cambr. Foss. p. 32: enlarged. 4 *a* and 4 *b*. Young forms of ditto, enlarged.

5. *Olenus Salteri*, Call.: enlarged.

6. *O. triarthrus*, n. sp.: enlarged. Drawn from a crushed specimen. The head-spines should be more forward, as in *O. Salteri*.

7. *Conophrys salopiensis*, Call.: enlarged. There should be only six thoracic segments.

8. *Lichapyge cuspidata*, Call. Pygidium only: enlarged.

9. *Theca lineata*, Call.: enlarged. There should be no transverse striæ.

10. *Bellcrophon shinetonensis*, n. sp.: enlarged.

11. *Lingulella Nicholsoni*, Call. 11 *a*. Interior of ventral valve. 11 *b*. Enlargement of part of 11 *a*, showing the striated area and mesial ridge of the pedicel-groove.

12. *Obolella sabrinæ*, Call. Interior of dorsal valve: enlarged.

13. *Macrocystella Mariæ*, n. gen. and sp.

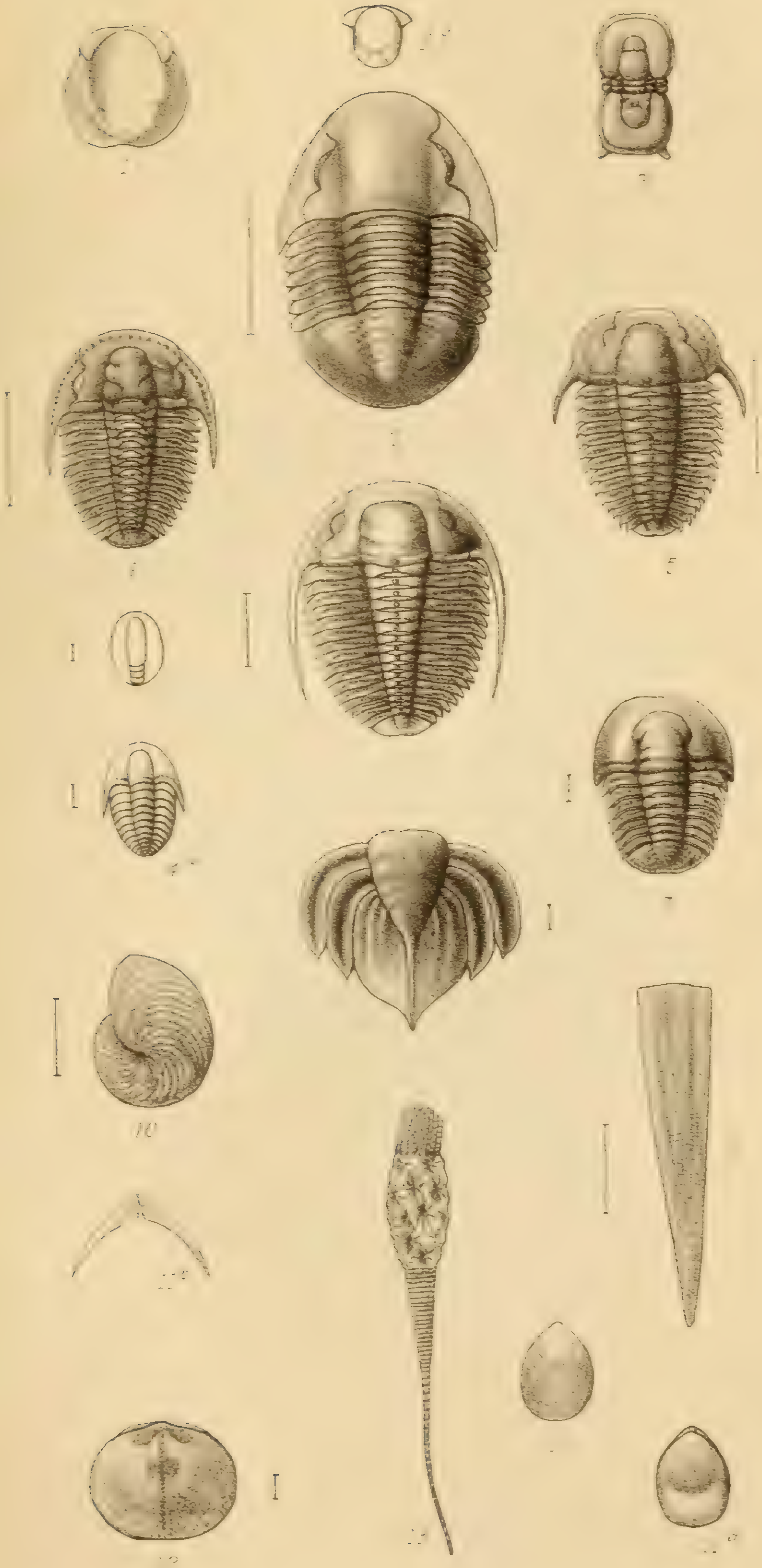
DISCUSSION.

Mr. ETHERIDGE thought the paper a very clear exposition of perfectly new ground. The correlation of the Shineton Shales with the *Dictyonema*-shales of the Malvern hills was important. These labours of Mr. Callaway in a new locality were valuable on account of his palæontological knowledge. The fossils exhibited by him seemed to be distinct species.

Mr. HICKS stated that two years ago he went over part of the Shineton area; and he congratulated Mr. Callaway on the completion of his work over difficult ground. The fossils generally may be regarded as belonging to a Tremadoc fauna; but some seem to belong a little higher in the series, perhaps to the Arenig.

Prof. HUGHES was glad to see the direction in which the author's inquiries were leading him, as they seemed to point to the fact that when there were no marked changes in lithological character in the Cambrian rocks there was a recurrence or mixture of the forms of life which elsewhere characterized better-defined horizons. He asked the author whether the lower portion of his upper group of grits and shales, with *Orthis testudinaria* &c., might not represent not only Caradoc, but part of the Llandeilo, and whether in the upper part of the lower group the Arenig beds also might not find an equivalent, as he thought it improbable that in that area the Caradoc would be found overlapping Llandeilo and Arenig and resting on Tremadoc.

The AUTHOR, in reply to Prof. Hughes, said that the shales were one homogeneous formation, marked throughout by the same fossils, the younger types occurring in the same beds with the older forms, and mixed indiscriminately with them. In the lower part of the upper series, also, there were no signs of transition into an older fauna, the species being common Caradoc forms. In reply to Mr. Hicks, he pointed out that the *Oleni* which, as Mr. Hicks stated, occurred in the Arenig, were of quite a different type from the Shineton *Oleni*, which were antique forms, similar to those in the Dolgelly beds.



C.L.Griesbach lith.

SHINETON FOSSILS

35. GLACIAL DRIFT *in the* NORTH-EASTERN CARPATHIANS. By R. L. JACK, Esq., F.G.S., and JOHN HORNE, Esq., F.G.S., of the Geological Survey of Scotland. (Read June 20, 1877.)

A. *General Introduction.*

WHILE most of the European ranges have been subjected to detailed investigations with the view of determining the existence and sequence of glacial deposits, the Carpathian chain has hitherto escaped any minute examination. Enough has already been accomplished through the labours of continental observers to justify an attempt to correlate the deposits occurring in other countries with their representatives in Britain. From the data already obtained it is obvious that, even in widely separated areas, the physical changes which transpired during the Glacial epoch must have borne a strong resemblance to each other. In the north of Europe there is the clearest evidence for the former extension of the ice; and even south of the limits of the northern drift the observations already made point to the same conclusion. They prove that, in regions where snow-fields no longer exist, glaciers must have filled the valleys, leaving behind them moraines and erratic blocks as memorials of their presence; while in those countries where glaciers still hold sway the hills and valleys must have been covered with ice, which ground and polished the slopes and accumulated underneath a mantle of stony clay. But on adverting to the evidence regarding the former prevalence of arctic and boreal conditions, it would appear that there is a general uniformity in the succession of deposits belonging to different countries. Not only in Britain, but in Scandinavia and Switzerland, we find deposits of sand, gravel, and lignite containing Mammalian remains and traces of Man, intercalated in the *moraine profonde* of the old ice-sheets. The inference seems to be that these beds indicate mild periods in the long duration of cold, when the ice retired or altogether disappeared. The physical cause of such alternations of climate may long remain a matter of dispute among geologists; but that the Glacial epoch was not characterized by an unbroken succession of cold conditions must now be considered beyond doubt.

It is not, therefore, unreasonable to hope that when the great chain of the Carpathians has been examined in detail, it will furnish evidence in support of the conclusions already arrived at regarding the oscillations of temperature in the Glacial period. It must be remembered that the altitude of the chain differs widely from that of the Alps; for even the greatest elevations do not exceed 8000 or 9000 feet. But when we consider the enormous dimensions of the old Alpine glaciers during the reign of extreme cold—that the glacier of the Rhone abutted against the range of the Jura, and stranded its boulders as far up the slopes as 3000 feet, and that towards the south-east it debouched on the plains of France, while towards the north it probably swelled the glacier of the Rhine; when we take into account that in the eastern Alps, glacial deposits have been met with in the valleys of the Traun and the Inn not far from their junction with the Danube, surely the inference is natural that the valleys of the Carpathians must likewise have possessed considerable glaciers, when a portion of the chain lies in the same latitude *. The Carpathians may be said to form a great crescent-shaped range, the north-western extremity of which terminates at Presburg, near Vienna. From this point it sweeps eastwards, forming the northern rampart of Hungary; and after circling round the sources of the Theiss, it bounds Transylvania on the east and the south, joining the Danube again at Orsova. The whole range lies mostly between the 45th and 49th parallels of latitude.

B. *Previous References to the Occurrence of Glacial Drift in the Northern Portion of the Range.*

As yet the officers of the Austrian Geological Survey under Von Hauer have only noted the existence of glacial deposits in the northern portion of the range, to which the following brief allusions are made in the explanations accompanying the geological maps:—(*a*) 'Geologische Uebersichtskarte der österreichisch-ungarischen Monarchie,' Blatt iii. p. 532, 1869. "Glacier drift in the form of large moraines along with boulders are specially noticeable on the north and south sides of the High Tatra." (*b*) 'Geologische Uebersichtskarte der österr.-ungar. Monarchie,' Blatt iv. p. 394, 1872. "After the same manner as in the eastern part of sheet 3, the diluvial and alluvial deposits are developed. In the northern part, as far south as the edge of the high plateau, the sand and shingle (*Schotter*) of the erratic diluvium are abundant; while to the south of the plateau, as far as the edge of the Carpathians, loess is abundant."

In Von Hauer's recent work, 'Die Geologie und ihre Anwendung auf die Kenntniss der Bodenbeschaffenheit der österr.-ungar. Monarchie,' p. 122, the following reference is made to the drift:—"In the Carpathians, which no longer possess glaciers, we find traces of their former presence in the shape of immense moraines on the southern slopes of the Tatra."

Another and more detailed reference to this subject is to be found in a paper by J. Niedzwiedzki, 'Beiträge zur Geologie der Karpathen' (Jahrbuch der k.-k. geologischen Reichsanstalt, 1876, vol. xxvi. p. 331). This author says:—"At higher levels than the modern alluvium of the river Sau occurs a deposit of chalky loam 15 metres thick, from which the author has obtained the remains of *Elephas primigenius*, and which he therefore considers diluvial loess. In places

* *Vide* the last edition of the 'Great Ice Age,' p. 419 *et seq.*, where an admirable summary is given of the evidence bearing on the former extension of the Swiss glaciers.

where the streams have cut through the loess, there occur in its lowest parts small rounded fragments of Carpathian Sandstone, and, mixed up with these, isolated larger and smaller erratic blocks of red granite and orthoclase porphyry—more rarely of gneiss and diorite. The whole of the diluvial deposits rest immediately on the Carpathian Sandstone. But there occurs at Przemysl yet another very peculiar accumulation of blocks, which is very different from the deposits described above as 'erratic.' The hills on the south side of the Sau valley, whose mean height is about 370 metres, are partly covered, over the lower portion of their northern slope, with a chalky loam, in which numerous rounded blocks of a light compact Jura Limestone lie bedded. Similar blocks occur in great numbers on the plains round the village of Kruhel-Wielki, where they have been quarried in pits 2–3 metres deep."

C. *Brief Description of the Rock-formation round the Head-waters of the Theiss.*

It was with the view of searching after traces of glacial action, and of comparing with their Scotch representatives any deposits which might cross our path, that we traversed in the autumn of 1874 one or two of the more important valleys in the eastern part of the chain. We selected the valleys of the Theiss and the Pruth as being among the largest lines of drainage in the north-eastern region. The former river receives many important tributaries before it issues from the range and enters the great plains of Hungary. We therefore inferred that, if a glacier once filled the Theiss valley, it must have been swelled by many accessions along its course, and, consequently, that the moraines or other glacial deposits would naturally accumulate in considerable force near the edge of the plateau. Our hopes were in some measure realized, though not to the extent we had anticipated.

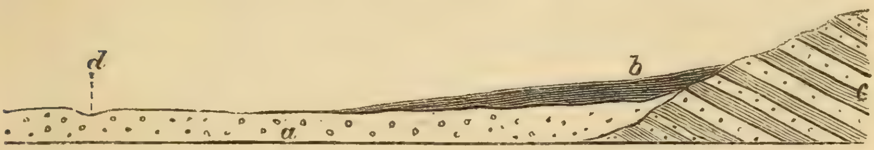
Before stating the results obtained by us, it may be advisable to sketch in a single sentence the various rock-formations which make up the structure of that portion of the Carpathians surrounding the head-waters of the Theiss. While passing through Vienna, we provided ourselves with the maps published by the Imperial Geological Institute, on the scale of about 9 English miles to an inch, which were of the greatest service to us along our route. From these it may be seen that along the western slopes of the chain between the crest and the right bank of the Vissö, one of the tributaries of the Theiss, there stretches a mass of highly crystalline strata. These mica-schists &c. (Glimmer-Schiefer, Primärformation), cross the Theiss between Trebousa and Bocskó Raho in an attenuated form, and eventually die out a few miles to the north-west. Here and there occur lenticular patches of Dyas (Permian) and Cretaceous rocks; but in this region by far the greater portion of the plateau is composed of a group of strata of Eocene age. These sandstones, clays, and shales, known by the name of the Flysch beds, attain a wonderful development, not only round the head-waters of the Theiss, but along the whole course of the Carpathians to Presburg. Owing to their comparatively soft and yielding character, in the eastern districts at least, the beds are not well adapted for preserving the ordinary effects of glacial action. Not only are the beds easily disintegrated by atmospheric agents, but the stones derived from them would not readily preserve ice-markings, if ever they were impressed with them. In consequence of such extensive areas being covered by these deposits, one looks in vain for those characteristic mamillated surfaces which are striking features in well-glaciated countries. But in addition to these rock-groups, there still remains to be noted the great development of trachyte and andesite lavas with their associated tuffs, of Tertiary age, which fringe the inner margin of the chain, and which are traceable at intervals westwards to the old volcano of Schemnitz. These are well seen round the outskirts of the head-waters of the Theiss, the terraced appearance of the volcanic masses being easily descried from the neighbourhood of Szigeth.

The town of Nagy Szigeth commands the entrance to the head-waters of the Theiss. Situated at the confluence of the Iza with the main river, it is about 45 miles distant from the crest of the chain, and about 40 miles from the point where the Theiss may be said to enter the great Hungarian plains. From this standpoint an extensive view is obtained of the crescent-shaped mass of mountains encircling the sources of the river, the chief elevations being the Czerna Gora, 6581 feet, and the Rusky Berg, 6732 feet; while the height of Nagy Szigeth itself, by aneroid measurement, is about 1800 feet. As seen from this elevation, the range seems to be traversed by a series of long, narrow, pine-clad valleys, cutting more or less obliquely across the strike of the strata. Our course was to follow on foot the windings of the river as far as Körösmezö, within a few miles of the crest, thence crossing the col and descending the valley of the Pruth to Kolomea, a distance of about 90 miles.

D. *Description of Drift-sections in the Theiss Valley.*

Before commencing the ascent, we retraced our steps to Kabalapatak, a village about three miles below Szigeth, for the purpose of examining some sections exposed in the line of railway. The cutting referred to extends from the village to the bridge across the Iza, and runs in an east-and-west direction. At right angles thereto, a fresh cutting has been made close by the stream which skirts the village. Both sections expose a true *moraine profonde.* The railway-cutting is about 20 ft. deep, and passes through a deposit of stiff gritty clay, the matrix of which is in a large measure composed of sandstone and trappean detritus. Near the base of the section occurs a lenticular patch of gravel about 3 ft. long by 1 ft. broad; but, with this exception, the deposit had no trace of stratification. The stones are scattered irregularly throughout the mass, and without any regard to their size. They consist mostly of fine-grained porphyry, which weathers with a rough surface, while next in order come Lydian stone, quartzite, and some mica-schists. Some specimens of reddish trap-tuff were also observed. Some of the trap boulders reach a considerable size, one block weighing upwards of half a ton; this, however, is exceptional. Many of the stones measure from one to two feet across. None of these are angular; they resemble in general form the blunted and smoothed stones of Scotch till. It must be observed that stones on which striæ can be recognized are not abundant; but those rocks which were capable of retaining the ice-markings, still show them more or less perfectly, conspicuous amongst these being the smaller Lydian stones and quartzites. There can be little doubt that this deposit is identical with the ordinary Boulder-clay of well-glaciated regions; while the lenticular patch of gravel is but the counterpart of similar thin layers in the till of our own country. This deposit appears to slope gently up towards the near wooded hills of the Flysch-beds, lying to the south. When traced in this direction it is found to be overlain by stratified blue clay containing only a few stones, which the Wallachs manufacture into bricks to serve as building-material for their rude huts. The following section (fig. 1) shows the relation of the various deposits.

Fig. 1.—*Section in a line north and south through Kabalapatak.*



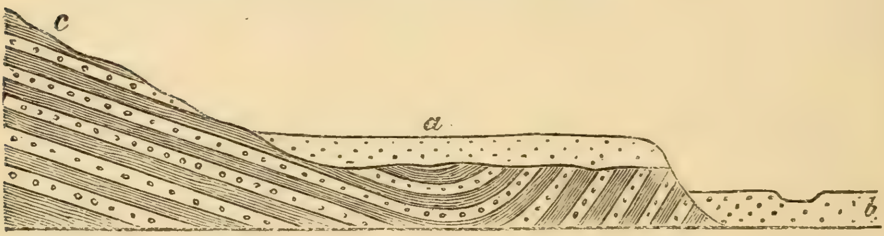
a. Stiff, stony Boulder-clay.
b. Fine blue clay.
c. Soft sandstones and shales. Flysch-beds.
d. Railway-cutting.

The section measures about half a mile.

On the west bank of the above-mentioned stream, which joins the Theiss at Kabalapatak, the Flysch-beds are exposed. They consist of very soft thin-bedded sandstones, on the top of which rest fine blue clays and shales. The same beds are seen in the Theiss between Salzkammer and Fejeregyhaza, dipping to the north of east at an angle of about 35°, and capped by about 5 feet of alluvial gravel. Further up the river, near Bocskó Lonka, the same dip is indicated by the general direction of the escarpments on the slopes of the near hill-range.

On the right bank of the river, from Szlatina to a point east of Salzkammer, a long terrace-shaped bank is traceable, which we found to consist of alternating beds of sand and coarse gravel. These are quite horizontal; and no indication of false-bedding was visible. This bank is from 20–30 feet above the modern alluvium, and is probably an old river-terrace. At Karacsonfalu, which is about 5 miles above Szigeth, the main road ascends to the level of the upper terrace, which sweeps south to the base of the hills. At this point the valley is only about a mile and a half broad, and seems to be filled entirely with alluvial deposits. The same fact is observable at Gross Bocskó, where the valley narrows to not much more than a quarter of a mile. Again, near Lonka, several excellent sections of these alluvial gravels are met with, which likewise stretch from the one hill-slope to the other. At this point there are also two well-marked terraces; the gravel of the upper terrace being upwards of 20 feet thick. The same horizontal bedding is discernible, while the deposit, as a whole, is pretty coarse, many of the stones measuring 2 feet across. Here the Flysch-beds are seen dipping up stream at an angle of 20°, and within a short distance reversed at a high angle, as shown in the following section (fig. 2).

Fig. 2.—*Section near Lonka.*



a. Old alluvial terrace.
b. Recent alluvium.
c. Sandstones and shales. Flysch-beds thrown into a synclinal fold.

Rather more than a mile beyond Lonka, the river flows between steep pine-clad hills with no alluvial or drift-deposits on either bank. Near this, however, three large erratics of quartz rock were observed, one of which measured upwards of 90 cubic feet, and another (partly concealed) upwards of 10 feet in length. Higher up the valley, in a roadside-cutting, the quartz rock is seen in place, and is rapidly succeeded by a fine-grained blue limestone, the latter probably belonging to the patch of Dyas or Permian rocks represented in Von Hauer's map. On the right bank of the Theiss, just about a mile and a half below the point where it receives the waters of the Vissö, another drift-section is exposed. It occurs on the roadside, and is about 100 feet above the level of the river. The deposit consists of stiff dark-blue clay, stuck full of stones, some of which range up to 8 cubic feet. The blocks, as a rule, are not rounded; and, though a careful search was made, no instances of striæ were observed. The absence of such may be accounted for by the fact that the stones consist mainly of soft brownish-grey micaceous sandstones, which would not readily retain glacial markings. This section is about 2050 feet above the sea-level, by aneroid measurement.

It is worthy of note, as exemplifying the relation between the underlying rocks and external form, that where the river traverses the crystalline strata above referred to, it flows along the bottom of a gorge about 600 feet in depth; but beyond this point, towards the Vissö, the soft sandstones and shales reappear accompanied by a more gentle slope.

The Vissö is one of the largest tributary streams in the upper reaches of the Theiss; and its course is one of the longest, as it takes its rise about 50 miles to the south-east on the slopes of the Csarkano Berg. This large affluent produces a marked deflection in the trend of the main valley; for at Rohapojana, where the two streams unite, the Theiss is bent round at right angles to its former course. The same effect is noticeable in the case of the Iza at Szigeth; and frequently along our route we had occasion to record this feature. These lateral valleys, like the principal one, are steep and narrow and thickly wooded with pine; and, in virtue of their own striking features, as well as from the influence which the tributaries exercise in perpetually changing the direction of the main line of drainage, they enhance considerably the effective scenery of the Theiss itself. There is one important feature connected with these lateral streams which must not be overlooked: it is the assemblage of large "cônes de déjection" immediately below their confluence with the main river. These, as will be indicated presently, were puzzling features at times, on account of their marked resemblance in external appearance to moraine mounds. In many cases they are being broken up and subjected to reassortment, thus furnishing material for the alluvial gravels of the Theiss. The existence of these conical heaps, and the angular nature of the contents, throw some light on the origin of those stretches of coarse gravel which characterize the older alluvial terraces.

Opposite the bridge which crosses the Theiss, towards the valley of the Vissö, an excellent section of drift is exposed on the road-side. It consists of stiff brown clay, packed with stones ranging from the size of one's fist to blocks several feet in diameter. These blocks have the regular blunted form characteristic of ordinary Boulder-clay. No scratches were detected on the smaller stones; but in the case of three large blocks we found unmistakable striæ. One of these blocks, weighing upwards of half a ton, was distinctly grooved on three sides; and on one side, especially, cross striæ were noticeable. These stones consist for the most part of a dark-blue calcareous rock, probably derived from the patch of Dyas occurring higher up the valley.

From Trebousa, which is about 16 miles distant from Szigeth, to Bocskó Raho, about 9 miles higher up, the Theiss flows along the bottom of a deep narrow defile, closely resembling that which has been already noted above Lonka. Along a great part of the way the sides are almost precipitous; but here and there the valley widens somewhat, and alluvial patches of no great extent intervene. These alluvial flats are hemmed in by rocky barriers, though occasionally on the slopes a sprinkling of angular rubbish is observable, evidently the result of the surface-wash of the hills.

When standing in the midst of these flats we seemed to be surrounded by a small amphitheatre of wooded hills with no apparent outlet, suggesting the probability of these basin-shaped hollows being silted-up rock-basins. This steep gorge is due mainly to the hard and durable material exposed to the agents of denudation; for between Trebousa and Bocskó Raho the rocks which cross the valley consist of mica-schists and beds characteristic of the Dyas. It is not unlikely that these narrow cuts, intersecting the highly crystalline strata, have been excavated in great part since Glacial times.

Just beyond Bocskó Raho the soft sandstones and shales of the Flysch beds reappear, attended with a corresponding change of feature. The valley gradually opens out, and the grassy hills, now almost bare of trees, slope gently away from the river.

At Borkut, which is about 12 miles from the crest of the chain, on the left bank of the river, one of the best drift-sections occurring in the Theiss is to be seen. This section is about 40 feet high, and is being gradually undermined by the river. It consists of a soft sandy Boulder-clay crammed with stones of various sizes, which are distinctly smoothed and blunted. The included blocks, as well as the matrix of the deposit, are composed of soft micaceous sandstone, which disintegrates easily when exposed to weathering. In spite of this, however, we found well-scratched stones, some of which were preserved. Within five miles of Körosmezö, below the point where the river which drains the Pietros Berg joins the Theiss, another platform of drift was observed, which in all likelihood is a fragment of the same deposit. Alluvial terraces were noticed at intervals as we wended our way to Körosmezö; but beyond this, to the summit of the range, no further traces of glacial deposits were visible.

Along the course of the Pruth to Kolomea we found no glacial deposits. Various sections were exposed at different places along our route, which consisted of loose rubbishy matter with angular stones, evidently the result of the decomposition of the rock. From Kolomea we travelled by rail to Adjud, and ascended the valley of the Trotus as far as Okna. The Trotus valley lies about 160 miles to the south-east of the col between the Pruth and the Theiss. We then crossed the low range of hills lying between Okna and the Oitos Pass, and followed the windings of this pass to near the crest of the range. The main valley (Trotus), as well as its tributaries, is mostly narrow and bounded by low hills not much wooded; but neither in the main valley nor in the Oitos Pass did we meet with glacial deposits. In the Oitos Pass, above Grosesti, at the mouths of the lateral valleys, we observed numerous conical-shaped mounds, which looked at first sight like ordinary moraines. They are made up of a curious assemblage of large and small angular blocks of sandstone lying irregularly in a loose rubbishy matrix. After a careful examination of the various sections, we came to the conclusion that they were "*cônes de déjection*" of lateral streams.

E. Conclusion.

From the evidence now given it is apparent that glacial deposits are not abundantly developed in the valleys of the North-eastern Carpathians. The drift in the upper reaches of the Theiss is of the most fragmentary character, being confined mainly to the broader portions of the valley. This is, perhaps, what might be expected when we consider the general features of the valley-system along with the nature of the materials which form the masonry of the range. There is, however, sufficient evidence for maintaining that the Theiss valley was filled with a glacier upwards of 45 miles in length. We were not able to determine whether this glacier ever debouched on the plains of Hungary, or whether it ever reached the edge of the Carpathian chain ; but it is not improbable that further examination will prove that such was the case.

36. *On the* Rank *and* Affinities *in the* Reptilian Class *of the* Mosasauridæ, Gervais. By Prof. Owen, C.B., F.R.S., F.G.S., &c. (Read June 6, 1877.)

§ 1. *Introduction.*—The fortunate acquisition by the British Museum of the "Van-Breda Collection," which includes the best specimens that have been found since the times of Camper and Cuvier of the large saurian and chelonian fossils from Maestricht—the Mosasaurian fossils brought to Europe from America by Prince Maximilian of Neu-Wied, and by Prof. H. Rogers, of Pennsylvania—supplemented by the richer collections of similar fossils from the western Cretaceous beds of the United States, due to the important and praiseworthy labours of Professors Leidy, Marsh, and Cope,—have accumulated a mass of materials by the study of which the rank and affinities in the Reptilian class of *Mosasaurus* and its near allies can, as I believe, be definitely determined.

When Cuvier * initiated the present inquiry his subjects had been referred to the *Cetacea* by Camper †, and to the *Crocodilia* by Faujas ‡; and Cuvier's comparisons, leading to the conclusions as to the closer affinities of the fossils to the *Lacertilia*, are preceded by the classical 'Ostéologie des Lézards,' from which he derives most of his illustrations of the genus which Conybeare had called *Mosasaurus.*

To the Ophidian order Cuvier makes but one reference, which is decisive as between Serpents and Lizards §; and he seems to have felt as little called upon to discuss the osteology and dentition of Fishes for a refutation of an early reference of parts of the *Mosasaurus* to that class.

The question, however, of the relations of Mosasaurians to Ophidians has of late grown to dimensions which command more detailed comparisons from the palæontologist who may be moved to discuss it.

In the 'Proceedings of the Boston Society of Natural History' for 1869 (p. 250), Prof. Cope determined the Mosasauroid character of certain Cretaceous fossils; he deduced from them the number of the cervical vertebræ, the structure of the posterior regions of the cranium, of the lower jaw, scapular arch and fore limb, and dia-

* Recherches sur les Ossemens Fossiles, 4to, 1824, tome v. 2de partie, p. 310.

† 'Philosophical Transactions,' 1786.

‡ Histoire Naturelle de la Montagne de Saint Pierre, p. 40.

§ Professor Cope meets the argument by denying the homology on which Cuvier founded it. Cope's "*palatine bones*," are, he affirms, "the pterygoids of Cuvier. The true pterygoids are rather short compressed bones, which are united by suture to the borders of a concavity of the palatine. They are toothless, and have no sutural connexion with the ossa quadrata."—*Report of the United-States Geological Survey of the Territories*, vol. ii. 'The Vertebrata of the Cretaceous Formations of the West,' 4to, 1875, p. 118.

gnosed a genus distinct from *Mosasaurus*, for which he proposed the name *Platecarpus*. In the study of all these fossils he became so impressed with their ophidian characters, that he concluded to raise the family Mosasauridæ to the rank of an order in the class Reptilia, for which he proposed the name *Pythonomorpha*.

The Cretaceous formations in the west of the United States yielding these and other instructive additions to the Mosasaurian group have been classified by the accomplished geologists Meek and Hayden. The lowest is a sandstone; the second consists of chalk and calcareous marl; the third, including yellowish and whitish chalks, is noted as the " Niobrara Epoch "*; the fourth and fifth series are laminated shaly clays and sandy beds. Prof. Cope adds a sixth series of " Lignite " or " Fort-Union beds." From the Niobrara group have been obtained most of the American fossils allied to *Mosasaurus*. Of these Prof. Cope has entered, in his richly illustrated Report:—

Of the genus *Leiodon*, 4 species;
,, ,, *Platecarpus*, 10 species;
,, ,, *Clidastes*, 10 species;
,, ,, *Sironectes*, 1 species;

and he remarks:—" These sea-serpents, for such they were, embrace more than half the species found in the lime-stone-rocks in Kansas, and abound in those of New Jersey and Alabama " †.

And here I may remark that some fossils of the kind alluded to, from a Neocomian or " greensand " formation in New Jersey, were brought over by Prof. Henry Rogers, of Pennsylvania, and submitted to my examination in 1848. One was a basioccipital bone of a reptile, about the size of the *Mosasaurus Hoffmanni*, Cuv. This fossil being associated with characteristic teeth of the genus, together with vertebræ of the Mosasaurian type, and what at the time was of especial interest, viz. phalanges of a limb of a natatory character, I referred the series of fossils to that Cretaceous genus of *Reptilia* ‡, and, from the modification of the teeth, to the American species which had been noted by Goldfuss as the *Mosasaurus Maximiliani* §.

Now the basioccipital is one of the bones in *Reptilia* which aid in determining the order, and perhaps minor group, in the class, and this by the character of the exogenous process or processes serially homologous with those termed " hypapophyses" in the vertebral centrums of the trunk.

§ 2. *Occipital Characters.*—In *Crocodilia* the basioccipital hypapophysis is single, median, long and large ||, and extends the syndesmotic connexion of this cranial centrum with the next centrum

* Report &c. p. 16.
† *Ibid.* p, 45.
‡ Quart. Journ. Geol. Soc. vol. v. 1849, p. 380, pl. x.
§ " Der Schädelbau des *Mosasaurus*," &c. in Acta Acad. Cæs. Leop.-Carol. Nat. Curios,' vol. xxi. p. 179 (1842).
|| Anat. of Vertebrates, vol. i. p. 135.

(basisphenoid) in front. In *Ophidia* also the hypapophysis of the basioccipital is single and median. In *Python tigris* it is "produced into a recurved point" *. In *Crotalus horridus* the single basioccipital hypapophysis forms the commencement of the strong ridge from the underpart of the basisphenoid. In all *Lacertilia* the basioccipital has a pair of hypapophyses. In the Monitors (*Varanus*) they are short, obtuse, and slightly divergent †. In *Rhynchocephalus* ‡ they are more lateral and divergent, abutting against the ends of the long pterygoids. In *Iguana* they more closely agree with the parial hypapophyses in *Mosasaurus*; and the basioccipital of *Iguana tuberculata* (Quart. Journ. Geol. Soc. vol. v. pl. x. fig. 6), with the homologous bone of *Alligator lucius* (ib. ib. fig. 7), were selected to illustrate the character of the basioccipital in *Mosasaurus Maximiliani* (ib. ib. fig. 5). In the great existing Sea-Lizard (*Amblyrhynchus cristatus*, Bell), the skeleton of which I had not then seen, the correspondence of the basioccipital with that of *Mosasaurus* is closer than in any other Lacertian §.

As the idea of an affinity of the Mosasaurian Reptiles with Serpents, whether marine or terrestrial, had not been broached in 1848, nor seemed likely to occur to a palæontologist from the data then at his command, no figure of the basioccipital of a *Python* was thought requisite.

The elements in the determination of the place of the Mosasaurians in the Reptilian series, additional to those discussed in detail by Cuvier ||, relate chiefly to the hind and fore ends of the skull, to its upper surface, and to part of the lower surface. I proceed to notice such supplementary evidences as have come under observation since the date of the paper quoted in the Society's Quarterly Journal.

The basisphenoid is a more characteristic bone in the present question than the basioccipital. In *Ophidia* its under surface is traversed by a single median hypapophysis in the form of a sharp and deep ridge ¶. In *Lacertilia* the corresponding surface of the basisphenoid is devoid of such ridge, is smooth, and slightly concave. A pair of hypapophyses from the posterior angles abut against those of the basioccipital. In *Mosasaurus* the basisphenoid is concave, almost canaliculate along the middle of the under surface, devoid of any ophidian median ridge; the pair of hypapophyses, or produced posterior angles abut against the pair from the basioccipital, but leave the broad truncate ends of these free, as in *Amblyrhynchus*.

The "pterapophyses" in *Lacertilia* are subcompressed laterally,

* Descriptive Catalogue of the Osteological Series in the Museum of the Royal College of Surgeons,' 1853, p. 128. no. 628.

† Anat. of Vertebrates, vol. i. p. 155.

‡ *Ibid.* p. 154.

§ Comp. Steindachner, 'Die Schlangen und Eidechsen der Galapagos-Inseln,' 1876, pp. 313–338, pls. xviii., xix.

|| *Tom. cit.*

¶ Osteol. Catal. cit. *Python tigris*, p. 129. no. 628; *Crotalus horridus*, p. 135. no. 640: "the strong ridge developed from the underpart of the basisphenoid" is specially noticed.

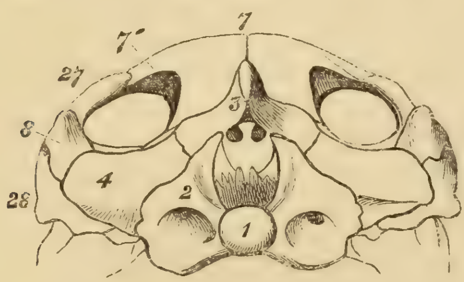
broad longitudinally, and come off from the antero-lateral parts of the basisphenoid, leaving a wide intervening smooth tract; the surface abutting upon the pterygoid is vertical.

In *Python* the pterapophyses are much shorter, are narrow longitudinally, broad transversely, with the surfaces on which the pterygoids glide horizontal; they are also close together, divided by the vertical hypapophysial crest. *Mosasaurus* agrees with the *Lacertilia*, and differs from the *Ophidia* in these parts also of the basisphenoid.

Cuvier, in his otherwise full and accurate illustrations of the craniology of *Reptilia*, gives views of the occipital surface of the skull in *Crocodilia* * and *Chelonia* †, but not in *Lacertilia*. *Ophidian* remains not having come under his personal cognizance at the date of the preparation of the great work on Fossil Bones, he does not enter into decriptions of the osteology of that order of Reptiles. In that of the other orders he defines and names the bones which contribute to form the otocrane, which he calls " la cage du labyrinthe " ‡. In the present inquiry I continue to use these names as most clearly defining the bones I have to refer to.

In the occipital region of a reptilian skull they are best shown in a Chelonian. In fig. 1 the basioccipital is marked 1, the exoccipital

Fig. 1.



Chelonian.
Occipital region of skull.

(" occipital latéral," Cuv.) 2, the paroccipital (" occipital extérieur," Cuv.)§ 4, the superoccipital (" occipital supérieur " Cuv.) 3; to these add the parietals 7, with the lateral extensions 7', the squamosal 27, and the mastoid 8: the proximal part of the " tympanic " is indicated at 28.

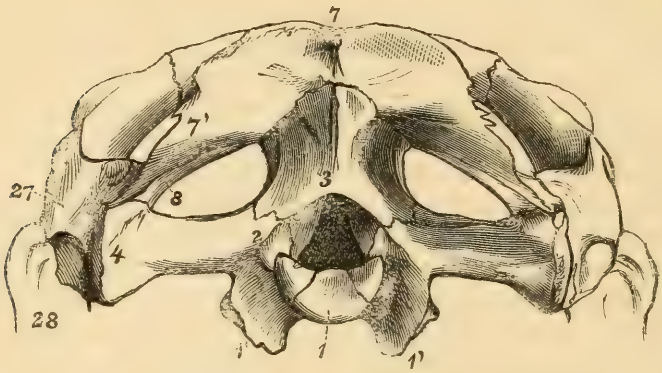
In the Lacertian order I select the skull of the sea-Lizard of the Galapagos Islands (*Amblyrhynchus cristatus*) for the present aim (fig. 2.) The chief modifications are (the suture between 2 and 4 being obliterated):—the greater extension of the transverse abutment, 2–4, against the joint contributed by the mastoid, 8, and squa-

* *Tom. cit.* pl. iii. fig. 5. † *Ibid.* pl. xi. fig. 4. ‡ *Tom. cit.* p. 181.

§ "Les occipitaux latéraux sont chacun divisés en deux parties, dont je me vois obligé d'appeler la plus externe *occipital extérieur.*" (Ib. p. 180.)

mosal, 27, for the suspension of the tympanic, 28; the pair of hypapophyses, 1′, from the basioccipital, 1; the greater proportion of the occipital surface contributed by the median part of the coalesced

Fig. 2.



Amblyrhynchus.
Occipital region of skull.

parietals, 7, and by the lateral extensions, 7′, which are relatively greater; the mastoid, 8, moreover, is pushed inwards by the junction of 7′ with 27; finally, the large vacuities between 7′ and 2–4 *.

An extreme modification of the occipital is shown in the Ophidian reptiles. In *Python reticulatus* the basioccipital forms the lower part of the condyle, fig. 3, 1, supported on a short peduncle, on each

Fig. 3.

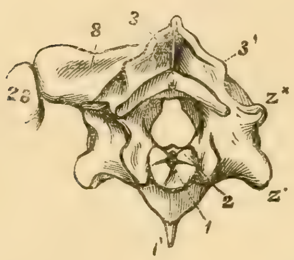
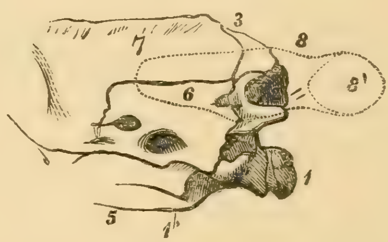


Fig. 4.



Python.
Back and side views of occipital region of skull.

side of the base of which is a low transverse ridge for attachment of the capsular ligament. The single hypapophysis is shown at 1′. The exoccipitals (2) contribute the upper and lateral portions of the condyle, and unite together above the occipital foramen. Each exoccipital has a small process supplementing that from the basioccipital for the attachment of the strong capsular ligament of the occipito-

* These characters are well shown in the corresponding view of the same species in Steindachner's Monograph, pl. v. fig. 8; but the constituent bones are not indicated, and the suture between the mastoid and parietal is omitted on the right side, and feebly marked on the left.

atlantal joint. Above this the exoccipital sends outward a strong process (z'), which, by its short extent, answers to the exoccipital, 2, of the tortoise, and terminates freely, not abutting against the tympanic or other bone, and suggesting the non-development of the paroccipital, 4. A second smaller process (z^*) affords attachment to part of the lower border of the mastoid (8) by intervening ligamentous matter. The superoccipital, 3, develops the diverging penthouse-like ridges, 3′, the lower and outer end of which gives a similar close ligamentous attachment to a part of the upper margin of the mastoid (8), opposite the part of the lower margin attached to the exoccipital. Much of the superoccipital is overlapped by the parietal; but the overlapping stops short of the occipital region, and the seeming bifurcation of the parietal crest is due to the superoccipital.

The most marked and characteristic modification of the part of the skull here compared is the limitation of the proximal joint of the tympanic, 28, to the mastoid, 8, exclusively. Besides this are to be noted the great length of 8, its free production backward for half that length beyond the occipital plane of the skull, and its liberation from all share in the formation of the otocrane. From this chamber the mastoid is excluded by the suture between the alisphenoid (fig. 4, 6) and the parietal 7, over which suture the mastoid, 8, extends in a squamous shape and manner, and so smoothly as to suggest a certain latitude of gliding motion in connexion with the more violent and extensive movements of the columnar tympanic (figs. 13, 28), which is suspended vertically from the free extremity of the mastoid, 8′. I append an outline (fig. 4) of the side view of this part of the skull in a Python, in which the alisphenoid is 6, the parietal 7, the superoccipital 3, the exoccipital 2, the basioccipital 1, its hypapophysis 1′, and the stronger continuation of the same on the basisphenoid is 5. The relative position and extent of the mastoid are shown in dotted outline.

Mosasaurus (fig. 5) shows the lacertian extension and connation of the ex- (2) and par- (4) occipitals, with the expansion and abutment of the latter, 4, against the mastoid, 8, and squamosal, 27,—all three bones, and especially the squamosal, combining to form the large articular cavity for the firm junction of the tympanic.

The superoccipital, 3, completes the great foramen above, has no penthouse ridge as in *Python*, but is overtopped by the parietal, which forms by its median part, 7, and its long lateral processes, 7′, the upper part of the occipital surface. The whole of this surface manifests the lacertian and departs from the ophidian modification of the reptilian skull.

The parial hypapophyses of the basioccipital, and the outward extensions of the ex- and par-occipitals, are figured in pl. xv. of Prof. Cope's work, in the Mosasauroids which he denominates *Platècarpus coryphæus*, *Plat. ictericus*, and *Plat. curtirostris*. The terminal abutment of 2–4 against the mastoid and squamosal is likewise indicated in the figures of cranial fragments in plates xv., xvi., xvii.; but these figures, like those of the skull of *Mosasaurus Hoffmanni*, cited by Cuvier (p. 319), are "sans explication ostéologique"—that is, have no symbols of reference to the constituent bones.

§ 3. *Upper Surface of the Cranium.*—An ordinal characteristic of *Reptilia* is afforded by the upper surface of the cranial and cranio-zygomatic part of the skull.

Fig. 5.

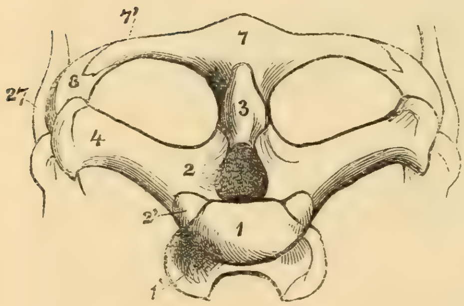
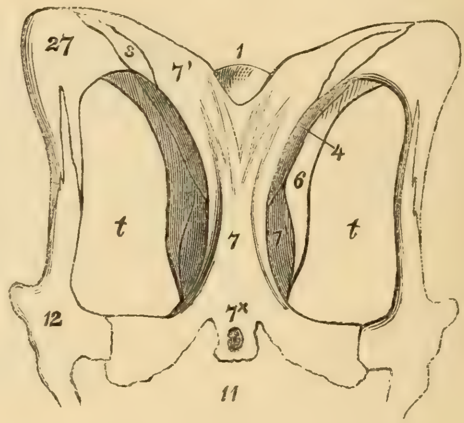


Fig. 6.



Mosasaurus.
Occipital region and upper surface of cranium.

Cuvier gives a view of this surface in two genera of *Crocodilia* †; but of the *Lacertilia* he limits his figures to oblique side views; and corresponding views of the *Ophidia* are omitted. I therefore append an upper view of the cranial characters in question in a Mosasauroid, fig. 6, a Lacertian, fig. 7, and an Ophidian, fig. 8, in illustration of the following remarks on this part of the skull.

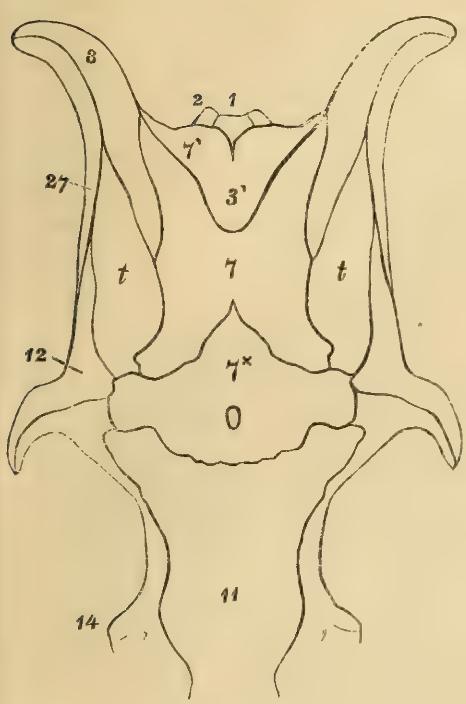
It is hardly necessary to do more than allude to the articulation of the postfrontal with the mastoid in *Crocodilia*, and the strong arch which these broad horizontally flattened bones send over the temporal fossa, to which, in some species, they form a complete roof. The parietal, also, is imperforate. If Cuvier had possessed the corresponding parts of the skull of a Mosasaur, he would doubtless have added convincing grounds against Faujas's view of the crocodilian affinities of that genus, and in support of his own lacertian conclusion.

In the type *Lacertilia* (*Monitor*, *Iguana*, *Amblyrhynchus*, &c.) the temporal fossæ, *t*, are widely open. Each is bounded mesially by the parietal, fig. 7, 7, laterally by the postfrontal, 12, and squamosal, 27, posteriorly by the mastoid, 8. The parietal bifurcates posteriorly, and develops a ridge from the hind part of the obliterated sagittal suture, which ridge bifurcates anteriorly, arching forwards and outwards to the postfrontal, 12; the flat fore part of the parietal, 7*, anterior to the latter bifurcation, is perforated by the "foramen parietale,"—in the Monitors and some other Lacertians,

† *Tom. cit.* pl. iii. figs. 1 and 6.

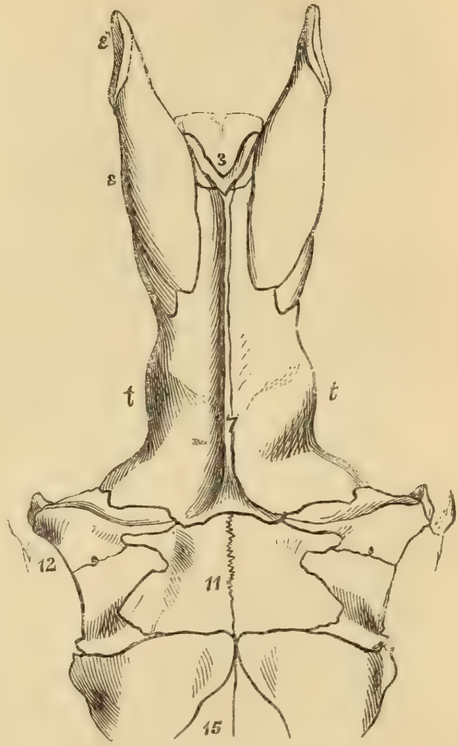
near the coronal suture; but in *Amblyrhynchus* and other Iguanians this foramen is in that suture.

Fig. 7.



Monitor niloticus.

Fig. 8.



Python.

Upper surface of cranium.

In the *Python*, fig. 8, and all other *Ophidia*, the temporal fossæ, *t*, have no outer boundary, there being no zygomatic arch: the "diverging appendages" of the maxillary, viz. the malar and squamosal bones, are suppressed. The parietal is feebly notched behind, not bifurcate. The mastoid, 8, overlaps the alisphenoido-parietal suture by a squamous articulation, projects far behind the occipital surface of the skull, and there supports the tympanic column by an oblique terminal flat articular facet (8′, and fig. 4, 8′). The parietal, 7, as in the *Crocodilia*, is imperforate.

In *Mosasaurus Hoffmanni* (fig. 6) there is a large foramen parielate (7 *), which, as in the *Monitor*, is wholly in the parietal, 7. The parietal bifurcates posteriorly; its prongs, 7′, extend backward and outward, and articulate with the mastoid, 8; and this bone curves outward and downward to join the squamosal, 27, and, with it, to form the articular surface for the tympanic. Anteriorly the squamosal unites with the postfrontal, 12. The long and wide temporal fossæ are thus bounded, externally, as in Lacertians, by a long and narrow zygomatic bridge, in the composition and proportions of which the Mosasaur most resembles the Monitors and Iguanas.

Prof. Cope figures the perforate parietal and portions of its posterior bifurcation in a fragment of skull of a Mosasaur, which he refers to a genus *Platecarpus* (*op. cit.* pl. xvi. fig. 4) *: he also figures a portion of skull showing the postfrontal and part of the backwardly extending long and slender squamosal, in the Mosasaur which he refers to a genus *Clidastes* (*op. cit.* pl. xvi. fig. 1). The cranial characters in European examples of Mosasaur and *Leiodon*, thus corroborated by transatlantic fossils, are decisive evidences for Lacertian, and against Ophidian, affinity.

The cranial cavity or brain-chamber is unclosed anteriorly by bone in *Lacertilia*; in *Ophidia* (*Python*) the bony parietes of the brain-chamber are continued anteriorly to the outlets of the olfactory nerves, closing the chamber elsewhere, in front. Prof. Cope gives, as the 12th character of his *Pythonomorpha*:—"The brain-chamber is not ossified in front" †. But this is a Lacertian character and is adverse to Pythonic affinity.

His 10th character is:—"There is no quadrato-jugal arch." But in no Reptile does the jugal or malar bone join the quadrate or tympanic bone.

In some *Lacertilia* (*Monitor*, *Varanus*, e. g.) the malar bone, after forming the lower part of the orbital frame, stops short; and the postfrontal, 12, intervenes between it and the squamosal, 27. But in the majority of lizards the malar does complete the zygomatic arch with the squamosal, either directly or by interposition of part of the postfrontal. The position of the zygomatic (malo-squamosal) arch is thus at a higher level along the side of the cranium than in the *Crocodilia*, *Aves*, and *Mammalia*; and the *Mosasaurus* shows the elevated position of the arch as in *Lacertilia*. But in the *Ophidia* the zygomatic arches, by whatever name they may be called, are altogether wanting.

Prof. Cope defines a "13th" character of his *Pythonomorpha* as follows:—"The squamosal bone is present, merely forming the posterior part of the zygomatic arch" (*ib.* p. 114). I am not, however, cognizant of any Vertebrate, recent or fossil, in which it forms any other part of the arch. Meanwhile the fact remains that the squamosal is wanting in all *Ophidia*: and thus the Mosasaurian evidences from the Cretaceous series of the Western States confirm the strongly distinctive character exemplified in our European fossils. The homologous bones being marked by the same numbers in fig. 8 (from a skull of *Python sebæ*, nat. size), the comparison with figs. 6 and 7 needs no other guidance.

§ 4. *Tympanic bone*—The tympanic bone, in the Breda Collection, of *Mosasaurus Hoffmanni*—the type of the genus and family of Mosasauroids—which is the subject of the following description, is of the left side (figs. 9–12). Its length is six inches 8 lines, its breadth 5 inches; the longitudinal extent of the proximal, or mas-

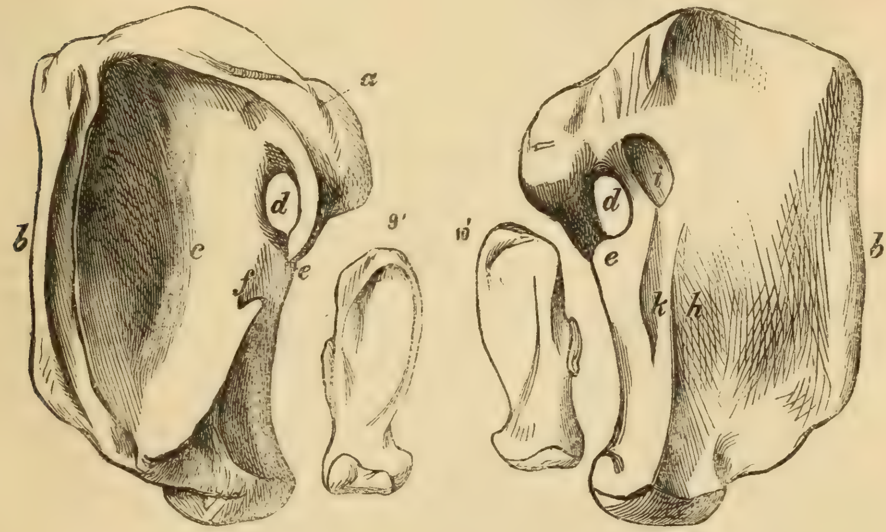
* In *Platecarpus curtirostris*, pl. xvi. fig. 4, and, again, in *Plat. ictericus*, pl. xvii. fig. 3.

† *Op. cit.* p. 114.

toid surface is 4 inches 2 lines; that of the distal, or mandibular, surface, is 4 inches 3 lines.

The proximal articular surface, fig. 11, *a*, is in great part rough for close ligamentous or fibro-cartilaginous union with the mastoid and squamosal: it is convex antero-posteriorly, curving downward and backward, as in *Amblyrhynchus*, leaving the fore part of the proximal end of the tympanic free and smooth. Transversely the rough articular surface, *a*, is flat or feebly concave. Any swinging movement of the tympanic seems not to be permitted by this joint. The fore part of the tympanic is a broad plate of bone forming that wall of the large tympanic cavity, fig. 9, *c*: the margin of

Fig. 9. Fig. 10.



Outer surface, Inner surface.

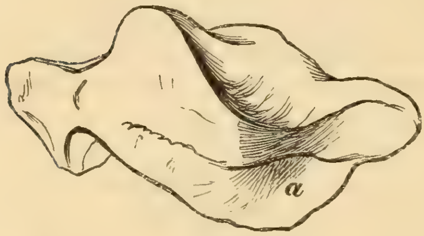
Tympanic bone of *Mosasaurus Hoffmanni*, $\frac{1}{3}$ natural size. 9′ and 10′, the same bone of *Python Sebæ*.

the plate, *b*, which is turned outward (laterad), is deeply grooved, as in *Amblyrhynchus*, for the attachment of the drum-membrane. The tympanic cavity, *c*, is vertically oblong, 5 inches in that direction across the outlet, 3 inches transversely across the upper end, and gradually contracting to $1\frac{1}{2}$ inch as it descends; its depth is 2 inches at the deepest part. The stapedial orifice, *d*, is at the upper and back part of the cavity, and is of a subelliptic form, 9 lines in long diameter. The proximal articular end arches over this aperture to within a line of the substapedial tuberosity, *e*. From the lower end of the grooved part of the frame the border curves backward and upward, with a sharpish ungrooved margin terminated abruptly by a notch, *f*, within an inch of the end of the upper arched border contributed by the mastoid articular surface.

The hind part of the inner wall (fig. 10) of the tympanic cavity is transversely convex where it is continued backward into the stapedial foramen and upon the substapedial process.

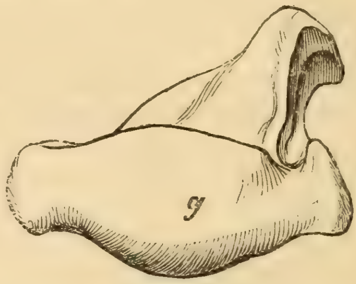
This convexity indicates the columnar part of the tympanic, which undergoes, as it were, a half twist to form the distal or mandibular articulation, the long diameter of which is transverse to the skull's axis, instead of being, as at the upper end of the bone, subparallel therewith. The long diameter of the distal joint, fig. 12,

Fig. 11.



Proximal end.

Fig. 12.



Distal end.

Tympanic bone of *Mosasaurus Hoffmanni*, × ⅓.

is 4 inches, the short diameter is 1 inch 9 lines at the middle part, narrowing to each end, and chiefly to the inner (mesial) end. The articular surface, fig. 12, *g*, is convex both lengthwise and across, and smoother than the upper surface. It is not concavo-convex for a ginglymoid joint, as in *Python*, but forms the ball of a simple ball-and-socket joint. There is a tuberosity, fig. 10, *k*, for the ligamentous attachment of the end of the pterygoid behind and above the mandibular articular surface.

The fore part of the tympanic is chiefly formed by the tympanic plate, which there shows a broad, smooth, slightly sinuous surface; the hind part is chiefly formed by the deflected portion of the mastoid surface above, and by the mandibular surface below. The inner (mesial) side of the bone is the narrowest, and shows a smooth elliptic cavity, fig. 10, *i*, with a sharp border, 10 lines by 7 lines in outlet diameters and 5 lines in depth: the long axis is subvertical: from the lower end of the cavity a subobtuse ridge, *k*, is continued downward for 1½ inch, ending abruptly. It is possible that this cavity may have received the end of a long outstanding paroccipital process, as in the *Lacertilia*: but I have not found a corresponding cavity in the recent skulls of the order which I have examined. There is no trace of such in *Python*, nor any abutment of paroccipitals, or produced exoccipitals, against the proximal part of the tympanic, as in *Lacertilia*.

I have noted a difference in the size and shape of the stapedial outlet of the tympanic cavity in tympanics of similar-sized Mosasaurs from the Maestricht Chalk, but not in a degree countenancing specific, much less, generic, distinction.

In the Mosasauroid referred to *Clidastes tortor* by Prof. Cope the proximal surface arches down to a somewhat lower part of the tympanic than in *Mos. Hoffmanni*, and the substapedial extremity is nearer the distal articular surface.

The tympanic is a characteristic bone in the orders and minor groups of *Reptilia*. In *Crocodilia* and *Chelonia* (fig. 1) it is wedged between the mastoid, squamosal, and pterygoid. In *Lacertilia* (fig. 2) the squamosal (27), instead of abutting upon the fore part of the tympanic (28), arches over it and combines with the mastoid (8) and paroccipital (4) in its suspension. In *Ophidia* (fig. 3) the squamosal is absent, and the tympanic (28) is suspended exclusively from the hind end of a long and backwardly produced mastoid (figs. 4 and 8, 8 & 8′, the tympanic surface). The tympanic in *Chelonia* is remarkable for its breadth in proportion to its length, and for the conspicuous degree in which its function of supporting the "membrana tympani" is shown, the entire, or nearly entire, circumference of the frame of that membrane being contributed by the tympanic.

In some *Lacertilia* (*Thorictes dracæna*, *Iguana*, *Tupinambis teguexin*, *Scincus*, and above all in *Amblyrhynchus*, fig. 19) the tympanic more or less resembles in shape that of the *Chelonia* in its relative breadth and the proportion of the frame of the membrana tympani which it exhibits; but a gradation may be traced to the more simple columnar shape, as in *Varanus*, *Lacerta*, *Stellio*, *Gecko*, *Chamæleo*.

In *Ophidia*, and especially in *Python*, the long diameter of the tympanic is in excess, and the swing of the suspended column is checked only by the abutment of the pterygoid, just above the articular surface for the mandible. Figures of the bone in *Python Sebæ* (9′ & 10′) are juxtaposed to those *Mosasaurus Hoffmanni* (figs. 9 & 10). In this species the tympanic is not only lacertian in type, but exemplifies the chelonian proportions in a greater degree than in any of the *Lacertilia*, in which order *Amblyrhynchus* comes nearest to the gigantic Sea-Lizard in this respect. The breadth of the bone in *Ambl. cristatus*, as in *Mosasaurus*, nearly equals the length; it frames, as in *Mosasaurus*, almost the entire circumference of the drum-membrane, and forms the tympanic cavity, which is conical and contracts from the basal frame to the otosteal orifice.

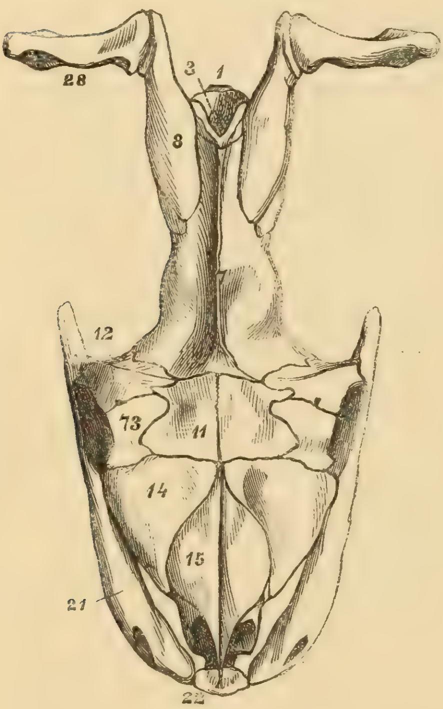
In *Python* the tympanic column is trihedral, and the angle between the fore and hind facets is turned outward as a thin plate; the contrast between this bone and the broad outwardly directed base of the subcircular hollow tympanic of *Mosasaurus* is extreme.

The tympanic bone alone suffices to refute the ophidian hypothesis of the Mosasauroids; and only the obligations palæontology is under to the enlightened and liberal administration of the 'Geological Survey of the Territories of the United States,' under the accomplished "Officer-in-Charge," F. V. Hayden, and the indefatigable devotion of Dr. Cope to the discovery and collection of the fossils figured in the fifty-seven plates of the richly illustrated quarto volume issued in 1875 from the "Government Printing-office, Washington," have imposed upon me the obligation to omit no point which may bear upon the right interpretation of those fossils.

§ 5. *Upper Surface of Face.*—A significantly characteristic part differentiating the skull of *Lacertilia* from that of the *Crocodilia* on the one hand, and of the *Ophidia* on the other, is the upper part of the fore end of the skull. Cuvier has pointed out and illustrated the characters of this region in existing species of both orders, to which I add, for my present aim, the analysis and a figure of the corresponding part of the skull in a species of the *Ophidia*.

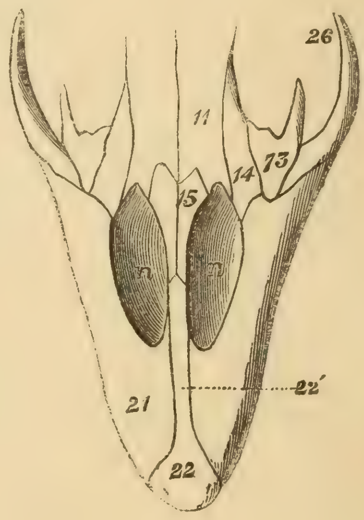
In this group, as exemplified in *Python* (fig. 13), the premaxillary (22) constitutes the smallest element of the region in question. It is a subquadrate or subtriangular ossicle, wedged into the fore part of the vomers and nasals, touching behind the vertical wall formed by the deflected median plates of the nasals (ib. 15), not interposed between the nasals, but contributing a little to the lower boundary of the nasal apertures, which are parial and open obliquely upon the fore part of the skull. The premaxillary is connected by elastic ligaments with the fore ends of the maxillaries, not by suture with those bones, which enjoy movements in the constricting serpents, independent of the premaxillary. This ossicle, 22, in *Python tigris* supports two teeth.

Fig. 13.



Python.

Fig. 14.



Varanus.

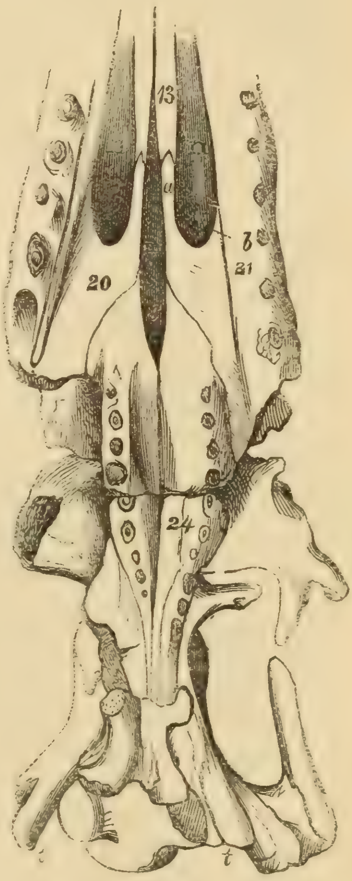
Upper surface of face.

In *Lacertilia* (fig. 14) the dentigerous part of the premaxillary (22) answers to the whole of that bone in *Ophidia*; but it is relatively broader, contributes a greater proportion to the fore end of the skull, and is immovably joined by suture, on each side, to the maxillaries (21). The most distinctive feature of the premaxillary is the production of its upper and middle part into a long and slender-pointed process (fig. 14, 22′), which terminates by wedging itself more or less deeply between the nasals (ib. 15). This structure is associated with a more backward position of the external nostrils (*n*, *n*) than in *Ophidia*, the degree of retrogradation being in proportion to the length of the nasal process of the premaxillary. Thus the characteristic process is longer and the external nostrils are placed further back in *Varanus* and *Monitor* than in *Amblyrhynchus* and *Iguana*; and in this respect, as in some others indicated by Cuvier, *Mosasaurus* (fig. 15) is nearer akin to the Monitors than to the Iguanians.

Fig. 15.

Leiodon.
Upper surface of skull.

Fig. 16.



Mosasaurus.
The bony palate.

Cuvier has rightly represented the backward position of the external nostrils in the *Mosasaurus Hoffmanni*, but does not refer to the anterior boundary of the right aperture, which is clearly and correctly shown in his plate (pl. xviii. fig. 1).

In the same figure is shown the nasal process of the premaxillary, forming the upper border of that part of the divided nostril. The fore part of the premaxillary (fig. 15, 22) in the Mosasaurians is subtriangular as in *Varanus*, and forms a more definite and larger proportion of the fore end of the skull than in *Python*; it supports on its under flattened surface two pairs of teeth, smaller than the maxillary ones; laterally it is suturally connected with the maxillaries (21). From the middle of the upper convex surface of the premaxillary there extends backward and slightly upward a nasal process (fig. 15, 22′) relatively as long as in *Varanus*, with the pointed apex terminating between the nasals. These bones (ib. 15) are continued, separately, a short way forward below the nasal process of the premaxillary; but the median suture, penetrated by that process, is soon obliterated in the nasals, at least of *Mosasaurus Hoffmanni*. These are thus continued backward as a single bone slightly expanding; and they are notched to receive the antero-median points of the frontals, 11, each of which is continued forward a short way along the side of the nasal, contributing a small portion to the periphery of the external nostril, and is there interposed between the nasal (15) and maxillary (21); further back the frontal joins the prefrontal (14). There is no trace of this premaxillo-naso-frontal structure in *Ophidia*; it is a Lacertian characteristic; and the modification shown in *Mosasaurus* most nearly resembles that of the *Varanus* and *Monitor* amongst existing *Reptilia*.

Prof. Cope diagrammatically indicates the most instructive features of this lacertian characteristic in the Mosasaurians which he refers to his genera *Clidastes* and *Platecarpus* *; but he omits the sutures which in *Mosasaurus Hoffmanni* and *Mosasaurus Maximiliani* define the nasal bones.

The more perfect example of the skull of the latter North-American species affords satisfactory demonstration of this strong differential character as between the Lacertians and Ophidians.

The locality of this skull, as noted by its acquirer, brings it within the Cretaceous series of the United States. The internasal suture persists in *Leiodon anceps*, fig. 15.

§ 6. *The bony Palate.*—A State-officer in relation to the Indians of the Upper Missouri obtained the fossil at the "Big bend of the river, between Fort Lookout and Fort Pierre," and brought it to St. Louis, where it was noticed by Prince Maximilian of Neu-Wied †, in the officer's garden, and was presented to the Prince, who brought it over to Europe and deposited it in the Museum at Bonn. This specimen afforded the subject of Prof. Goldfuss's excellent monograph ‡, in which the components of the bony palate, not yielded by Cuvier's specimen, are supplied. The illustration of this structure in fig. 16 is founded on the text and plate viii. of Goldfuss.

The vomer (fig. 16, 13) is parial; each lateral portion is long and slender; they diverge posteriorly as in the *Monitor* §, before uniting, each by a similar angular suture, with the palatines.

* *Op. cit.* plate xxxviii.

† See his 'Reise in das Innere von Nordamerica,' Bd. i. p. 348.

‡ "Der Schädelbau des *Mosasaurus*," &c. in the Acta Acad. &c., above cited.

§ Cuvier, *tom. cit.* pl. xviii. fig. 3.

These bones (ib. 20) are edentulous. Each sends forward a slender process, *a*, to join the vomer; and the junction with the maxillary commences by a similar but shorter process. Between the two processes the fore part of the palatine is deeply emarginate to form the hind boundary of the palato-naris, *n*. The palatines do not join each other mesially; the intervomerine fissure is continued backward between them, as in the *Monitor*. In *Iguana tuberculata* * there is no intervomerine fissure; and a small interpalatine one is insulated from the interpterygoid fissure, *s*, by a second median suture continued to the junction with the pterygoids.

In the *Amblyrhynchus cristatus* it is interesting to find the linear fissure between the hind ends of the vomers (13) continued between the fore ends of the palatines (20), and thence gradually expanding to be continued into the interpterygoid vacuity. Thus the common median fissure, *m s*, shown in the Monitor and Mosasaur, fig. 16, is repeated in the marine Iguanian.

But here the palatal correspondence between the small existing and great extinct Lacertians ceases. The pterygoids, in *Mosasaurus*, (fig. 16, 24), approximate not far from their separate anterior beginnings, unite in the mid line and so close the interpterygoid part of the common fissure, *s m*; and this union continues to near the hind end of the dentigerous plate, where the pterygoids again recede to send off the long divergent processes, *t*, to abut against the tympanic. The number of teeth is 9 or 10 in each pterygoid. The processes for junction with the ectopterygoid and the pterapophysis of the basisphenoid are well shown in the outer and inner side views of the well-preserved pterygoid bones of the type skull figured by Cuvier†. But there is one significant connexion with an adjacent and peculiarly lacertian bone, shown in the *Mosasaurus Maximiliani* (fig. 18), which I will illustrate by a corresponding view of the skull of *Amblyrhynchus cristatus* (fig. 19).

In this figure, on the upper and outer surface of the pterygoid, 24, about midway between the two ends of the bone, there is a low eminence, *x*, excavated by a shallow pit in which is lodged the peculiar lacertian bone denominated, from its shape, "columella;" the upper end of this slender straight vertical pillar (fig. 19, *y*) abuts against and is firmly attached to the orbitosphenoid, or anterior continuation of the alisphenoid‡.

In the skull of *Mosasaurus Maximiliani* (fig. 18) a corresponding view of the pterygoid (ib. 24) shows the base of a slender, but broken, vertical pillar, *y*, ankylosed to a similar articular eminence, *x*. The "columella" of Cuvier is wanting in *Ophidia*, as in *Chelonia* and *Crocodilia*.

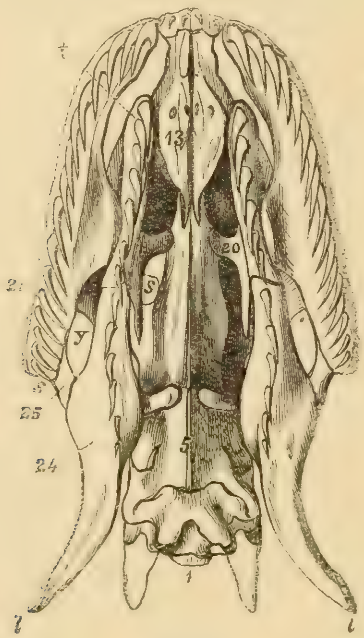
In general shape and proportions the pterygoid of *Mosasaurus* more resembles the pterygoid of *Hydrosaurus* than of *Amblyrhynchus*, but differs in the dentigerous character, in which the recent Sea-

* Cuv., *tom. cit.* pl. xviii. fig. 2, B.
† *Tom. cit.* pl. xviii. fig. 1, *k*, *l*, *m*.
‡ Cuv., *loc. cit.*

lizard (*Amblyrhynchus*) agrees with the rest of the *Iguanidæ* and some other Saurians.

The main distinction of the pterygoids in the great extinct Sea-lizard (fig. 16, 24) is their extensive median suture, by which these bones have their fixity more assured, and contribute a greater share to the roof of the mouth. It is probable that observation of this character may have led Prof. Cope to reject thedetermination by Cuvier of the pterygoid nature of these bones, and to propound their homology with the palatine bones of the *Reptilia*, and especially with those in *Ophidia* (fig. 17), in which these bones, 20, as well as the pterygoids, 24, support teeth.

Fig. 17.



Python.
The bony palate.

The narrow fore end of the ophidian pterygoid (fig. 17, 24) articulates by a squamous suture with the palatine (ib. 20); a similar suture attaches the low outer angle to the "transversal" or ectopterygoid, 25, and the opposite inner one to the pterapophysis of the basisphenoid. The elastic connecting tissue allows some yielding motion at all these joints. There is no trace of a columellar articular process on the upper part of the bone in any Ophidian, nor is there a trace of the "columella." The long hinder extension of the tympanic process, *l*, so characteristic of the pterygoid bone, is as well developed in *Ophidia* as it is in *Lacertilia*; but it is more bent in *Python* than in *Amblyrhynchus* or in *Mosasaurus.*

The true palatine bone in *Mosasaurus* (fig. 16, 20) is edentulous, as in all Lacertians; it is much smaller than the pterygoid; it contributes by a smooth, wide, anterior emargination to circumscribe, posteriorly, the palato-naris, *n*, and has the same connexion with the vomer, maxillary, and pterygoid as in *Amblyrhynchus*.

In *Ophidia* the palatines (fig. 17, 20), besides supporting teeth, have a narrow, elongate form, and seem to be a forward continuation of the pterygoids. They unite by a posterior narrow squamous suture with the pterygoid, 24, and send off a process from near the middle of the inner surface, which unites with the presphenoid; the anterior ends have a loosish ligamentous connexion with the vomerine bones, 13. In every particular in which the veritable palatines of the Mosasaurians differ from those of Serpents they agree with those of Lizards, and of the Monitors more especially. I may here note the many and characteristic vacuities in the palate of the *Python* (fig. 17); viz. the vomero-maxillary, *t*, the palatonarial, *n*, the interpalatal, the interpterygoid, *s*, *s′*, and the pterygomaxillary, *y*.

Cuvier, who appended views of the palate in an Iguana and a Monitor to elucidate the character of that part of the skull in *Mosasaurus*, tersely propounds the case as follows:—"Jusqu'ici l'animal de Maestricht seroit donc plus voisin des monitors que des autres sauriens; mais tout d'un coup nous trouvons dans ses os ptérygoïdiens un caractère qui l'en éloigne pour le porter vers les lézards proprement dits et les iguanes; ce sont les dents dont ces os sont armés qui constituent ce caractère."

Then, after noticing the absence of palatal teeth in the *Crocodilia* and several genera of *Lacertilia*, Cuvier proceeds:—"Les iguanes, les anolis, les lézards ordinaires, les marbrés et un certain nombre de scinques, parmi les sauriens, partagent seuls avec plusieurs serpens, batraciens et poissons cette armure singulière. Mais les iguanes et autres sauriens la portent aux ptérygoïdiens seulement; les serpens, aux palatins comme aux ptérygoïdiens; les grenouilles, les rainettes, les salamandres, aux vomers, les premières sur une ligne transversale, les autres sur une ligne longitudinale. Plusieurs poissons," &c.* But it is unnecessary to follow further the great palæontologist's exhaustive analysis. Suffice it that he hits the fact which distinguishes *Mosasaurus* from the *Ophidia*, and which unites it with the *Lacertilia*. The advocate for the sea-serpentism of the extinct Mosasauroids determines the pterygoids to be the palatines; and if so, the missing bones posterior to Prof. Cope's palatines might also have borne teeth, and thus the ground taken by Cuvier, in the sole comparison which he makes with serpents, would be cut away. But, irrespective of the obvious concordance of the bones figured by Prof. Cope as palatines with the unquestionable pterygoids of the specimen cited, and before me as I write, it is much more likely that the smaller, true, edentulous palatines should have escaped observation and collection than the larger and more posteriorly situated pterygoids; it is hardly conceivable that these should be missing in every one of the numerous and well-preserved specimens which the North-American Cretaceous series has afforded.

* *Tom. cit.* p. 322.

§ 7. *The Mandible.*—In the lower jaw of Lacertians (fig. 20) may be noted the following pieces in each ramus:—32, dentary; 33, splenial; 31′, coronoid; 29, articular; 30, angular; 31, surangular.

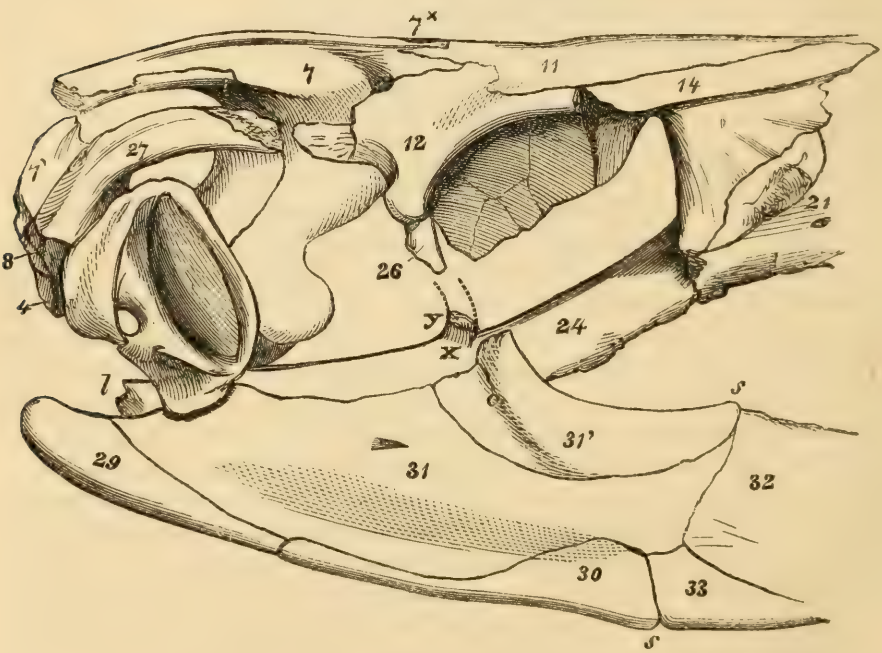
What is first noticeable in the connexions of these bones, in a comparison of *Lacertians* on the one hand with *Crocodilia* and *Chelonia*, and with *Ophidia* on the other hand, is the greater tendency in certain sutures to mark off an anterior half of the ramus, including the dentary, and splenial, from the posterior half; with this modification, that in the Iguanians (fig. 19) the coronoid piece, 31′, would go with the anterior division, and in the Monitors (fig. 20) with the posterior one.

The subvertical suture in *Amblyrhynchus* (fig. 19, *s*–*s*) runs from above downward, first between the surangular, 31, and coronoid, 31′; then between the surangular and the combined splenial 33, and dentary, 32.

In the Monitor (*Varanus niloticus*) (fig. 20) the subvertical suture, *s*–*s*, runs, first between the surangular, 31, and the dentary, 32; then between the angular, 30, and the combined dentary and splenial. A small part of the fore end of the coronoid, 31′, supplements the upper end of this subvertical suture.

In the *Mosasaurus* (fig. 18) this subvertical division, *s s*, of the

Fig. 18.



Mosasaurus.

ramus follows more closely the pattern of the Monitor than of the Iguanians. The chief modification is the formation of the lower part of the suture by the angular, 30, and splenial, 33, exclusive of the dentary, 32 ; but this unites with the surangular, 31, and a small part of the coronoid, 31′, as in the Monitors. In all these Lacertians the increasing thickness of the ramus toward its lower border augments the breadth of that part of the subvertical suture. But the sutural line, *s s*, in each instance describes a more or less zigzag or angular course, impeding transverse yielding or movement of the fore upon the hind half of the ramus.

Definition of the constituent elements is clear in the perfect mandibles of *Mosasaurus Hoffmanni* and *M. Maximiliani*, in which latter they bear the Cuvierian letters in Prof. Goldfuss's monograph*.

In the least-mutilated of the subsequently discovered American mandibular fossils, ascribed by Prof. Cope to his genus *Clidastes*†, the sutures, though the pieces they join are not lettered, are sufficiently traceable to afford sure ground of comparison with the Lacertian type of mandible on the one hand and the Ophidian type on the other. The vertical joint between the angular and splenial is unmistakably defined, and, with the indications of the other sutures, show, as in *Mosasaurus Maximiliani* (fig. 18) the Monitorial, not the Iguanian pattern.

All the portions of Mosasaurian mandibles which are figured by Prof. Cope‡, with literal references to the constituent pieces, afford ample means of deciding the affinities of the fossils in the Reptilian series, as such affinities are exemplified in this guiding part of the skull.

Of the bones of the Maestricht specimen described and figured by Cuvier (*tom. cit.*), and the type of the genus *Mosasaurus*, the most complete is the mandible. The notes and comparisons by the great palæontologist, by which the Lacertian affinities, as against the Crocodilian and Cetacean ones are illustrated, extend over three pages (319–322) ; they are a model for his successors. My additional evidences confirm (or, I should say, accord with), the characteristics assigned by Cuvier to the "mâchoire inférieure bien entier," from Maestricht § ; and there remains only, in relation to the present aim, to add a few comparisons of the Mosasaurian mandible with that in the *Ophidia*. In *Mosasaurus* (fig. 18) the tympanic articular surface is excavated chiefly in the surangular, 31, and is simply concave, corresponding to the convexity of the tympanic condyle.

In *Ophidia* (*Python*, fig. 21) the articular surface is excavated in the one bone, 31, formed by confluence of the articular, the angular, and the surangular elements : the surface is "ginglymoid," the transverse convexity equalling the longitudinal concavity.

The angular process is almost obsolete in *Python*, being repre–

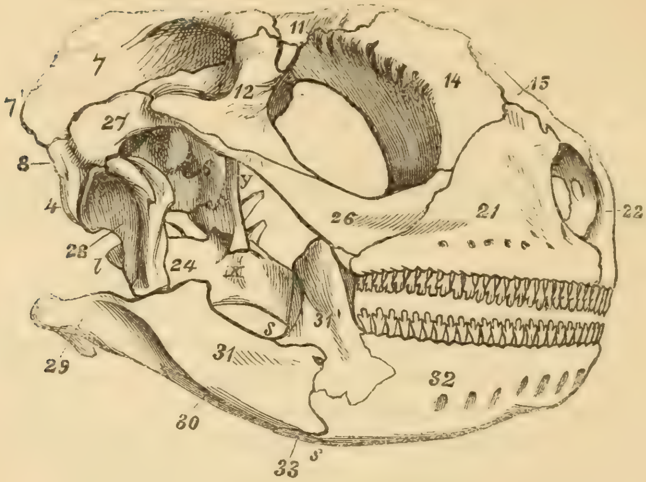
* *Op. cit.* Taf. vii.

† *Tom. cit.* pl. xiv. figs. 1 and 2.

‡ Plate xxii. figs. 3, 4 ; pl. xxvi. figs. 2, *a*, *b*, *c* ; pl. xxviii. fig. 2.

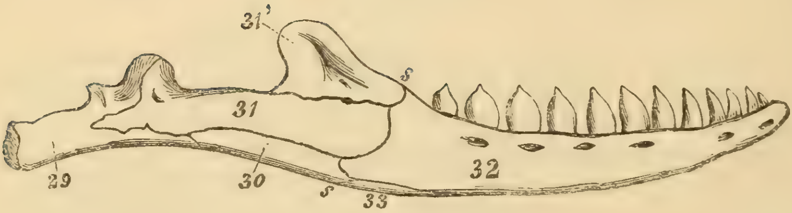
§ I have only to remark that, in pl. xviii. fig 1. the letter *x*, indicating the "surangular" in the *Monitor* (ib. fig. 5) and *Iguana* (fig. 6), is placed upon the "operculaire" (my "splenial") in the Mosasaur (fig. 1). The references (p. 321) to "figs. 2 et 3," should be to "figs. 4 et 5," in pl. xviii.

Fig. 19.



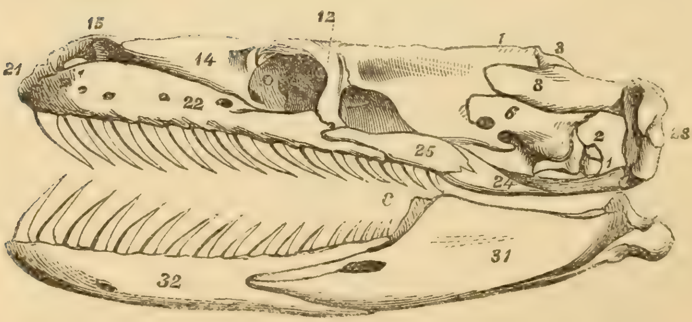
Amblyrhynchus.

Fig. 20.



Monitor.

Fig. 21.



Python.

sented by a mere tuberosity at the back of the articular surface. In *Mosasaurus* this process (fig. 18, 29) ("l'apophyse, *b*, pour le muscle analogue du digastrique," Cuv., p. 820) is relatively as well developed as in *Amblyrhynchus* (fig. 19, 29) and terminates, as in that Sea-lizard, subacutely; in *Monitor* (fig. 20, 29) it is longer, and terminates obtusely. In all these lacertians the process is developed from the "articular" element, not from that called "angulaire" by Cuvier.

The coronoid process is formed by the "coronoid element," 31′, in *Mosasaurus* as in *Monitor* and *Iguana*; in the Python it is an exogenous lamelliform process of the surangular plate of the angulo-surangular element; to the antero-internal part of this element the coronoid (fig. 21, *c*) is applied, slightly projecting in front of the coronoid process, and chiefly disposed, like the "splenial," to cover the groove at the postero-internal part of the dentary element.

The "splenial," 33, extends, in *Mosasaurus* (fig. 18) from the angular, 30, and surangular, 31, elements along the inner surface of the dentary to near the symphysis, as in the Monitor; in the Python it extends from the angular part of the angulo-surangular to the back part of the dentary, joining the "coronoid" plate above and not extending forward beyond that plate: the length of the entire splenial, here, is but one fourth that of the entire mandibular ramus. This small splenial plate in *Ophidia* is imperforate; in *Mosasaurus* it is perforate*, as in *Monitor* and *Iguana*. In *Python* the outer plate of the dentary (fig. 21, 32) is deeply notched behind by a long angular depression which receives a process of similar shape of the angulo-surangular element, 31. In *Mosasaurus*, as in *Monitor*, the outer plate of the dentary, 32, terminates in a subvertical line; this is curved in *Iguana*, less so in *Monitor*, still less in *Mosasaurus* †, where it seems to have suggested to Prof. Cope the idea of a movable articulation with the hinder part of the ramus: but the relative overlapping position of the mandibular elements, causing the angular break of the line *s s*, on the outer side of the ramus, and in a greater degree upon the inner surface of the ramus, must have as effectually opposed such flexion in *Mosasaurus* as is the case with Lacertians and, *a fortiori*, with Ophidians.

The movements of the mandible in serpents, and especially in Pythons and Boas, in relation to the engulfiing of large prey, are chiefly subserved by the absence of a "symphysis" or anterior articulation of the right and left branches of the mandible. These are here connected to one another by elastic ligaments.

In *Mosasaurus* the relative extent of the symphysial joint of the mandible is greater than in existing Lizards, in which the symphysis is completed by inelastic or unstretchable fibro-cartilage.

In *Mosasaurus Hoffmanni* the outer plate of the dentary is pierced by about a dozen holes in a regular longitudinal series. There are six or seven corresponding foramina in the *Monitor* (fig. 20), and

* "Il'y avoit une petite ouverture dans l'operculaire." *Tom. cit.*

† "Le sur-angulaire se joignant carrément avec le dentaire." *Tom. cit.* 321.

five to seven in *Iguana* and *Amblyrhynchus* (fig. 19); there is but one in the *Python* (fig. 21).

The argument which Prof. Cope derives from a study of the mandibular fossils of his Mosasaurians runs as follows:—

"Swallowing their prey entire, like snakes, they were without that wonderful expansibility of throat due in the latter to an arrangement of levers supporting the lower jaw. Instead of this, each half of that jaw was articulated or jointed at a point nearly midway between the ear and the chin. This was of the ball-and-socket type, and enabled the jaw to make an angle outward, and thus widen by much the space inclosed between it and its fellow"*.

My first impression in reading the above was that the right and left rami were meant by "each half of that jaw," and that the "ball-and-socket" joint related to the form of the tympano-mandibular articulation which differentiates the *Mosasaurus* from both existing Lizards and from Serpents. But at p. 122 Prof. Cope illustrates his meaning by a diagrammatic cut (fig. 4) which "shows the appearance of the normal flexure of the ramus," at the part, viz., which is marked *s s* in figures 18, 19, and 20, of the present communication.

§ 8. *Vertebræ.*—In testing the affinities of the *Mosasauridæ* by the characters of the vertebræ, I premise a brief notice of such in the largest of the existing Lizards which have marine habits, viz. the *Amblyrhynchus cristatus* † of the Chatham and Charles's Islands of the Galapagos group, in one of which the abundance of these lizards has given to an inlet which they frequent the name of "Iguana Cove."

The following are dimensions of the skeleton of an individual of the species under review:—

AMBLYRHYNCHUS (OREOCEPHALUS, *Gray*) CRISTATUS, *Bell.*

	ft.	in.	l.
Length of entire skeleton	4	4	0
,, skull		3	5
,, trunk (from occiput to sacrum)	1	3	6
,, sacrum		1	0
,, tail	2	8	0

Number of vertebræ 79, viz.:—

of the neck	4 ‡
of the dorso-lumbar region	20
of the sacrum	2
of the tail	53

* *Tom. cit.* p. 45.

† Bell in 'Zoology of the Beagle,' Reptiles, 23; also in 'Zool. Journal, vol. ii. p. 204, pl. 12. This species is called "*Oreocephalus cristatus*" by Gray, in his 'Catal. of Lizards,' 12mo, 1845, pp. xviii, xxv, & 189. Its osteology is well figured by Steindachner, 'Die Schlangen und Eidechsen der Galapagos-Inseln,' p. 303, taf. iii.–vii., and in 'Zeitschrift zur Feier des fünfundzwanzigjährigen Bestehens der k.-k. zoologisch-botanischen Gesellschaft in Wien,' 4to, 1876.

‡ Those, viz., without free pleurapophyses.

The anterior hypapophysis of the atlas forms the lower third of the cup for the occipital condyle, the two upper thirds being modified præzygapophyses of the neural arch. A short thick diapophysis projects behind the præzygapophysis, and a small tubercle from the outside of the base of the postzygapophysis. The neurapophyses are confluent by their apices, without developing a spine. The centrum of the atlas (" odontoid process ") sends downward and backward a longish compressed posterior hypapophysis; the anterior one has more fore-and-aft extent, and is in the form of a vertical plate or keel.

The axis and four following vertebræ have each a hypapophysis not confluent with the centrum, but articulated to a projection from the hinder border, so as to seem wedged into the interspace between its own and the next vertebra.

The fifth vertebra, counting from the occiput, has free pleurapophyses; and these elements are present and free in the succeeding vertebræ, to the sacrum. They then suddenly gain thickness, with more length in the first sacral, and are confluent with the diapophyses. The ilium is a similarly thickened homotype, or " serial homologue," of the second portion of the fully developed thoracic costal arch; and the pubis is a similarly modified homotype of the hæmapophysis, sternal rib, or costal cartilage of the type thoracic segments.

The completion of the arch by the latter element occurs in the ninth vertebra, and ceases at the sixteenth, which is followed by eight vertebræ with pleurapophyses only. The transverse process of the first and ten following caudal vertebræ is as long as the di-pleurapophysis of the last trunk-vertebra, and includes the same elements coalesced. The diapophyses disappear at the twenty-first caudal vertebra. The hæmal arch shows the usual type of " chevron bone," with a spine equalling the neural one above.

The hæmapophyses articulate to tubercles at the back part of their centrum, and leave no articular mark on the fore part of the following centrum; but their base extends over the intervertebral space.

The main vertebral character by which the existing Sea-lizards (*Amblyrhynchus*) differ from the terrestrial or arboreal Iguanians * is in the absence of zygosphene and zygantrum, and the limitation of the articular processes of the neural arch to the normal præ- and post-zygapophyses; according to the rule of the Lacertian order.

And here we gain another capital test of the affinities of the Mosasaurians. In the posthumous edition of Cuvier's ' Leçons d'Anat. Comparée,' the editors added the fact that in the vertebræ of Ophidians the articular processes were double, the superadded pairs being situated internal to the normal ones, and at the base of the spinous process †.

* Anat. of Vertebrates, vol. i. p. 57, fig. 48, "trunk-vertebra of *Iguana tuberculata*.

† " Les apophyses articulaires sont doubles; les unes extérieures, représentant les apophyses articulaires ordinaires à facettes horizontales; les secondes intérieures sont situées à la base de l'apophyse épineuse." Vol. i. 8vo, 1835, p. 216.

This character materially aided in the determination of the Ophidian nature of the Eocene vertebræ described in the 'Transactions of the Geological Society,' vol. vi. 2nd Series, 1839, p. 209, pl. xxii.; and the character in question is again illustrated in the 'Proceedings' of the Society for January 7th, 1857, p. 196, pl. iv., in the extinct genera *Palæophis* and *Laophis*, and in the existing genera *Python*, *Coluber*, and *Crotalus*. By virtue of these superadded processes (zygosphene and zygantrum) the vertebræ interlock by a double "tenon-and-mortice" joint.

In the course of the comparisons for determining the fossil vertebræ submitted to me from the Eocene clay of Sheppey and Bracklesham *, and from an undetermined Tertiary formation at Salonica, I came upon a similar complexity in the arboreal or terrestrial lizards of the genera *Iguana* and *Metopoceros*; and to this day they form, as far as my examinations have extended, the sole exceptions in the Lacertian order. It was with much interest therefore that I availed myself of the opportunity of examining the vertebral characters of the great marine Iguanian lizard of the Galapagos Islands, in the specimen from Iguana Cove, Charles's Island, presented to the British Museum by Commander Cookson, R.N. The dimensions of the skeleton are given above. Its vertebræ differ from those of *Iguana* proper, and retain the simplicity of articulations common, with the exceptions noted, to all Lizards. I know of no exceptions to the rule of the complexity of the vertebral articulations in *Ophidia*, unless *Mosasaurus* be shown by this character to be a a great sea-serpent.

But then it might be objected, if vertebræ of any mosasaurian species should show the zygosphene and zygantrum or their rudiments, that these would exemplify, like the pterygoid teeth, the affinity of such exceptional species to the Iguanian Lizards.

In *Amblyrhynchus* and most other Lacertians the neurapophyses of the atlas touch each other above by a small surface, and then, commonly, coalesce. In *Mosasaurus* they appear to retain their individuality, at least in the fossils. The neurapophyses narrowing to a blunt point above have been found ununited there, and usually pushed or fallen asunder, as in the specimen of *Mosasaurus Hoffmanni* figured by Hoffmann and Cuvier (*tom. cit.* pl. xx. fig. 14, *a a*). Cuvier conjectured that the upper interspace might have been closed by a distinct piece (flattened neural spine), as in *Crocodilia*; but no part answering to this was in the Breda collection, nor has been recognized in the American specimens. In the latter, as in the Maestricht fossils, the atlantal neurapophyses are ununited above †.

Python differs from *Amblyrhynchus* and *Hydrosaurus* in the much

* Monograph on the *Crocodilia* and *Ophidia* of the London Clay, p. 53, pl. xiii. figs. 33, 36, vol. of Paleontographical Society for 1850.

† Prof. Cope writes:—"The atlas consists of a basal and two lateral pieces only" (*op. cit.* p. 114). And again (p. 122):—"The atlas consists of the three pieces, the basal and two lateral." He does not notice the differential character in *Python*, nor recognize, as Camper rightly did, the odontoid process as the body of the atlas (comp. Cuvier, *loc. cit.* p. 330).

greater expanse of the upper ends of the atlantal neurapophyses, which unite by bone to form a broad subquadrate platform above the neural canal *. I have not seen this character of the atlas in any Lacertian. Save in the non-union of the apices of the neurapophyses, *Mosasaurus* agrees closely in the type of its atlas vertebra with that order of *Reptilia*.

Beyond the axis, the vertebræ in most *Lacertilia* offer well-marked modifications. Those with the diapophyses and with a hypapophysis wedged into the lower part of the interspace between this centrum and that of the next vertebra are, in *Amblyrhynchus*, two in number; then comes a vertebra with a pleurapophysis projecting freely from the end of the diapophysis; and the centrum continues to show the hypapophysial pit upon both the fore and hind part of its under surface. At the fourth vertebra from the axis the hind pit disappears, the pleurapophysis elongates; at the seventh vertebra from the axis the pleurapophysis is connected, through a hæmapophysis, with the sternum. If this vertebra be reckoned the first dorsal, then *Amblyrhynchus* has eight cervicals; if the foremost vertebra with free pleurapophyses is the first dorsal, then this Sea-lizard has but four cervicals.

There are eight vertebræ which may be called "typical" in having their hæmal arch complete; and in these it is to be noted that the partially ossified portion of the rib is in two parts, or formed by a transversely divided hæmapophysis. Then follow the eight vertebræ with progressively shortening pleurapophyses, terminated each by a free cartilaginous portion. Not any of the trunk-vertebræ beyond the sixth, including the atlas and axis, has a hypapophysis.

In *Ophidia* the hypapophysis is exogenous. In *Python tigris*, with 291 vertebræ, such inferior process (fig. 24, *hy*) is present in the 74 anterior vertebræ. In *Boa constrictor*, with 305 vertebræ, a hypapophysis is developed in the 60 anterior ones. In *Crotalus horridus*, with 194 vertebræ, 168 develop hypapophyses as long as the neural spines, and all these vertebræ support movable ribs. In *Naia* there are as many vertebræ similarly characterized. The presence of the long hypapophysis in the dorsal vertebræ of *Laophis crotaloides* supported the conjecture that it might belong to the poisonous section of *Ophidia* †.

Passing over the two sacral vertebræ of *Amblyrhynchus*, we then come to the caudals, in which the character and position of the hæmal arch has already been indicated.

In *Ophidia* the tail-vertebræ have not the freely jointed hæmal arch with the concomitant pits or articular surfaces. In *Python* the caudal hypapophyses form a transverse pair confluent with the centrum above, descending parallel to each other, and terminating freely and apart below. The transition from the single hypapophysis of the trunk-vertebræ is made by the bifurcation of the tubercle to which the hypapophysis is reduced in the hinder abdominal vertebræ

* Monogr. *Crocodilia* & *Ophidia*, Palæontographical vol. for 1850, pl. xiv. figs. 38, 39.

† Quart. Journ. Geol. Soc. vol. xix. p. 197, pl. iv. fig. 3.

of *Python*; and the pair of tubercles rapidly elongate in the caudal series to the proportions shown in figure 42 of plate xix. of the above-cited Monograph. Moreover, in certain anterior caudals of *Python regius*, the di-pleurapophysis is bifurcate (fig. 41, pl. xix., Monogr. cit.). 62 out of the 70 caudal vertebræ of *Python tigris* have each the pair of parallel exogenous hypapophyses.

In *Coluber natrix* hypapophyses exist upon all the vertebræ, of which there are 170 of the neck and trunk, and 40 caudal; in no Ophidian have I found a chevron-bone.

Thus there are well-marked characters distinguishing the Ophidian from the Lacertian vertebræ, which should be brought to bear upon the question of the affinities of the Mosasaurians.

The latter, as is well known, agree with both orders and with procœlian crocodiles in having the fore surface of the centrum concave, the hind one convex. The two vertebræ which follow the axis have a single hypapophysis (fig. 23, *hy*) the terminal portion of which (*hs*) is distinct, seemingly in the state of an epiphysis. Cuvier's figure 1, pl. xix., shows the rough concave surface of this single hypapophysis, to which the free portion * was attached; thus a smaller portion of the hypapophsis is free than in *Amblyrhynchus*, no portion being free in *Python* or other serpents. Beyond the fifth of the anterior vertebræ, including axis and atlas, in *Mosasaurus*, the hypapophysis, after becoming reduced in size, disappears, and is not again developed †.

The diapophysis, in certain trunk-vertebræ, shows a terminal surface for the rib. Prof. Cope, in his restoration of a *Mosasaurus* (pl. lv.), gives it 37 pairs of ribs, all terminating freely, as in *Ophidia*. But I do not find the authority for this in the special descriptions of the fossils described by him *in situ* ‡.

The diapophyses, in *Mosasaurus Hoffmanni*, decrease in vertical extent as the vertebræ recede from the neck, and lose, at an undetermined part of the trunk-series, their zygapophyses; the centrums also lose in length. The diapophyses exchange their vertical for transverse breadth, and gain in length, apparently in the part of the trunk where the free pleurapophyses cease; and here, in *M. Hoffmanni*, the centrum assumes a triangular form. In the tail, where a hæmal arch (chevron bone) is articulated, as in *Amblyrhynchus*, to a pair of hypapophyses near the hind surface, and coexists with diapophyses, the centrum becomes pentagonal; where the diapophyses disappear and the spine of the hæmal arch is prolonged, the centrum becomes vertically ovate; further back the hæmal arch coalesces with the centrum; its spine is grooved in front, and exceeds in length the neural arch and spine (Cuv. pl. xix. fig. 6), but it gradually shortens and finally disappears; the centrum with a small

* A homologue of hæmal spine articulating to a hypapophysis.

† Prof. Cope states that "the dorsals have no hypapophysis" (p. 123), in which distinction from Ophidians his supplementary species of Mosasaurians agree with the type species.

‡ He admits:—"I do not possess any specimen with complete vertebral column" (p. 124).

coalesced neural arch represents at last the entire vertebra. All these modifications, shown in the plates of Cuvier and Goldfuss, are repeated in the figures of the vertebræ of Mosasaurians in plates xviii., xix., xx., xxi., xxiii., xxiv., xxvi., xxvii., xxix., xxx., xxxiv., and xxxv. of Prof. Cope's great work; in every figure the zygosphene and zygantrum are absent.

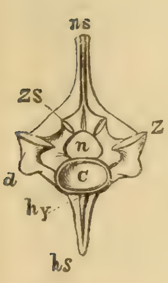
In most of these characters the Mosasaurians retain the type of the Lacertian vertebræ, and especially of the existing marine kinds. Where the Mosasaurian vertebræ depart from that type, the characters are peculiar to the extinct group. In no genus are Ophidian modifications manifested. In the speedy loss of the zygapophyses there is a Cetacean analogy; but it is adaptive, in relation to the locomotion of the great Sea-lizard.

A few words on a character which Prof. Cope assigns to his genus *Clidastes*, viz.:—"the vertebræ united by the zygosphenal as well as the usual articulation; the zygosphene elevated but little above the plane of the zygapophyses"*.

In the plates xviii. and xxiii. given to the vertebræ of the species *stenops* and *planifrons*, the parts and processes are, as usual, not indicated. In plate xiii. of the 'Monograph of the Fossil Reptilia of the London Clay' (Palæontographical volume for 1850), the zygosphene in *Python* and *Iguana* is marked *zs*, and the zygantrum *za*.

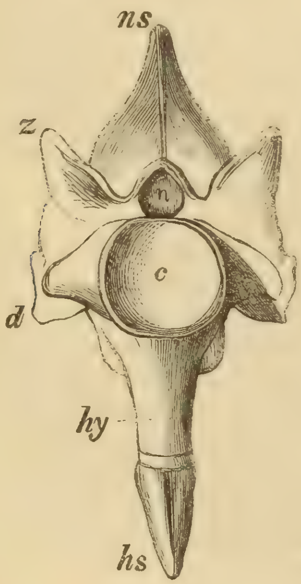
I subjoin a figure (fig. 23) of, apparently, the best-preserved vertebra

Fig. 22.



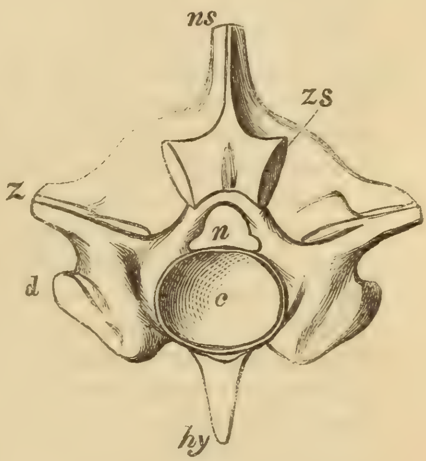
Iguana.

Fig. 23.



Clidastes.

Fig. 24.



Python.

of *Clidastes stenops* (Cope, pl. xviii. fig. 4*a*), and corresponding figures

* *Op. cit.* p. 130. If Prof. Cope could spare me, out of his abundance of pythonomorphous vertebræ, one which has the zygosphene and zygantrum, I will, with pleasure, acknowledge and figure the structure, and give such vertebra a prominent position in our Mosasaurian cabinet.

of a vertebra from the same (fore) part of the spinal column in an *Iguana* (fig. 22) and a *Python* (fig. 24). In the two latter the parts are symbolized by the same letters as in the monograph above cited, viz. :—*c*, centrum (anterior surface or cup); *n*, neural canal; *d*, diapophysis; *z*, præzygapophsis; *zs*, zygosphene; *n s*, neural spine; *hy*, hypapophysis, with, in the Lacertian (fig. 22), the autogenous appendage marked *hs*, as representing a hæmal spine. The corresponding letters are added to the homologous parts in the figure (fig. 23) from Cope; but I find no place for *zs* in that figure.

As the absence of a sacrum does not affect the Mammalian grade of the *Sirenia* and *Cetacea*, so neither does it the Lacertian nature of the Mosasaurians. That negative character is of as little value in an advocacy of the Ophidian affinities of the Ichthyo- or Plesiosaurians, as of the same affinities of the Mosasaurians.

§ 9. *Limbs*.—The determinations by Cuvier of certain bones and portions of bone in the original Camperian collection of remains of the Maestricht Mosasaur as scapula, coracoid, pubis, antibrachial, carpal, and phalangeal bones *, established the capital fact that it was a reptile with both scapular and pelvic arches, and their appended limbs. Evidence had been obtained at the date of the 'Bridgewater Treatises' to enable Buckland to define these limbs as "flippers," like those of the Plesiosaur.

The subsequent discoveries of Professors Cope † and Marsh ‡ have confirmed these determinations, and extended our knowledge of the nature of the limbs as natatory ones, and with phalanges manifesting the proportions of those of the Plesiosaurs and sea-Chelonians rather than of the Ichthyosaurs. But the number of digits in each limb and of the phalanges in each digit remain to be determined.

Sternal or episternal elements of the scapular arch seem not to have been recognized in the American series of fossils; but ample evidence has been secured of those parts of the frame of the Mosasaurians which bear decisively on the question of their rank, position, and affinities in the Reptilian class.

Professor Cope, in support of his proposition that the Mosasauroids "present more points of affinity to the serpents than does any other order" §, on which proposition he founds his name *Pythonomorpha*, accepts the fact of their well-developed limbs by the following remark :—"As there are many *Lacertilia* without limbs and some serpents with them, their presence in this order is irrelevant in this connection, especially as the arches supporting them are most like those of Tortoises and Plesiosaurs" ‖. But supposing, which is not the case, that the scapula of *Mosasaurus* was like that of a Tortoise or a Plesiosaur, Serpents have not got such scapula or any other element of the limb-bearing arches.

* *Tom. cit.* p. 336. pls. xix., xx.

† Proceedings of the Boston Society of Natural History, January 1869, p. 250 (scapular arch and fore limb).

‡ American Journal of Science and Art, June 1871, p. 472 (pelvis and hind limbs).

§ *Op. cit.* p. 126.

‖ *Ibid.* p. 115.

As to the "many *Lacertilia* without limbs," the facts are as follows:—

In 344 genera of *Lacertilia*, scapular and pelvic arches with well-developed digitate fore and hind limbs are present and functional in locomotion: in about 23 genera, the limbs are so reduced in size as to take little if any share in active locomotion; still they are limbs, are conspicuous in most of these as such, and do not need dissection to demonstrate them. The genera where they may be termed rudiments are extremely few. The limbs are very short in *Chalcis* and *Sauropus*; but there they are, and attached, moreover, respectively to a scapular arch and to a pelvic arch. The fore pair may be inconspicuous or wanting, as in *Pseudopus*; but the scapular arch is there, and the diminutive hind limbs have their pelvic arch. Both arches, moreover, are represented in Lacertians (*Anguis*, *Aprasia*, *e. g.*), where the limb appendages are gone.

How stands the statement that some Serpents have limbs?

In certain *Ophidia* dissection has revealed a small styliform bone on each side the cloaca; in a few it is tipped with horn in the shape of a claw; this is externally conspicuous in *Python*, and is serviceable, where so developed, in the act of coition. Whether these appendages to the generative parts be homologous with the "claspers" of sharks, or with the ventral fins, and if the latter, with the hind limbs of Lizards, is yet an open question *.

But as unquestionable fore and hind limbs are the rule in *Lacertilia*, and the questionable and outwardly visible rudiments of the hind pair are exceptional in *Ophidia*, the presence of both a fore pair and hind pair of limbs in the Mosasauroids is relevant, and will so be held, to the problem of the nature and affinities of those marine *Reptilia*.

§ 10. *Teeth.*—Prof. Cope, in his characters of *Pythonomorpha*, gives, as the 17th:—"The teeth possess no true roots" †. In the subsequent descriptive expansion of this character, he writes:—"The crowns are covered with enamel, and their forms indicate the carnivorous habits of these reptiles" ‡.

The teeth of Mosasauroids have an enamelled crown and cement-clad root. The enamel develops a pair of opposite low ridges which are minutely crenate: the crenation becomes abraded at the apical part of used teeth, but is demonstrated in unworn and unextricated crowns. Many Saurians, both Crocodilian and Lacertian, show the creno-bicarinate character; but no Ophidian does. I do not dwell upon the formal differences between the Mosasauroids and Ophidians in the proportions of length, breadth, and thickness of the dental crown, the structural difference being more decisive. The speedy confluence of the radical cement with the surrounding bone, and the thickness of the osseous mass so resulting and forming the broad conical base of the tooth, are features of resemblance to the Lacertians called "acrodont;" but the way and degree in which the

* "Some cold-blooded vertebrates, *e. g.* Murænoids and Ophidians, have neither fore nor hind limbs."—*Anat. of Vertebrates*, vol. i. p. 179.

† *Op. cit.* p. 114. ‡ *Op. cit.* p. 116.

acrodont character is developed in the dentition of the Mosasauroids are a family characteristic. The root, as well as crown, is developed before the successional tooth is extricated or protruded. Camper observed and rightly noted this fact: "A small secondary tooth is formed complete with its enamel and solid root in the osseous substance of the temporary tooth."

§ 11. *Skin.*—In the 'American Journal of Science and Arts,' April, 1872, Prof. Marsh announced his discovery of fossilized dermal scutes in Mosasauroid reptiles; their preservation in a petrified state implies their osseous basis; and their imbricate arrangement and dimensions are noted. The epidermal layer which they probably supported would add to their thickness. This discovery adds an important element in determining the affinities of *Mosasaurus*, especially within the limits of the present inquiry. The scales in certain *Lacertilia* have a bony basis. In all *Ophidia* they are epidermal only, and unfossilizable.

§ 12. *Conclusion.*—The foregoing comparisons lead to a retrospective glance at the period when any evidence of the extreme modification of the Reptilian type to which the term "ophidian" can be intelligibly given, has been recognized.

I am not cognizant of such prior to the Tertiary epoch. There are indications of anguiform Saurians in the lithographic slates; and the *Dolichosaurus* * of the Chalk shows a number of trunk-vertebræ equalling those of the snake-like Lacertians (*Pseudopus*, *Ophisaurus*, *e. g.*); but genuine ophidian characters are wanting. They were first made known to the writer by the vertebræ of *Palæophis* from the London and Bracklesham clays.

Characters which have been noted as lacertian modifications of the Reptilian class begin to appear pretty early in the series:—the parial hypapophyses of the basioccipital † for example; the bony connexion of the paroccipital with the exoccipital, forming the long and strong beam of bone extending from the side of the occiput to abut against the mastoid and tympanic ‡; the posterior bifurcation of the parietal, the prongs of which diverge and support the mastoids §; the foramen parietale ||; the length, slenderness, and elevated position of the zygoma, the fore pier of which arch is formed by both maxillary and postfrontal, and the hind pier by the mastoid and upper end of the tympanic ¶: all these cranial characters are combined with those of the theriodont and anomodont orders in the

* Dixon's 'Geology of Sussex,' &c., 1850, p. 389.

† *Dicynodon lacerticeps*, 'Descriptive and Illustrated Catalogue of the Fossil Reptilia of South Africa,' 1876, pl. xxiii. fig. 3, 1′, 1′; *D. leoniceps*, ibid. pl. xxvi. fig. 2, 1′, 1′.

‡ *Ptychognathus*, ibid. pl. xlvi. figs. 1 & 2, 2, 4.

§ *Oudenodon*, ibid. pl. lx. fig. 2, 7, 8.

|| *Galesaurus*, ibid. pl. xviii. fig. 8, 7′. Cuvier notes a Liassic instance of this character in his classical chapter on the *Mosasaurus*:—"On doit remarquer un trou qui est naturellement percé dans le pariétal à peu près vers le milieu, et qui se retrouvera dans beaucoup d'autres sauriens, et jusque dans l'*Ichthyosaurus*." —*Tom. cit.* p. 257.

¶ *Oudenodon*, ibid. pl. lx. fig. 1, 21, 12, 26, 27, 8, 28.

Triassic Reptilia of South Africa. Some of these now lacertian peculiarities, combined with ichthyo- and plesio-saurian ones, are carried on to Cretaceous times. Between the orders manifesting such combinations and the Mosasaurians, links are, indeed, still wanting; but so much as is now known, fragmentarily, of the Cretaceous *Polyptychodon*, indicates one of the transitional steps. The portion of skull, at least, which is figured in t. iv. fig. 1 of the Monograph of Cretaceous Reptilia, in the volume of the Palæontographical Society for 1860, shows the lacertian hinder bifurcation of the parietal, the articulation of the long prongs with the mastoids, and of the mastoid with the posterior part of the long, upper, slender zygomatic arch. The foramen parietale, moreover, is exhibited, and under the Amblyrhynchian modification, viz. its perforation at the suture between the parietal and frontal bones.

In not one of the steps by which, in those old and more or less generalized reptilian forms, purely lacertian are associated with crocodilian or chelonian characters, and with others that have passed away, is there a single strictly or truly ophidian modification. I have sought for such in vain in the evidences of the Mosasaurians, where the lacertian characters predominate; and when these are departed from, as in the simplification of the neural arch through loss of the zygapophyses, in vertebræ beyond the middle of the trunk, the great Cretaceous Sea-lizard looks whaleward rather than snakeward.

If I were to hazard a guess as to any antecedent form leading toward the earliest certainly known *Ophidian*, viz. the pythonic and perhaps marine forms of the Eocene period, it would be the *Dolichosaurus* of the white Chalk of Kent that would suggest itself. In this extinct form as many as 57 vertebræ appear to have intervened between the skull and the sacrum. But the sacrum exists, and there are likewise scapulæ and humeri. The vertebræ, moreover, as in *Mosasaurus*, retain the lacertian character of zygapophyses and of the absence of the hypapophysis in the anterior and succeeding trunk-vertebræ.

No true ophidian characters have been found in any fossils indicative of a serpent exceeding in size the largest of the Constrictors; and these existing giants of the ophidian order are terrestrial. The average length of the existing Sea-serpents (Hydrophidæ) is 3 feet; and the experienced herpetologist, Dr. Günther, F.R.S., informs me that he has seen no specimen of the family which exceeded 8 feet in total length.

But the Lacertian modification of the reptilian class continued to be represented as lately as the drift-period in Australia by a genus (*Megalania*) * of which I have now before me dorsal vertebræ measuring 5 inches 2 lines in transverse diameter, 5 inches 9 lines in vertical diameter. A comparison of such vertebræ with the ad-

* Phil. Trans. 1858, p. 43, pl. vii.
† *Op. cit.* pp. 135 and 137.

measurements given by Prof. Cope of a dorsal vertebra of his *Clidastes planifrons*, which he calls "a large species," is in favour of the quaternary lizard :—

Admeasurements of Trunk-vertebræ.

	Clidastes.	*Megalania.*	*Palæophis.*
Length of a median dorsal centrum...............	0·072	0·090	0·032
Width of the ball of a median dorsal centrum...	0·048	0·060	0·010
Depth " " " " " ...	0·040	0·048	0·009

Megalania, like *Amblyrhynchus*, may have been a lizard of aquatic habits ; but evidence of the limbs has not yet been obtained.

Thus *Mosasaurus*, as a Lacertian, is represented by a successor of similar dimensions; as an Ophidian it has shrunk to the insignificant proportions indicated in the preceding Table, unless the "great sea-serpent" of our newspapers should establish its claims for admittance into the scientific catalogue.

But size, of course, is no criterion of affinity; and if a marine animal, scientifically entitled to be called "serpent" should be discovered of a size surpassing the hugest *Mosasaur*, it would not affect the Cuvierian determination of the great Sea-lizard of the Cretaceous period.

To what are such forms as the Pliosaur and Geosaur tending or pointing, from their upper Jurassic scene of life? To the special Ophidian or the special Lacertian modification of their cold-blooded class?

Hardly to the Serpents; for these are themselves plainly modifications of an already specialized Lacertian group; they are a still more specialized offshoot from the common Saurian stem. We trace the transition, or recognize signs of such passage in *Pseudopus*, *Anguis*, &c.

The nearest of kin to the *Geosaurus* of the Lower Kimmeridge of Monheim, and to the *Leiodon* of the Upper Kimmeridge or Portlandian Marls of Portel, are the Mosasaurians of the Chalk.

These Reptiles plainly mark a progress to a more specialized Saurian type, which prevails in the present life-world under the manifold modifications of the great Lacertian order.

While retaining the marine habits and mode of motion of the Pliosaurs and Polyptychodonts, the Mosasaurians show not a single step toward the further and extremer modifications exemplified in the probably marine and unequivocal Ophidian genera of the Eocene period.

To call the Maestricht reptile a "Pythonomorph" is to raise a delusive beacon, misguiding the voyager in the discovery of the true course of organic change. When the Mosasaurians "tempested the ocean" the time of the sea-snakes had not yet come.

Professor Cope, rejecting the determination deduced from the facts submitted, affirms (after a summary of the characters which he ascribes to the osseous and dental systems of his *Pythonomorpha*) "that they possess more affinity to the serpents than does any other order"*.

To this I respond that the fossil evidences of the Mosasaurians hitherto made known do not yield a single character peculiar to and characteristic of the Ophidian order.

In the single occipital condyle and the composite structure of the mandible the Mosasaurians are *Reptilian*; in the procœlian vertebræ they accord with the existing representatives of the class; in the double occipital hypapophyses, in the bifurcate and perforate parietal, in the columella, in the composite formation of the suspensory joint of the tympanic, in the type of the tympanic, in the frame of the parial nostrils, in the composition of the mandible, and in the structure and attachment of the teeth they are *Lacertian*; in one special dental modification they are *Iguanian*; in another they are *Monitorial*. In the broad cemental basis of the enamelled tooth, in the more extensive fixation of the pterygoids and ossification of the roof of the mouth, in the large proportion of the vertebral column devoid of zygapophyses, in the confluence of the hæmal arch with the centrum of certain of the caudal vertebræ, in the natatory character of the fore and hind limbs they are—what they are—viz. *Mosasaurian*.

Are they entitled, through the last category of modifications, to the rank of an order in the reptilian class?

The order Lacertilia, in the class Reptilia, is a taxonomic equivalent of the order Carnivora or Feræ in the mammalian class.

In the Feræ there is a group which, by modifications of the skull, teeth, vertebræ, and, especially, limbs, takes rank as a suborder or subordinate group, viz. the Pinnipedia or Phocidæ. I estimate the Mosasaurians in the Lacertian order to be equivalent to the Seals in the Ferine order; and I concur with the judicious and experienced palæontologist Paul Gervais in correlating his group Mosasauridæ, in the Lacertian order, as to taxonomic value, with his Iguanodontidæ and Megalosauridæ in the Dinosaurian order †.

In conclusion, I may confess that I should hardly have been moved to trouble the Society with facts so familiar to my palæontological colleagues had it not been for a stray reference to "*Pythonomorpha*" in the excellent "Address" to which we listened at the last Anniversary with so much pleasure, from our esteemed and accomplished President.

* *Op. cit.* p. 126.

† "Ces genres et plusieurs autres qui l'en rapprochent, paraissent constituer trois familles distinctes, toutes absolument étrangères aux faunes post-cretacées, et que je distingue par les noms de *Mosasauridæ*, *Megalosauridæ*, et *Iguanodontidæ*."—*Extrait des Comptes Rendus des séances de l'Académie des Sciences*, tom. xxxvi, séances des 28 fevrier et 14 mars, 1853, p. 5.

37. *On the* Vertebral Column *and* Pelvic Bones *of* Pliosaurus Evansi (Seeley), *from the* Oxford Clay *of* St. Neotts, *in the* Woodwardian Museum *of the* University *of* Cambridge. By Harry Govier Seeley, F.L.S., Esq., F.G.S., &c., Professor of Geography in King's College, London. (Read March 7, 1877.)

Knowing how many Plesiosaurian genera have left their remains in the great Pelolithic system formed by the Oxford Clay, Ampthill Clay, and Kimmeridge Clay, and that triangular teeth have not been obtained from the Oxford Clay of St. Neotts, some amount of indecision may be justifiable in the generic determination of this species. Nevertheless the cervical and dorsal vertebræ closely resemble in typical characters those of Pliosaurs from the Kimmeridge Clay; and I do not detect in them or in the pelvic bones indications of approximation to the known characters of any other genus.

The remains are from the well-known pit in the lower part of the Oxford Clay at Eynsbury, near St. Neotts, which yields *Ammonites Duncani*, *A. Lamberti*, *A. coronatus*, &c. They comprise thirty-seven vertebræ in sequence, of which twenty are cervical and about sixteen dorsal; and there is one pubic bone and one ischium. But the vertebral bones were obtained at a former period, and the pelvic bones after an interval of some years. We owe the discovery and preservation of these fossils to J. J. Evans, Esq., of St. Neotts, who presented them to the University of Cambridge: and it is in honour of the discoverer that I propose the species should be named.

The Atlas and Axis (figs. 1, 2).

These vertebræ, though in close contact, do not appear to have been ankylosed together. They have lost their neural arches, like all other Pliosaurian vertebræ. A large subvertebral wedge-bone beneath the atlas (*c*) projects forward to form the lower half of the atlantal cup; and behind this, so as to be continuous with it, was a second subvertebral wedge-bone, lost before fossilization, which reached backward to within $\frac{5}{8}$ of an inch of the posterior border of the axis. The extreme length of the two centrums along the neural canal is $3\frac{1}{8}$ inches, each vertebra measuring about $1\frac{1}{2}$ inch, while they are parted by an interspace of $\frac{1}{8}$ inch. The antero-posterior extent of the basal border to the margin of the anterior wedge-bone is 4 inches, of which the wedge-bone occupies $1\frac{3}{4}$ inch. This wedge-bone has its anterior outline convex; and its posterior margin, which is subparallel, is gently concave. The extreme transverse measurement of the bone is $2\frac{5}{8}$ inches. Externally (that is, inferiorly) it is convex from side to side, and slightly convex from front to back: it has a small median posterior eminence, and a prominence where it terminates on each side. The superior or atlantal surface of the wedge-bone is deeply concave from side to side, nearly flat from within outward, with the articular surface directed outward and downward so as to meet the inferior external surface in a rounded border. Its antero-posterior extent in the middle is $1\frac{1}{8}$ inch, but becomes less laterally. The line in which it joins the atlas is concave, but is in a vertical plane.

On each side the wedge bone terminates superiorly in a flattened triangular surface, to which were attached the bases of the neural-arch elements. The neural-arch bones are not preserved. Each had a broad union with the atlas, which widens laterally (*b*, fig. 2) from $\frac{3}{4}$ inch below to the entire width of the centrum superiorly. These surfaces look obliquely outward, forward, and upward, and therefore have a tendency to converge upward and forward, where they are $\frac{7}{8}$ inch apart at the anterior margin of the neural canal (*d*, fig. 1).

Fig. 1.—*Anterior aspect of Atlas*, $\frac{1}{2}$ nat. size.

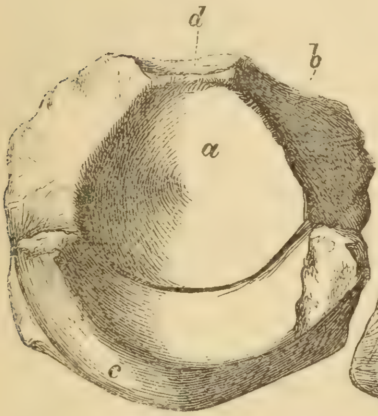
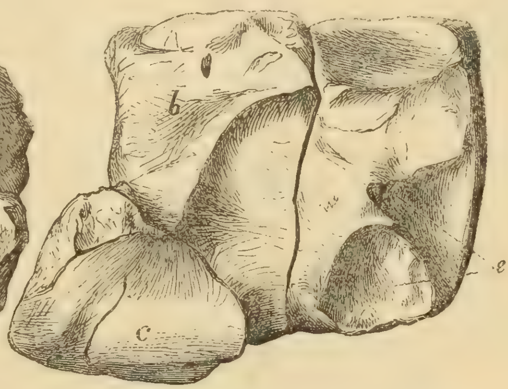


Fig. 2.—*Left side view of Atlas and Axis*, $\frac{1}{2}$ nat. size.



a. Articular face of centrum.
b. Surface from which the neural arch has come away.
c. Subvertebral wedge-bone.
d. Base of neural canal.
e. Articulation for rib.

The neural surface is $1\frac{1}{2}$ inch wide posteriorly, slightly concave from side to side, and has vascular foramina on its lateral margins—three conspicuous foramina on the left side, and smaller foramina on the right side.

The anterior face of the centrum (*a*) is necessarily small and four-sided ; but it has a subtriangular aspect, owing to the shortness of the superior margin of the neural canal and the width of the wedge bone forming its curved base. It is concave and deepest in the centre, though not much impressed.

The extreme width of the centrum, just behind the neurapophysial facets, is rather less than $3\frac{1}{4}$ inches. The lateral non-articular surfaces of the centrum (fig. 2) are below these points ; they are small and subtriangular, about $\frac{7}{8}$ inch from side to side, and $1\frac{5}{8}$ inch from above downward.

The axis is not so well preserved as the atlas, being a little weathered on the neural surface and a little crushed on the posterior part of the basal surface; it is a transverse ellipse, $2\frac{15}{16}$ inches wide posteriorly and $2\frac{7}{16}$ inches deep. The articular surface is concave, and terminates laterally in a slightly bevelled border.

The lower part of the side of the centrum has an articulation for a rib (*e*, fig. 2). The facet is on a level with the base of the centrum, and looks outward and somewhat downward. Its pedicle is slightly elevated, subquadrate, and separated from a very small superior facet by a narrow groove; it does not reach within $\frac{1}{4}$ inch of the posterior border of the centrum.

Other Cervical Vertebræ (figs, 3, 4).

As the cervical vertebræ succeed each other backward they increase slightly in size and length, but do not appear otherwise to materially change their characters, except in the gradual elevation of the articular facet for the cervical rib.

The third cervical has the centrum $2\frac{5}{8}$ inches deep and 3 inches wide in front. The margin of its articular face is conspicuously bevelled. The base of the centrum is marked with a median ridge, between which and the pedicles for the ribs are depressed areas, each showing in the centre a vascular perforation.

Fig. 3.—*Right Side of Fourth Cervical Vertebra, showing the divided articulation for the rib*; $\frac{1}{2}$ nat. size.

Fig. 4.—*Posterior Articular Surface of Centrum of Fourth Cervical Vertebra*; $1\frac{1}{2}$ nat. size.

The pedicles for the ribs are $1\frac{1}{2}$ inch deep, $1\frac{1}{8}$ inch wide where widest, and divided into two subequal parts by a transverse groove; each of these articular areas is deeply concave. The antero-posterior measurement of the centrum on the neural canal is $1\frac{1}{2}$ inch; but it is rather longer at the base. The articular face of the centrum is somewhat concave, and has in its centre a puncture-like depression.

The sixth and seventh are adherent vertebræ, with portions of displaced neural arch and cervical ribs preserved. They have the pedicles of the neurapophyses strong and ovate in section and moderately compressed from side to side, and thus far different from the typical neural arch in Kimmeridge-clay species of *Pliosaurus*. The neural spine is not preserved. The rib has a divided articular head, the two parts being separated by a transverse groove.

The rib is $1\frac{7}{8}$ inch long, is compressed from above downward, more and more so to its extremity; and it is compressed from side to side, but at its free end expands from behind forward. The proximal end is $1\frac{1}{8}$ inch deep; the distal end is $1\frac{1}{4}$ inch wide.

The eleventh cervical has the centrum $1\frac{5}{8}$ inch long, $2\frac{7}{8}$ inches deep, and $3\frac{1}{8}$ inches wide transversely on the posterior face. The articular surfaces for the neural arch are more horizontal, somewhat narrower; and each is distinctly four-sided. There is a large oval vascular impression adjoining the middle of the neurapophysial facet on each side.

The pedicles for the ribs are more elevated, though still less than half an inch high; they are nearer to the posterior margin of the vertebra. The base of the centrum is already becoming more rounded from side to side.

The seventeenth vertebra has the articular face of the centrum $3\frac{3}{4}$ inches broad and nearly 3 inches deep. It is of more elliptical outline than the preceding vertebræ, and has the articular face flatter, but preserves the central depression. The antero-posterior measurement at the base is $1\frac{15}{16}$ inch. The base has become more convex from side to side, and measures transversely, between the bases of the pedicles for the ribs, $2\frac{3}{4}$ inches. The articular faces of these pedicles are vertically ovate, $1\frac{3}{4}$ inch deep, $1\frac{7}{16}$ inch wide, concave, and without any trace of division; so that the head of the rib may now be presumed to have become single. The articular areas for the neural arch are relatively narrower, and the width of the flat surface of the neural canal is greater, than in the preceding vertebræ.

The 19th vertebra has the rib preserved in contact with the centrum; its articular end has an elevated tubercle such as would fit into the depression on the corresponding pedicle on the side of the centrum. This is about the last true cervical vertebra; for in the 20th the articulation for the rib has risen so high as to be partly supported on the neural arch. The base of the centrum has necessarily become much more convex from side to side. The face of the centrum is 3 inches deep. The 21st vertebra also has the rib partly on the centrum and partly on the neural arch; and therefore these two vertebræ between the neck and the back form the region named pectoral.

Dorsal Vertebræ (figs. 5, 6).

The 22nd centrum may be regarded as the first dorsal. The intervertebral articular face has become much more nearly circular, being $3\frac{1}{8}$ inches deep, and $3\frac{5}{8}$ inches wide. The articular faces are slightly concave, with a large ill-defined eminence below the middle—a character also seen in subsequent vertebræ. The centrum is compressed from side to side below the attachment of the neural arch. The width of the facet for the neurapophysis is $1\frac{5}{8}$ inch. The antero-posterior measurement of the centrum is $2\frac{1}{4}$ inches. The lateral or visceral surface of the centrum now becomes more perfectly rounded

Fig. 5.—*View of the Right Side of the First Dorsal Vertebra*, $\frac{1}{2}$ nat. size.

a. Sutural surface for the neural arch.

Fig. 6.—*Posterior Aspect of the First Dorsal Vertebra*, $\frac{1}{2}$ nat. size.

a. Interspace between the articular face of the centrum and the neural arch.

from side to side. There are (on the 29th) two rounded vascular foramina on the base, separated by an interspace of an inch to an inch and a half. The neurapophyses approximate nearer together, being $2\frac{3}{8}$ inches apart in outside measurement.

The 34th vertebra has the centrum $2\frac{13}{16}$ inches long, with the anterior articular face $3\frac{7}{16}$ inches deep, and $3\frac{3}{4}$ inches wide; it is nearly flat. There is a decided forward hang of the upper part of the centrum, as in the dorsal vertebræ of Pliosaurs from the Kimmeridge Clay; and the centrum still has its greatest antero-posterior measurement below the middle, though the swelling of the bone on the articular faces in that position has disappeared.

The three remaining dorsal vertebræ are badly preserved.

If this animal be generically identical with the larger Kimmeridge-clay Pliosaurs, it makes known for the first time the number of vertebræ in the neck in that genus, and the modifications of character which the cervical vertebræ undergo, and also shows the relative size of the neck-vertebræ to those of the back.

Os Pubis.

The bone which I regard as a right os pubis of *Pliosaurus Evansi* is of oblong form, is very thin except in its articular portions, and is preserved upon the original slab of clay on which it was found and forwarded to Cambridge by Mr. Evans.

The transverse diameter of the bone at the femoral articulation is $14\frac{1}{4}$ inches. This posterior outline consists of two portions:—an internal concave margin about $7\frac{1}{2}$ inches long, which, with the ischium, enclosed a foramen; and a thick external area slightly convex in length, about $7\frac{1}{2}$ inches long and about $3\frac{1}{2}$ inches deep in the middle. The inner half of this area presumably gave a strong attachment to the ischium, while the outer half contributed with the adjacent surface of the ischium to form the articular cavity for the femur.

The *inner margin* of the bone, which adjoined the other pubic bone in the median line of the body, has a length of about $21\frac{1}{2}$ inches. It is not straight, but subconvex, making an angular bend in the middle, where for the length of about 7 inches the bone thickens moderately to form an articular surface for union with the pubic bone of the opposite side.

The *anterior margin* is nearly straight, is 11 inches long, and very thin. The greatest length of this bone, from the middle of this margin to the posterior angle of the articulation for the ischium, is 22 inches.

The *external margin* is about 4 inches shorter. It consists of:—an anterior portion 10 inches long, convex in outline from front to back, and terminated by a cartilaginous margin; and a posterior portion concave from front to back, which terminates in a perfectly ossified rounded border: these two portions make an angle with each other.

The surface of the bone is evenly flattened, except at the inner posterior corner, where it is conspicuously compressed.

There is a close correspondence in form between this bone and the still larger pubic bones of Pliosaurs from the Kimmeridge Clay of Ely.

The Ischium (figs. 7–9).

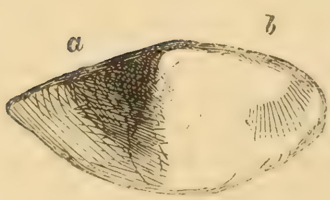
This bone when found was a good deal crushed; and coming to the Woodwardian Museum at a time when I was absent, no record is available of the outline of the very thin broken posterior portion, the preservation of which was found by Mr. Keeping to be impracticable; but I should infer that the missing portion completed a hatchet-shaped outline (fig. 7). As preserved the extreme length of the bone is 18 inches; when perfect, I estimate its extreme length, in the median line where the ischiac bones joined each other in a straight union, to have been about 23 inches. Its greatest posterior width was about 20 inches, near to the hindermost border of the bone; the greatest anterior width is 13 inches, just behind the femoral articulation. Externally between these points the lateral margin is deeply concave. At the articular surfaces for the femur and pubis the bone becomes greatly thickened, as usual (fig. 8). The length along these surfaces is 8 inches. The femoral area is the larger, being $4\frac{1}{2}$ inches long and $3\frac{3}{4}$ inches thick; it is very slightly concave in length, makes about a right angle with the adjacent posterior lateral border, and makes a very large angle with the pubic articulation, which is more compressed from above downward.

The *anterior margin* is $9\frac{3}{4}$ inches from the pubic articulation to the median suture of the body. This margin is concave externally

Fig. 7.—*Left Ischium, drawn so as to show the Median Suture,* $\frac{1}{6}$ nat. size. (The posterior part of the bone restored in outline.)

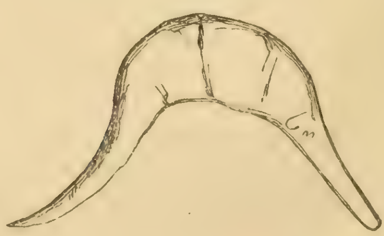
a. Pubic surface. *b.* Femoral surface. *c.* Median suture.

Fig. 8.—*Ischium.*



a. Pubic sutural surface.
b. Femoral articular surface.

Fig. 9.—*Ischium.*



Median articular surface.

and imperfect internally, where it is very thin and extends further forward than the outer part of the bone.

The *median sutural surface* is greatly thickened anteriorly, being about $2\frac{1}{4}$ inches thick, while for a length of about 11 inches it is bent into a remarkable rounded V-shaped fold (*c*, & fig. 9), having the bone thickest in the middle and compressed anteriorly and posteriorly. The convexity of this fold I suppose to have been directed inward; it rises about $5\frac{1}{2}$ inches above a base-line. The crest of the fold is 5 inches from the most anterior part of the bone.

The shape of the bone is very similar to that of the coracoid bone in *Murænosaurus*; and this influenced me in hesitating to identify it as the ischium. But I am acquainted with no coracoid in which there is such a fold of the bone in the median suture, while I have noticed some approximation to such a condition in the ischia of certain Plesiosaurs; and, although not very conclusive, this seems to me more important than the form of the bone. On the other hand, the bone is not paralleled in shape by any known Plesiosaurian ischium, and is quite unlike an ischium from the Kimmeridge Clay of Ely which I attribute to *Pliosaurus*. Being found close together, there would seem to be an *a priori* probability that the two expanded bones described should belong to the same animal, and to the same region of the body; but then the pubic and ischiac bones are not the elements which would be expected in association with the anterior portion of the vertebral column which is preserved. I have no doubt that they are not the two bones of the pectoral arch; but the form of the coracoid in *Pliosaurus* may sometimes have been so similar to that of the ischium as to justify the slight doubt which this account of the bone implies.

Professor Philips, in his 'Geology of Oxford' (p. 350), with great boldness has attempted a restoration of the pelvis of *Pliosaurus*, which seems to me to be in the main correct, the forms attributed to the bones being not dissimilar to those here described.

38. *The* Exploration *of the* Ossiferous Deposit *at* Windy Knoll, Castleton, Derbyshire, by Rooke Pennington, Esq., LL.B., F.G.S., and Prof. Boyd Dawkins, M.A., F.R.S. By Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S. (Read June 20, 1877.)

Contents.

1. *Introduction.*—In the spring of 1876, by the courtesy of the owner of the land, Mrs. Champion, we were able to carry on the exploration of the ossiferous deposit at Windy Knoll, near Castleton, begun in 1874 by Mr. Rooke Pennington, and described in the 'Quarterly Journal' (May 1875, p. 241), with the following results*.

If reference be made to the above paper (p. 242) it will be seen that the fissure in which the remains were first met with was traced to a sort of basin filled with clay and packed full of bones of animals and large and small blocks of stone. We resolved to have this thoroughly examined by a body of experienced miners, working under the constant supervision of Mr. John Tym, of Castleton, while we were, as far as possible, present during the six weeks spent in the work.

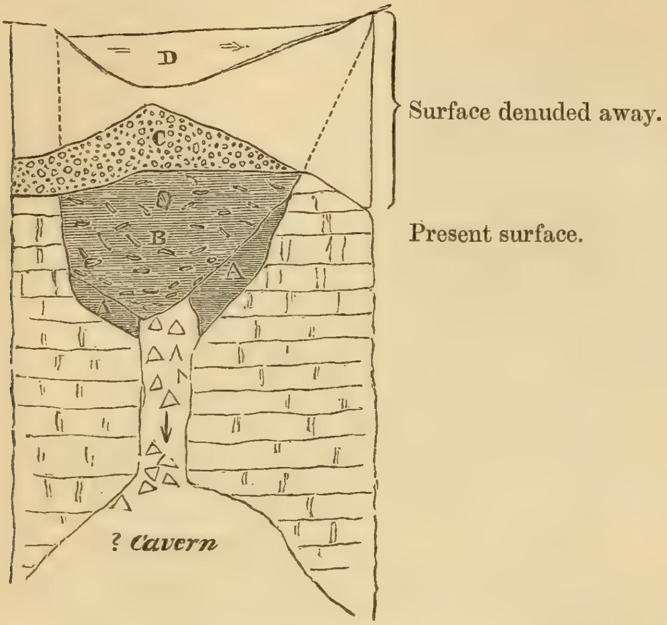
2. *Exploration.*—We began operations on the east side of the mound of clay, and rapidly exposed the following section (fig. 1) in descending order:—

C. Clayey débris forming the summit, without bones, and probably rubbish piled up when the quarry close by was worked at that level .... 6 feet.
B. Yellow clay with large blocks of limestone, fragments of Yoredale shale washed down from the adjoining heights of Mam Tor, bits of elastic bitumen or elaterite, and of fluor spar derived from the deposits of those minerals close by, together with bones of bison, reindeer, wolf, fox, and grisly bear .... 8 „
A. Below this a stiff yellow loam without any fossil remains rested on the surface of the limestone .... 4 „

3. *Association of Remains.*—The bones and teeth of the animals from the ossiferous yellow clay are, for the most part, perfect, and had been buried in their natural positions. The limb-bones of bison, for example, and of reindeer had their proper articular surfaces together, and the sesamoids, tarsals, and carpals in place. The dorsal vertebræ of a reindeer were found in one continuous chain.

* This was done at the joint cost of Mr. Rooke Pennington and the Manchester Museum, the Owens College.

Fig. 1.—*East-and-West Section through Windy-Knoll Fissure.* (Scale 20 feet to 1 inch.)

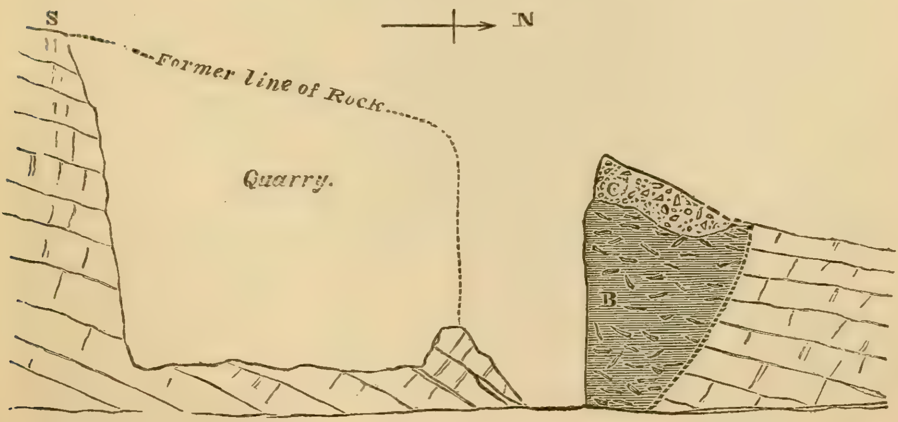


The whole skeleton of a reindeer was to be seen in the upper part of B; but it was so fragile that it was impossible to preserve more than a few insignificant fragments.

Other remains had been scattered after the death of the animal to which they had belonged, as, for example, a lower jaw of grisly bear which rested side by side with two lower jaws of reindeer. Very many of them were crushed by the weight of some of the large blocks of stone. One block of stalagmite measured 8 × 6 × 2 feet.

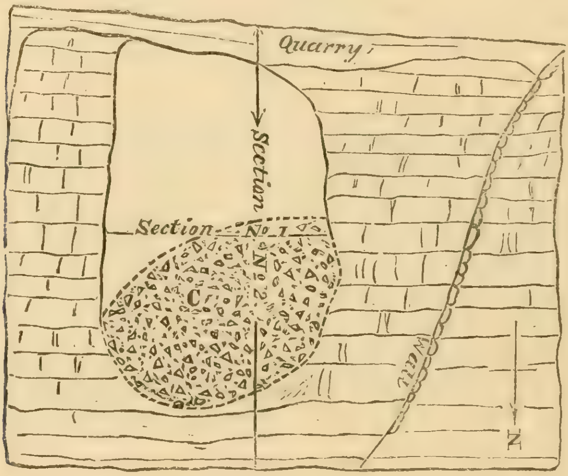
As the work proceeded, the limestone floor began rapidly to descend (fig. 2), and the ossiferous clay to thicken, until it reached a thick-

Fig. 2.—*North-and-South Section through Windy-Knoll Fissure.* (Scale 20 feet to 1 inch.)



ness of 21 feet, through the whole of which bones were scattered, but in far greater quantity below than above. In one part the remains of fox, wolf, bison, and reindeer were all matted together; and in another on the west side there was a stratum of bones, mostly decayed, which measured 4 × 3 × 2 feet. On the west side also, close under the rocks, the bones were soldered into a compact breccia by the infiltration of carbonate of lime. Close to this two perfect skulls of bison lay crosswise, the one over the other. Ultimately the rock-basin began to narrow, and the ossiferous clay to disappear; we traced it downwards until it rested on loose angular fragments of limestone which filled a vertical shaft (fig. 1). We cleared it out on every side except the north; and into that we tunnelled for 5 or 6 feet, till further excavation became dangerous. The rock also reappearing at the surface (figs. 2 & 3) showed that it did not extend far in that direction, and rendered further work unnecessary.

Fig. 3.—*Ground-plan of Windy-Knoll Fissure.*
(Scale 40 feet to 1 inch.)



4. *The Rock-basin a Swallow-hole.*—It was obvious (see section and plan, figs. 1 & 3) that the bottom of the rock-basin ended in a vertical shaft, and that it belonged to the class of "swallow-holes," "chaudrons du diable," or "katavothra," which are to be found in most limestone regions, and which have been formed by the convergence of water charged with carbonic acid on a point of weakness in the rock offered by the intersection of two or more systems of joints. In the immediate neighbourhood of Windy Knoll these swallow-holes abound; and through them the drainage of the upland valley to the west passes into the series of caverns that underlies the limestone ridges, averaging 1600 feet high, separating it from the valley of Hope and Castleton to the east. In the quarry close by, a cavern has been discovered of very considerable size, in which one of these swallow-holes may be studied from the underside. On descending through a small hole, just big enough to admit a spare and agile explorer,

you find yourself in a lofty chamber; and at the further end of this all further passage is barred by a large conical talus, or shoot, of angular blocks of limestone mingled with clay, which has fallen through an aperture blocked up by the apex of the cone. In all probability the vertical shaft (fig. 1) under the ossiferous deposit in Windy Knoll ends in a similar cave, and has been blocked up in a similar fashion by the slow wearing away of the limestone.

5. *A Pool formerly in the Rock-basin.*—Nor could there be any reasonable doubt as to the mode in which the ossiferous clays were introduced. The Yoredale shales of Mam Tor command the lower ridges of limestone in the immediate neighbourhood; and the heavy rains have spread their weathered fragments over the boundary dividing them from the limestones. Consequently several of the swallow-holes have been lined with impervious clay, which has converted them into pools. One of these is a few yards from Windy Knoll. We may therefore infer that the clays in question were slowly accumulated in a pool in an ancient swallow-hole, and that they were derived from the Yoredales of Mam Tor, from whose precipitous sides the fragments of shale and gritstone met with in the exploration were torn by the streams.

6. *Geographical Change since Accumulation.*—This mode, however, of accounting for the clays of Windy Knoll implies a great geographical change in the district. At the present day Windy Knoll, as its name denotes, forms a ridge standing out from the general level of the ground, and overlooking the valley on the west, and the hollow which separates it from Mam Tor. No débris from the Yoredales could now find its way so far as the ossiferous swallow-hole, because all the streams are intercepted by the hollow. It may therefore be concluded that this has been excavated since the deposition of the clay in question.

At the time when it was being deposited also, the sides of the limestone-basin must have stood higher than now, since the imbedded blocks of limestone are the results of their being weathered away. The large mass of stalagmite also, mentioned above, and the numerous broken stalactites scattered through the clay show that there was an overhanging ledge of limestone, if not a cave, at the side of the basin, so placed that its ruins could fall into the latter. The general level of the limestone may therefore be concluded to have been lowered since the time when this was a pool at the bottom of a valley, a pool which has now disappeared along with its upper margins of limestone (fig. 1, D). We were unable to find any evidence that this denudation was brought about by the action of ice. The lowering of the limestone rocks of Windy Knoll, and the excavation of the valley separating it from Mam Tor, imply a very high antiquity for the ossiferous clays, if the present trifling rate of denudation be taken as a measure of the past.

7. *The Remains of the Animals.*—The remains of the animals belong to the bison, reindeer, bear (*U. ferox* and *U. arctos*), wolf, fox, and hare, associated together in the following proportions, vertebræ and fragments being ignored:—

	Bison.		Reindeer.	
	Adult.	Young.	Adult.	Young.
Skulls	10			
Horn-cores	15			
Frontals and antlers	......	......	42	
Upper jaws	14	1	4	
Lower jaws	30	4	27	
Upper molar series	173	......	55	
Lower molar series	157	......	41	
Incisors	21			
Upper milk-molars	......	22	......	11 ?
Lower milk-molars	......	31		
Scapulæ	95	4	31	
Humeri	103	37	34	
Radii	79	17	65	
Ulnæ	46	6	19	
Carpals	184	......	11	
Metacarpals	111	12	62	
Pelves	98	35	11	
Femora	152	77	60	
Patellæ	47	11		
Tibiæ	92	24	19	
Tarsals	223	35	71	12
Metatarsals	116	43	47	
Fore phalanges 1	101			
" 2	68			
" 3	75			
Hind phalanges 1	130	25	70	15
" 2	62	11	42	6
" 3	75	......	5	
Articulations of metatarsal or carpal	......	60		
Sternal bones	25	......	2	
Totals	2302	455	718	44

	Bear.	Wolf.	Fox.	Hare.
Skulls	10	1		
Upper jaws	10	5		
Lower jaws	28	3	10	
Teeth	60	6	7	
Scapulæ	8	2	4	
Humeri	20	7	13	3
Radii	18	3	6	3
Ulnæ	26	9	6	1
Carpals	38			
Pelves	2	......	......	4
Femora	23	5	13	5
Tibiæ	26	9	14	8
Fibulæ	8	1		
Tarsals	36	......	1	1
Metacarpals, Metatarsals	100	14	50	
Phalanges 1	28	3	2	
" 2	11	2	2	
" 3	1			
Totals	453	70	128	25

The number of young bisons under three months old confirms the conclusion at which I had arrived in the paper already laid before the Society* as to the presence of that animal in the district in the summer, while the absence of young reindeer of that age renders it very probable that the reindeer herds were here in the winter. The association of these two forms in this deposit proves the truth of the views held by Lyell and myself as to the seasonal migration of the Pleistocene animals. The remains of the other species need no remark.

This vast accumulation of the remains of the animals, amounting altogether to 6800 catalogued specimens (4195 in the present exploration), was found in an area not more than 25 × 18 × 8 feet, and was obviously the result of the animals crowding into the pools and being drowned. It is on the route by which the bisons and reindeer must have passed from the pastures of the valley of Hope over the Pennine Chain into the plains of Cheshire, the two passes of the Winnetts and Mam Tor converging at that very point. It is an exact parallel to those great accumulations of the remains of bison which, according to the recent admirable monograph of Dr. Allen ("On the American Bisons," Memoirs of Museum of Comparative Anatomy at Harvard College, Cambridge, Mass., iv. no. 10) and the numerous accounts of travellers in the far west, whiten the sides of the drinking-places, and show the former range of the animal over a vast tract from which it has been driven by the hunters.

8. *The Deposit of late Pleistocene Age.*—On reviewing the whole evidence as to the age of this remarkable deposit, the great numbers of reindeer and bison, coupled with the absence of the extinct species, such as the mammoth and woolly rhinoceros, which have been found in the district, induce me to refer it to the late Pleistocene age, and to a later era than that of the caves of Creswell Crags. It may probably be referred to a time when the hyæna, lion, mammoth, and rhinoceros were no longer found in the district. And it may be correlated with the ossiferous gravel discovered by Captain Luard at Windsor in 1866, in which the bison, reindeer, horse, bear, and wolf were lying side by side, as well as with that near Rugby, which furnished the remains of the bison and reindeer submitted to me by the Rev. J. M. Wilson.

* Quart. Journ. Geol. Soc. vol. xxxi. p. 246.

39. *On a number of* NEW SECTIONS *around the* ESTUARY *of the* DEE *which exhibit* PHENOMENA *having an important bearing on the* ORIGIN *of* BOULDER-CLAY *and the sequence of* GLACIAL EVENTS. By D. MACKINTOSH, Esq., F.G.S. (Read June 20, 1877.)

CONTENTS.

Introductory Remarks.—In his Survey 'Memoir on the Geology of North Wales,' p. 207, Professor Ramsay remarks "how necessary it is to map every possible formation in detail before we can arrive at just conclusions concerning either the completeness or the fragmentary nature of the succession of strata." It is only by keeping a keen outlook in a particular district or districts for new sections that such details can be obtained. As regards drift-deposits, sections are likely to vary so much with the extent of the excavations, the state of the weather, &c., that, before they can furnish reliable facts, it is necessary that they should be leisurely and repeatedly observed. Though familiar with a number of sections around the estuary of the Dee for many years, I have lately seen the necessity for making a series of more connected and systematic observations than time had previously permitted; and as some of the sections may soon become obliterated, I lose no time in communicating the results to the Geological Society.

Results of Additional Visits to the Dawpool Sea-coast Section.—Since the time I very briefly described this section in the Quart. Journ. Geol. Soc. for Nov. 1872* I have often visited it, and on

* I must here correct two errors into which I was led during my earlier visits to Dawpool (Quart. Journ. Geol. Soc. for Nov. 1872). The grey facings of the fractures in the upper clay are not a chalk-wash, as was suggested to me by an eminent geologist; and their nature and origin have not yet, I believe, been satisfactorily explained. Though not at the points where I then examined the Dawpool cliffs, the upper clay of Cheshire does contain much decomposing "greenstone," as well as the lower. Both clays contain carbonate of lime, which, if it did not come from the chalk of Ireland, may have been derived from the limestone of Westmoreland, N.W. Lancashire, or W. Cumberland.

each occasion have seen *fresh faces* exposed by the rapidly encroaching sea, at intervals, along the whole cliff-line, which is about three miles in length. In every instance the

Line of Junction between the Lower and Upper Boulder-clays, whether straight or undulating, was so well defined as to suggest the idea that the surface of the lower clay had become either hardened or denuded before the upper clay was deposited. This line, in one place, appeared as represented in

Fig. 1.

Deposits at the Base of the Lower Clay.—At intervals in the lower clay there were pockets and layers of small stones, and likewise of sand. At the base, in several places, the clay graduated into, or became interstratified with beds of bright reddish brown sandy loam (without stones and with stones), which in one place exhibited a quaquaversal arrangement. I could see few or no shells in these loamy beds; and there was no appearance of an old sea-bed having been worked up into the substance of the clay above. There were no contortions, such as occur in the drifts all round the borders of the Lake-district. A few feet above the level of the beach the clay resumed its typical character. At Blackpool there are similar loamy beds on the same horizon relatively to the lower clay (Quart. Journ. Geol. Soc. vol. xxv. p. 412).

Character of the Striated Erratic Stones.—On the day above mentioned I saw many kinds of erratic boulders and smaller stones I had not previously noticed. Next to "greenstone," Criffell granite was again found to predominate, but in greater variety, including the grey kind with large, sharply defined crystals of felspar, and the reddish-brown kind (resembling Shap granite). Granite of the kinds now quarried in the neighbourhood of Creetown, Kircudbrightshire, were represented, especially the white Fell granite. Most of the stones, both small and large, were striated as follows:—

1. Irregularly scratched all round (by land-ice before they were transported?).

2. Irregularly scratched all round, with the addition of superinduced flattened surfaces and single or cross sets of parallel grooves.

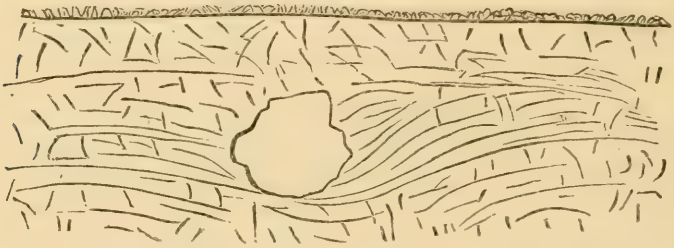
3. Merely flattened surfaces, with single or cross sets of parallel grooves.

The grooves run in all directions relatively to the longer axes of the stones, including large boulders. They are so fresh-looking and cleanly cut as to suggest the idea that the stones were not retransported or jostled about after the grooves were imprinted. The uniformly flattened surface, and the character of the grooves, would both seem to point to rapidity of movement in the glaciating agent.

Floating coast-ice holding the stones firmly fixed in its base, and grinding them against projecting sandstone rock-surfaces in a shallow sea, would seem to offer the most satisfactory explanation*. In the upper clay the stones are similarly grooved, with this exception, that irregular scratches and cross sets of grooves are not nearly so frequent.

Signs of Boulders having been dropped.—South of Dawpool Cottage I once saw two instances (in the lower clay) in which boulders had evidently fallen from a certain height, so as to press the clay violently, develop its latent lamination (?), and cause the laminæ to rise up at the sides (fig. 2).

Fig. 2.—*Fallen boulder, Dawpool.*



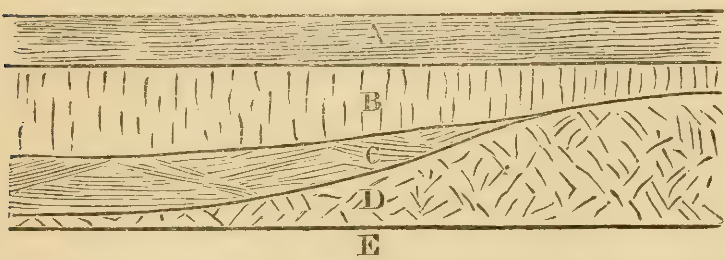
Sections on the West Shore of the Estuary of the Mersey.—A long section, exhibiting phenomena which are a repetition of those seen at Dawpool, extends for some distance on each side of Egremont Ferry. Mr. De Rance, F.G.S. (who has done much to establish the threefold division of the drifts in Lancashire, and who has offered many excellent suggestions concerning the origin of these drifts), notices a part of this section in Quart. Journ. Geol. Soc. vol. xxvi. p. 644. I have lately carefully examined it under favourable circumstances, as many fresh faces (April 1877) have been exposed in excavations for bricks, &c. An extended survey shows that the lower clay here is not invariably separated from the upper clay by stoneless sand and loam; while the latter, so far as I could see, likewise occur in patches and beds in the lower clay. But the line of junction between the two clays, *where clay-slips have left fresh faces*, can easily be detected. The upper clay, with its frequently recurring grey-faced and vertical fractures, is seldom more than 12 feet thick. In a brick-pit east of Egremont Ferry it has been excavated down to a level floor of sand. The existence of two clays is well known among brickmakers. While the upper is found to be the best brick-clay, the lower is too "strong" for making good bricks. There is likewise a difference in the number of contained stones, and in the colour of the two clays; but it ought not to be forgotten that the colour of all clays changes with the amount of moisture they contain. During recent excavations to obtain a foundation for a sea-wall, the lower clay (of which there is a great

* During repeated observations I have seen few or no stones similarly glaciated on the hill-sides or in the valleys of the Lake-district.

thickness above high-tide level) was found to extend to below low water.

New Dock-sections near Bootle.—Further north than Egremont, and on the opposite side of the Mersey, a series of extensive excavations are now in progress for the purpose of obtaining sites for new docks. They have been visited by several geologists; and Mr. Morton, F.G.S. (in whose company I first saw these sections), has given a very brief account of them in the Geol. Mag. and in the Report of the British Association for 1876. Since then I have twice examined them, with the assistance of Mr. Sutcliffe, the acting engineer. An unwary visitor to No. 1 dock (going north) might at once conclude that the three drifts are there very strikingly displayed—the upper clay, middle stratified sand and gravel, and a great thickness of lower clay. What can be plainer? he might say. A close and leisurely inspection, however, would show that his upper-clay had been *artificially redeposited* over a considerable thickness of Postglacial sea-sand with numerous shells. The last time I examined these excavations a number of new and instructive sections were in course of being exposed (see fig. 3). In one spot a group of

Fig. 3.—*Section exposed in the second New-dock Excavation, April* 1877.



A. Postglacial sand, about 6 feet; B. Upper Boulder-clay, about 12 feet, separated by a very distinct line from C, current-bedded middle sand and fine gravel, a sprinkling of which is continued along the line of junction between the two clays; D. Lower Boulder-clay, with an average thickness of about 12 feet; E. Triassic sand and rock *in situ*.

workmen stood on the partially uncovered and well-defined top of the lower clay, wielding spades, with which they speedily removed the upper clay*, while a throng of navvies, armed with picks, were attacking the base of the lower clay, which had been found to be too compact and stony to yield to spades. Towards its base the lower clay might be seen graduating both horizontally and vertically into masses of rounded gravel (partly consisting of erratic stones) or into sand; and I was informed that in some places much sand had been found beneath it. The line of junction between it and the underlying Triassic sand and sandstone-rock could be easily traced. In several places (during a former visit) I found the middle

* Where fresh faces have been exposed by clay-slips, the upper clay here shows more or less of the grey partings by which it is generally, but not always, characterized.

sand-and-gravel occupying deep hollows in, and resting on the rock-surface at the same level with the lower clay; but these appearances (which are of frequent occurrence elsewhere) afforded no proof that both had been contemporaneously deposited. Though the upper clay in these sections contains fewer small stones than the lower, it is charged with a greater number of large boulders, contrary to the general rule; but it ought to be remembered that large boulders generally occur in groups instead of being equally scattered. Besides "greenstone," Eskdale granite is frequent among the boulders of the upper clay, though Criffell granite, so far as I could see, is limited to the lower clay or the gravels derived from it. A difference in the granites of the two clays is likewise seen at Dawpool and elsewhere, though I should not like to affirm that Criffell granite is everywhere entirely absent from the upper clay.

Sections around Birkenhead, showing the Relations between the Boulder-clays and the underlying Rock-surfaces.—On both sides of the Borough Road, between the new Mission-house and the water-works, a number of brick-pit and other sections have lately been exposed. Behind the Mission-house an excavation (April 1877) shows, under a deposit of upper Boulder-clay, a Triassic rock-surface planed down unconformably to structure, in a manner suggesting the sudden and forcible grounding of a mass of floating ice. A few yards to the south-west, a continuation of the planed surface is covered with grooves (afterwards to be described). Further on, at a somewhat higher level, a similarly planed-down rock-surface may be seen. Higher up on the other side of the road a number of excavations show:—(1) the lower Boulder-clay or its hard loamy representative graduating downwards into an unwashed Boulder-gravel, consisting of rounded erratic stones and angular sandstone fragments worked up from the underlying rock; (2) the same clay reposing in one place on an uneven, in another on a straight surface of rock or rock-sand *in situ*; (3) the upper Boulder-clay, never graduating into rock or rock-sand downwards, but separated from them sometimes by an uneven, but generally by a straight line. In digging the foundations for the head master's new house, Birkenhead School, the upper Boulder-clay in several places was seen to rest on a cleanly shaved-off surface of coloured Triassic sand *in situ*.

Derivation of the Component Materials of the Boulder-clays.—In the neighbourhood of the estuaries of the Dee and Mersey, and, I have no doubt, in most places where either or both of the Boulder-clays exist, the following description will, I believe, be found more or less applicable. A great part of the two formations consists of broken-up or ground-down Triassic sandstone (in some districts evidently of Permian or Carboniferous sandstone). In specimens from the sections above described, the residue, after washing, consists of coarse sand, which, to a great extent, is composed of rounded and subangular quartz grains, and small subangular stones from Bunter and other Triassic sandstones. The erratic stones, which are seldom very small, were apparently brought by a cause distinct from that which produced the sandy and gritty part of the formation; and I believe the same remark applies to the clay of which the formation mainly consists. Icebergs from an ice-sheet, or from glaciers, in the Lake-district and south of Scotland, could not have brought the *whole* of the deposit with its local grit, erratics, and clay, while icebergs, carrying both clay and erratic stones, and dropping them at intervals into the slowly accumulating local materials, would have left a deposit much less uniform in its character and structure*. Wide-spread and thickly congregated masses of floating coast-ice from the Lake-district &c. may have brought the erratic stones (with more or less sand and clay). The structure therefore of these deposits can perhaps be best explained by supposing a *threefold* origin:—(1) the local grit and sand furnished by ordinary sea-action; (2) the clay washed out from beneath the ice-sheet or glaciers of the Lake-district, and generally distributed by currents; (3) the stones, principally erratic, but to some extent local, supplied by floating coast-ice. There is generally more grit, and a greater number of stones in the lower than in the upper clay; but still they are too much alike to require a different explanation.

Persistent Line of Demarcation between the Middle Sand and the Upper Clay.—When the upper clay rests not only on surfaces of rock or rock-sand, but on the middle sand-and-gravel (in which position it is chiefly found), there is almost universally a clean and straight or undulating line of junction, without the slightest commingling of materials; so that, even within the vertical space of an inch (as in the recent long railway-cutting between Chester and Delamere), the typical clay, with parts of intensely glaciated stones, is separated from the equally typical sand with entirely unglaciated stones, excepting in the case of a few instances of very limited extent, where the sand has been cleanly interlaminated with loam or clay. The sharpness of this line of junction and its persistence over large areas would seem to indicate the shaving-off or denudation of the sand before the deposition of the clay. It would likewise seem to show that the clay could not have been brought by land-ice, *because land-ice could not have pushed its* moraine profonde *for scores of miles over an extensive deposit of yielding sand and gravel without confusedly mixing up the two formations.* But the most difficult fact to explain is one to which Professor Hull, Mr. De Rance, and others some time ago called attention, and which is strikingly exemplified in the above new railway-sections, namely the evidence of a *great leap* from an interglacial sand-and-gravel period, when no glaciated stones were floated by ice over the submerged plains, and when scarcely any clay was deposited, to a period when clay with intensely glaciated stones began to accumulate†.

* It may likewise be remarked that the depth of the sea, indicated by the vertical range of either of the Boulder-clays, could not have floated icebergs.

† Mr. Shone, F.G.S., of Chester, can corroborate what I have here stated. He has now collected a great number of shells from the upper clay of the Chester and Delamere railway-cutting, and has found additional species indicating a very cold climate.

What could have obliterated all signs of the interval during which the change from non-glacial to glacial conditions took place? The revolution in temperature may certainly have occurred during an intervening period when dry land existed. But as there are no traces of a land-surface, so far as I have seen, between the middle sand and upper-clay, I would suggest that the commencement of the upper-clay submergence may have been sudden, so as to generate an earthquake-wave capable of accomplishing the sweeping denudation of the sand which is so forcibly suggested by the clean and persistent line of separation above described.

Striated Rock-surfaces and their Relation to the Direction in which Erratic Stones have been carried.—I very lately saw a fresh exposure of intensely striated rock, from which a covering of upper Boulder-clay had been removed. It is a part of a more extensive display which has been demolished by quarrying operations, and occurs about a quarter of a mile south of St. James's Church, Birkenhead. The striæ, including large grooves, point to between 25° and 30° west of N. A short distance southward I found striæ pointing W. 30° S. As the extent to which the directions of the striæ vary in the neighbourhood of the estuaries of the Dee and Mersey does not seem to be generally known, I would state that I have seen an extensive series near St. Silas's Church (north of Prince's Park, Liverpool) pointing N. 35° W., with a few cross striæ running between N. 38° W. and N. 40° W. In Toxteth Park, Liverpool, Mr. Morton, F.G.S., has found striæ pointing N. 42° W.; at Kirkdale, N. 15° W.; and at Oxton, Birkenhead, N. 30° W. I have re-examined grooves (including one more than three inches in breadth) close to the new Mission-house, Borough Road, Birkenhead, which were first noticed by Mr. Bostock, and found them pointing N. 45° W. If we connect these instances with that found on the east side of Hope Mountain, near Caergwrle, where I found the striæ pointing to about N. 45° W., we shall have striæ ranging from N. 15° W. to N. 45° W., which will *include* the main directions in which erratic stones (including Cumberland and Kirkcudbrightshire granite and Irish chalk-flints)* have travelled from their respective points of dispersion, though we have no reason to suppose that they travelled in straight lines. As Mr. De Rance lately observed at a meeting of the Liverpool Geological Society, these striæ can be much better explained by floating ice than by land-ice; and it may be added that the floating ice may have been blown by wind as well as carried by currents, as proved by observations made by the late Austro-Hungarian Expedition in the neighbourhood of Franz Josef Land. It is well known that the directions of the striæ above noticed are crossed in the Isle of Man by striæ from the E.N.E., and in Anglesey by striæ from between N. 25° E. and 30° E.,—that is, from the direction of the Lake-district. In Anglesey there are true *roches moutonnées* (Geol. Mag. for Jan. 1872), but there are no decided instances

* These flints are most numerous about Parkgate. They thin out S. and S.E. until they come into collision with flints from the eastern counties, which thin out westward.

of such around the estuaries of the Dee and Mersey. Even on Hope Mountain the apparently mamillated form of the surface is chiefly the structure of the beds of Millstone-grit developed by denudation.

Horizontal and Vertical Range of the two Boulder-clays of the Basin of the Irish Sea.—These two Boulder-clays are often separated over large areas by middle sand and gravels, as proved by the geological surveyors in Lancashire, and as may be seen in Cumberland between the estuary of the Duddon and Ravenglass (Geol. Mag. for June 1871). To the south of the Mersey the upper clay is generally found lying on the surface of the middle sand; and, excepting in hollows, there is very little lower clay further south than Chester, though, under the middle sand, it is often represented by a loam with erratic stones, but without shells, which would appear to be the equivalent of the base of the formation further north. In many places in Shropshire this loam is the only drift-deposit. The small quantity of typical lower clay south and south-east of Chester may be accounted for partly by supposing a southerly diminution in the supply of subglacial clay, and partly by the evident *using up* of the stony contents of the lower clay during the accumulation of the middle drift which, for a great distance south and south-east, contains lower-clay erratics. The lower clay is much the same along the shores of the Irish sea from the Solway Frith to the neighbourhood of Chester, and from that neighbourhood to Anglesey, as I have had many opportunities of ascertaining. The upper clay is likewise the same from the banks of the Eden, near Carlisle, to Crewe in Cheshire, and from Crewe to Anglesey. The greyish-faced fractures are not always present; but they frequently recur. At the Dalton brick-pits, Barrow-in-Furness, and at Crewe, they impart a general bluish-grey colour to the clay; and all the way between these two places they may often be seen. They likewise frequently recur in Shropshire and Denbighshire. They resemble the ash-coloured partings of the Hessle clay described by Mr. Searles V. Wood, jun. As regards vertical range, the lower clay nowhere, so far as I have seen, maintains its low-level or shelly character at a greater height than from 100 to 150 feet, as Mr. De Rance long ago pointed out; but it is certainly continuous with a deposit of mixed loam, clay, and gravel which runs up the hill-sides to a great altitude. I have never seen typical upper clay at greater heights than from 400 to 600 feet; and it generally loses its shelly character before it reaches these heights. Mr. S. V. Wood, jun., has not found the Hessle clay (with which he is disposed to correlate the north-west-of-England upper clay) at a greater height than about 300 feet in Yorkshire, while in South Lincolnshire it does not reach higher than about 50 feet above the sea-level. The upper clay of the north-west does not penetrate into the valleys of the Lake-district, or into the valleys of Wales, with the exception of the Vale of Clwyd and the valley traversed by the Mold-and-Denbigh railway, in which it does not rise to the level of the water-parting. On the east slopes of Halkin Mountain it thins out upwards at about 400 feet, and east of Glossop at about 600 feet.

Horizontal and Vertical Range of the Middle Drift.—The middle drift of the plain loses the character of a deposit of fine sand and gravel in the neighbourhood of the mountains, where it becomes horizontally continuous with a coarser formation, especially in the upper part, which consists of large rounded stones, often reaching a foot in average diameter. In among the mountains it contains large boulders, some of which are striated. It likewise graduates or dovetails downward into a boulder-clay or loam, by which it is sometimes horizontally replaced. Where it penetrates into the mountain-valleys it gradually loses its shelly character, as if the increased freshening of the sea-water, by melting snow, had proved inimical to the existence of mollusca. The shells hitherto found at high-levels in this country have been limited to the outer slopes of the mountain districts, in positions facing what once must have been comparatively wide and salt seas.

Is there any "true Till" at low levels in the Basin of the Irish Sea?—The mere fact that bricks can easily be made out of both the low-lying shelly clays of the basin of the Irish Sea would be looked upon by a Scotch geologist (as I was some time ago assured by an eminent glacialist) as sufficient to prove that they are not "true till," while the enormous distances which the erratic stones found in these clays have been transported would be regarded as corroborative of the idea; for there is perhaps no point on which glacialists are more agreed than that the constituents of "true till" (including stones) are more or less local. But in one of these clays at Wolverhampton (I have not yet determined which) Scotch granite is found which must have travelled 170 miles; and in the lower Boulder-clay of the estuary of the Dee similar granite is found in abundance which must have travelled 100 miles. Scotch granite may be found at Upton-on-Severn, near Worcester, which must have been transported 200 miles (as the Rev. W. S. Symonds informs me), or a distance about equal to that between the Moray and Solway Friths; and I think a consideration of relative levels will show that it could not have been retransported from the southern end of a till-distributing ice-sheet. At New Colwyn Bay, North Wales, and the neighbourhood, a very stiff blue clay without shells, and with stones almost entirely local, may be traced along the sea-shore. Above it there is a representative of the base of the lower brown clay, a bed of sand-and-gravel, and the upper clay on the top. The latter contains many erratic stones. This blue clay is apparently on the horizon of the blue clay of the Marron valley, the neighbourhood of Keswick, the Yorkshire valleys, and some parts of Lancashire (where Mr. De Rance regards it as a clay formed under land-ice). If there is any low-lying "true till" in the basin of the Irish Sea, I think it must be this blue clay.

[This paper is intended to be introductory to one on the Correlation of the Drifts of the north-west of England with those of the Midland and Eastern counties, a task, I believe, which can only be satisfactorily accomplished by one observer going over the whole ground.]

Supplementary Notes.

Sept. 1877.—Since this paper was written I have again examined the Dawpool cliffs, accompanied by Mr. Shone, F.G.S. Fresh clay-slips have revealed a considerable thickness of normal middle sand extending horizontally for several hundred yards. I have likewise examined a newly cut section (Aug. 1, 1877), nearly 200 yards long, at Egremont, which shows a striking difference between the lower and upper clays. The columnar structure of the latter is here strikingly developed; and the greyish-white faces of its fractures make it appear almost like a range of chalk cliffs. The sand at its base is evidently on the same horizon as the thick bed at Codling Gap, some distance to the south. The surface of this bed presents the appearance of having been finely ripple-marked immediately before the tranquil deposition of an inch in thickness of leaf-like laminæ which, within the vertical space of a few inches, graduate into the typical upper clay. Similarly marked junctions may be seen near Chester. The last time I visited the Bootle new dock-sections I particularly noticed that the striæ on the flattened surfaces of the large boulders (nearly all of which are so-called greenstone) ran in various directions without any special relation to the longer axes of the stones. Having been unable to trace these (and kindred boulders at Dawpool) to the Lake-district, I sent specimens to Mr. James Geikie, F.R.S., who, along with Mr. Horne, recognized them as having come from the outskirts of Criffell Mountain.

Professor Hull has enabled me to trace a large boulder of calcareous conglomerate (which may be seen in an upper-clay brick-pit south of Wrexham) to the lower Keuper beds of the Delamere or Peckforton hills, from which its course must have been nearly at right angles to that of the Eskdale granite with which, in the brick-pit, it is associated.

40. *On an hitherto unnoticed* Circumstance *affecting the* Piling-up *of* Volcanic Cones. By Robert Mallet, Esq., F.R.S., F.G.S. (Read June 20, 1877.)

Besides the two great groups of conditions which mainly determine the general form and shaping-out of volcanic cones, many secondary forces concur in greater or less degree in the production of the varied and often complicated phenomena which constantly or occasionally are observable in or around these cones. Some of these forces are mechanical, others physical or molecular, acting separately or, more often, in combination. It is not my intention here to enter upon any systematic discussion of the play of these varied forces, which, it may be remarked, have never yet been submitted to a careful and systematic analysis by the mechanical and physical philosopher, and which remain amply to reward competent labour, when bestowed upon them, but which can only be adequately treated at a length and in such detail, descriptive and analytic, as must extend to a volume, or at least to a succession of memoirs.

My present purpose is merely to notice prominently one circumstance, very commonly belonging to the piling-up of volcanic cones, which, so far as my knowledge extends, has entirely escaped hitherto the observation of vulcanists, but which, nevertheless, must often exercise important influences upon the exterior form and internal structure of volcanic cones, especially at and about their lower portions, and may even occasionally affect surrounding strata, entirely outside the circuit of the base of the cone. Volcanic cones as found upon our globe, when largely viewed are little else than "cinder-tips," aggregated of the loose material blown out in a heated but discontinuous state, and of fused matter belched or poured forth. They are therefore evidences of that explosive action which characterizes fitfully, or constantly, all existing volcanic action, and which appears to me, in common with many able American geologists, to distinguish it from those quiet and unexplosive overflows of melted matter, which often take place upon a scale much vaster than anything which is presented to us by existing volcanic action. Such outflows appear referable to a geological epoch more or less anterior to those which belong to the existing volcanic *régime* of our globe. We cannot as yet fix with any exactness the boundaries in geological time when the earlier system, roughly called that of "fissure-eruption" gradually ended, and the existing "system of ejection" at explosive foci, and the heaping-up of cones of ejected material, began.

I have ventured to express my belief that our existing volcanic system does not go back much beyond the Tertiary period. Upon this much difference of opinion may exist, and is justifiable in our existing ignorance of the actual circumstances of almost all the volcanos of our globe; and years of the patient labour of many future vulcanists will have to yield up their fruit before our knowledge of even the external and visible phenomena of volcanic action can be rescued from the region of guesswork and of assumption, and explained without *lacunæ* by the acknowledged laws of matter and motion as part of the *physique du globe*. This much, however, we are so far probably justified in affirming, that the channels leading to existing volcanic foci, very commonly, if not generally, reach the surface through comparatively recent rock formations, and through stratified rocks the beds of which are seldom of great thickness—rocks which, considered lithologically, are inferior in hardness, rigidity, and cohesion, and which are occasionally found to be intercalated with formations presenting still less mechanical resistance to forces externally applied. To these general facts there are, however, remarkable local exceptions. Thus the volcanic cones or *puys* of Auvergne appear for the most part to be based upon an enormous tabular granite formation of unknown depth, through which the volcanic ducts or channels had reached the surface without serious dislocation or breaking-up to any considerable extent of the rigid material through which they have pierced, by a mechanism as to the nature of which we had best confess our ignorance ; for we have no evidence of a trustworthy character to indicate whether those ducts which have reached the surface have followed between the jaws of preexisting fissures, and where the resistance of the solid granite had previously been weakened, or whether at certain local spots hypogean heat, whencesoever originating, had gradually reached the surface, more or less disintegrating and softening the rock in its progress upwards by conductivity, until at length the softening and breaking-up by heat, extending from the more or less deep foci of fusion to the surface, had advanced so far that the admission of water, whether meteoric or already deposited and drained from river-channels or lakes and reaching the interior through fissures, commenced that explosive action by which the volcanic duct was opened to the air and the heaping-up of ejecta into a cone commenced. Many circumstances connected with the *puys* of Auvergne, more especially the general uniformity and fine comminution of the material of which they consist, as well as their extinction after a brief period of activity, induced me to conjecture that they were thus originated, and that the material of the respective cones consisted of tufaceous or other disintegrated material preexisting at no great depth beneath the huge table of granite through which it has been eviscerated. Unless we except the case of Monte Nuovo in the Phlegræan Fields, no volcano has ever been seen by any competent observer in the act of bursting forth. Even in this solitary instance, although the facts recorded by the only two personal witnesses who have left a record of their observations of the outburst make quite clear the leading phenomena of the new birth of the mountain, some of the statements as to minor phenomena throw some doubt upon their competence as observers.

However, no record exists as to the state of the ground prior to the outburst and it would have been highly important to know whether in this, as in many other observed cases, not far distant from active volcanic vents spots or portions of the ground at the surface had become more or less highly heated before any visible mechanical disturbance had taken place. In all volcanic districts numerous spots are to be found where the ground is highly heated by the emission of small divided streams of steam (probably superheated), and of heated gases: but this is not a case in point; for here the heat is evected and brought to the surface by these elastic fluids, of which well-marked examples are found at Il Stufi, in the Island of Lipari, and in the neighbourhood of Pozzuoli. In the island of Vulcano, however, (one of the Lipari group,) I observed well-marked instances where the ground, consisting of volcanic pebbles and sand, was too hot to stand upon; and in one case, a few yards outside the sea-margin the sea-bottom of volcanic sand was too hot to be borne by the naked foot, although the sea-water covering the bottom was nearly a yard in depth; yet here not a bubble of gas (steam might have been condensed) was seen to be emitted or to rise from the water. Many other instances of heated soil without emission of steam or gases are to be found scattered through the pages of observant travellers; and I need not adduce instances from these. We may be justified in presuming that this sort of local thinning and softening of certain spots may be one of the ways (however incapable as yet of being explained fully in all its details) in which new volcanic vents are opened.

However the penetration of the surface may take place, the material which is ejected from the opened orifice is deposited and heaped up around, the ring-formed mound being continually increased in height and in diameter by additions of material showered upon it, or added to it in a liquid state by overflow or injection. If the origin d penetration be through a level plane surface, whether of discontinuous or of coherent rock-material, the first deposits must conform to the contour of the plane on which they rest. But as deposition proceeds and each layer of matter is brought to rest upon the uppermost of those previously deposited, so, could we dissect and separate the successive layers of deposit, we should find that the inclination of the layers, at least upon the exterior side of the ring-formed mound, continually increased, up to a certain limit of slope or angle of repose, dependent upon the nature of the material itself—after which the angle of slope of succeeding deposits does not increase, but the slope is more or less disturbed and modified by great slippages of the already deposited material taking place at one or at many points round the circumference. Such slippages also occur, and still more frequently, from the internal slope; and these falling back into the crater-orifice are again ejected; but the interior of the mound or cavity of the crater, being in fact constantly exposed to a high temperature, and to the baking and chemical actions due to contact with the torrent of heated gases, vapours, and solid ejecta rushing past, becomes like that of the vast flue of a furnace, indurated; so that the angle of the interior of the crater is not the same as that of the exterior, being always much steeper, and often even vertical, and no longer dependent, as is the slope of the exterior, mainly upon the angle of repose of the material.

For our present purpose, however, it is unnecessary to enter upon the more complex conditions which affect the building-up of the interior sides or craters of volcanic cones. Enough has been said to show that, as the deposition of the matter of the cone proceeds, the pressure of the huge mass upon the base on which it rests continually increases with the increase of deposited matter; and if we assume that the material of the cone is discontinuous and free from intercohesion of its parts—an assumption quite allowable considering the very small cohesion observable in all known volcanic materials, regarded in large masses, such as those of entire cones,—then the pressure upon the base per unit of surface will be approximately as the vertical depth of material above that unit of base; and as the depth of deposited material is greatest at and about the summit of the volcanic cone, so the maximum pressure upon the unit of base will be situated in the line of a closed curve, approximating to a circle, not far distant from the summit of the interior slope, or, in other words, beneath the closed curve drawn through the junction of the anticlinals of the inner and outer slopes. But the area of the crater of all terrestrial volcanos is so small in proportion to the whole base of the mountain, that it will be sufficiently accurate for our purpose to consider the pressure upon the unit of surface of base to increase constantly from the outer toe of the slope of the exterior of the mountain to the centre, and to be everywhere proportionate to the depth of material resting on the unit of base. If the ejected material, be deposited upon a plane of coherent material, such as, in the exceptional case referred to, is the table of granite underlying the *puys* of Auvergne, then the arrangement of the material, deposited as just described, must remain unaltered, excepting so far as future violent efforts of volcanic force, or the external changes in form producible by rain-torrents, &c., may affect it. If the base of the mountain consists of less-resistant strata, as in the case of the softer and more pliable stratified formations, and in the instance of Etna, it may yield more or less to the constantly accumulating weight of matter deposited upon it, and be depressed more or less below the position which it occupied prior to the deposition of the cone. It follows, therefore, that, could we lay bare such a base, we should find that the originally flat or level surface had been depressed so as to form a saucer-shaped or, roughly, an inverted conoidal concavity, the depression being greatest at or near the central parts of the base, and becoming evanescent around the margin or toe of the outer slopes of the mountain. It will follow from this, that as the earliest deposited strata of the cone, as has been already shown, sloped outwards at a very small angle, so, during the progress of very slow descent of the mass following down into the concavity made by its own weight, the descent being greatest nearest the centre, these lowermost strata of the cone, could we lay them bare, would be found either to slope outward at a less angle than they did at first, or, the amount of depression being sufficient, to have changed their direction of slope altogether, and now to slope synclinally towards the centre of the mountain, following in fact, more or less, the shape of the concavity of depression of the base; and this change of inclination will become less and less as we ascend higher in the mountain mass. Furthermore, if the material of the base be still less resistant, so as to present, when viewed on the great scale, a certain semblance of plasticity, then the concave depression of the strata beneath the base may give rise around the foot of the mountain to uprise of the strata, and their swelling into protuberances of greater or less height; so that the final form of repose of the base, after the cone shall have arrived at a certain magnitude, would consist of a central saucer-shaped depression surrounded by a low convex ring of irregular protuberances, rising somewhat above the level of the original plane, and at their outward boundary falling into or coinciding with that plane. Nearly the same succession of phenomena will take place, whether the cone be deposited as we have so far assumed, upon a base more or less yielding of non-volcanic formations, or whether, as is so often the case in old and great areas of volcanic action, the newly formed cone shall have been deposited upon the spread-out ruins of former volcanos or upon the volcanic strata constituting the flanks of preexisting cones. Thus the enormous masses of Monte Vulture penetrate directly through and are based upon the Apennine limestones and other recent strata; but Monte Nuovo and numbers of other cones of the Phlegræan Fields have pierced through and rest upon volcanic formations, to a large extent the ruins of previous cones.

It follows, from what has been stated, that we should be prepared to find the lower portions of many volcanic cones sloping not outwardly at all, but inwardly and towards the centre of the mountain; and that the beds around the base have, by the movement resulting from the depression of the base of the mountain, had their position altered so that for a considerable distance around, though not beneath the base, they also slope inward and downward synclinally, coinciding more or less with the form of depression of matter below the base. Those who are unacquainted with the phenomena of displacement, and the extent of movement that can take place in the material of our earth's surface, induced by inequality of loading, may perhaps at first regard with some degree of incredulity the reality of such movements due to natural causes as have been already described; but facts are well known to civil engineers and architects, which sufficiently prove that we do not exaggerate the effects of like forces operating upon the gigantic scale of nature. Railway embankments for example, when they exceed a very moderate altitude, force themselves by their own weight into the ground upon which they are placed, so that the previously flat surface becomes depressed into a hollow or long shallow trough, in breadth equal to the base of the embankment; and very frequently the surface of the ground at one or both sides of the embankment is forced up into a long swelling mound, more or less nearly equal in length to that of the embankment, and often fissured or cracked transversely by deep clefts. Again, the extent to which the ground beneath the foundation of ponderous architectural structures, such as cathedral-towers, has been known to become compressed, is as remarkable as it is instructive and curious. The amount of depression in some cases may be measured by feet; and although the foundation may be laid in material of great apparent uniformity, its resistance to superincumbent weight when sufficient to cause displacement may prove far from uniform. Thus the Campanile, or leaning tower of Pisa, and the great square brick tower (only the lower half of which remains) at Bologna (the upper half having fallen off), have had the ground beneath each of them compressed unequally, and at one side to the extent of several feet*. Yet the extreme pressure imposed on the unit of surface of any architectural or engineering structure upon our globe is but a feather-weight as compared with the pressure per unit of surface beneath the base of any volcanic or other mountain of even moderate height.

While the controversy raged between the advocates of "craters of elevation," led by Von Buch and Elie de Beaumont, and those who with Lyell expressed the more rational notion, which may now be considered *established*, that volcanic cones and their craters are consequences of deposition, the advocates of those respective systems were much more occupied with finding arguments in favour of their own, and against the views of their opponents, than with carefully examining the actual facts in the structure of volcanic cones; and hence the important fact of the change in position and of level in the bases of volcanic cones during the long periods occupied by their deposition, has, so far as my knowledge goes, hitherto entirely escaped the notice of geologists. Yet the phenomenon, although frequently difficult of observation, must be of such frequent occurrence as to deserve the prominence and explanation here sought to be given to it.

In addition to the cause which has been already referred to, for the alteration of direction and position in the lower beds and beneath the bases of volcanic cones, namely the effect of mere weight in forcing downwards the lower part of the mountain, another adjuvant cause must very frequently, if not always, come into play, producing depression and alteration of slope in the lower parts and beneath the base—namely, the excavation and honeycombing and evisceration which is continually going on beneath such mountains. Where such excavation takes place at considerable distances from

* The Campanile or Leaning Tower of Pisa, built in the 12th century, is cylindrical and about 150 feet in height; and the dense clay upon which it has been founded has compressed unequally, so that the tower at one side overhangs its base by about 14 feet. The two square pyramidal towers of brick at Bologna were also built in the 12th century; the higher and nearly complete one, usually called Il Torre d'Asinelli, after the name of the founder, is 256 feet in height, and stands nearly plumb; the other, called Garisenda, is only about half that height, and leans over to one side so that the summit overhangs the base by about 9 feet. The latter tower is referred to by Dante in the 31st canto of the 'Inferno.'

the axis, through ducts situated at very great depths, no falling-in or alteration of surface may be apparent, just as the filling-up of cut-out beds of coal by the "creep" or gradual forcing-up by superincumbent pressure of the "coal seat" until that reaches the roof, gives no evidence at the surface of such subterranean movements; but where the excavation goes on at but an inconsiderable depth, portions of volcanic cones give way and fall, so that the descending material more or less fills up the previous cavity. This I consider to be the mode of production of the Val del Bove, and of the singular wall-sided cavity known as the Cisterna, and situated upon the Piano above. Both these vast depressed and wall-sided cavities appear to me to present many unmistakable evidences of having been thus formed by dropping down, whether at one or at successive times, of portions of the mountain, whose support beneath had been eaten out until it became insufficient. The forms of the rocky steeps surrounding these cavities, more especially that of the Cisterna, forbid the supposition that they were anywhere the flanks of ancient craters; on the contrary, they have all the characters presented by rock masses which have been broken up and fallen from want of support beneath. In my earthquake-expedition of 1857, I observed in the great mountain gorge of Compostrina, which separates the Val di Diano (where the river is called the Calore) from the next valley lower down (where it assumes the name of Tanagro), a considerable number of deep wall-sided cavities precisely resembling in physical character that of the Cisterna—though not volcanic, yet produced by a mechanism closely analogous in its effects.

The water of the Calore debouches from the Val di Diano by two channels diverging from the same spot: one of these is a subaërial torrent, as muddy as all the rest of the river, which finds its way through the tremendous gorge into the lower valley; but another, subterraneous channel, into which a prodigious volume of water enters, finds its way in darkness beneath the solid limestone rock of the mountain, and only reappears at the mouth of the great cavern called St. Michael, where the water, now become perfectly pellucid by subterranean deposition, reappears and joins the muddy stream of the subaërial torrent. The wall-sided cavities just referred to are seen to form an irregular chain on the flank of the mountain, and are no doubt situated vertically above the irregular duct below, which, continually eroding its whole walls and weakening its covering rock, has in some places caused the latter to drop down. Some phenomena well known to the inhabitants definitely support this view of the formation of these vast pits with wall sides, and a bottom covered with huge fragments of broken-up rock. On more than one occasion the water discharging from St. Michael has suddenly become turbid and for a time greatly diminished in volume; and on such occasions a new cavity has been found to have formed somewhere on the mountain.

It is only necessary to examine the forms of these great pits, so greatly resembling the Cisterna and those to be found in many places on volcanic mountains, to come to the conclusion that both have been formed by falling-in of superincumbent masses deprived of support beneath, although in the one case the removal of support has been produced by volcanic erosion, and in the other by that of running water in subterraneous channels. For a more particular account of these curious cavities see vol. i. of my Report, to the Royal Society, on the great Neapolitan earthquake of 1857. Besides large areas, such as those of the Cisterna and Val del Bove, which by the mechanism assigned had fallen in, though gradually or piecemeal, yet with sufficient rapidity to be denominated *per saltum* movements (which can only occur where the surface-rocks of the cone are massive and coherent), it cannot be doubted that the continual evisceration always proceeding from active vents by the blowing-out of dust and lapilli must be attended with gradual creeping-in of subterranean ducts and equally imperceptible descent in the whole body, and more especially in the lowermost parts of the mountain mass.

We have thus, in conclusion, established the existence of two separate but cooperative causes, operative in all active volcanic cones, unless perhaps those few which are based upon solid and practically unalterable rock (such as the Puys of Auvergne), tending to alter the position and level of the strata of deposition of volcanic cones. The modifying forces have therefore seemed to me of sufficient importance to deserve the somewhat fuller, though still imperfect, explanation of them which I have here attempted. With the exception of the very brief reference, in application of the facts, to be found in my paper on the Dykes of Somma (Quart. Journ. Geol. Soc. vol. xxxii. page 493, commencing at line 32 from the top) I am not, as has been already stated, aware that the matter treated of in this paper has been noticed by any previous writer on volcanos*.

* Assuming, as may safely be done, that volcanic cones are on the whole discontinuous masses, the pressure upon the unit of surface beneath the base of such a mountain will be everywhere proportionate to the vertical depth of the material superimposed thereon. If, therefore, we assume a cone 20,000 feet in height, and take the density of its material to be as low as 112 lb. per cubic foot (the figures which I have adopted in my paper on "the Nature and Origin of Volcanic Heat and Energy," Phil. Trans. pt. i. 1873), the pressure on the base would be 1000 tons per superficial foot; and if the whole mass were of a density as great as that of pyroxene, the pressure would be about one half more. This is but a rough approximation, and probably much below the truth, as the discrete material must of itself acquire increased density with time by the pressure of its own superincumbent mass. It is a difficult physical question to determine conjecturally whether if, given discontinuous material, as actually found in nature, the pressure on the base, the depth being given, will decrease inversely as the surface thereof; for there is little to guide us to an accurate opinion as to whether the base of an entire mountain can compress the material beneath it to a greater or less extent than the same amount of pressure would compress a single square foot of the same base. The base in such large instances, however rigid, unless it be of continuous and coherent rock, must transmit the vertical pressure outwards laterally in all directions, somewhat after the fashion of the quaquaversal pressure of liquids; and many complex considerations enter into the question of how far in any given case those lateral pressures may extend.

To contrast this roughly with the actual pressure visited upon the unit of

Discussion.

Prof. Judd said that the subject treated of by Mr. Mallet was one of great importance in considering the phenomena of the formation of volcanic cones. At the same time he remarked that the subject had by no means been altogether overlooked by previous writers. The inward dip of some beds had been noticed in Icelandic volcanos, and also by Mr. Darwin in some of those observed during the voyage of the 'Beagle,' and described in his work. The same phenomenon also occurred in New Zealand. Prof. Judd said that he had himself shown in the case of the great volcano of the island of Mull that the admission of this dip towards the centre is essential to the comprehension of the structure of that volcano, and calculated the amount of change that has taken place in the inclination of the materials of which it is composed. He also stated that he could find no difference in the mode of volcanic action in older and more recent times.

The Author, in reply, said he perceived he had laid himself open to the remarks which had been just made by not having sufficiently distinguished in his paper between the effects due to evisceration and those which he attributed to subsidence by the continually increasing weight of material evolved from the base of a volcanic cone. There was nothing new in the fact that evisceration must produce subsidence; that had long since been noticed by writers on volcanos; and the depression thus produced may affect the form of the base of the cone in any way. The point to which the author intended specially to draw attention was, that the heaping-on of matter in the production of a volcanic cone must alter the base in a definite form, so that, assuming the cone to be deposited upon an originally level plain, the effect of the imposition of the cone would be to depress the base into the form of a saucer or bowl.

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base of architectural structures, let us assume a round brick chimney stalk (such as examples existing in the neighbourhood of Glasgow and elsewhere), the diameter at the base being 40 feet, the thickness there 5 feet, and the height 400 feet, the batter and reduction in thickness with height being as usual in such cases. Assuming the brickwork to weigh 112 lb. per cubic foot, the pressure per square foot of base would be only about 6 tons. But as the designers of such structures judiciously enlarge the area of base by external offsets and other means until the area is doubled or more, so the actual pressure would in this instance be only from 2 to 3 tons per square foot. Yet such lofty and narrow structures as that here adduced visit a more severe stress upon their base and foundations than probably any others within the whole range of architecture and engineering. All reference is of course excluded here from piled or other purely artificial foundations, such as are employed beneath the piers of large bridges, &c.

41. Notes *on some* Recent Discoveries *of* Copper-ore *in* Nova Scotia. By Edwin Gilpin, Esq., M.A., F.G.S., Mining Engineer. (Read June 20, 1877.)

Although for many years the presence of various ores of copper was known in this province, it is but recently that discoveries have been made of economic value.

In the early French expeditions to Canada and Acadie (now Nova Scotia) were men similar to those styled by Sir Humphrey Gilbert "rare refiners of mines;" and their reports on the supposed mineral wealth of Nova Scotia and Cape Breton excited much interest in Paris, and formed one of the reasons that France struggled so strongly to retain her supremacy in British America.

Lescharbot, writing in 1609, speaks of the native copper of the Bay of Fundy as being "very pure in the stone," and adds, "many goldsmiths have seen it in France, which do say that under the copper-mine there might be a golden mine, which is very probable." The stone he alludes to is the trap associated with the Triassic sandstones of the Bay of Fundy; copper is found scattered through it in small grains and lumps, but has not yet been found in workable quantity. Although this trap resembles that from the famous Lake-Superior copper-district, the zeolites and other minerals characteristic of the Nova-Scotia trap are wanting in the Lake-Superior trap; and on no ground, so far I am aware, can any equivalence of age be established.

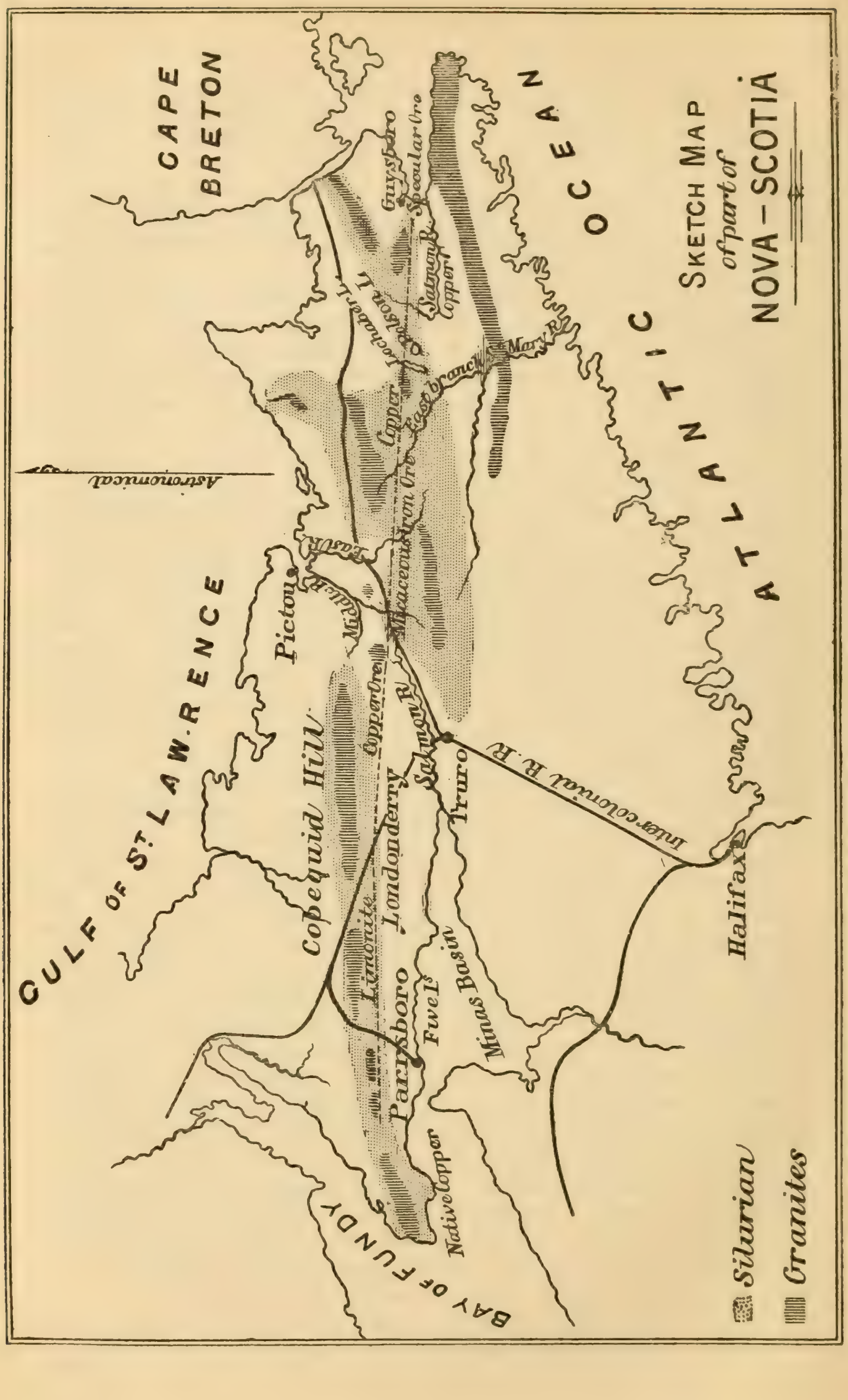
Passing over without notice the numerous unsuccessful attempts that have been made to open productive copper-mines in Upper and Lower Carboniferous strata, we find that the eastern part of the province gives the best indications of permanent deposits.

On reference to the accompanying geological map of part of the province (p. 750), based on the map prefixed to the second edition of Dr. Dawson's 'Acadian Geology,' it will be seen that the northern part of Nova Scotia is traversed longitudinally by a band of strata of Upper and Lower Silurian age, higher in geological sequence than the auriferous measures of the Atlantic coast, and covered at one point by a narrow band of Lower-Carboniferous age.

In this Silurian series, and pursuing a general east-and-west course, are numerous large bands of granites, reddish syenites, in places composed of red felspar, hornblende, porphyry, compact felspar, and diorites, with ash, &c.

Pursuing a course roughly parallel to these bands is a tolerably well-defined series of large fractures, extending from Parrsboro to the East River of Pictou, and thence to Guysboro. The course of this line of disturbance is marked by metamorphic action, ores of iron and copper, and by dykes and masses of diorite, &c.

From Parrsboro to Londonderry valuable brown hæmatite deposits are found, with micaceous and specular ores, goethite, &c., running


SKETCH MAP of part of NOVA-SCOTIA
CAPE BRETON
GULF OF ST. LAWRENCE
ATLANTIC OCEAN
BAY OF FUNDY
Astronomical
Pictou
Cobequid Hill
Londonderry
Parrsboro
Five Is.
Minas Basin
Truro
Halifax
Intercolonial R. R.
Salmon R.
Copper Ore
Limonite
Native Copper
Micaceous Iron Ore
Copper
East branch
Mary R.
Guysboro
Specular Ore
Copper
Silurian
Granites

east and west (astr.). At Londonderry copper-pyrites is found in the iron veins in small quantity, and also at Five Islands, associated with heavy spar.

On the Salmon River, near Truro, very pure carbonate and grey sulphuret of copper are found, probably, however, owing to organic matter. On the head-waters of the Middle River are veins of specular ore and limonite; continuing to the east a few miles, a vein of specular ore is met running east and west, and 20 feet wide in places. This vein has been traced for about three miles, and, although no fossils have yet been found in its vicinity, is generally considered to be in strata of the same age as the Londonderry ore.

Following the line to the eastward, the iron ores are now chiefly spathic and micaceous, forming the gangue for copper-pyrites. About five miles eastward of the large vein of micaceous ore above referred to, the first traces of copper-pyrites are met, which are repeated in a small vein on the east branch of the St. Mary river.

The copper deposits now attain their greatest development near Lochaber and Polson's Lakes; and the traces continue to be found for miles to the eastward. On the Salmon River the Primrose property shows a small vein, which was tested to some extent a few years ago, and contains very rich copper-ore. From analyses made by Dr. Hayes, State Analyst, Boston, U. S., the ore contained from 37 to 39 per cent. of copper, and was composed of copper-pyrites and embescite.

Finally, near Guysboro, specular ore of very fine quality occurs, but is not yet proved to be of economic value. Specimens of native copper in diorite (?) have been brought to me from this district; but I have no detailed information respecting it.

At Lochaber Lake, where a great deal of work has been done, the deposits appear to be of unusual value, and are being prepared for mining-operations.

The deposits form a series of veins, cutting at oblique angles black and red shales and quartzites, and thrown for a short distance 30° out of an east-and-west course by a dyke, apparently a diorite containing talc and serpentine.

The first vein met going east is about 2 feet wide. I have no details of its contents. The second vein, 80 feet distant, has been proved to a depth of 85 feet; it varies in width from 5 feet 6 inches to 6 feet 3 inches, and holds about 20 per cent. of copper-pyrites evenly distributed in talcose slate, greenstone and quartz, and micaceous iron-ore.

The third vein, 216 feet distant, is from 1 foot 6 inches to 2 feet wide, and holds copper-pyrites, with embescite in bands, with quartz and talcose greenstone.

The fourth vein, 130 feet distant, is about 5 feet wide, and carries about 10 per cent. of rich ore with much quartz.

The fifth and sixth veins are respectively 50 and 150 feet further east; they are each 3 feet wide. These leads also contain large percentages of ore, but have not yet been examined. In these last the micaceous ore has been to some extent replaced by carbonate of iron, which is the chief gangue of the Polson's-Lake ore.

The sixth vein is gradually returning to its east-and-west course; and at a further distance of 300 yards it has been opened again, and proved to be 4 feet 6 inches wide; and nearly half a mile to the east, on the strike of the vein, two small veins have been found holding very good ore, and large boulders proving the passage of the larger veins.

The course of the cupriferous band has been traced, by surface-indications, from this point, about four miles, to Polson's Lake, where, during the past summer, a very fine vein of spathic ore, holding copper-pyrites and a little iron-pyrites, was traced for several hundred feet through dark blue and olive slates. Its width varied from 6 to 11 feet; and its course was about N. 70° W. (astr.). Dr. Dawson gives the average of copper in this ore at 10·8 per cent.; I should judge from samples shown me that it is considerably higher.

The age of the strata holding these deposits is not yet clearly settled. Dr. Honeyman, in a Geological Report to the Provincial Government, stated that the Polson's- and Lochaber-Lake strata were of Devonian age.

From following the line joining the copper and iron districts, it will at once appear, on mapping the exposures and strikes, that these measures are on the same geological horizon as those holding the limonite and micaceous ores of the East and Middle Rivers of Pictou.

These latter measures, both at the East River of Pictou and at the Cobequids, are overlain by strata of Lower-Helderberg age. On the other hand they are readily referred to a later age than the auriferous rocks of the Atlantic coast. No fossils have yet been found clearly defining their position; and, in the absence of a reliable geological survey, they may be provisionally considered as filling a place near the middle of the Silurian strata.

The metamorphism of this range of iron- and copper-bearing strata would appear to have taken place before the commencement of the Lower Carboniferous epoch; for we find conglomerates and shales of that age deposited around diorite dykes on the East River, and the former holding pebbles identical with the ore-bearing slates. The date of the filling of the fissures with ores does not appear equally certain; for the Lower Carboniferous sandstones and limestones, which in places overlie the ore-strata, frequently contain small veins of specular ore, which, with magnetite, also occurs in the fissures of the Triassic trap.

The quality of the Lochaber ore is unusually good; the chief variety met is copper pyrites with a small admixture of carbonate of copper and embescite. The gangue at Lochaber is chiefly micaceous iron-ore, with a little spathic ore; at Polson's Lake exclusively the latter, which yielded on assay 35 per cent. of iron.

An average of the large veins gave, on analysis by Dr. How, of Windsor:—

Metallic copper	19·21
Metallic iron	25·31
Sulphur	22·65
Carbonate of lime	5·15
Oxygen	4·07
Gangue	23·01
	99·40

An analysis of the pyrites from the second vein gave the writer:—

Copper	29·00
Iron	29·70
Sulphur	31·50
Silica	3·40
Moisture	·20
Carbonate of iron	6·20
	100·00

A sample from the third vein gave at Swansea 31·25 of metallic copper.

From the above notes it will be seen that Nova Scotia may soon appear on the list of copper-producing countries; and it is confidently expected that during the approaching summer fresh localities will be proved to contain copper-yielding veins.

42. *The* Precarboniferous Rocks *of* Charnwood Forest.—Part I.

By the Rev. E. Hill, M.A., F.G.S., Fellow and Tutor, and the Rev. T. G. Bonney, M.A., F.G.S., Fellow and late Tutor, of St. John's College, Cambridge. (Read June 6, 1877.)

Contents.

Introduction and General Description.

Charnwood Forest, as is well known, is a hilly district composed of a number of rather parallel ridges with a general trend from N.W. to S.E. These hills rise to a height of a few hundred feet above an undulating plain of Mesozoic rocks, which on the eastern side is interrupted by the wide valley of the Soar. They consist of rocks most of which are more or less metamorphic; but some are igneous; isolated bosses also crop up here and there from the surrounding Trias. This deposit runs, as it were, in fjords into the recesses of the older rocks, besides dividing the district by a kind of strait or sound. To the S.W. and S. the Trias stretches far away; but on the W. (not, however, much modifying the configuration of the district) lies the Leicestershire Coal-field. A boss of hornblendic granite, Mountsorrel, crops up at the western edge of the Soar Valley; and three or four masses of a somewhat similar rock occur at a greater distance to the south. These most likely are all outliers of the highland region of the forest, which is really the culminating point of an old mountain-land. This was probably to some extent defined before the Carboniferous epoch, and formed a scattered group of hilly islands in the Triassic waters.

The district has been investigated by Professor Sedgwick, Professor Jukes, Professor Ansted, the Rev. W. H. Coleman, and several others. An exhaustive list of the papers upon it will be found in 'The Geology of Leicestershire,' by W. J. Harrison, Esq., F.G.S.

According to the map published by the Geological Survey, the Forest consists chiefly of rocks of Cambrian age. These, for about $2\frac{1}{2}$

square miles in the N.W. corner, pass insensibly into "felspathic porphyry," of which a few isolated patches are also marked in the south-east hills. Some large masses of syenite, more or less connected, occur in the southern part, and two others nearer the centre. Bardon Hill is coloured as a large mass of "greenstone," which rock is also shown in the neighbouring Birchwood Plantation, and in several small isolated patches on the N.E. of the Forest. From several important points in the above mapping, as will be seen hereafter, we are compelled to differ, as well as from the memoir published by the Survey.

It must be remembered that in the Forest, while it is usually tolerably easy to recognize the general character of the rocks, the task of coordination and correlation presents peculiar difficulties, owing to the prevalent absence of cliffs, ravines, or continuous sections, the large amount of country covered by vegetation or cultivated soil, the insulation of the exposures by these, the absence of indications of dip, with other peculiarities in some of the coarsest fragmental deposits, and, lastly, to a certain perversity, as one might almost call it, in the country, which seems always to cover up just the most critical part of a section. Hence the authors wish it to be understood that the order of stratigraphical sequence assigned to the sedimentary rocks in this paper must be regarded as open to revision, and as the best hypothesis which, under the circumstances, they have been able to frame.

The rocks of Charnwood Forest are usually described as forming a great anticlinal, the axis of which runs from N.W. to S.E., along a valley rather on the eastern side of the district. This, however, is only true in a general sense. Still it will be convenient for description to retain the term, and to carry our sections from either side up to this "anticlinal valley," where the dip of the beds changes. We shall describe the principal exposures in order along a series of sections, beginning from the north-eastern or Loughborough end of the region, going southwards to Woodhouse Eaves and Swithland, and then round the other side of the anticlinal by Bradgate, Markfield, and Bardon, to the extreme northern end at Whitwick and Gracedieu. Certain localities, which cannot be conveniently grouped under any of these sections will be separately described.

Description of Sections.

1. Leaving Loughborough by the Loughborough Lane, we first see live rock in an old quarry on the left-hand side of the road, called on the map Forest Gate. There was formerly another on the right-hand side. Unfortunately, we were not then aware of the importance of this rock, and took no specimens. It is now filled up. As far as we remember, it was ordinary blue slate; and the fragments in walls in the neighbourhood confirm this. Professor Jukes describes it as compact slate, with faint cleavage, greatly cut up by joints, and with a few faint streaks of colour giving a N.E. dip of 85°. The rock on the left-hand side is very singular. Its dip is well marked, very

steep, almost vertical, and E.N.E. (85° and N.E., Jukes). It consists of a series of alternating beds, some of fine-grained good slate, some of a greenish ashy aggregate of pebbles and fragments of slate, quartz, and felspathic materials. It is rather schistose, with a silvery lustre. Rounded grains of quartz, felspar, and a black mineral, possibly hornblende, may be detected; parts of the rock have a very soapy feeling; and altogether it has the aspect of a volcanic ash, mingled with other detrital materials waterworn and greatly compressed.

About half a mile further, the road ascends a hill, not named on the map, but called Nanpanton in the neighbourhood. Here there is a fine exposure of what will be called throughout this paper banded slates. As this is the most common rock of the Forest, we may describe it here once for all. It is an alternating series of finer and coarser sedimentary materials—the former generally bluish or green, sometimes whitish or pink, and felspathic or argillaceous, the latter generally quartzose. The finer often weathers white for some distance inside. It is not often perfectly cleaved, but is generally very hard, so indurated sometimes as to almost resemble a porcellanite or hornstone; its surface will sometimes turn the edge of a knife. The strike in this part of the Forest is rendered conspicuous by differences of colour, while in other parts it is only made visible by unequal weathering of the different bands. Dip is, of course, always obvious and easily measured. These slates are only contorted in one or two localities; but the strike and dip frequently change a little within a very short space. While the series, as a whole, is remarkably distinct, there is the greatest difficulty in tracing any one bed from point to point; nor are we aware that, before this paper, the attempt has ever been made.

At the top of the hill is a coarser bed of a greenish slaty ash, barely, if at all, showing stratification.

The small patch on the crest of the hill, coloured greenstone on the map, is correctly indicated. It is more strictly a syenite, like that of Garendon, which will be described hereafter; some ashy grits show out near to it. The exposure south-east of Longcliff consists of banded slates, with the strike but slightly indicated. That of Kidney Plantation we have not examined; and beyond it, at Lubcloud, we are on the other side of the anticlinal.

The rocks exposed at Longcliff are mainly slightly banded slates, intermingled with coarse grit bands. About the middle of the ridge there is a bed of a coarse lumpy ash, with some included fragments of slate.

2. Starting again south of this section from the Buck-Hill woods, there is an exposure (at the word "out") which we have not examined. The patch, coloured "greenstone" on the Survey Map, consists almost entirely of banded slates, some of the most distinct and characteristic examples of these rocks in the district. There is, however, at the north extremity, as Jukes says, "a small quarry of a true close-grained greenstone" similar to that above-mentioned.

Low down in the series, on the S.W. side of a singularly steep and rather picturesque ridge, is a bed, about three yards thick, of coarse ashy grit, composed of quartz and felspar grains, with here and there small fragments of slate. Below it banded slates again occur, which are also shown in various exposures to the south at Blackbird's Nest and Beacon Cottage. No rocks are visible in the direct line of the section for about three quarters of a mile, till on the crest of Whittle Hills we find an exposure of dark-green coarse slate (dip not shown), agreeing with a similar exposure at the top of Nanpanton. Two or three hundred yards beyond is the little quarry whence the Whittle Hill derives its name, where the banded slates are so compact in texture and indurated as to produce whetstones of the very best quality. Some of these show curious distortions of their stripe, due to the pressure which has produced their cleavage. At some distance above this is a bed of coarse whitish ashy grit; and a whitish slaty schistose-looking rock is exposed to a small extent in a field on the opposite side of the lane. Beyond this runs the anticlinal line.

3. The district next to be described, that of the Hanging Rocks and Beacon Hill, is one of the highest interest and variety, and gave the first clue to the structure of this side of the country. It is also extremely beautiful in its scenery, and is open to all visitors by the liberality of the owner, Mrs. Herrick. The Hanging Rocks (Hanging Stones of the Ordnance map) is the name given to a series of wild crags, three quarters of a mile long by a quarter broad, in a grassy park, a demesne of Beaumanoir House. Outside this, at the farmhouse by Pocket Gate, is a knoll of ashy slate, in which is a quarry. The rock is much slickensided and crushed; and though the map assigns it a dip, we could not satisfy ourselves as to its true inclination. But within the park, at the north extremity, is a quarry showing banded slates magnificently, here extremely hard, with conchoidal fracture, the finer beds, some of which are rather thick, almost a hornstone. They dip at angles of from 40° to 50° in a direction E. 10° N. On one of the great bedding faces are seen two of those curious arrangements of concentric rings which have been supposed to be organisms. The resemblance to any known organism is of the most superficial character; and one objection seems fatal. They lie in the plane of bedding, which makes a high angle with that of cleavage. Though the latter is well marked, the rings suffer no distortion. The larger, which is about seven inches in diameter, consists of about three rather rippled concentric flat rings; the smaller is only about two inches in diameter. We regard them as an accidental structure, due to some local peculiarity, but have a decided opinion only on one point, viz. that they are inorganic.

Above this quarry are banded slates, with some coarser beds. The lowest exposure, perhaps 100 yards further, is a massive gritty greenish rock, not itself showing bedding, containing many small fragments of slate, with some pebbles and larger pieces, which sometimes attain a length of several inches. At the south end there is another slate-quarry. As is usually the case where the cleavage is good, the colours are not much contrasted, but the bands are perfectly distinct. The dip is much the same as that of the beds in the north quarry; but the strike would bring them above those. Ascending the same knoll, and unquestionably continuous with these slates, we find intercalated among them a series of remarkable beds. These are conglomerates of pebbles (subangular to well-rounded) in a greenish ashy matrix. The pebbles are generally not larger than a horsebean, but occasionally two inches in the longer diameter; some are quartz and quartzite; but most of them are felstone or an indurated felspathic mud and a fine slate. The beds are from one to two feet in thickness; and there may be four or five of them, each a yard or two apart, occupying a thickness of at least 20 feet; turf hides the base of the series. These beds cannot be traced very far, perhaps only some fifty yards along their strike, the direction of which slightly changes in this short distance, so that, though in full view of and at no great distance from the beds exposed in the north quarry, it is impossible to say whether the latter overlie or underlie them. We incline to the latter view.

The uppermost bed of these conglomerates seems to pass into a grit-bed, of which more hereafter; and this into blue slate of slightly ashy character.

Unquestionably well below these beds, in the centre of the space, is a fine outcrop of massive rocks, forming a cliff twenty or thirty feet high. This consists of a mass of pinkish fragments and crystals of felspar in a dark slaty matrix. There are small grains of slate in it, but little if any quartz, and no quartz granules. Here and there is an appearance of large included fragments, but very few. It is, we have no doubt, a bed of volcanic ash. Dip is shown by banded slates just below it, and by an intercalated bed of whitish felspathic matter, very hard, and closely imitating an intrusive dyke, but undoubtedly sedimentary. At one point this has an appearance of rather considerable contortion, though only on a small scale, probably a result of false-bedding. Below this thick mass are exposures of banded slates, and beneath these again another thick ash bed, very like the one just described, but apparently not so thick. This may agree with the similar bed some 200 yards north, previously described, though it does not look quite the same. Beyond this nothing more is visible in the grounds of the Hanging Rocks. Crossing the road and entering the moorland of Beacon Hill, we ascend its long slopes, only occasionally meeting with exposures. Careful search on the left side shows more than appear at first sight, but very far short of a good series. They are all banded slates; and the summit of Beacon Hill itself is entirely composed of the same rocks. The cliff at the north end affords an excellent section; but there is no trace of any thick ash bed or breccia, or any thing which one could hope to identify.

There are no further exposures till the Anticlinal is reached.

4. The next district, that of Woodhouse Eaves and Broombriggs, contains a number of isolated exposures, whose relative position it is not easy to determine. Woodhouse windmill stands on a high

knoll, on which there are many outcrops of rock. The highest of these are banded slates. In the field in which the mill stands, one bed shows a good deal of breccia. Its matrix is a green ash with dark bluish stains or blotches, and small included fragments of felspathic rock and slate. Close to the mill is a large thick greenish ashy bed, with distinct included fragments; below this are banded slates, in which is at least one other bed of breccia with slaty fragments. The strike of the bed on which the mill stands would suggest its correspondence with the great central ash bed of the Hanging Rocks; but it does not quite resemble any of these, its colour being paler, its matrix finer, but its fragments coarser and apparently less crystalline. We think, however, it is probably one of that series of ash beds. We have not been able to identify the pebble beds. We have not, indeed, visited every one of the exposures on Broombriggs; but all that we have seen are banded slates, similar to those on Beacon Hill, of which this ridge is the continuation. Two of the coarser beds on the summit are somewhat peculiar in structure: one is a hard, dark greenish grey rock, containing numerous small rounded grains of quartz, of felspar crystals, and apparently of a fine quartzite; there is a good deal of minutely crystalline epidote in the matrix. The other is a thick grit-bed of similar materials to the above, but much coarser. The matrix does not appear to have so much epidote. The general colour is greenish, weathering brown. These beds are intercalated among finer grits and banded slates, some apparently containing many fragments of felspar crystals. Beyond the crest of Broombriggs no more rock is exposed.

A quarry in the village of Woodhouse Eaves, at the back of the church and school, affords a fine section. The slate was good enough to be worked, and a cave has been cut out to a depth of some yards; but the quarry has long since been abandoned. The dip is well shown (60° to E. 30° N.). The rocks in the field above, continuous with but below these, are ordinary banded slate. These appear to be above the rocks by the mill; however, any faulting or curving might easily make them below. For the most part nothing but banded slate is to be seen beyond these in the direction of the section; there are, however, at Maplewell some grit-beds resembling those of Broombriggs, and on their line of strike.

5. The region of Swithland, the Brande, and Roecliff (fig. 1, p. 762), which comes next in order, is one of the most important in the whole forest, on account both of its numerous exposures and of the information to be derived from them. The highest rocks visible seem to be those of the great quarry at the cross-roads, well known to all who have visited the district. The cleavage is well developed; and the quarry is still, or was till very recently, worked, good roofing-slate besides slabs for various purposes being obtained. The slates are faintly banded, colours dark greenish grey to purple; but the strike is fairly distinct, the beds dipping about 30° to E.N.E. The cleavage, which is nearly vertical, strikes about W.N.W., and so makes an unusually large angle with the strike of the bedding.

Within the grounds of Alfred Ellis, Esq., west of the meeting of the lanes, is a large abandoned quarry, of precisely similar slate. Here a rapid little stream separates two steep and extremely picturesque hills, on the northern one of which, called the Brande, stands the house. Mounting the spur of the southern hill, we find the slate greener and coarser in texture, and presently meet a bed of grit, with minute fragments of slate and felspathic rock; similar beds occur a little further on, then pebble beds, intermingled with schistose ashy slate bands more or less fine, no base being seen. These beds, however, can be studied to the best advantage in the fine sections of the northern hill, where they form a series of cliffs facing west, now judiciously laid out as a sort of wilderness. In these every detail of the rock can be perfectly studied. It consists of a series of beds of pebbles, interstratified with finer grits and slate. The thickness of the pebble beds is usually about 6 inches. The compression which produced the cleavage has arranged the pebbles on end in the strata. The pebbles themselves are not generally more than half an inch long, and consist mainly of slate, but with many of a felsitic material, and some quartzose ones, all in a greenish white decidedly ashy matrix. The intermediate slaty bands have also the silvery sheen often belonging to ashy materials. The lowest visible rock, exposed on a wooded spur, is a massive unstratified ash, with angular fragments and blocks of slate of considerable size. Over the pebble beds, well seen above a drive through a cutting about 6 feet deep, is a quartz-grit bed, apparently about 8 or 10 feet thick, here and there getting bluish in patches. The quartz seems in places to have been dissolved out of the rock and redeposited on the surface in a glaze; and we suspect that some at least of it is of secondary formation, coming from the decomposition of felspathic materials.

In the spinney north of the grounds of the house is an exposure of fine-grained pale greenish slate, not banded. This is probably below the pebble beds, as in the same spinney, close to the lane about the word "Brande" on the map, is another exposure of pebble beds, here a good deal decayed and flaking up with a coarse cleavage, and an ashy sheen, weathering red on the surface of open joints or cleavage-planes. These beds strongly reminded us of those first described at Forest Gate, where the silvery sheen is also apparent, and beds of workable slate also exist above them. The conglomerates, though their pebbles are smaller, can be identified with those of the Hanging Rocks by the occurrence of the grit beds above; and both are underlain by thick ashy beds. We may therefore conclude that these beds of the Brande and the Hanging Rocks are on the same horizon, and with much probability also place there those of Forest Gate.

South of the lane to Newtown Linford the slates have also been worked in one or two quarries. Mr. W. J. Harrison, F.G.S., tells us that he has found the grit-beds there. This discovery decides a point of which we were doubtful, viz. that the slates of the pit in Swithland Wood lie below the rocks of the Brande. This pit is

80 yards deep, and is actively worked. The slate is purple, blue, and sometimes greenish, showing faint bands in its upper part. Some vertical sheets of rock in the pit closely resemble intrusive dykes. They are, however, affected by the cleavage; and the seeming junctions follow cleavage-planes. They are probably due to decomposition extending from the sides of fissures which have passed down planes of cleavage. Outside the wood, and underlying the rocks of the quarry, is a knoll in a field showing a series of banded gritty slates. Other small knolls show similar rocks.

By the back carriage-drive to Roecliff Hall is a thick gritty bed. A fine set of banded slates is exposed in the outcrops north of the cross lanes, but the colours are rather less marked than in the Woodhouse region. Those of Ling Hill and Crow Hill are of the usual character. The dips in all this part of the Forest are E.N.E. or E. by N.; the due east direction of the arrows on the Survey map is misleading.

In the hollow lane at the Brande a tiny fault of about a foot throw can be seen. It is quite possible that there are others about, of much larger dimensions, which cannot be determined.

The last district on the east of the anticlinal is a series of rocks in two spinneys, just outside Bradgate Park—the northern one called Blore's Hill, the southern unnamed on the map. The beds in the southern spinney are a very beautiful set of banded slates of the ordinary type and strike. Those of Blore's Hill are interesting, from showing, as we go northward and westward, a gradual curving of the strikes from E.N.E. or E. to S.E. Now the dips beyond the anticlinal in this part of the Forest are S. The materials are mainly banded slates, green, of moderately fine grain, and at the north end considerably indurated. The most important bed is that which is coloured red and marked F on the map. This is a large thick unstratified bed of breccia. It has a green ashy matrix containing many small fragments of felspar crystals and larger pieces of felsitic rock and of a fine-grained green slate. Here and there are dark shining fibrous spots, probably the result of the decomposition of some magnesian mineral. The larger fragments, of fine-grained green slate—and many are of enormous size—are contorted in fantastic ways. One included piece is full six feet long, bent back on itself into the shape of a U. This bed is identical in all respects with the breccia on Old-John Hill, only a quarter of a mile off, towards which indeed the strike (if the same as that of the neighbouring beds) would carry it; this, however, is beyond the anticlinal, and dips S. instead of towards the east as here.

Before commencing the description of the Bradgate rocks, we must mention that the exposure in the Park nearest to the Holgate entrance also dips E.N.E. and contains a conglomerate of slaty pebbles with felspathic fragments. It does not look exactly like the pebble beds of the Brande, but, being 1½ mile distant, might nevertheless belong to them. The strike would carry it below; but being so close to the anticlinal (for within 100 yards are beds dipping south) and in a region which is faulted, as we shall show, not much stress can be laid on this.

Fig. 1.—*Section through Blore's Hill and Swithland Wood.* (Scale about 4 inches to 1 mile.)

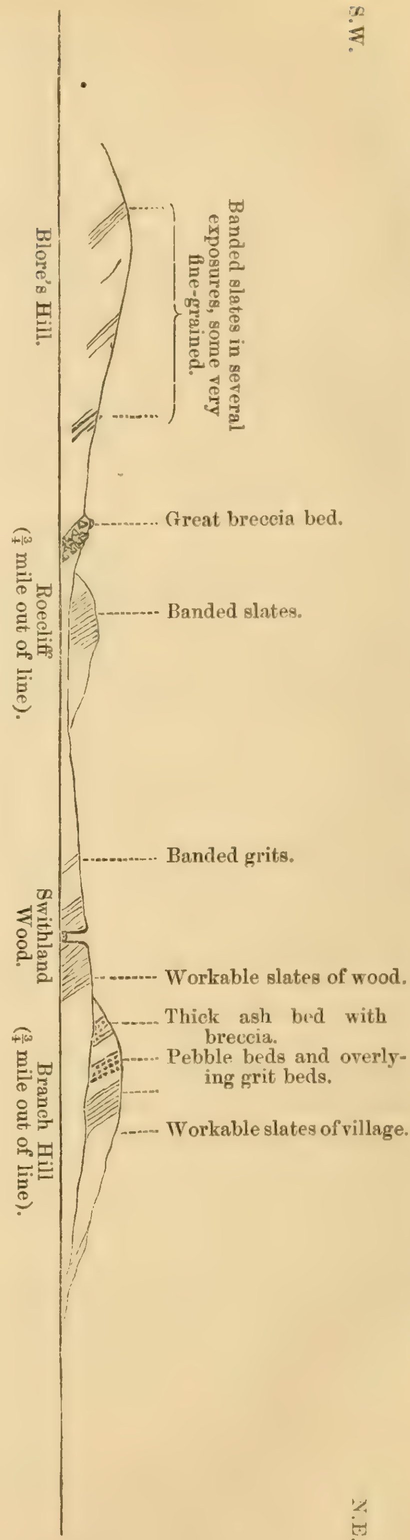
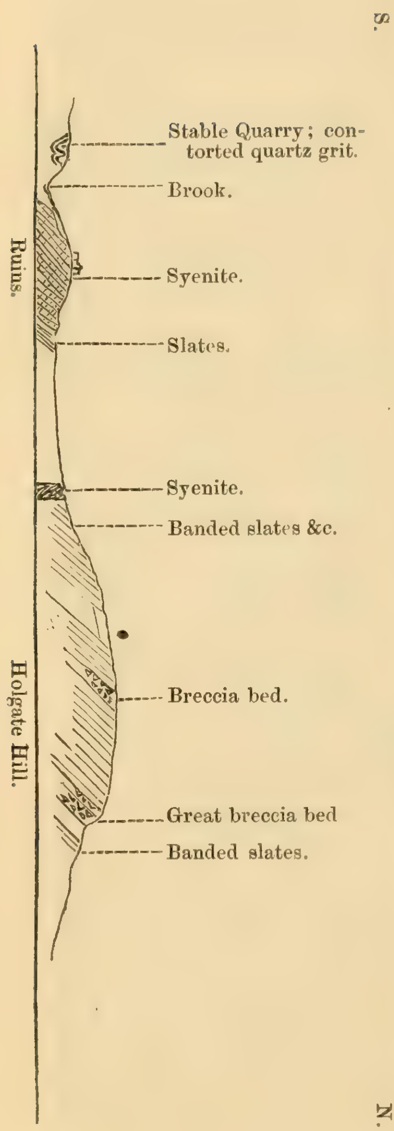


Fig. 2.—*Section through Stable Quarry and Holgate Hill.* (Scale about 4 inches to 1 mile.)



6. In the country west of the anticlinal line, on which we now enter, is a good deal of igneous rock, which considerably complicates its structure. The relation, however, of the igneous to the stratified rocks we purpose to defer to the last section, and so shall, as far as possible, pass it by for the present.

Almost the whole of the S.W. portion of Bradgate Park is syenite; but there is one isolated patch of stratified rock, correctly indicated as such on the map. This is shown in the little quarry opposite the Ruins and across the brook, which, from a range of stable-buildings pulled down some twenty years ago, is usually called the Stable Quarry. It is a very puzzling place. The following appears to be the most probable explanation. A bed of slate interstratified with grit has been bent into a series of small parallel folds of unequal height; and the harder grit has in places caught and as it were "nipped" the softer slate in the folding. The general strike of the slate is a few degrees S. of W.; and the folds rise roughly towards the W.N.W. The grit is very hard, with occasional small quartz veins, and some indications of bedding and of a faint cleavage. It consists chiefly of quartz grains with some minute granules of a nearly black mineral. It is remarkably like the quartz grit which we find at Swithland overlying the series of the pebble beds. The slate is a pinkish grey felsitic rock with ill-defined dull-green chloritoid spots, the sort of rock that we might expect to result from the rearrangement of a fine ash or the denudation of a not very acid lava.

There are two good lines of exposure in the park, that along Holgate Hill (fig. 2) and that up the south spur of Old John. They have the same general character, as will be seen from the following description:—

Starting from the north wall of the enclosure of the Ruins (within which all is syenite), and ascending the slopes of Holgate Hill, we soon come to exposures of banded slates. One of these, a sort of cliff, at a distance of about 200 yards, gives a good section of indurated banded slate. (There is a small patch of syenite close to this to which we shall recur in the last part of this paper.) Proceeding obliquely across the line of strike, we pass over or near frequent exposures; so that, though the rock cannot be seen continuously, there are but few points not in the line of strike of some visible outcrop. These for a considerable distance are all banded slates—indeed, until the crest of the hill is reached, a steep rise of about 30 feet. Sometimes the bands are rather coarse-grained.

Keeping in the same direction, across the strike, over the plateau at the top of the hill, we continue on banded slates for some 100 yards, when we find a slate passing into a bed of coarse greenish mottled ash. Banded beds succeed; and about 50 yards further a mottled ash recurs, here containing fragments of fine-grained slate. Alternations of banded slates and mottled ashes follow, until after about 120 yards comes the lowest rock seen, a large mass of unstratified greenish mottled ash with vast contorted fragments of fine-grained green slate, precisely equivalent to the great agglomeratic bed at Blore's Hill. These greenish mottled ashes, as we have called them, are difficult to describe. They contain glittering felspar crystals, pinkish felstone, and smaller pieces of the fine slate, of which all the large fragments (so far as we have seen) are composed. Some of the last are two or three feet long. The bed is also well exposed at the col connecting this hill with Old John, just by the usual path to the summit. There are many segregation-veins of white quartz, as is not seldom the case in these agglomerates. The slate fragments are much indurated, of the usual pale greenish-grey colour, and almost flinty texture ; some are distinctly bedded. They lie in all directions ; and the cleavage-planes of the bed itself can be traced, though imperfectly, through them. One piece, bent almost into a quadrant, is about 4 feet long. The general aspect of the matrix suggests that it has consisted of an ash not rich in silica, such as that of an andesite. The dip of all the beds we have described is southerly, usually about 30°, but sometimes as much as 50°. The dip of the beds on the col, where they can be seen, is in the same direction ; but the strike of the great agglomerate bed is in a line with that of the smaller one first described above. We have little doubt that a fault with a throw of some 50 or 60 yards has shifted the Holgate beds about 120 yards forward from these.

The section up the south spur of Old John is of much the same nature. It begins with banded slates, some so fine and hardened as to be almost porcellanites. One bed is an exceedingly compact greyish-green rock with dark green spots (? hornblende), a subconchoidal fracture, and not very conspicuous cleavage, one of the finest-grained rocks in the Forest. After these come coarse ashes, and on the summit a bed of not very coarse agglomerate, followed again by banded slates. The great agglomerate bed, which can be traced along its strike up the greater part of the east spur, is lost sight of at the top. The line of strike passes through a plantation where no rocks can be seen ; but as the last outcrop shows the rock rather shattered, there is possibly another fault.

Descending the hill northwards we see no more exposures till we quit the park by the footpath, through a small spinney, which in the Survey map is coloured red and marked F. Very few rocks are to be seen ; but those are curious. We have first at the east end a little patch of well-marked banded grits dipping, as usual, south. They are rather too coarse to be called slates, indicating bands by weathering rather than colour. Underlying these are a set of rocks, without visible stratification, isolated, but no doubt *in situ*, and the relics of a bed of highly altered pale greenish crystalline-looking rock, containing a good many felspar crystals, a few small grains of quartz, and some fragments of slate. Examined microscopically it is seen, as we shall show, to be pyroclastic and altered. On a line of strike below this, at the west end, is a bed of felspathic grit, rather resembling felstone—and below this again fine-grained green slate, the dip of which can be detected with a little trouble, and is also south.

Quitting the spinney and going down to the lane, we find in the fork of it a small exposure of ordinary banded slates dipping S.E. 25°.

7. The section cannot be carried further across the strike. We must pass obliquely to the north-west and enter Benscliff (fig. 3, p. 768). In the field outside and south of this wood are two or three outcrops, all slates or ashy gritty beds of an ordinary type, showing the usual southerly dip. Entering by the ride that runs along the crest of the hill, we find successively two exposures of greenish- or bluish-banded gritty slates, showing clearly the dip to S. About 20 yards further is another, slightly redder. Then, after some distance, comes the exposure marked red on the Survey map, with the letter F, the symbol of so-called "felspar porphyry." This is a great mass of coarse agglomerate, with no clear indications of bedding, cut up by great divisional planes rather irregular in direction. The material of this rock is a greenish ash, with a very few granules of quartz, some rather ill-defined crystals and fragments of felspar, a few small particles of dark slate, and numerous included fragments of a felsitic rock, often so ill-defined externally as to resemble large patches or blotches. As the matrix weathers to much the same colour, they might often at first sight be mistaken for mere spots; but they are certainly included fragments. Under the microscope the pyroclastic origin of the rock becomes evident, as we shall show hereafter. The rough lumpy weathering unmistakably shows it to be an ash, but gives few indications of large imbedded fragments. The colour of the matrix is not uniform, but mottled with shades of green. Separated from these rocks by a few yards of turf is another group of rocks, similar in external character. The divisional faces have a slight look of a roll; but in these massive Charnwood rocks it constantly happens that the stratification is wholly obliterated and the divisional surfaces have no connexion whatever with it. The materials are exactly the same as those of the previous masses.

Yet a yard or two further, all forming part of the same knoll, is a ridge of rock consisting of an ash which includes large fragments of an extremely flinty, pale green, fine-grained slate, much like the fragments in the Old-John breccia-bed, but more altered. The matrix also is not the same, being much more homogeneous. There are appearances of a dip southerly; but these cannot be relied on.

Some way further we come upon ridges of very fine hornstone-like slate. The dip is almost certainly S.; but as no bands are visible it cannot be demonstrated.

Passing along the ridge we come to the second red spot, marked F on the map. This also is a pile of massive unstratified ashy rocks, so precisely resembling those previously described that hand specimens cannot possibly be distinguished. So far as the dip can be conjectured, it is S. Just beyond are fine slates, showing lines of bedding which indubitably have that dip. It is natural to surmise that this second coarse ash, so like the former, is in fact the same repeated by a fault. But the breccia at the base of one cannot be seen underlying the other; and, on the whole, we are inclined to think them on different horizons.

We now go on about 200 yards before seeing any exposures of importance, and then come to a pinkish ashy grit, followed about 60 yards further by rocks whose south dip is shown beautifully by the weathering-out of their bands of bedding. Hence we descend to the north corner of the wood by a series of five or six vertical cliffs, each from 20 to 30 feet high, giving beautiful sections of a rock consisting of indurated slate in finer and coarser bands, the structure being rendered conspicuous by weathering. The lowest exposure, however, scarce 100 yards from the corner of the wood, consisting of only a few square feet of rock, but apparently *in situ*, is the massive greenish ash which forms the great unstratified beds described above. Its colour varies in the same way, though the pink patches are less apparent, and the grain is rather finer; perhaps also there are more quartz-granules and fewer felspar-crystals; still it can hardly be regarded as a different rock.

The patch marked F and coloured red on Green Hill lies in the centre of a small wood there, and consists of another vast mass of these unstratified ashes, differing from that first described only in being in all respects somewhat coarser and having fewer or none of the felspar crystals. No rock can be seen on the south of it; but on the north are banded slates, dipping in a southerly direction. If the slight evidence of dip in it may be trusted, that is here S.W. by S. The exposure marked with an arrow on Black Hill is ordinary banded slates dipping E., as indicated on the map, and so seems to belong to the other side of the anticlinal line.

There is a small wood at the junction of the lines west of Benscliff and east of Ulverscroft Abbey, which contains another mass of this coarse unstratified greenish or greyish ash. It is much decomposed, but, so far as can be seen, is of similar character. The appearances of dip vary from S.S.W. to S. It passes up into very compact slate of doubtful dip. A few yards further south we come to a distinctly banded indurated slate, somewhat disturbed; for its dips vary from S.S.W. to S.

The strike of these beds would bring them exactly on the same horizon as the second massive ash-bed of Benscliff, the material of which is similar to the bed in this spinney. So also the strike given by the slates of Green Hill would place its coarse ashes on the same horizon exactly as the corresponding beds in the northernmost exposure of Benscliff. Notwithstanding this persistence, when we consider the remarkable resemblance of these coarse ashes, the fact that the underlying rock (when visible) is in each case fine slate, and the close proximity of the anticlinal line, along which runs a considerable fault, the probability is on the whole in favour of their being the same bed repeated by another subordinate fault. Any great dislocation frequently has minor faults striking off from it. The range of successive cliffs above described may possibly be owing to parallel joints produced by the same cause.

8. Outside Bradgate Park, just north of Newtown Linford, are

two exposures of slates. One is almost in contact with the syenite, and shows well-marked bands with a dip S. 5° W. There is a peculiar rippled structure on some of the joint-faces, probably a result of pressure. The stripe of this, and, we believe, of the whole south-western part of the forest between Bradgate and Bardon, is shown by texture rather than by tint. The bands weather out; and the peculiar pink and white striping of Beacon and Nanpanton is absent. The difference, however, may not be of any importance. The other exposure is in a field a few yards off, opposite the lane leading to Ulverscroft. It also exhibits banded slates, greatly indurated, some of the usual pale green colour and flinty texture, and one thick bed, curiously like a felstone of rather compact texture, greenish grey with dull green spots. Microscopic examination shows it to be of clastic origin.

Across the lane, at the spot called on the map Ulverscroft Mill (fig. 3), is a long narrow ridge of rock, by the side of a brook, clothed with trees. The uppermost beds of this are a gritty slate with narrow and inconspicuous bands, which dip at angles of 50° or 55° in a direction 10° W. of S. Below these are beds of breccia, containing many fragments. The matrix is grit, with, as usual, a sprinkling of quartz granules and crystals, dull greyish and coarse in the upper, with a considerable number of quartz grains, finer and bluer and much less quartzose in the lower. The larger fragments consist of a pinkish slate highly altered, almost like a felstone, weathering to a dark red. There are also a few very small fragments of a pale green slate, and some of a darker green.

Almost identical beds occur in the angle between the lanes to Ulverscroft and Swithland—the same fine-banded grits above, with the same breccias below; while just above the grits is a fine slate highly altered and indurated, and below the breccia fine grits with such minute bands that eight or ten can be counted in the inch.

Gritty, slightly banded slates are exposed east of the Ulverscroft lane, about 300 yards from these.

The strike of the above breccia-bed would, if it continued uniform, carry it just above all the Old-John rocks of Bradgate. If, however, we make allowance for the curving of the strike indicated by the change from S. in Bradgate to S. 5° W. and S. 10° W. here, we should reach some point on the south spur of Old John. The same effect might be produced by a moderate fault. This Ulverscroft breccia-bed is very different from the coarse breccia of Old John; for its matrix is much more homogeneous, and the fragments of pink slate in the former are quite unlike those of pale green slate in the latter. Nevertheless, as there are also fragments, though small, of the pale green slate, and the two beds are so close, we are disposed to consider it part of the same series, though we cannot at present precisely identify it with any one bed among those exposed in Bradgate Park.

Henceforward, till we reach Bardon Hill, exposures are few and isolated. There is no approach to a continuous section throughout the whole of this extensive district; so that we must describe the groups of rocks separately.

Fig. 3.—Section from Ulverscroft Mill, through Benscliff, to Greenhill. (Scale about 4 inches to 1 mile.)

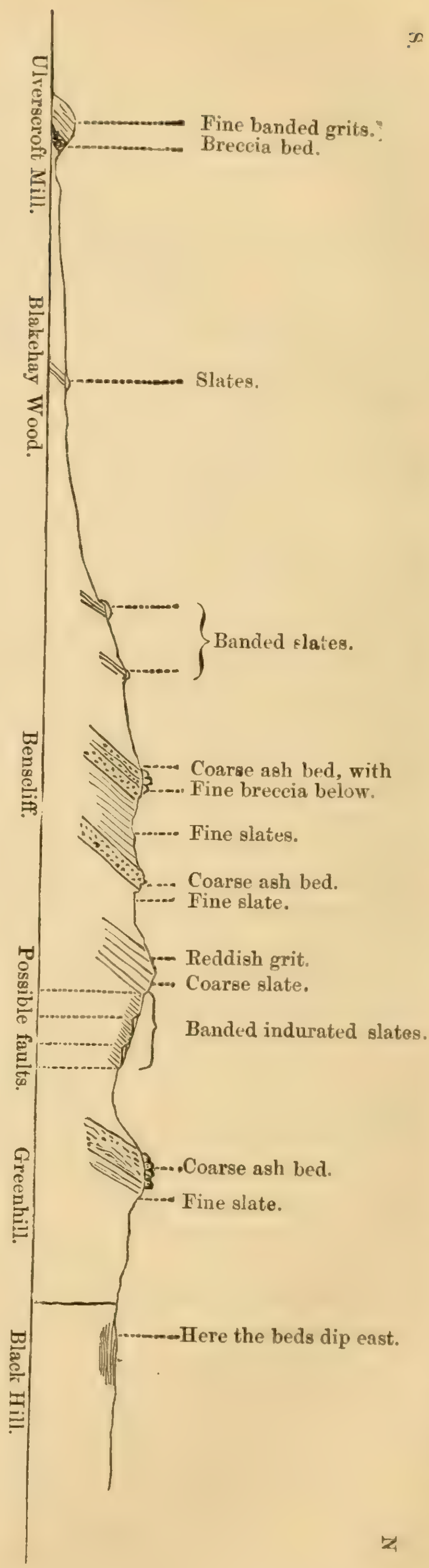
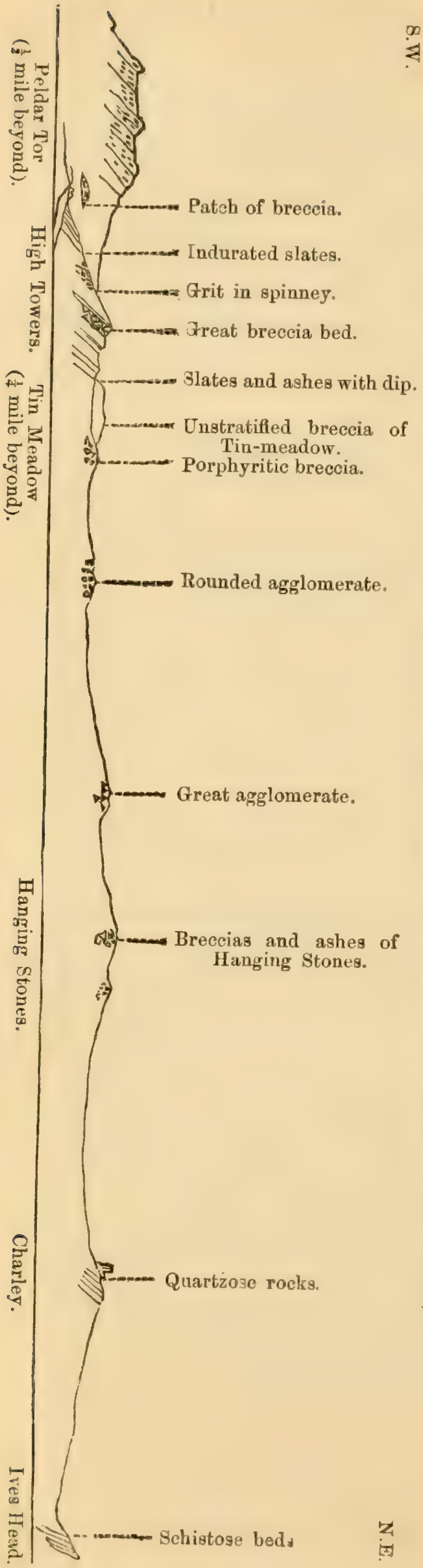


Fig. 4.—Section from High Towers to Ives Head. (Scale about 4 inches to 1 mile.)



9. The series of exposures round Groby Lodge are cut off from all hitherto described by syenite, which probably extends in a broad belt from Cliff Hill by Markfield to Groby Pool, Sheet-Hedges Wood, and Bradgate. This group of small ridges and knolls all consist of fine slate, generally coloured purplish or green, sometimes reddish, rarely and obscurely striped; so that the dip is ascertained with difficulty. The dips, so far as ascertained, look very irregular; but we think they may be combined so as to indicate a rolling of the strata. Near Groby Lodge is a large quarry, where the rock is worked for slabs and gateposts, the cleavage being too imperfect for roofing-slate. The westernmost exposure is not marked on the map. It is by the side of the lane leading to Markfield Field, about east of Whittington Grange, and in nature resembles the rest, with an apparent but uncertain N. dip. The small exposure by "Steward's-Hay Spring" is a purplish quartzose grit, apparently containing a few grains of magnetite. Under the microscope it is seen to be formed of rounded and subangular quartz grains, with a few resembling a subcrystalline slate set in a cement of similar aspect, more or less stained with black iron oxide. Close to this, and just within the wood, is a small quarry in syenite and an ashy slate reminding us of that in Bradgate-Stable Quarry. We could not decide which of two sets of planes indicated the dip of the grit. The strike of either, if protracted, leads to Groby Pool, on the north shore of which (by the boathouse, about 30 yards from the last patch of syenite) is a small outcrop of a very hard quartzose grit, which only differs in appearance from this in being a shade finer. It seems to show a very faint indication of a cleavage, striking W. 10° N., and is remarkably like that of Swithland. Now, since both at Swithland and here there are workable slates on the very outside of the country, and both are underlain by a rather peculiar quartz-grit bed, it seems highly probable that the slate and the grit in each place belong to the same bed. If, however, the quartz grit of the Stable Quarry in Bradgate be identical with these beds, as seems very probable, great faulting must exist—a thing easily credible. To this point we shall return hereafter.

10. There is a rather remarkable isolated patch of rock at Sandhills Lodge. The lowest portions are indurated flinty slates, very much jointed, dip uncertain. But a few yards higher is an old quarry which consists of a mass of coarse, ashy, slightly brecciated rock. It is bluish green, with small bits of dark green slate and pink felsitic material, and is a little fibrous in texture, with surfaces of a lustrous dark-green chloritoid mineral. This rock seems to resemble that hereafter to be described at Kite Hill, near the Monastery. The dip appears to be W.S.W., but undulating. Just above the crest, and between this and the indurated slate mentioned above, is a slate showing stripes very much contorted and dislocated, and with a platy conchoidal cleavage or fracture. This looks at first like a fragment; but examination seems to show that it is interstratified with the coarse ash bed with a roughly southerly dip, but that both have been squeezed together with great but irregular force.

Another small patch, marked on the map a little to the south, seemed to be ordinary banded slates; but we have not examined it closely. The outcrops between Newtown and Markfield, close to the lane, consist of green slates, highly indurated, very flinty in texture and fracture.

The gap between the exposures of Newtown and Markfield is less considerable than appears from the map. There is an outcrop of coarse gritty slate in the wood called Cover Clotts.

At the fork of the highroads north of Markfield is a remarkable ridge of rocks, sometimes called the Altar Stones, marked red on the map, as if igneous. It is really distinctly stratified, the beds all dipping S.W. at about 45°, while the cleavage strikes a little W. of N.W. They are best seen just by the windmill. The section gives banded slates, with rather small and numerous bands at top; next come two bands of slaty agglomerate, with fragments of slate; then a bed of fine grit, followed by a much coarser agglomerate with large fragments of slate, some as much as 5 feet long; and lastly about 30 or 40 feet of fine-grained banded grits, with here and there some traces of false-bedding.

The matrix of the above agglomerates is a felspathic grit, or mass of minute fragments of rather rounded aspect, dull green mottled with specks pink in colour, such a rock as might result from a mixture of a volcanic mud with triturated fragments of lava and felspar crystals, subsequently much metamorphosed, and now containing a good deal of minute epidote. Some of the included fragments are a dark fine-grained slate; but most are the same pinkish slaty rock, resembling a felstone, which occurs in the breccia by Ulverscroft Mill, near Newtown Linford. Here, as there, the overlying and underlying rocks are fine banded grits; and some of the specimens from the two places could hardly be distinguished from each other. The matrix of each is of the same general nature; and much alteration might be expected in a distance of two miles. The strike is certainly for a point much above the Ulverscroft-Mill beds; but the strike there seemed to be curving in this direction, and the disturbance of the rock at Sandhills Lodge gives countenance to the idea of a fault. We think that with considerable probability we may take these sets of beds to be on the same horizon.

These great masses of agglomerates die out very rapidly; a hundred yards S.E. all trace is lost. If, however, we are right in believing the breccia to be of volcanic origin, this is not surprising, and indicates the proximity of a neck. Yet breccias of like nature can be traced along to the extreme south-east of the blue colour on the map, by the 106 milestone, east of the road, there overlying a large thickness of slates.

The rocks of White Hill are slates, the higher of which show faintly but clearly a W.S.W. dip; the lower do not indicate bedding, but contain a distinct pebble-bed. The pebbles are very well rounded, about an inch long, of whitish quartz in a white slaty matrix, the line of junction being sharp. Both pebbles and matrix contain small specks of limonite. On the east side of the road are some slaty rocks, one of which seems to be a bed of slaty breccia.

At Chitterman Hill, in a field north of the lane, is a pile of loose almost boulder-like rocks, which, however, are pretty certainly *in situ*, and rest on beds of slate dipping S.S.W. The latter show alternating bands of dark-blue flinty slate and grit, which weathers white. The loose rocks are unstratified, showing their ashy texture by their lumpy weathering, and consist of a brecciated mass of curiously varied materials. The matrix is a green mottled ash ; and there are a few fragments of a hard dark-blue slate ; but the bed is to a great extent composed of fragments, often not very clearly defined, of the pale-pinkish rock which occurs in Benscliff. It is much more abundant here ; but we think the two deposits are undoubtedly identical. That this rock is *in situ* is thus proved :— Slates with a marked dip are exposed in a field south of the lane, which, from their strike must overlie it ; and in Barnby Wood, at the corner of the lanes, distant $\frac{1}{4}$ mile, the coarse ash can be seen with similar slates resting upon it. At the same time, as in Benscliff we are disposed to think there are two beds of this nature, so here the horizons need not be quite the same. The ridge of exposures extends some way ; but we have not examined the whole of it.

Our identifications are supported by the fact that the distance across the strikes from the Markfield beds to these is the same as that from Ulverscroft Mill to the first ash-bed of Benscliff.

11. The rocks of Billa Barrow are fine-banded ashy grits or slates. They show signs of compression ; and the strata curve, so that one and the same bed can be followed from horizontality to a dip of nearly 50°. An outcrop marked in the Survey Map near this, by the high road, cannot now be seen.

The Rice Rocks are a beautiful series of banded flinty slates, without any trace of breccia, dipping very steeply, and not quite uniformly, as shown on the map. Much the same description applies to the beds of Beggar's Nook, also a very fine exposure in an abandoned quarry. The slate here has a slight conchoidal fracture, with very sharp edges ; it is evidently highly altered.

The rocks at Hilltop, the west end of the ridge of Bardon, well seen in the back yard of the little inn, are pinkish slates and grits much jointed and disturbed. The dip is nearly vertical, in a S.W. direction ; but the rocks are evidently much disturbed. We shall recur to them in connexion with Bardon.

The rock at Copt Oak is exposed in a small pit by the church ; as it is much decomposed, it is not easy to determine its nature. It dips at about 45° to W.N.W. ; the cleavage, which is nearly vertical, strikes W. 10° N. It has a very ashy aspect, and appears to contain crystals of felspar, either broken or imperfectly developed, probably the former. We do not notice quartz ; were it not for the absence of this, it would bear some resemblance to the rocks of Peldar Tor, hereafter to be described. It is also in their line of strike ; and though equally in the line of strike of the Chitterman-Hill beds, we shall show hereafter that there may have been a dislocation in this neighbourhood ; so the latter may not correspond.

The rock of Birchwood Plantation, coloured as greenstone on the

Survey Map, is a very homogeneous rather crystalline rock, without signs of stratification. Further, the jointing and weathering are such that one cannot be surprised at its being mistaken for an igneous rock, though one would have rather expected it to be called a felstone. Microscopic examination, however, shows it to be of clastic origin, containing many imperfect felspar crystals, apparently included fragments, and not of subsequent development. The whole rock, however, has been much metamorphosed; and the difficulty of studying it has been increased by the quantity of epidote that has been subsequently formed *. It forms a narrow ridge about half a mile in length, along which there is a series of isolated outcrops in the midst of a thick plantation.

No rock can now be seen at the point three quarters of a mile N. of Copt Oak, marked with a dip arrow on the Survey Map.

The hill of Hammercliff is entirely syenite.

12. Hitherto the strata described have had a general likeness, and the beds, though here and there faulted, can, as we have seen, be arranged with little difficulty and much probability. In the region on which we now enter the variety of the rocks, the contradictory appearances of bedding, and the confusion resulting from faults are enough to make a geologist despair. We have made many observations and have drawn some inductions from them, but are prepared to have these disputed, and even disproved, by future and more successful surveyors. It is difficult even to select the best way of describing this intricate country. On the whole we think it best to continue the course hitherto adopted of describing successive sections up to the anticlinal axis. Bardon Hill, however, may be deferred with advantage, as without a knowledge of the rest of the country its structure is unintelligible.

At Green Hill is a mass of ash-beds apparently, but obscurely, dipping S.W. The matrix is a fine green gritty ash crowded with imperfect crystals of felspar and with grains of quartz indicating sometimes an imperfect crystal form, some as large as a pea, or even a bean, projecting from the weathered surface.

Proceeding N.E. we pass over some distance without exposures, and then come to the bastion-like corner of Timberwood Hill, standing as an outwork to the solid masses of High Towers and Peldar Tor. It consists of a series of ash beds which appear to dip W.S.W. at an angle of 45, and contain rounded fragments of all sizes up to that of a cricket ball. The rock itself consists of fragments of a pinkish felsitic rock in a rather ashy-looking greenish matrix, in which are numerous grains of quartz. As on Benscliff, these included fragments have a rather ill-defined boundary, and give the rock a mottled aspect. There is a considerable area covered by these beds; and apparently their thickness is not small. They much remind us of the Benscliff and Chitterman-Hill coarse ash-beds. Moreover the distance of Chitterman Hill from the Markfield slate breccias is much the same as that of Timberwood Hill from the line of strike of the

* We find that Prof. Ramsay ('Catalogue of Rock Specimens' &c., p. 20) has recognized this as an altered rock.

crest of High Towers, where also, as we shall see, are breccias, including slate.

The line of this section protracted passes through an outcrop near Charley Wood. It is an isolated narrow ridge by a farm-house. The dip is clearly indicated by colour stripes as 55° to S.W. by S.; the rock is much decomposed and stained, but appears to be partly an ash, if not an agglomerate, in a siliceous matrix, partly a siliceous grit, partly a rather well-cleft slate showing minute stripes of bedding. The ash is mottled, rather like the Benscliff beds; the grit and slate are greyish, with peculiar red stains from infiltration. The ash is at the north end, the slate at the south. The slate seems to underlie the grit.

13. For the next section (fig. 4) we may start from the cross roads near High Towers, where stands the Forest Rock Hotel. At the corner of the lanes is a pinkish indurated slate, better seen in a quarry a few yards off. Here we find a series of grits and exceedingly fine-grained slates, highly altered so as to resemble a hornstone, with splintery conchoidal fracture. The lowest bed is the most compact. Its colour is dark slaty blue, weathering white or pink. Under the microscope it appears to be composed of very minute fragments of felspar, part of the matrix remaining dark with crossed prisms, perhaps owing to the minuteness of the fragments; while there are scattered in it small crystals seldom more than ·002 inch in diameter of felspar, apparently fragmental, both orthoclase and plagioclase, with a little iron oxide and a few minute epidote crystals. The beds dip W.S.W. at about 15°. Similar beds are seen, much jointed and broken, about 100 yards up the lane towards the north.

In a spinney west of the cross lanes is found first a dark grit with quartz grains and felspar crystals, rather cut up with veins, and not showing its bedding; this we have not seen again in the neighbourhood; next some whitish ashy slates and grits with rather variable indications of dip, usually about west, and seeming to pass under the indurated slates last named.

The wild moorland of High Towers affords numerous but rather disconnected outcrops of rock. The first, just beyond the spinney, shows a dip of 60°. Its highest visible bed is a large breccia, whose matrix is green slate; the included fragments are large and very various in material. One rock weathers a uniform pink; another is a mottled, highly altered rock, with some resemblance to a syenite, not improbably a felsite with epidote. Some are fragments of a dark purple porphyritic rock, which, as will be seen, is common in this neighbourhood. There are also quartzites and slates.

Passing S.E. along the ridge in the line of strike we repeatedly find this breccia containing great fragments of banded slate, so large and so contorted that an unaccustomed observer might not recognize the fact of brecciation. One imbedded piece near the south end of the ridge is about six feet long by three deep. At this end there are also fragments of a highly indurated apple-green flinty slate. The matrix is extremely variable, in parts much mottled, but more usually a green gritty ash. At this end a fine indurated slate shows above the breccia, and coarser slate below. The section therefore, unless faulted, seems to be—(1) fine indurated slate at the cross roads, (2) coarse grit, (3) ashy slate (in spinney), (4) another fine indurated slate seen at the south end (missing at the north, unless corresponding with that higher up the hill by the lane), (5) the great breccia-bed, (6) slates, and (7) the rocks which we proceed to describe. A few yards beyond the crest, in the line of the section, is a singular band of very dark purple slate with a little white grit, and a few cavities left by decomposed crystals; below it is a breccia with fragments of a similar slate, and of the usual mottled pinkish and greenish felsite-like rock. About 200 yards further is a group of rocks, dip and bedding undistinguishable; a breccia whose fragments are mainly of the dark purple porphyritic rock mentioned above. About 200 or 300 yards further in the same direction, but a little to the right of the line of the section, by a wall in the line of the drainage from a small reservoir, is a mass of agglomerate, or possibly conglomerate; for the fragments are highly rounded, of all sizes up to that of a man's head. The matrix is a green ashy grit with a few shining felspar crystals scattered about it. But the included fragments compose the greatest part of the rock, and they appear to be entirely of the above-named slightly mottled pink and green felstone-like rock, rather resembling that of Birchwood Plantation.

Crossing the next field and going again 200 or 300 yards to the N.E. beyond a wall, where a private road crosses a low ridge, is a remarkable agglomerate. The matrix is dark green, fibrous, and not very coarse; the included fragments are a similar rock to the last, a mottled pinkish and greenish subcrystalline rock. This agglomerate is remarkable for the size and abundance of its included fragments, many of which are not less than 15 or 18 inches in diameter. They are heaped confusedly together, and make up the major part of the rock. Divisional planes, which look like bedding, are numerous, but shift their direction from point to point in contradictory ways; and the matrix weathers out in lines suggestive of false bedding. The weathered fragments stand out in unusually bold relief. The ridge of rocks extends some distance, showing everywhere these wonderful masses of volcanic agglomerate, the ruined fragments in all probability of some long-vanished cone.

Some distance further we reach the last ridge of the High-Towers moorland, where the last letters of the words Hanging Stones are engraved on the map. Here the rocks are a large coarse ash showing a considerable mass of breccia, whose fragments are mainly of purple porphyritic rock. A line of cliffs runs in a south-easterly direction through woods surrounding a house, apparently a continuation of these, which were only cursorily examined during a search for a base to this series. They seemed of the same general character.

The line of this section continued leads us to Charley church. Round this are a few rocks visible at different points. Those nearest it on its west side are a greyish pink ashy grit, weathering dull red, with some peculiar cavities here and there, due to the decomposition of some constituent. About 200 yards north is a pale ashy slate with like cavities, and patches of coarse grit.

On the opposite slope of the valley are the rocks seen round Lubcloud. Those on Lubcloud Hill are rather schistose. They seem a greyish slate with quartz granules, but are much obscured with veins, and with red stains along the planes of cleavage. The rock north of the farm-house, between it and Ives Head, is a similar one, but in a better condition. It is a greenish or greyish ashy slate with minute lines of stripe, and like that just described by Charley church.

The outcrops on Ives Head consist of a series of banded grits. The highest bed is a thick, rather schistose mass containing quartz granules and felspar crystals and cavities. It is much stained with red, as are all the rocks in this neighbourhood. Professor Jukes considers this due to the oxidation of iron in the rocks along joints; but may it not be owing to infiltration of waters from the Trias?

14. Taking a section parallel to the last, and one much the same as that drawn on the Survey map, if we go far enough N.W. to clear the quarry of indurated slate, the first rocks we meet are a mass of greenish white ash, containing white decomposed crystals of felspar, quartz grains, and small fragments of slate and other rocks. The dip is about 15° in a W.S.W direction, which can be established both by apparent dip-faces and by a large bed of breccia on its upper portion, whose general direction and thickness can be made out. The fragments are very numerous and large, some being 9 inches or a foot long. They consist mainly of two rocks:—one a very characteristic specimen of the dark purple porphyritic kind already mentioned; the other a compact, hard, rather fine-grained porcellanized rock, sometimes rather resembling the last without its crystals.

It is not easy to say whether the indurated slates pass over or under these rocks. The latter seems more probable; for the line of strike of this breccia passes so close under the rocks at the east corner of Peldar Tor that there seems no interval for any overlying beds. Yet below this breccia we find the rocks of Tin Meadow, next to be described, within so short a distance, that the space seems insufficient for the indurated slates to lie between. We cannot explain this difficulty satisfactorily.

A ridge of rocks in a plantation towards Tin Meadow consists entirely of greenish ashes with decayed white crystals, intercalated with breccias, containing fragments up to a couple of feet across. Some of these are the compact rock just described; but most are of the purple porphyritic kind. We noticed no slate. There is no distinct evidence as to the direction of the dip.

Between this and the knoll (Kite Hill), now crowned by the monastery and its beautiful grounds, is a considerable breadth in which are no outcrops. There they are abundant, but hard to unravel; and we do not profess to have cleared up the difficulties. At the north end, outside the grounds, a small quarry has been opened, where there are indications of a steep dip to E.S.E. The material is a very variable dark green, rather schistose ash, with occasional small included fragments of felspar and slate. It is not very unlike the rock of Sandhills Lodge near Newtown. The rocks round the cross also show no dip, but contain distinct fragments of some size.

In the kitchen-garden is an outcrop of indurated pinkish slate striking E.N.E., but not sufficiently exposed in breadth to show dip. It is overlain by a mass of a very handsome rock—a bluish ash, mottled almost like a coarse mosaic, with pink fragments of a compact gritty rock. It would look well polished. We think it identical with the rocks of Timberwood Hill. Some distance further east, beyond the monastery grounds (about a quarter of a mile west of the cross lanes by Charley), is a crag, of which the upper portion consists of distinct greenish banded fine grits dipping south (not S.S.W. as on the map). Below them is a thick, massive ash, somewhat variable in character, some specimens being coarse, schistose and mottled, but in colour dark, others a green grit with quartz grains and small fragments of slates and of felspar, others resembling the first with patches of a felspathic material. What underlies this cannot be seen.

On the other side of the lane, north of the monastery, is a small patch of rock similar to that of Kite Hill, dark green gritty ash, with some paler bands in it, from which, perhaps, the dip might be ascertained.

Distant from this about a quarter of a mile (by Upper Blackbrook) are some rocks we have not seen; but a small quarry in the hollow of the north bend of the brook contains a pinkish ashy slate with fine banded markings, closely resembling in colour and peculiar aspect the Charley and Charley-Wood slaty beds.

Immediately N.W. of our starting-point for the last section lies the range of crags called Peldar Tor. The rock is a remarkable one, with a dark bluish matrix, sometimes weathering pale green, but usually dark, containing large porphyritic crystals of felspar, and grains of quartz often as large as peas. These stand out conspicuously from the weathered surfaces, often showing an imperfect crystal-form. The rock is very uniform, so that dip can only be guessed at from planes of separation &c. These at the south end are tolerably distinct, indicating a W.S.W. dip of about 20°; but at the north end there is some slight appearance of curving round to a west dip. We have not noticed any certain indications of breccia throughout this Peldar-Tor area; and the highest beds only differ from the rest in being rather greener and more decomposed. Microscopic examination shows that the rock, though much altered and obscured by the secondary formation of numerous groups of epidote crystals, is of fragmental origin. The base of these beds cannot anywhere here be seen.

Just north of Peldar Tor, separated from it by a belt of arable land, is a ridge running N.E., bearing on the map the name of Ratchet Hill. The various isolated outcrops of rock between this and the outskirts of Whitwick are difficult to correlate. One of them at least contains a good deal of breccia, which, however, is probably connected with that in the quarry by Whitwick village rather than with the rocks which we now proceed to describe. Ratchet Hill itself, commencing from the little spinney at its S.W. end, affords an almost continuous series of exposures. The uppermost are a succession of beds of greenish and greyish gritty ash, dipping in all probability to W.S.W. But about the middle the character of the rock changes, and we find a breccia containing large fragments of the purple porphyritic rock so often met with. The matrix becomes schistose; quartz grains and felspar crystals occur, showing a passage to the Peldar Rock. Just before reaching the N.E. end of the ridge there is another breccia, also containing large fragments both of the above porphyritic rock and of altered ashes, slates, and quartzites. Under an overhanging crag is a knob bearing a close resemblance to an intrusive felstone; but the small extent exposed is not sufficient to give distinct evidence. The rock at this end of the ridge is not quite the same as the Peldar Rock some 200 yards distant; but their identity can hardly be doubted. The rocks of Gun Hill, though in a line with those just described, fall more naturally into the next section.

15. Postponing for a while the Whitwick-village quarry, and starting from the point where the lane from the Castle meets the main road, we cross the steep ridge of High Cadman, one of the highest points in this district. It consists of hard greenish and whitish ashy grits, much altered. The meeting of these enables the dip to be made out at one point of the south end; it is W.S.W.

The long craggy and picturesque ridge of the rocks of High Sharpley commences about 100 yards from the fork of the lanes. It consists of a dark blue, rather schistose rock; containing imperfect felspar crystals and quartz grains, which, however, are less abundant and smaller than those on Peldar Tor. Surfaces apparently of bedding are numerous, dipping W.S.W. Parallel, and to the south, is another much shorter ridge of the same rock; and outcrops of it occur up to the very wall of the spinneys on Great Gun Hill, and form the knoll on which stands the tower-like cottage there.

After careful comparison of the Sharpley Rock, that of the basement beds of Ratchet Hill, and the rock of Peldar Tor, we consider them the equivalents of each other. They show a successive alteration of character; the change begun at the second place is carried further at the third. We are also inclined to think that the rocks of Green Hill form a continuation of the series.

The spinney on Great Gun Hill is separated from the cottage-garden and from the outer moorland of Sharpley by two stone walls, running N.E. and S.E. All outside is Sharpley rock; but the instant that we enter the spinney we come upon perfectly different beds. The north wall must run along the very line of a large fault; and it is not unlikely that the west one does the same. The rock within is a whitish ash, dip uncertain. Not far off to the S.E. is a coarse breccia. No continuous section of these rocks can be found. They are only seen in three or four isolated knolls in the wood. About the middle of the spinney we find outcropping rock on which weathered bands dip S.E. by E. or S.E.; but it is very probable that this is false bedding. Another knoll, close to the lane, shows a large breccia, which has some appearance of dipping E.S.E. By the side of the wood, by the west wall, about 100 yards from the lane, in a line with some outcrops in the field outside, Sharpley rock can be traced within the wall of the wood, and all but up to contact with the ash. Here also there is plainly a fault, as the two are side by side. There is also a very small outcrop of similar rock just across the lane, hedged round in the field. Here, again, similar lines of weathering give an appearance of a dip to S.S.E. We cannot satisfy ourselves that any bed here dips S.W. according to the arrow on the Survey map. We cannot at present decide whether these beds, faulted here, as they undoubtedly are, agree with those of High Towers or the Cadman breccias; we lean rather to the latter idea. The rocks seen on the banks of the old reservoir we have not examined. Professor Jukes describes them as similar to the quartzite met with near Blackbrook toll-gate, which we will describe in the next section.

16. In this remaining section the presence of faults seems almost a certainty. The ridge of High Cadman runs N.W. to Gracedieu grounds. Four separate rock masses are exposed, the southernmost of which has already been described; but we do not feel certain that they are equivalents.

The large rocky mass which supports a tower (from which is a fine view) shows divisional planes, apparently of bedding, dipping W.S.W., at an angle of 25°. There is here a large bed of breccia whose matrix is a green ash with a few quartz grains, while the included fragments are a pink felstone-looking rock, like some of that on High Towers. Further N.W., along the ridge where stands a small oratory with a tapering spire, the rocks are intensely altered:—those on the west slope whitish and felspathic, with little quartz, and small dark slaty-looking grains; those on the ridge dark with many granules of quartz.

Not very much further, perhaps 200 or 300 yards, there is a curious quarry, by the side of the road, just short of the small triangle of lanes. The rock is mainly extremely indurated slate, cleavage rather imperfect, seemingly much disturbed, with numerous very sharply cut joints. At first sight a band of colour seems to give a dip towards the hill. Examination, however, shows that this appearance is due to decomposition along a line of jointing. The side nearest the hill is a coarse grit; and the junction between this and the finer slate can be followed by close scrutiny, and shows a dip away from the hill. Also we found on a spur of the central mass, not quarried away, a bed of slate coarser than the rest, which similar close scrutiny proved to have indeed a dip away from the hill in a direction somewhere about W.S.W., but also to be contorted and compressed with extreme and abrupt flexures.

A small quarry a few yards to the south of this contains a whitish ashy grit. The rocks outcropping a short distance to the north, at the back of a small school-house, are coarse agglomerates of great thickness, containing numerous large fragments. Among these, some are the purple porphyritic rock, some are hardened ash, some other materials. Beyond this a succession of low outcropping ridges run roughly N.W. down to the Gracedieu lane, and at Hobs Hole cross some distance to the other side. The first of these, about 200 yards from the school-house, is also a great mass of agglomerate, containing, at Hobs Hole, pieces a foot or more across. The others are also ash, until, at a point about north of the S in the word Swannymote on the map, the rock becomes a hard blue ash of finer texture. Possibly the Sharpley rock is commencing here; but the lack of outcrops makes this uncertain.

A patch of rock, however (south of the last letter of the above word), consists of ash and breccia beds, resembling those breccias of Ratchet Hill which lie at the summit of the Sharpley-Peldar series.

On the north side of the Gracedieu lane, at the east end of Gracedieu lawn, is an outcrop of slates and grits dipping at about 20° W.S.W. The slate is green, of not very fine grain; but a more compact rock shows a little further west. Yet a little further is a small quarry, the beds in which seem to dip steeply in the opposite direction. Across a valley, perhaps 100 yards further, is a mass of slaty rocks resembling the banded slates which have hitherto been wanting over so wide a stretch of country. The dip, however, cannot be detected in this outcrop; but a few yards off, in a small patch of rock in a field north of a farm-house (on Warren Hill), a bed of breccia overlies fine slates with a dip of about 10° or 15° to W.S.W. This breccia consists of pieces 8 or 10 inches long of dark purple slate (rather like the rocks of a narrow bed described on High Towers). Very little is exposed; and the rock, so far as we know, is not seen again. These dips are evidence of a roll in the strata; and near the fork of the lanes is an isolated mass of Sharpley rock apparently dipping south. This is an additional indication of disturbance.

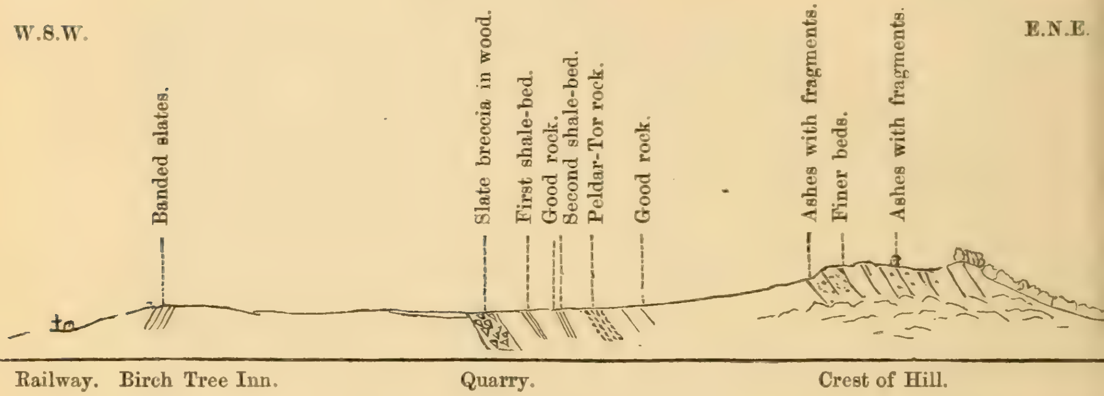
The beds south of the high road, west of Blackbrook toll-gate, are a whitish quartzite with reddish stains, very like the quartzites of Charley. They show distinct stripes indicative of bedding, and dip (according to Jukes) W. 20° S. at an angle of 60°.

17. We proceed now to the Whitwick breccia. It forms a ridge on the right bank of the stream, at the boundary of the blue colour of the Survey map, and is well shown in two quarries, one on each side of the lane towards High Cadman. It consists of ash, containing a great mass of fragments, themselves probably of an ashy material. The dip, as indicated by certain main divisional planes, and by the lie of the included fragments, seems to be very steep and to the north. There are indications of an imperfect cleavage dipping about 70° to E. 20° N. The matrix is ashy; it contains angular and subangular fragments, variable in number, but often rather crowded, showing much better on fresh broken faces than on the old weathered surfaces, which is contrary to the usual habit of the Charnwood breccias. Another rock closely resembles the fragments in a breccia which will be described on Bardon Hill. The rocks of the great

agglomerate of the centre of High Towers resemble these in some respects ; but there the weathering renders the fragments exceedingly conspicuous.

18. The section (fig. 5) given by the great quarry in Bardon Hill is

Fig. 5.—*Section at Bardon.* (Scale about 4 inches to 1 mile.)
This section cuts the beds very obliquely.



the best in the forest, but is nevertheless rather obscure. The small patch marked as Greenstone near Robin Butts, cannot now be seen. The quarry on which it was founded was "small and deserted" in Jukes's time, and is now filled up. He describes the stone as "compact earthy trap-rock, having much the appearance of an altered rock." The exposures at Hill Top are well seen in the back yard of the Birch Tree Inn, where banded slates and grits, much shattered, dip at the steep angle of 80° to W.S.W. An old pit in a neighbouring garden shows also slates with gritty bands, and a similar dip. The cleavage is rather imperfect. From this point to the mouth of the quarry is a distance of about a quarter of a mile, with no rock exposed. Then the ground begins to ascend rapidly, forming a long, high, and narrow ridge, rising at its centre to the highest elevation of the county, 902 feet. The dip of the rocks is seen in two shaly bands cut by the quarry, which strike E. 15° S. or E.S.E., and dip, at a steep angle of about 60°, to N.N.E. The lowest visible rock is in a small knoll in the wood to the right of the entrance to the quarry; it is a breccia of large fragments of greenish slate in a coarse ashy matrix, not very unlike that of the Bradgate breccias. The rocks at the entrance to the quarry, which cannot be many yards above these, are also breccias, but are much indurated, of much finer matrix, and with included fragments of entirely different material, more resembling those at Whitwick. The matrix is ashy, but variable, generally greyish, and speckled. The included fragments have very ill-defined boundaries, and are usually darker. Then follows the first shaly bed, which, as well as the subsequent one, is so much rotted by the percolation of water, that it is difficult to say what its constituents are. We have been inclined to think it like the isolated patch of slate by Copt-Oak church. Upon this lies the first "good rock," so called by the quarrymen, worked for road-metal. It is greyish green, slightly mottled with paler colour, and very hard. It appears to be a highly altered slate. Then comes the second shaly bed, about six feet thick, and traceable along its strike across the whole quarry. It is followed by more "good rock." At the distance of about 30 yards from it, on the north side of the quarry, is a considerable thickness of a rock somewhat ashy in its matrix, containing crystals of felspar and grains of quartz generally as large as peas, and in the upper part even larger. It much resembles the rock of Peldar Tor. It occasionally shows signs of brecciation, and in the lower part passes into a breccia containing fragments of a pinkish felsitic rock in a matrix of good rock. It appears to change its character very rapidly; for at the same horizon, at the opposite side of the quarry, the quartz granules almost, if not quite, disappear, and the rock becomes less distinctly porphyritic. The pink fragments may still be traced, but seem rather less clearly defined.

In the upper quarry, whose floor extends to the top of the face of the lower quarry, there is on the left corner a breccia containing fragments resembling those of the dark-purple porphyritic rock already described, in a fine purplish matrix. The whole rock seems to have been highly metamorphosed, as if it had been almost fused. The rock just above it is also dark purple in colour, but schistose in structure, and rather porphyritic.

The representative of the quartz and felspar rock of the lower quarry appears to be a breccia in the north-east corner, at the proper distance from the shaly bed. The matrix contains felspar crystals, though not very plentifully. The fragments consist of a pinkish felsite-like rock, mottled with epidote. The principal mass of "good rock" worked in the upper quarry overlies this, and must be included between it and the above-named purple breccia. This, however, we have not identified on the opposite side. The quarrymen think that the "good rock" runs up the hill to the summit; and the strike of the strata shows that, if the "good rock" be a particular bed, this is not very far wrong.

Mounting the ridge of the hill, which here runs about N.E., we find a considerable distance, probably more than 200 yards, intervening before the next rocks, which, after that, are nearly continuous to the summit. Those first seen are thick beds of ash with included fragments, some of considerable size, rather sparsely scattered about. They have some resemblance to the beds at the right-hand corner of the upper quarry, and might, so far as the trees allowed us to see, be on its strike. The other succeeding rocks do not in general differ very much from this, though some are of rather finer grain. Usually they are coarse ashes (rather finer near the cairn), indistinctly stratified, but, so far as can be ascertained, dipping in the same direction as the beds in the quarry. Included fragments can be detected at several points, especially near the summer-house at the top. The summit is a long, narrow, nearly level ridge, with a pile of stones erected by the Ordnance surveyors at the south-west end, a summer-house at the middle, and a grove of trees at the north-east end. The slopes of the hill are clothed with trees to a considerable distance. We have passed through a large part of the wood and have seen no outcrops beyond those of the ridge itself. This ends with a sudden descent, almost a cliff, at the north-east end, where the dip is, as usual, uncertain; but the more probable indications denote that previously seen. From here, across the valley, to the nearest outcrop on Green Hill is a space of full three quarters of a mile.

The rocks on the crest, with their ashy matrix and included fragments, recall those of Ratchet Hill and Cadman*. The porphyritic rock with large quartz grains of the lower quarry, closely resembles, as we have said, the rock of Peldar Tor; and though it changes so much in the breadth of the quarry, yet its structure on the south side is somewhat similar to that of the Green-Hill beds, which we consider the continuation of that series, and is the point of it nearest to Bardon. If so, the general structure of the hill is that of a ridge cutting very obliquely across an anticlinal whose axis passes between the mouth of the quarry and Hilltop. The upper beds corresponding with those of High Cadman or Ratchet Hill, and the middle with those of Peldar Tor, the lowest ones would naturally be the equivalents of the highest visible on High Towers. But that is a slate breccia, as is this lowest breccia on Bardon. Lithologically, therefore, there is fair evidence in favour of the identification of the Bardon group with those already described.

There are, however, one or two difficulties in these identifications. On High Towers an indurated slate overlies the breccia; and this is not visible in Bardon, while the shaly beds of the latter are not seen on the former. Also we have seen no indication of the "good rock" of the upper quarry on Ratchet Hill, which would be its natural place. We may, however, answer that the base of the Peldar series is nowhere visible, that there is space enough between Green Hill and High Towers for the shaly beds and others also, and that between the quarry and the slate breccia near its entrance there is plenty of space for the indurated slates or their equivalents. It is also quite possible that the above beds may greatly change their character in such a distance as that which separates the two localities. The last remark may be applied to the absence of the "good rock" from Ratchet Hill. Still the beds there, if a little finer in texture, and sufficiently altered, would, we think, resemble it. Further, the passage-bed there leading into the Peldar series is a breccia, containing a purple porphyritic rock, which is apparently identical with that in the breccia occupying the same position on Bardon.

Microscopic examination confirms the opinion which we have formed on the spot—that there is no true igneous rock in the pit. The good rock of the upper quarry is extremely like a felstone; but

* This is noticed also, we find, by Professor Hull, in the Memoirs of the Geological Survey.

we are of opinion that even this is only an altered rock*. The hill consists throughout of highly altered rock, into which volcanic breccias enter largely. The porphyritic rock, with the quartz granules and felspar crystals of the lower quarry, corresponds very closely, not only in general appearance but also in microscopic structure, with that of Peldar Tor. The change in character of this rock in passing from the north to the south side of the pit is remarkable; but there is no sign of a fault down it, and microscopic examination shows a general correspondence in the character of the rock. Both consist of a fine streaky matrix, composed apparently, to a great extent, of comminuted angular crystals of felspar, containing larger crystals of the same, both orthoclase and plagioclase, with much epidote, and some viridite of secondary formation. The specimen from the north side seems to have a rather more granular matrix, and has the large subcrystalline quartz grains, which, however, are not quite absent from the specimen collected on the south side. The fragments examined from the breccia on the south side of the pit, as well as one from the breccias forming the upper part of the hill, may possibly be of sedimentary origin; but the full discussion of these is reserved for the second part of this paper. We may say, however, that their microscopic structure closely corresponds with that of those which they are stated to resemble—the Peldar-Tor and Cadman series.

19. One isolated patch of rock, entirely different from all others, occurs in the centre of a plantation at Bawdon Castle, nearly in contact with syenite. It is a very dark, rather altered grit, containing many small included fragments. Microscopic examination shows it to be a pyroclastic rock.

The rock of the quarry at Moorley Hill, on the extreme north boundary of the forest, is a series of coarse banded slates or grits, with an occasional imbedded crystal of magnetite. The beds dip "at an angle of 35° true N.E. The cleavage is imperfectly developed" (*Jukes*). They do not resemble those of Ives Head, near them but on the other side of the anticlinal line.

The gneiss of Brazil Wood appears in an isolated knoll a few yards distant from a mass of hornblendic granite, which is probably intruded into it. This rock has received full notice from preceding observers. It is quite isolated from and unlike the other rocks of the forest, and may possibly belong to an earlier series. The microscopic structure is remarkable. It consists of a fine granular base (doubtless an altered felspathic mineral) with some small grains of quartz, probably of secondary origin, and a large quantity of rather

* It has been more than once stated that I consider Bardon Hill to show a plug or dyke of felstone. At one time, before I had completed my examination of the pit, or had studied the rocks microscopically, I inclined to this view, and expressed it incidentally in a letter to a member of the Geologists' Association before their visit to Charnwood. The publication of this letter was quite unauthorized, as I had not come to a definite conclusion on the point. Further examination has shown me that the whole of this igneous patch in the Survey map must be effaced; and I beg leave to recall this erroneous statement.—T. G. B.

fibrous mica. Of this mineral there are two species:—the one olive-brown, rather strongly dichroic; the other in larger crystals, nearly colourless, with almost unmarked dichroism, showing brilliant colours with polarized and analyzed light, and a strong sodium-line with the spectroscope. Both the micas appear to be orthorhombic; the microscopic structure of the rock much resembles that of a minette. We conclude therefore, since the appearance of the rock in the field seems to prove its sedimentary origin, that it was formerly a finely levigated mud, and has been intensely metamorphosed.

Correlations.

To correlate beds such as those described above, without fossils, with very variable lithological conditions, and with much subsequent alteration, is a most difficult task; and it is impossible to do more than conjecture; but we think, from what has been stated above, that the following are probably on the same horizon:—

(i) The Forest-gate pebble and ash beds, the pebble and overlying grit bed of the Hanging Rocks by Woodhouse, the pebble and grit beds of the Brande and Swithland, the quartz grits of the Stable Quarry in Bradgate Park, of the Boathouse by Groby Pool, and of the small patch south of Bradgate-House Wood (Stewards Hay Spring) of the Ordnance map.

(ii) The coarse slate breccias of Blore's Hill (F on the Map), of Holgate Hill and Old John, the breccias of Ulverscroft Mill, of Markfield, of the entrance to Bardon Quarry (of this last we are more doubtful), and at the western end of High Towers.

(iii) The coarse unstratified ash beds, usually coloured red (as igneous rocks) on the Geological map, of Benscliff, Chitterman Hill, and Barnby Wood, the eastern ridge of Timberwood Hill, and two isolated exposures, one at the H of Hanging Stones, the other in the kitchen-garden of the Monastery.

(iv) The quartzites and ashy banded slates and schists of the outcrop near Charley Wood, Charley church and its neighbourhood, Upper Blackbrook, and Blackbrook Tollgate.

The sum of the intervals between these horizons, measured along the surface, is slightly over two miles; while there is in addition a considerable depth, perhaps about 1000 feet, of fine workable slate, seen at Swithland and Groby, overlying the horizon at which this estimate commences; and the lowest beds of Ives Head seem not less than 1500 feet below the point where the above section terminates; so that, if the average dip of the beds be taken as 30° (which seems a fair estimate), the thickness of the strata included in our description would be at least 7500 feet.

The principal difficulties in the way of the above classification are—the absence of the Bradgate breccias from Broombriggs and Beacon Hill, of the Benscliff ashes from the east side of the anticlinal, and of almost the whole of the rocks of the north-west corner from every other point whatever. We can only reply that on Broombriggs and Beacon Hill, except at one or two places, exposures are very few, and there is nothing like a continuous section. Between Nanpanton and the Whittle Hills, and on Longcliff, there are ash beds which may be on horizon No. ii. The Benscliff ash bed is probably below the surface, unless the patch marked F, half a mile south of Alderman's How, represents it. The rocks seen there are all boulders; but their materials are of a similar nature.

The rocks of the north-eastern corner are almost entirely volcanic agglomerates; and these are naturally very inconstant and local. If the Peldar-Tor beds correspond with those on Bardon Hill, they must have thinned out to 40 feet in the latter, and so may very well have disappeared elsewhere. The great agglomerates of the central part of High Towers may die out in the White-Hill pebble beds. Besides, it does not seem impossible that the vent from which they were ejected may have been close at hand, and thus the whole deposit be of an extremely local character, interrupting the continuity of the strata. The seeming reappearance of familiar beds at Warren Hill and Gracedieu Lane may possibly lend a slight support to this hypothesis.

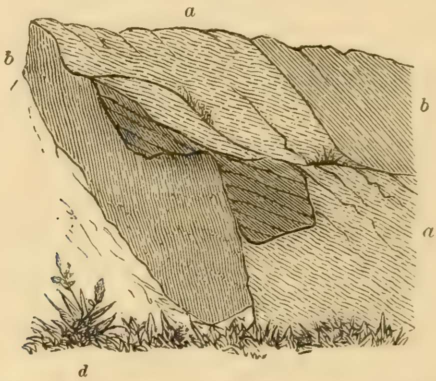
We may also notice that the interval between ii. and iii. is everywhere remarkably deficient in exposures. Even between Bradgate and Benscliff there are wide extents without outcropping rocks; and these are but isolated on High Towers itself.

The arrangement of the rocks of the north-west (the so-called "Porphyry" Region) seems to be:—first, the indurated slates of Whitwick Village, then the rocks of High Cadman, passing down into those of Sharpley and Peldar Tor. The base of this series is nowhere clearly seen; but the beds on Green Hill probably represent it. Then come the beds by the Forest Rock Hotel, the slate breccia at the crest of High Towers, the great agglomerates east of that, and the thick ash beds round the Monastery, which seem to overlie the ash beds of Timberwood Hill.

Relations between the Igneous and Stratified Rocks.

It will be observed that, if these correlations and groupings be correct, the western side of the district has been subjected to great dislocations, while the eastern is almost undisturbed. The quartzite of Bradgate-Park-Stable Quarry is distant fully two miles from that of Groby Pool and Steward's-Hay Spring. The strikes of the Markfield breccia, and the ash beds of Chitterman Hill and Barnby Wood, seem to carry them nearly a mile from the corresponding lines of High Towers and Timberwood Hill. The one disturbance seems connected with the great mass of syenite which extends from Bradgate and Groby to Markfield, the other with the syenite hill of Hammercliff. This gives rise to the suspicion that these syenites may be intrusive; and if so, the other igneous rocks of the forest may be the same. To obtain evidence of this we have examined the boundaries of every igneous patch in the district, and at length, in the woods of Bradgate House, discovered a small quarry in which the junction of the syenite and the slate has been exposed; and its intrusive character can be seen. This is just within the wood called, on the Map, Steward's-Hay Spring, on the continuation of the blue patch which marks the quartzite quarry. The patch is rightly continued on the Map to within the wood; but the syenite, on which nearly all the latter grows, is only indicated as existing near the house, a quarter of a mile further north. The quarry is small, old, and quite shallow; and a pheasant-feeding house stands on its floor. On the north side is rather coarse ashy slate, much jointed; on the south is syenite, which becomes a little more finely crystalline (but only a little) as it approaches the slate. We found the junction at the right-hand corner of the pit, and traced it some way across the floor. No one accustomed to examine junctions of igneous and sedimentary rock can for a moment doubt the nature of this. The line of contact is wavy and slightly irregular. Further careful examination shows a large piece of slate caught up by and included in the syenite (see fig. 6); from this we succeeded in obtaining

Fig. 6.—*Syenite intrusive in Slate, Steward's-Hay-Spring Pit, in Bradgate-House Wood.*



a. Syenite. *b*. Slate. *c*. Débris and vegetation, partly covering up the joint-face of the slate, which seems to have passed in places almost along the junction, so as to leave a flake of slate adhering to the syenite.

junction specimens, which we have since subjected to microscopic examination. The result of this fully confirms, were there any need of it, the evidence of the section.

About 250 yards further west, north of the walk, in the midst of the brushwood, we again found the syenite and slate in contact. Here, also, though the slate is more highly altered than at the other spot, the nature of the junction is quite as evident. The irregular line of contact can be traced for several feet; and a few feet below it is another bed of ashy slate, into which also the syenite can be seen to intrude. The slate at each of these places bears a considerable resemblance to that of the slate-quarry in Bradgate Park—an additional evidence for the identity of the quartzite beds in the two localities.

At the point on the Map where there is a dip-arrow under the L of Linford, banded slates can be traced up to within a yard (even less if a projecting fragment be really *in situ*) of the syenite. The latter somewhat changes its character as it approaches the slate, which is highly altered, becoming a very splintery hornstone-like rock; but the actual junction is not visible above ground. The slate is dipping in the direction usual in the neighbourhood. These Charnwood intrusions, except in a very few cases, do not seem to disturb the dips in their vicinity. The apparent curving of the planes of dip at this end, from south-west at Markfield to south at Bradgate, may, however, be due to the great intrusive mass here, whose area is apparently two or three square miles.

In Bradgate Park the peculiar contortions and slickensides of the beds in the Stable Quarry long ago suggested to us the probability of the neighbouring syenite being intrusive; but it was not till after we had found the above junction that Mr. Hill discovered fragments, showing syenite and banded slate in contact, built into the wall surrounding the ruins, and picked up one beautiful contact specimen a little further up towards Old-John Hill.

About the last letter of the word Bradgate on the Map, is a small patch of syenite, here rather less coarse than usual, with a large mass of banded slates within five or six yards. The slate here is almost a hornstone, showing a sort of rippled marking, seen in some other places near the igneous rock, and a platy jointing. The syenite, as usual, becomes rather more finely crystalline as it approaches the slate, and is in contact with the sedimentary rock, though the very small portion of the junction visible is not quite sufficient to determine the precise character of the latter. Microscopic examination shows that the nature of the junction is indubitable, and that the syenite is intrusive.

There is therefore no doubt that the mass of syenite in Bradgate Park is also intrusive; and it is quite possible that careful search within the ruins may yet detect the junction *in situ*.

An outcrop of syenite, with slate on both sides of it, can be seen at Groby-Park Farm. On the eastern side the two can be traced to within six feet of each other. The slate is much jointed; and the syenite here and there shows the platy jointing often noticed in an igneous rock parallel to its junction-surface; but the evidence here, without excavation, would not be quite conclusive. However, after that obtained elsewhere, no difficulty can be felt in admitting intrusion here also. At Markfield, and at Cliff Hill, no slates are seen sufficiently near the syenite to give any information; and the same is the case at Hammercliff, though it is just possible that the plantation may contain exposures which, up to this time, have escaped our notice. At Bawdon Castle the syenite becomes compact, and may be seen almost in contact with the breccia*. Birchwood and Bardon Hill, though highly altered, contain no igneous rock. The syenite (greenstone of Map) on Buck Hill is restricted to a small patch at its northern end. We have no doubt that the syenite here is intrusive; but the evidence is not quite so absolutely unquestionable as at the localities mentioned above. This syenite is always less coarsely and distinctly crystalline than that of the more southern district. The sedimentary rock here happens to be of a somewhat gritty texture; so that there

* We discovered this instance after the paper was read; details of it will be given in Part II.

is not quite so marked a contrast as is usual between the two when weathered and decomposed; and both rocks near the junction are much cut up by small quartz veins. The rock also is much masked by turf and furze. Hence, though we could in one place see that the junction lay somewhere in about half a square yard of a small outcrop, we could not hit it with absolute certainty. At the same time we do not consider that there is the slightest evidence of a passage from the sedimentary rock to the syenite; we have no doubt whatever that the latter is intrusive; but in order to demonstrate this by the evidence of specimens, it would be necessary to blast away a few cubic feet of the more rotten rock.

On Longcliff, at the southern end, the syenite forms the foot of a hill, the crest of which is of banded slates; and the appearance of the rock suggests that it is approaching a junction. At the northern end of the wood there is a small hill of banded slate, at the foot of which is a little outcrop of syenite. The two rocks can be traced to within three or four yards of each other; and the slate is highly altered; but the two cannot be seen in contact, though this could be exposed by a very small excavation. Mr. Hill, however, picked up in the vicinity a loose fragment which clearly shows an intrusive junction between the syenite and a rather coarse quartzose grit, a bed of which occurs in another part of the hill.

The contorted condition of the Brazil-Wood gneiss was long ago noticed. The granite also of the opposite knoll assumes a very different aspect in the portions of it which are nearest to the gneiss. Here also, we think, there can be no doubt that the granite is intrusive. Still, as there is also a mass of diorite not far off, and a dyke of similar rock (to be described hereafter) in the granite itself at a very short distance, one cannot, without excavation, absolutely determine to which agent the disturbance is due.

On the whole, then, we feel justified in asserting that all the Charnwood syenites are intrusive. The quarzite which they disturb at Bradgate and Groby forms almost our highest horizon. The overlying workable slates are thrown by them at Groby into great rolls. Hence they are posterior in time to the whole of the Charnwood series. Their lines of junction with the surrounding strata, when clearly exposed, are sharp and unmistakable. Hence there is no evidence of transition from sedimentary to igneous rock anywhere in this region; for even in the northern district; that of the "felstone porphyries," there is rarely any thing more in these rocks than the most superficial resemblance to a true felstone. Charnwood Forest therefore must be removed from the number of localities which can be adduced as affording evidence of such transition.

In the second part of this memoir we purpose touching upon the dislocations of the strata, and describing in detail the igneous masses mentioned above, together with certain dykes more or less associated with them. Besides these, the group of igneous rocks protruding from the Trias in the vicinity of Narborough will be described*.

* Since this paper was read we have been fortunate enough to obtain evidence

We shall also discuss at greater length the microscopic structure of the rocks, both sedimentary and igneous, and offer some remarks upon the comparative lithology of the former and upon their probable geological age, which Mr. Bonney has already stated to be, in his opinion, not Cambrian (Survey), but about that of the Borrowdale series of the Lake district.

The authors desire to express their thanks to A. M. P. De Lisle, Esq., Mrs. Perry-Herrick, Alfred Ellis, Esq., and other owners of property, who have most kindly allowed them free access to every place, and to the owners and managers of the various quarries for similar facilities. They have also to thank A. Hill, Esq., of Cooper's-Hill College, for assistance in the field-work.

Discussion.

Prof. Ramsay said that though it was many years since he saw the country described in this paper, and twenty years since it was mapped, he and the officers of the Survey, who did the work, were quite convinced that a proportion of the so-called igneous rocks were only igneous in the sense of extreme metamorphism.

Rev. T. G. Bonney said that in this district in most cases the metamorphism was not extreme. There is no porphyry; and much of the felspar which is present porphyritically is detrital.

Mr. Hicks was surprised to find so great a resemblance between the rock specimens now exhibited and those he had recently brought before the Society from the pre-Cambrian rocks of St. David's. He would draw particular attention to the conglomerate shown, as it contained distinct pebbles of schists and indurated shales, derived primarily from rocks in a state of metamorphism. That these pebbles were in this state previous to being cemented together to form the conglomerate was clear from the fact that the pebbles still retain their distinct outline; and the matrix is not apparently much altered. It is clear also that these masses could not have been derived from the Cambrian or Lower Silurian rocks, as all evidence so far obtained in regard to the physical conditions of the Cambrian and Lower-Silurian epochs in Western Europe goes to show that these rocks were not elevated out of the horizontal position until the close of the Lower-Silurian, and hence that they could not have been previously indurated sufficiently to yield pebbles of this nature. He felt convinced that some at least of these rocks would prove to be of pre-Cambrian age, and would have to be correlated with those he had recently described under the names "Dimetian" and "Pebidian."

Prof. Ramsay altogether denied the absence of pebbles in the rocks referred to by Mr. Hicks. There were plenty of them, both of Cambrian and of Silurian age.

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that these are also intrusive in slaty rock, which doubtless belongs to the Forest series.

43. *On the* Structure *and* Affinities *of the Genus* Siphonia.

By W. J. Sollas, Esq., M.A., F.G.S., late Scholar of St. John's College, Cambridge, and Associate of the Royal School of Mines, London. (Read May 23, 1877.)

[Plates XXV. & XXVI.]

1. Introduction.

Some years ago my friend and tutor Mr. Bonney was kind enough to procure for my examination a collection of phosphatic nodules from the Gault of Folkestone, amongst which were included several specimens of what I considered to be species of *Siphonia* in a phosphatized condition. Knowing well, from a previous investigation of phosphatized Ventriculites from the Cambridge Greensand, how perfectly sponge-structure is sometimes preserved in this state, it occurred to me that I had here a good opportunity of determining the minute structure of this sponge and its relations to recent forms.

Accordingly I requested Mr. Cuttell, of 52 New Compton Street, Soho, to prepare a series of transparent slices from my specimens; and on examining under the microscope the beautiful sections he made for me I saw displayed, in all its details, the characteristic structure of a Lithistid sponge. I then submitted my preparations to my kind friend Mr. Carter, who not only confirmed my observations, but gave me the benefit of several valuable suggestions, and generously sent me pieces of the recent *Discodermia polydiscus*, Bocage, for comparison. Subsequently Mr. Vicary, with great kindness, put a large number of siliceous specimens of *Siphonia* from the Blackdown Greensand at my disposal, and I obtained from Mr. Bryce Wright an example of *Siphonia* (*Hallirhoa*) *costata*, Lamx., from the Greensand of Wiltshire. Finally my friend Mr. Moore afforded me every facility for the examination of the beautiful collection of Choanites preserved in the Liverpool Free Museum; and transparent slices taken from specimens of that genus were sent me from the Woodwardian Museum, Cambridge, by the courtesy of Professor Hughes.

After a thorough examination of the material I had thus acquired, my next step was to work out the literature of the subject; and this proved to be a more laborious and unsatisfactory undertaking than could have been expected. A knowledge of the minute structure of fossil sponges is the first essential towards determining their natural affinities; and of this minute structure palæontological works tell us little or nothing. As a general rule, all one can learn from published figures and descriptions relates to external form and coarse structure only; and consequently without a personal examination of the forms described one is not always in a position to determine whether they are rightly assigned to a particular generic group or not. Moreover the external form of the same species of sponge is often so variable that when one has decided as to the genus of a particular form, one is still not at all sure as to whether it should rank as a distinct species or not. In the face of these difficulties one must either restrict one's self to mentioning those species only which have fallen under one's own immediate attention; or otherwise, in giving a complete history of the group, with each of its described species, one must be prepared to reserve judgment on a large number of forms, leaving their definite determination to future research and other observers. The former is the less laborious of the two alternatives; the latter, however, is more thorough; and though it leaves us in a state of indecision on many points, it indicates on the other hand the *lacunæ* which remain to be filled up, and by supplying a reference to each described species serves to save time in future inquiries. These reasons appear to me sufficient to justify its adoption in the following account.

2. History.

Descriptions of fossils more or less resembling *Siphoniæ* occur in the works of Langius, Scheuchzer, Bourguet, and various other early writers on petrifactions; but the first important paper on the subject we owe to Guettard.

1751. Guettard. 'Hist. et Mém. de l'Acad. Roy. des Sci.' (Paris), tom. lxiv. p. 239.

In a paper entitled "Mémoire sur quelques corps fossiles peu connus" several specimens which are evidently *Siphoniæ* are described and figured (plate i. figs. 1–4, plate ii. figs. 1–4, plate iii. fig. 1) as possessing a more or less globular body, supported on an elongated conical stalk below, and excavated at the summit to a greater or less depth by a large circular cavity, into which smaller radiating canals open. It is shown that these are not fossilized fruits, as the common people of Normandy and Touraine imagined, and as, indeed, some of the labourers in Devonshire believe even now; and that they differ in important respects from the organism to which Scheuchzer compared them—the *Alcyonium ficus*, Linnæus, described by Marsilli as "Figue de substance d'Éponge et d'Alcion," which Guettard considers, justly enough, to be a sponge, while the "petrified pears" (our *Siphoniæ*) he assigns to the corals.

1758. Baier. 'Oryctographia Norica' (Norimbergæ), J. J. Baier, p. 46, and Supplement, p. 59.

In the body of this work the "fossil figs" (tab. i. figs. 30, 31) are considered to belong to his division "*Lusus Naturæ*;" but subsequently in the Supplement they are referred to fossilized marine vegetables resembling the *Alcyonia* (tab. vii. fig. 12).

1769. Walch. 'Das Steinreich systematisch entworfen' (Halle), J. E. J. Walch, p. 196, tab. xxiv. fig. 3 *b*.

Under the name "Corallinischen Feigen" our fossils are here referred to a group of marine Fungites.

1770. Guettard. 'Mém. sur les Sci. et Arts,' tom. ii. p. 100, "De la structure des Polypites ou Polypiers fossiles;" p. 317, "Arrangement méthodique des Polypites."

In these papers a very full and accurate description, illustrated with numerous figures, is given of various *Siphoniæ*. They constitute as "Caricoïdes" the first genus of the class of polypites, which are defined as "marine fossil bodies of various forms, branched or not, pierced by simple or stellate holes, and which in their original state were formed by polyps contained in these holes."

After a definition of the genus very similar to that of 1751, a number of species are described and figured, including among them a "Caricoïde with five or six ribs," which is a veritable *Siphonia costata* (*Hallirhoa*, Lamx.).

Altogether, in Guettard's hands, the Caricoïdes form a very natural group.

1778. Schröter. 'Vollständige Einleitung in d. Kenntniss u. Geschichte d. Steine u. Versteinerungen,' vol. iii. p. 431.

To this work I have unfortunately not succeeded in obtaining access.

1808. Parkinson. 'Organic Remains of a Former World,' vol. ii. p. 95, plate ix. figs. 4, 7, 8, 11, 12, 13, plate xi. fig. 8.

Parkinson considers that we must in most cases give up every idea of distinguishing between *Alcyonia* and sponges in the fossil state. He refers Guettard's forms to one or the other without deciding which, and at the same time regards some of them, *e. g.* that figured by him on plate ix. fig. 4, as presenting, along with characteristic differences, a very striking resemblance to *Alcyonium ficus*, Linn.

Parkinson's contributions to our knowledge of the genus consist chiefly of quotations from Guettard, and of figures of sections taken longitudinally and transversely through the sponge (plate ix. figs. 7, 12, 13).

1814. T. Webster. 'Geological Transactions,' ser. 1, vol. iii. p. 378, pls. 27–30.

In a letter to Sir Henry Englefield, dated Aug. 21, 1811, this author describes some silicified remains of sponges, one form of which he names "tulip-alcyonium." This consists of a head, composed of a group of more or less parallel tubules, without a central cloaca at the summit, and supported below on a slender stem some four or five feet in length; it occurs abundantly in the Greensand of Western Lines, Isle of Wight.

This form appears to be a true *Siphonia*, though it possesses no central cloaca, and as a consequence its excurrent canals are arranged in a longitudinal fascia, and open on a plane area at the summit—an arrangement which is usually regarded as diagnostic of *Jerea*.

1821. Lamouroux, J. 'Exposition méthodique des genres de l'ordre des Polypiers (des Zoophytes, Ellis et Solander),' pp. 72 and 79, tab. 78. figs. 1, 2, 3.

Lamouroux describes certain Siphonian forms (*S. Websteri*, Sow., *S. piriformis*, Goldf. (?), *S. costata*, Lamx.) under his two genera *Jerea* and *Hallirhoa*, differentiating the latter from the former on the ground that it possesses a central cloaca, which *Jerea* does not. *Hallirhoa* is made to include two species, *H. lycoperdoides* (tab. 78, fig. 2), a smooth form, possibly corresponding to Goldfuss's *Siphonia piriformis*, and *H. costata* (tab. 78. fig. 1), distinguished by its longitudinal ribs. The ribs are said to vary in number and size, and to be of merely specific importance; their elevation to the rank of a generic character was a mistake of subsequent writers. *Jerea* is represented by but one species, *J. pyriformis*, probably identical with *S. Websteri*.

Lamouroux refers both *Jerea* and *Hallirhoa* to the last of his three divisions of the Polypiers; but he does not include them in the same order; on the contrary, while *Hallirhoa* goes into the eighteenth order, or Alcyonées, *Jerea* is placed, along with *Montlivaltia, Chenendopora*, &c., in the twentieth order, or Actinaires.

1822. Mantell. 'Fossils of the South Downs,' p. 178, tab. xv. fig. 2; tab. xvi. figs. 19, 20, 21.

The genus *Choanites*, of Mantell, which is in this place very vaguely defined by him, professes to be founded on *Alcyonium ficus*, Linn., as a type, and consequently embraces several of the Alcyonites referred by Parkinson to the same alliance. The forms specially claimed by Mantell are represented on pl. ix. figs. 1, 3, 4, 6(?), 8, pl. xi. fig. 8, of Parkinson's 'Organic Remains.'

Two species of the genus are described and figured: one, *Choanites subrotundus* (tab. xv. f. 2.), from the Upper Chalk of Lewes, is a true Myliusian, or lantern-jointed Hexactinellid, previously and correctly described by Toulmin Smith as *Cephalites subrotundus*; the other form, from the chalk flints of Lewes, appears to be a large conical *Siphonia* without a stem, and is named *Choanites Königii* (tab. xvi. figs. 19, 20, 21).

An *Alcyonium* (?) *pyriformis* is mentioned as occurring at Hamsey, South Bourne, near Beachey Head, in grey Chalk marl.

1826. Goldfuss. 'Petrefacta Germaniæ,' pp. 16–18, 97, 98, 221; pl. vi. figs. 7 to 11; pl. xxxv. figs. 10 to 12; pl. xlv. figs. 13 and 14.

The *Siphonia* of Goldfuss is simply Guettard's genus *Caricoïdes* under another name, and (since it is made to include Lamouroux's genus *Jerea*) with a slightly wider definition; and yet, without any reason being alleged, its authorship is assigned to Parkinson. But that Goldfuss quotes Guettard's memoirs on this subject, I should imagine he had never seen them.

The genus is classed with the Polypites, its polyparium stated to be polymorphic, fixed or free, with thick fibres, which were probably subgelatinous (!) in the living state; the distinction of its canals into two groups is noticed, the one longitudinal, and opening into a central ostiole or upon a plane surface, and the other transverse, terminating in the ostioles scattered on the lateral surface.

Nine species are described and figured, all of them, with one exception, which is assigned to Münster, being claimed as new.

TABLE OF SPECIES.

				p.	Pl.	fig.
S. ficus	Goldf.	Quader Sands.	Quedlinburg.	221	65	14
,, *punctata*...	Münst.	,, ,,	Goslar.	,,	,,	13
,, *piriformis*	Goldf.	Chalk (?)	Chamont.	16	6	7
		Jura Kalk*.	Streitberg.	97	35	10
,, *excavata* ...	,,	? ?	?	17	,,	8
,, *præmorsa* .	,,	? ?	?	,,	,,	9
,, *pistillum*†.	,,	Firestone.	Paris, Courtagnon.	,,	,,	10
,, *incrassata* .	,,	Greensand.	Coesfeld, Westphalia.	,,	32	5
,, *cervicornis*	,,	... ...	? ?	18	6	11
				98	35	11
,, *ampullacea*	,,	... ...	... ...	,,	,,	12

1831. Deshayes. 'Description des Coquilles caractéristiques des terrains,' p. 255, pl. xi. figs. 1 and 3.

This author simply notices the occurrence of *Siphonia costata* and *S. pyriformis* in the Cretaceous strata.

1831. Benett. 'Catalogue of Organic Remains of Wilts,' pp. 8, 9, pl. 1 to 8.

Miss Etheldred Benett describes and figures a large number of fossil sponges, including several forms of *Siphonia*, from the greensand of Wilts. They are all placed in the same genus *Polypothecia*, Benett, a somewhat heterogeneous mixture of forms, grouped together apparently on insufficient grounds of resemblance, and separated into species on insufficient degrees of dissimilarity in external form. Her drawings, however, are very valuable, since they present us with what appear to be two gradational series of *Siphoniæ*, diverging from *S. pyriformis* into *S. costata* on the one hand, and into *Polypothecia expansa* on the other. The latter series is the least complete; but it appears to mark a passage from *S. pyriformis*, through an open cup-like form (*P. complexa*) resembling a *Siphonia costata* opened out, to a wide shallow saucer-shaped species *P. expansa*, which resembles, at least superficially, some forms of *Corallistes*. The other series commences with *P. sphærocephala*, which is simply a smooth ovoid specimen of *S. pyriformis*;

* The occurrence of this species in the Jura Kalk, of which the figure leaves us in no doubt, is a very interesting observation. Goldfuss remarks that it is one of the very few fossils common to the Chalk and Jura Kalk.

† This is subsequently identified with *Jerea pyriformis*, Lamx.

this is succeeded by a true *S. pyriformis*, but with faintly longitudinally wrinkled sides; then follows *P. biloba* (*S. costata*), which shows the incipient lobation of the preceding in a more advanced stage; from being irregular and vague, it has become definite, and exhibits two regular longitudinal ribs. The lobation thus commenced is continued by specimens with from three to six or even seven lobes: so great, indeed, is the tendency of this form to lobation, that in *P. triloba* the three principal folds are in one specimen subdivided into secondary ones by a depression running longitudinally down each; and in a variety of *P. sexloba* the six chief ribs are also separated into secondary ones, but in this case by transverse instead of longitudinal constrictions. So easy do the transitions between the varieties in this series appear to be, as to leave great doubt in one's mind as to the specific distinction between the extreme forms of *S. pyriformis* and *S. costata*.

1832. Passy. 'Description géologique du département de la Seine-Inférieure, p. 339, pl. xvi. fig. 9.

In this work we merely find a notice of the occurrence of a form which the author calls *Choanites pyriformis*, a variety of *C. Königii*. It is from the Upper Chalk in the department of the Eure, and appears from the figure to be a small form of *C. Königii*.

1830–37. Fischer-de-Waldheim. 'Oryctographie du Gouv. de Moscou,' pp. 178, 179, tab. xlviii. figs. 3 and 4.

The genus *Siphonia* is here included with the Polypiers, and Goldfuss's definition is repeated. A new form is figured and described as *S. radiata*, a variety of *S. pyriformis*, from Bouchevoë, ten rsts from Moscow, in Upper Chalk.

1834. Blainville. 'Manuel d'Actinologie,' p. 536, pl. 95. fig. 1.

Blainville defines the genus according to Goldfuss, and enumerates as its species *S. pyriformis*, *excavata*, *præmorsa*, *pistillum*, *incrassata*, and *cervicornis*. A recent sponge from the Mediterranean, exhibiting a certain superficial resemblance to *Siphonia*, is referred by Blainville to this genus, and not only so, but constituted its type, under the name of *Siphonia typum*, De Blainv., pl. 95. fig. 1, Mers de Sicile.

Now, in the first place, this *S. typum* appears to me to be identical with the *Alcyonium ficus*, Linn., described by Count Marsilli, and considered by Scheuchzer and Parkinson to be the living representative of *Siphonia*, for which reason they referred *Siphonia* to Alcyonia. Thus this particular species (*S. typum*) has considerable interest for us, especially as it was adopted so recently as 1867 by the late Dr. Gray, who introduced it into his proposed arrangement of the sponges as a member of the Keratacea (Proc. Zool. Soc. 1867, p. 509). The fossil *Siphonia*, however, is, as we shall show, a Lithistid sponge; and it would certainly be curious if a recent

Lithistid had been known to Blainville in the shape of *S. typum* at this early date; there is a strong *à priori* improbability about such a supposition; and what is better, we have certain information which decides this point, since Mr. Woodward informs me that a section of the original so-called *S. typum* has been prepared and examined microscopically by Mr. Savile Kent, and that this exhibits the structure of a Renierid sponge; *i. e.* its skeleton consists of acerate spicules bound together into fibres. This fact, which was known to Dr. Gray, and appears in the MS. correction of his original classification in the possession of Mr. Carter, clears up the whole matter. In the first place *Siphonia typum* is not a *Siphonia* at all, since it belongs to the Renieridæ, while the *Siphoniæ* belong to the Lithistidæ, an altogether different order of sponges; thus the error of Blainville is rectified; and next, if *S. typum* be the same thing as *Alcyonium ficus*, as I firmly believe it is, then Parkinson's mistake is also indicated, and the clear insight of Guettard, who plainly saw and insisted on the important differences in general structure between *Caricoïdes* (*Siphonia*) and *Alcyonium ficus* (*S. typum*), receives at length its true recognition.

1836. Sowerby. 'Trans. Geol. Soc.' ser. 2, vol. iv. pl. 2. p. 340, pl. xvi *a*. fig. 169.

In this paper, which is an appendix to Dr. Fitton's memoir on the strata below the Chalk, Sowerby describes and figures specimens and sections of a species which he terms *Siphonia pyriformis*, Goldf., and which is found in the Greensand of Blackdown. He states that it exhibits as much variety in form as the fruit from which it derives its name. His figures are superb, and beautifully illustrate the general form and structure of the specimens described: they have in consequence been copied by many succeeding authors, too often, I regret to say, without due acknowledgment.

Sowerby's *S. pyriformis* is not spherical or obconical in shape, like Goldfuss's specimens, but more or less conical, and with a general resemblance to *S. ficus*, Goldf.; probably, however, in a type so variable these forms are but varieties of each other.

1839. Lee, J. E. 'Magazine of Natural History,' vol. iii. new ser. p. 10, figs. 2 to 6.

Lee describes two species, which he refers to *Siphonia*, as *S. clava* and *S. anguilla*, both forms from the Chalk of Bridlington, Yorksh. Neither, however, appears to agree in general characters with this genus; and as microscopic structure is not adduced, conclusive evidence as regards their affinities is wanting. A very interesting observation is made, to the effect that whilst the fibres of the roots of these sponges are often perfectly preserved in the Chalk, yet in no instance have they been found attached to a foreign body. This fact strikingly illustrates the similarity in habit between the old

Chalk sponges and those which live half-immersed and unattached in the Atlantic ooze of the present day.

1840–41. Römer, F. A. 'Die Versteinerungen des norddeutschen Kreidegebirges,' p. 4, tab. ii. figs. 1, 2, 3.

The genus is assigned, as in all works subsequent to Blainville, to the sponges; its characters are defined afresh; and eight species are described from Cretaceous strata, of which three, *S. cylindrica* (tab. ii. fig. 1), *ocellata* (ib. fig. 2), *oligostoma* (ib. fig. 3), are new, while a fourth, *S. Goldfussii*, is the *Manon pyriforme* of Goldfuss, renamed and transferred, I think rightly, to *Siphonia*.

S. oligostoma appears to be a Lithistid of some sort; but there is nothing to show that it possesses the essential structure of *Siphonia*; the two other new species exhibit no characters by which we can determine even their ordinal affinities.

A reference is made to *Choanites* as "*Scyphia* (*Choanites*) *Koenigii*," on page 8, where we find its right to generic independence strongly questioned, and its true place indicated as belonging to the *Scyphiæ*.

List of Species.

*S. punctata.**	Upper Chalk Marl	Sudmerberg, near Goslar.
	Lower ,, ,,	Ilsenburg and Coesfeld.
S. ficus.	Upper ,, ,,	Sudmerberg, near Goslar.
	Grey Chalk (Pläner)	Steckelnburg near Quedlinburg.
S. Goldfussii.	Lower Chalk Marl.	Near Coesfeld.
S. cylindrica.	Pläner.	Steckelnburg.
S. ocellata.		
S. oligostoma.	Chalk marl (Pläner)	Near Ilsenburg.
S. multiformis†.	Lower Chalk.	Near Peine.
	Greensand (glauconie).	Vouziers, Ardennes.
S. cervicornis.	Lower Chalk Marl.	Near Lemförd and Coesfeld.

1840–47. Michelin. 'Iconographie Zoophytologique.'

The additions to our knowledge of the genus made here consist chiefly in descriptions of a number of species, one of which, *S. arbuscula*, is a very interesting form, since it presents us with a composite *S. pyriformis*, characterized by a number of sponge-bodies borne on pedicels branching from the main stem.

Blainville's mistake in reference to *S. typum* is repeated, and my opinion in regard to its identity with *Alcyonium ficus*, Linn., confirmed by anticipation.

In the following list of species those which are printed with an asterisk either certainly do not belong here, or only doubtfully.

* This is considered identical with *S. incrassata*, Goldf.

† *S. pistillum* is supposed to belong to this species.

S. acaulis	Mich.	Cretaceous.	Cap la Hève.
,, *arbuscula* ...	,,	,,	Environs de Tours.
,, *ficoidea*	,,	,,	Poitiers.
,, *Fittoni*	,,	,,	Cognac, Loudun.
,, *incrassata* ...	Goldf.	,,	Nogent le Rotrou, Tours, Rémalard, Guilbaut, Coulonges.
,, *lagenaria** ...	Mich.	Oolitic.	Caen.
,, *lycoperdoides**	,,	Cretaceous.	Luc, Ranville (Calvados)
,, *multioculata*	,,	,,	Tours.
,, *nuciformis* ...	,,	,,	Tours, Honfleur.
,, *pyriformis* ...	Goldf.	,,	Rouen, Havre, Tours, Chateauvieux, St. Aignan, Rémalard.
,, *ramosa**	Mich.	,,	Tours.
(*Hallirhoa*)			
H. brevicosta	,,	,,	Tours (*P. agariciformis*, Benett, Wilts).
,, *costata*	Lamx.	,,	Vaches-noires, Nogent-le-Rotrou, Rémalard, Cap la Hève.
,, *Tessonis*	Mich.	,,	Vaches-noires, Villers-sur-Mer.

1845–46. Reuss, A. E. 'Die Versteinerungen der böhmischen Kreideformation,' vol. ii. p. 72.

Mention is made of six species, of which four are described as new.

List of Species.

S. ternata, Rss., Lowest Chalk marl, S. foot of Borzen, near Bilin; Tripelberg, near Kutschlin. Pl. xvii. figs. 1 and 3.
S. pyriformis, Goldf., Upper Chalk marl, Kutschlin.
S. elongata, Rss., Upper Chalk marl, Kutschlin, Hundorf, Radowessitz. Pl. xliii. fig. 1.
S. heterostoma, Rss., Lowest hornstone-like conglomerate, S. Borgen, S. Hradisst; Lowest Chalk marl, Schilling, near Bilin. Pl. xvii. figs. 4, 5.
S. biseriata, Rss., Conglomerate, southern foot, Borzen. Pl. xvii. fig. 6.
S. cervicornis, Goldf., Upper Chalk marl, Kutschlin, Hundorf; Lower Chalk marl, Bilin; 'Pyropensand' of Tržibletz.

S. ternata, the *Cnemidium ternatum*, Rss., of an earlier work (Geogn. Skizz. ii. p. 298), possesses the general structure of a *Siphonia*, and is in all probability a Lithistid, closely allied to, if not identical with our genus.

S. elongata. This appears also to be a Lithistid, and is very likely a *Siphonia* as well.

S. heterostoma and *biseriata*. These are both Hexactinellids, with no relations to *Siphonia*; on the other hand they closely resemble *Stauronema*, mihi, in the coarseness of their sexradiate fibre, and in the simplicity of its nodes; they are like this genus in general form also, and will therefore, I expect, on closer examination be found to be allied to it.

S. cervicornis is said to be exceedingly similar to the lower part of *Jerea arborescens*, Mich.

1850. D'Orbigny, A. 'Prodrome de Paléontologie,' vol. ii. pp. 186 and 285.

D'Orbigny includes *Hallirhoa* and *Choanites* with *Siphonia*, and enumerates the following species from the "étage Cénomanien" (p. 186):—

1. *Siphonia costata*, which includes *Hallirhoa costata*, Lamx., and *H. Tessonis*, Mich.

2. *S. acaulis*, Mich.

3. *S. ficus*, Goldf., which includes Sowerby's *S. pyriformis*. From the "étage Sénonien" (p. 285):—

1. *S. lycoperdites*, D'Orb., in which are merged *S. piriformis* and *S. incrassata*, Goldf.

2. *S. Königii*, *Choanites Königii*, Mantell, to which he adds, as belonging here, *Spongia terebrata*, Phil., and *Scyphia (Cnemidium) pertusum*, Reuss. Of course, without a knowledge of the intimate structure of these species, it is impossible to deny the justice of these identifications; but the figures of Phillips (Geol. Yorks. pl. i. fig. 10), and of Reuss (Böhm. Kreid. pl. xvi. figs. 7 to 12), exhibit a very marked difference from the *Choanites* of Mantell, since they possess only one set of canals, the longitudinal group being absent.

3. *S. tuberosa* equivalent to *Scyphia tuberosa*, Römer (Nordd. Kreid. pl. ii. fig. 9). Römer figures the minute structure of this sponge; it is a true Hexactinellid, and has nothing to do with *Siphonia*.

4. *S. dichotoma* is Michelin's *Scyphia dichotoma*; and the reference here is doubtful, to say the least, since the minute structure is not known.

5. *S. infundibulum*, D'Orb., is *Scyphia terebrata*, Mich.; another of those generic identifications which rest on no sufficient basis.

6 to 9. *S. arbuscula*, *ficoidea*, *Fittoni*, *brevicosta*, all Michelin's.

10. *S. elongata*, Reuss.

11. *S. ternata*, Reuss.

12. *S. multiformis*, Bronn.

1851. Bronn. 'Lethæa Geognostica,' Th. v. p. 73, t. xxvii. fig. 20.

Bronn considers that there is no essential difference between *Siphonia*, *Hallirhoa*, and *Jerea*; at the most they are subgenera. There can be no doubt that as regards the first two he is right; and with respect to the third the probabilities are in his favour; the *Siphonia* of the Folkestone Gault differs in no important particular from the *Jerea pyriformis* of Lamouroux and Michelin; but without an opportunity of examining more species of *Jerea* I do not feel able to pass an opinion upon the whole group. Bronn also describes and figures a new species, *Siphonia multiformis* (*Jerea pyriformis*, Defr. Dict. Sci. Nat., Atlas des Polyp. xlix. fig. 2); this does not possess the usual central cloaca of *Siphonia*, but otherwise strongly resembles it. The various other species of the genus, which he quotes and rearranges from other authors, will be found referred to him in the appended catalogue, pp. 825-833.

Choanites he maintains as a distinct genus, partly on account of its spiral canal; and his *C. Kœnigi* is made to include *Spongia terebrata*, Phill., and *Scyphia heteromorpha*, Gein.

1852. D'Orbigny. 'Cours élém. de Paléontologie et Géologie,' tom. ii. p. 212, fig. 336.

The sponges are here divided into two groups, those "à squelette corné" and those "à squelette testacé;" the latter, characterized by a stony calcareous skeleton, are wholly fossil and extinct, the former recent and never found in the fossil state. Our *Siphonia*, therefore, along with all other fossil sponges, belongs to the testaceous division, and, with six other genera, it constitutes the family "Siphonidæ."

The figure of *S. ficus* (fig. 336), so often quoted as D'Orbigny's is adopted without acknowledgment from Sowerby's beautiful drawings of *S. pyriformis*.

1853. Mantell, G. A. 'Medals of Creation,' p. 230.

A short account of the genus and some of its characteristic species is given, accompanied by woodcuts (lign. 73. figs. 1 to 5). A form very similar to *S. pyriformis* is said to occur somewhat abundantly in the Portland limestone; this confirms Goldfuss's observation on the range of this species.

A new species, *Siphonia Morrisiana* (lign. 69. fig. 3), is next described from slices commonly used at Brighton and in the Isle of Wight for mounting in brooches; but no evidence is produced to show whether this is a *Siphonia* or not.

Choanites Königii (lign. 75) is again described, and said to differ from *Siphonia* in the absence of a stem. The spiral tube which was detected by Mr. Cunnington winding round its central cavity, is stated to be inconstant.

1854. Morris, John. 'Catalogue of British Fossils,' p. 30.

The species of *Siphonia* recognized by Professor Morris as occuring in Britain are as follows:—*S. anguilla*, Lee; *cervicornis?*, Goldf.; *clava*, Lee; *costata*, Lamx.; *Morrisii* (*Morrisiana*, Mantell); *pyriformis*, Goldf.; *terebrata* (*Spongia terebrata*, Phillips); *Websteri*, Sow.

1857. Pictet, F. G. 'Traité de Paléontologie,' tom. iv. p. 541, Atlas, pl. cx. figs. 15, *a*, *b*, *c*.

Follows D'Orbigny in his views of the structure and relations of *Siphonia*, adopting D'Orbigny's tribe of Siphonidæ, and placing this along with all other fossil sponges except Clionides, *i. e.* boring sponges, in his family PETROSPONGIDÆ, which corresponds with D'Orbigny's "sponges with testaceous skeletons," minus the Clionides before mentioned.

In addition to *Hallirhoa*, *Polypothecia* and *Choanites* are included as synonyms.

1859. Fromentel. "Introduction à l'étude des Éponges fossiles;" extrait des Mém. Soc. Linn. de la Normandie, vol. xi. pl. i. f. 12 et 12 *a*.

The order "Spongitaires" of this author corresponds to Pictet's Petrospongidæ; and his suborder of *Spongitaria tubulosa* embraces the three families Eudéens, Siphonocœliens, and Jéréens, the first two of which receive most of the genera of D'Orbigny's Siphonidæ, and are distinguished from the latter by the isolation of their tubules, which in the Jéréens are grouped together in fasciæ or in series. This difference the author is able to maintain in the case of *Siphonia,* apparently by never having examined actual specimens of the genus; at all events among his *réchauffées* figures of Sowerby's *S. pyriformis,* taken at second hand from D'Orbigny, there is one illustrating a section said to have been made longitudinally through the sponge, which does not exhibit the longitudinal tubules which are the most well-marked canals of all in Sowerby's faultless drawings, and in all specimens which have come under my own observation. Any thing more misleading than the section, fig. 12 *a,* pl. i., can scarcely be imagined.

Siphonia is distinguished from the other genera of this family by being borne on a stalk, and is divided into two distinct new genera, *Siphoneudea* and *Polysiphoneudea,* the latter founded on *Siphonia arbuscula,* Mich., and distinguished from the former by bearing several sponge-bodies on its raceme instead of a single one. The distinction is a trivial one, and scarcely of specific importance even.

The mistake made by earlier authors of regarding the specialized pore-areas on the exterior surface of the sponge as representing oscular openings is repeated here, and, I believe, by every one who has had occasion to mention them both before and since.

1861. Courtiliier, A. "Éponges fossiles des sables du terrain Crétacé supérieur des environs de Saumur, étage Sénonien de D'Orbigny" (Extrait des Annales de la Société Linnéenne de Maine-et-Loire).

This author simply describes a number of species of *Siphonia*, the names of which will be found in the appendix. His specific distinctions are founded on slight variations of external form, so slight sometimes as to lead one to wonder whether he has not given a separate name to each individual specimen in his collection.

1864–66. Römer, F. A. "Die Spongitarien des norddeutschen Kreidegebirges," Palæontographica, vol. xiii. pp. 1–64.

Römer follows D'Orbigny and Fromentel in his classification, adopting, as Pomel remarks, the errors of both, which he modifies according to Etallon, or from his own inspiration, or Toulmin Smith.

The Siphonidæ are stated to possess "wurmförmig" (Lithistid) structure externally, sometimes combined with a "gitterförmig" (Hexactinellid) structure in the interior. This is as mythical a combination as the organism of the legendary "Griffin," and can only be explained on the supposition that a Lithistid sponge has grown over a Hexactinellid to the extent of enclosing it. In the forms I have examined certainly nothing of the kind is to be seen.

The genus *Siphonia* is defined according to Fromentel, whose genus *Polysiphonia* is accepted without comment; while the *Astylo-*

spongia * (*Siphonia excavata*, Goldf.), which occurs in the Silurian, is retained as a member of the family.

The species described are *S. ficus*, *Kœnigii*, *tuberosa* (*Scyphia tuberosa*, Römer, 1840), *ornata*, *astroides*; the last two of which are new, while *S. tuberosa* (as before mentioned p. 799) is a true Hexactinellid, and has no place with the *Siphoniæ*.

S. pyriformis and *S. punctata* are referred to *Jerea*; and many other species of previous authors find their place amidst new and strange relationships, going into various other genera and even different families. The new arrangements proposed by this reformer are indeed bewildering, and help to show what, unfortunately, is only too sufficiently obvious, the utter and distracting confusion in which the classification of the fossil sponges is involved, and which must continue without any prospect of order or finality till the ultimate structure of the forms described is made the basis of their arrangement, as in the case of recent sponges.

The multiplication of synonyms which has grown up in consequence of all absence of a guiding principle in the grouping of forms will be seen in the appended Tables (pp. 825–833), the value of which would be greater but for the fact that even the ordinal characters of a great number of the species which are therein named are unknown, and cannot be discovered from an examination either of the figures or the descriptions of their authors.

1866. D'Eichwald, E. 'Lethæa Rossica,' vol. i. p. 329; vol. ii. sec. 1, pp. 100–102.

In vol. i. p. 329, a new species, *Siphonia cylindrica* (Eichw. non Reuss), is described from the Orthoceratite bed of Zarskoje near St. Petersburg. There are no characters about this sufficiently marked for its reference to the sponges at all, and certainly none to show that it is a *Siphonia*. *Siphonia præmorsa* and *excavata*, Goldf., are given from the same horizon at Zarskoje, Poulkowa, and various other localities.

In vol. ii. p. 100, we find a description of the genus *Siphonia*, which is said, partly on the evidence of the species cited in vol. i., to range from the Palæozoic into the Mesozoic periods, attaining its maximum in the Cretaceous.

Two new species, *S. pirum* (pl. vi. fig. 8), a doubtful member of the genus, and *S. rivuligera* (pl. vi. fig. 7), a large and symmetrical form very similar to *S. pyriformis*, Sowerby, are described and figured from the Neocomian; and *S. radiata* of Fischer is mentioned as occurring in the Cretaceous of Bouschevoyé, near Moscow.

1868. Bowerbank, Dr. J. S. "A Monograph on the Siliceo-fibrous Sponges," pt. ii. (Proceedings of the Zoological Society, 1869, p. 342, pl. xxv. figs. 6 & 7).

Dr. Bowerbank gives the name "*Purisiphonia*" to a new genus of

* Zittel shows that this sponge is a true Hexactinellid (Abhandlungen der k. bayer. Akademie der Wiss, ii. Cl. xiii. Bd. i. Abth. pp. 35 & 44).

vitreo-hexactinellid sponges, apparently out of a vague impression that *Siphonia* and it are near relations. I merely make mention of the fact here in order to state definitely that *Siphonia* and *Purisiphonia* resemble each other in nothing except their names.

1872. Pomel, A. 'Paléontologie de la Province d'Oran,' p. 124.

This author makes a decided advance in regarding the differences in the skeletal tissue of sponges, whether vermiculate or lattice-like, as of fundamental importance; to the class characterized by the former tissue he refers the Siphonidæ; but he mars the value of this by assigning a calcareous composition to these sponges, a mistake probably due to his having had before him specimens which had undergone a mineral replacement.

Beyond the statement that the Siphonian skeleton is throughout vermiculate, this author, though he writes much, does not appear to add any thing new.

1872. Nicholson, H. A. 'A Manual of Palæontology,' p. 70.

After a brief description of the genus, Dr. Nicholson gives it as his opinion that the *Siphoniæ* present a very curious resemblance to the *Holteniæ* (sarco-hexactinellid sponges) of the Atlantic ooze, and were probably, like them, inhabitants of a deep sea.

What resemblance there may be lies wholly on the surface and is not very remarkable even there. The ultimate structure of the two genera is as completely different as it can well be; and the "gisement" of most *Siphoniæ* is a greensand deposit, which was laid down, not in the depths of the Cretaceous ocean, but in the shallower waters not far from its shores. "*Choanites*," however, appears to be the deep-sea form of the genus.

1873. Thomson, C. Wyville. 'The Depths of the Sea,' p. 486.

After describing a new species of sponge, *Cœlosphæra tubifex**, "an aberrant group of the Esperiadæ" (Gray's ?), Prof. Sir Wyville Thomson goes on to remark that *Choanites* may be some relation of this form, on grounds of resemblance which are given in the following paragraph:—"From points apparently irregularly placed on the surface of the sponge, tubes about 3 mm. in diameter run out in all directions; the walls of the tubes are thin and delicate, being more so towards the distant ends, where the tubes contract slightly to an open orifice. At the proximal end, at the junction between the tube and the sponge-body, there is also a contraction, and a slight pit-like involution of the surface of the sponge. There is something very characteristic in this peculiar form of junction which it is not easy to define, but which almost forces the conviction that there is the closest relation between these recent forms and tube-bearing fossil sponges such as *Choanites*."

The Professor, in his attempts to discover resemblances between

* *Histioderma appendiculata*, Carter, Ann. & Mag. Nat. Hist. ser. 4, vol. xiv. p. 4, pl. 18.

fossils of the Chalk and the living forms of the Atlantic, seems here to have been led astray: the tubes of *Cœlosphæra* are external, and those of *Choanites* internal, to the sponge-body; and the peculiarity in the junction of these tubes with the body of the sponge in *Cœlosphæra* is not alleged to have been observed in the case of *Choanites*. For my own part I certainly have never seen it. But it would be useless to argue the matter further on these grounds, since *Cœlosphæra* is, in spiculation, closely allied to *Halichondria incrustans*, Johnst., while *Choanites*, on the other hand, possesses the genuine Lithistid skeleton, and belongs without doubt to the genus *Siphonia*.

3. Description.

General Form and Structure.—The outward form of *Siphonia* is exceedingly variable; and it is by not making due allowance for the extreme polymorphism of the genus that its species have been so extensively multiplied. Its principal part consists of a head or body, which is usually, but not always, supported on a distinct stem.

The stem, when present, is more or less cylindrical, straight near the head, but generally irregularly undulating lower down; it exhibits great variation both in length and breadth, sometimes becoming so short as to render the sponge-body almost sessile (*S. curta, cylindrica,* etc., Court.), at others attaining a length many times that of the sponge-body—*e. g.* in *S. Websteri*, Sow., which presents us with a slender stalk some four or five feet long; between these two extremes every intermediate gradation may occur. It is usually simple, but sometimes becomes branched (*S. arbuscula*).

At its proximal extremity it breaks up into a number of diverging irregular ramifications, by which it appears to be attached to the surface of some foreign body.

It rarely is found entire, having in most specimens been broken off at a greater or less distance from the head. When absent, as it sometimes is in *S.* (*Choanites*) *Königii*, it is replaced by a number of rooting fibres which ramify in all directions through the surrounding matrix of the fossil. With this substitution of anchoring filaments for a process of attachment may be correlated the fact that *S. Königii* is the chalk or deep-sea form of its genus, while the species provided with stalks are characteristic of greensand deposits, and consequently flourished in a somewhat shallow sea.

The same kind of adaptation is exemplified in the case of *Euplectella*, which is an anchoring sponge when it floats half immersed in the chalk-ooze of the Atlantic, but becomes fixed and adherent when it enters the shallower waters near the coast.

The sponge-body presents almost every possible variety of form. Commencing with *S. pyriformis*, Goldf. (tab. vi. f. 7 *a*), we have a head nearly spherical in shape; this by elongating vertically gives rise to a series of more or less prolate ellipsoids, *S. ovata*, Court., *nuciformis*, Mich., *pyriformis*, Sow. (*loc. cit.* f. 3 & 9); by becoming flattened at the extremities these assume a cylindrical shape, *S. cylindrica*, Court. On the other hand, a shortening of the globular form along its vertical axis produces a series of oblate ellipsoids, *S. incrassata*, Goldf.; and again, if it enlarges at the base, conical forms result, *S. conica*, Court., *ficus*, Goldf., *Fittoni*, Mich., *pyriformis*, Sow.; or if at the summit the forms become obconic, *S. piriformis*, Goldf., Mich., Court.; several heads of this form borne on a branching raceme constitute *S. arbuscula*, Mich. Finally, by unequal lateral growth, lobations more or less numerous and pronounced arise, and we have the different varieties of *S. costata*.

At the apex of the body is the opening of a central canal, which descends for a variable depth towards the base of the sponge, sometimes nearly reaching the stem, at others forming only a shallow saucer-shaped depression; while occasionally, as in *S. Websteri*, it may be altogether absent. In breadth it is equally variable: in some cases a large sponge is perforated by a long but very narrow canal; in others a much smaller specimen is widely excavated by a broad funnel-shaped cavity; and if *S. expansa* be, as I believe, a member of the genus, the widening and deepening may become so great as to convert the canal into a large cup-like hollow.

In a unique specimen lent me by Mr. Wm. Vicary, of Exeter, the sponge is incompletely divided by longitudinal fission into two parts, each of which possesses its apical opening and central canal.

The sides of the central canal or axial tube are perforated by a number of round or oval openings about $\frac{1}{20}$ to $\frac{1}{30}$ inch in diameter, situated at about equal distances from each other, but not exhibiting either a quaternary or quincuncial arrangement; they manifest, however, a tendency to succeed one another in tiers of circular rows.

These openings are seen in vertical sections to be the distal terminations of a number of canals which diverge from the axial tube and perforate the sponge; those which open into the basal part of the tube continue its axial direction downwards, and are prolonged into the interior of the stem below, while those which open into the sides spread out in descending curves. As the canals open nearer the summit of the central tube, so they lie nearer the exterior of the sponge; and as they approach the exterior, so they become more parallel with its contour.

In many specimens the most exterior of these canals are freely exposed on the surface, radiating away from the edge of the summit, opening as winding, bifurcating, and occasionally anastomosing furrows. From this we might infer that the more internal canals, which are not so clearly revealed, possess the same characters; and a tangential section made through one of the phosphatic specimens from Folkestone proves that such is really the case, the windings, branchings, and anastomosis being all well displayed.

We have now described the "excurrent" system of the sponge. The axial tube is the "cloaca;" and the openings in its walls are the "oscules" of the longitudinal or excurrent canals.

The exterior surface of the sponge-body is pitted by a number of irregularly dispersed more or less circular holes about $\frac{1}{12}$ inch diam., which are the openings of canals which radiate inwards, normal to the surface, towards the cloaca of the sponge, crossing the excurrent canals on the way. These radiating canals are smaller than the excurrent ones, and also differ from them in not being continuous for any considerable distance, very few extending from the circumference to the centre. Following one of them as it leaves the exterior surface it is found to proceed for a shorter or longer distance inwards and then to terminate in one of the longitudinal or excurrent canals; but other radiating tubes start afresh from the vicinity of the place where it disappears, and, after proceeding further inwards and crossing several excurrent canals on the way, terminate like the one they have replaced; and so by easy stages the central cloaca is at length attained. Thus a succession of radiating canals maintains in connexion the exterior of the sponge and the various longitudinal canals. These radiating canals constitute the "incurrent" system; and their external openings are the functional mouths or specialized pore-areas of the sponge, and not "oscules," as is stated in works on palæontology.

The interior of the stem is occupied by longitudinal canals in direct continuation with those of the sponge-body. Radiating canals are not obviously present; but a number of small openings occur on the exterior, from which, in some cases, superficial branching canals radiately diverge and, after wandering for some distance over the surface, become gradually lost.

The interstices between the canals are occupied by an irregularly reticulate, originally siliceous skeleton, the examination of which must next engage our attention.

Minute Structure.—To investigate this the phosphatized specimens from the Folkestone Gault (Plate XXV. fig. 7) were in the first place employed. These specimens had become somewhat worn by the action of water before they were deposited in their latest "gisement," and, according to the extent of the attrition they have undergone, vary in colour from grey to black, just as may be observed in the case of the coprolites of the Cambridge Greensand. In outward form they are globular, ellipsoidal, spindle-shaped, and pyriform, varying in size from $\frac{3}{4}$ to $1\frac{1}{2}$ inch in length and breadth, with no constant ratio between the longitudinal and transverse diameters. At one end a round scar or broken stump remains to indicate the place of attachment of the pedicel now broken off; at the other extremity is a plain surface in the centre, from which, in some specimens, radiate for a greater or less distance down the sides a number of low smooth rounded ridges, about $\frac{1}{32}$ inch broad; these undulate somewhat in their course, and anastomose with each other laterally; between them the surface of the sponge is depressed and minutely pitted. The central plain area indicates the place where the interior excurrent canals originally opened on the surface, or, perhaps, in a few instances, according to Mr. F. G. H. Price, F.G.S., the summit of a cloaca now filled up with foreign matter. The radiating ridges are the phosphatic casts of the exterior excurrent canals, and the intervening depressions the skeletal interspaces, the pitting of which has been produced by the removal, in solution or otherwise, of the skeletal network exposed on the surface.

From these specimens, which I believe to be chiefly forms of *Siphonia Websteri*, Sow., slices were taken in the following directions:—1. Along the longitudinal axis of the sponge, *longitudinal* sections (Pl. XXV. fig. 7 *a*); 2. Transversely through its centre, *transverse* sections (Pl. XXV. fig. 7 *b*); 3. Parallel to the vertical axis, but at some distance from it nearer the exterior, *tangential* sections. In examining these sections we find the internal canals, owing to their having been partially filled in with chalk marl and other earthy material, are distinguished from the other parts by being more opaque and lighter in colour, so that with reflected light they are dull grey, and by transmitted light almost black in appearance; they are not, however, limited by definite walls, but shade into the surrounding substance, *i. e.* the phosphatic material which now occupies the place of the original sarcode of the sponge. This is more or less transparent, dark brown by reflected, and light amber or yellowish brown by transmitted light; it is everywhere traversed by the skeletal network, which is transparent and colourless, and always sharply defined from its matrix.

Skeletal Network.—The structure of this may be best examined with powers of from 60 to 140 diameters and by transmitted light.

Selecting a favourable portion (Pl. XXVI. fig. 1) of any one of the sections, we observe, well marked off from the surrounding brownish phosphate, a small circular colourless area (0·002 of an inch in diameter) (fig. 1 *a*), which is the cut end of a smooth cylindrical rod that has been traversed at right angles by the plane of the section; from this circle, then, *i. e.* from the end of the cylindrical rod, radiate three smooth cylindrical arms, 0·005 to 0·016 of an inch long and 0·002 of an inch broad, which terminate, either without or with previous bifurcation, by dividing into a number of rounded or hemispherical apophyses, between which are left corresponding rounded concavities, the whole termination roughly resembling a small bunch of grapes. The arms make various angles with each other, maintaining no constancy in this respect.

The structure thus described is that of a Lithistid spicule (Pl. XXVI. fig. 2), which, as it exists in recent sponges, likewise presents us with a principal cylindrical shaft, also dividing into three chief radiating arms, which terminate after one or, it may be, two bifurcations, by breaking up into a cluster of botryoidal processes.

The bunch of irregular knobs and sockets which ends one spicular ray fits into and interlocks with the similar cluster at the end of the ray of an adjoining spicule, the knobs of the one fitting into the sockets left between the knobs of the other.

This articulation affects all the spicules alike; the ends of none of them are free; and thus a skeletal network results which is as resistant and rigid as that of the Vitreohexactinellids, though it is arrived at in a totally different way; for in the latter sexradiate spicules are cemented into a glassy fibro-reticulate structure by a coating of silica which completely envelops them, while in the Lithistids no such cement is present, the junction of their trifid spicules, which are thus naked, being effected solely by the interlocking of their extremities (Pl. XXVI. fig. 3).

In many instances the rounded apophyses can be distinctly seen in our phosphatized specimens, lying within but quite distinct from the containing sockets, while in others the effects of fossilization have gone so far as to obliterate the distinction between the two, and to fuse the articulated clusters into a more or less solid homogeneous mass.

In some parts of the sections (Pl. XXVI. fig. 1 *b*) simple circular areas occur, unconnected with the radiating arms; these are due to the section having passed through the shaft of a spicule at some distance above its point of trifurcation. In others, again, the arms are seen without a central circular area (fig. 1 *c*), owing to the section having passed through the plane of the arms beyond the end of the shaft, and thus separated the shaft with the upper half of the rays from the lower half, which remains imbedded in the slice.

In the spicules of recent Lithistids one may often observe, in the axis of the shaft, a central canal, which, at the point of radiation of the arms, gives off three branches, one for the axis of each arm ; and in a section of a fossil sponge which was sent to Mr. Carter as taken from a *Polypothecia*, he has observed * not only all the details of Lithistid structure which we have described in *Siphonia*, but has also detected this very quadriradiate canal as well, occupying the axis of the spicular shaft and rays exactly as in the recent forms. In my specimens of phosphatized *Siphoniæ* I have carefully searched many times for these canals under a magnifying-power of from 140 to 500 diameters, but always without success; they have apparently disappeared during the mineral replacements to which the substance of the spicules has been subjected. Their absence, however, is of no consequence in our inquiry, since the characters which remain are in every detail so exactly those of a Lithistid spicule as to make the production of further evidence on this head unnecessary; and in so considering them I have the unreserved support of Mr. Carter.

Besides the Lithistid network the sections also exhibit a number of simple finely-pointed acerate spicules (Pl. XXVI. fig. 5 & 5 *a*) of variable size, but sometimes attaining very respectable dimensions, ranging in length from 0·02 to 0·045 of an inch, and in breadth from 0·0015 to 0·007 of an inch.

Arrangement of the Spicules.—The spicules of the skeletal network, though they do not exhibit a very regular arrangement in detail, are not, however, scattered without order through the sponge, but present on a large scale a definite and regular disposition.

Longitudinal Section (Pl. XXVI. fig. 1). Selecting a band of network lying between two radiating or incurrent canals, one finds it to consist of several series of spicules, the filigreed or botryoidal ends of which for each series lie along lines radiating from the exterior towards the centre of the sponge, *i. e.* in the same direction as the radiating canals ; the smooth arms of the spicules are likewise ar-

* Ann. & Mag. Nat. Hist. ser. 4, vol. xii. p. 349, "On the Hexactinellidæ and Lithistidæ."

ranged in radiating series, those of each row lying approximately parallel with each other and concentric with the centre of the sponge, *i. e.* transverse to the direction of the radiating canals: thus we have bands of filigree and rows of smooth trabeculæ radiating towards the centre of the sponge and regularly alternating with each other in a vertical succession. This results, as will be seen in fig. 1, Pl. XXVI., from the fact that the points of trifurcation of the spicules are confined more or less to certain radiating lines, and that two out of the three resulting rays, which diverge in a plane at right angles to the shaft, remain short and divide into their clustered apophyses at once, while the remaining ray is elongated in a concentric direction for a certain distance (the breadth of the series) before it breaks up into filigree; and, to keep the series uniform, it often happens that the points of trifurcation of the spicules are placed alternately on opposite sides of the series, so that one spicule divides into its three rays on the line where the long rays of the adjacent spicules terminate, and sends its long arm to divide into tubercles on the same line as that on which the trifurcation of its neighbours takes place.

Transverse Section (Pl. XXV. fig. 5). A similar arrangement is to be seen about the radiating canals here, while in both the transverse and longitudinal sections the circular ends of truncated shafts appear scattered, isolated amidst the network, or attached to rays which diverge from them. These show that the series of spicules exhibited in transverse section are connected by more or less vertical shafts with similar series above and below, and, similarly, that those series shown in longitudinal section are connected by horizontal shafts with similar series on each side—in other words, that the circles of the transverse section represent the shafts of the longitudinal one, and *vice versâ.*

From this it follows that the skeletal walls of the incurrent tubes are composed of cylinders of a complex network consisting of parallel bands of the interlocked terminations alternating with parallel rows of the smooth rays of Lithistid spicules, the smooth rays lying concentric with the axis of the canals, but the series they form parallel with them. Thus a minute observer entering one of these canals would see around him, as it were, a number of ladders, the "rungs" represented by the smooth arms, and the side pieces by the clustered tubercles of the spicules; and he could walk from end to end on the same ladder without crossing from one to another, except where two ladders might merge into one.

The bands of network, although their direction is from the circumference towards the centre of the sponge, do not extend uninterruptedly the whole way, but they are exposed in the sections for a short distance only; this probably arises for the most part from the interference of the longitudinal canals with the course of the incurrent ones, by displacing or absorbing them, and, to a less extent, in the case of the transverse sections from the fact that while the incurrent canals follow approximately lines radiating towards the centre of the sponge, the sections, on the other hand, are taken simply at right angles to its axis, and consequently if they pass, as they are sure to do, a little above or below its equator, will intersect the canals and their surrounding network obliquely.

The arrangement about the longitudinal canals differs from the preceding, though it appears partly to result from it. Walking up one of these canals, one would pass alternations of knotted ends, or of bands of knotted ends, and series of smooth trabeculæ, resembling altogether a chain made of links of two alternating patterns; *i. e.* we should make our way from one spicular series to another.

It only remains to repeat that the arrangements just described are subject to very considerable modifications; but these, however great they may be, leave the general tendency always observable.

The simple acerate spicules (p. 808) also present us with a more or less obvious arrangement, generally lying in groups parallel with one another and with the direction of the adjacent longitudinal or radiating canals.

This exhausts, so far as my observation goes, the minute structure observable in the phosphatic specimens from the Gault; and it will now be worth while to determine how far similar characters are to be detected in species from other localities and in different states of fossilization.

Specimens from the Haldon Greensand near Exeter. S. pyriformis, Sow. (Pl. XXV. fig. 1), *S. cylindrica* (Pl. XXV. fig. 4) and *conica*, Court., *S. Fittoni*, Mich. (Pl. XXV. fig. 6).—These fossils are not much else than the deciduous skeletons of the sponges they represent, unaltered to any great extent by processes of fossilization. Scarcely any foreign material has entered to fill up the canals and interstices of the interior; and thus it happens that it is next to impossible to prepare transparent sections from them: the brittle siliceous network breaks away in the processes of cutting and grinding down, and none but thick, almost opaque, slices can be procured. Fortunately, however, this perfection of preservation has its own advantages; for, owing to it, we can dispense with section-cutting and preliminary preparation altogether; with no other apparatus than a low-power microscope, say of 60 diameters, and a common Haldon *Siphonia*, we can, by examining the latter under the former with reflected light, solve at once the characters and affinities of this long misunderstood genus. That the solution has not come before is due to the ignorance in which we have been left so long regarding the nature and existence of the Lithistina. Almost directly we have attained a knowledge of these we have also arrived at a solution of *Siphonia*.

On examining the natural surface of the Haldon specimens under a power of 60 diameters, one perceives that the spaces between the pore-areas are entirely occupied by a skeletal network (Pl. XXVI. fig. 4) possessing the true Lithistid structure. The quadriradiate spicules interlocked by their tubercular extremities are plainly visible throughout, and may be viewed here as solid objects of three dimensions, and not merely as linear figures drawn in the plane of a section; as regards outward appearance, many of these spicules are as whole and perfect, and clean and vitreous, as those of a recently dead sponge.

With regard to their arrangement, it will be observed that while previously (pp. 806–810) we described the cylinders of network about the radiate canals from upper, lower, and lateral longitudinal aspects, we are here viewing them transversely or end on; and thus no arrangement of spicules in series appears. What especially strikes one is:—first, the uniform length of the radiating arms, which here lie more or less parallel with the plane of the surface, while the spicular shafts pass inwards at right angles to the surface; and next the fact that the arms diverge from one another more frequently at angles of 120° than in the interior lateral views, so that they are generally equiangular.

Sections taken from these specimens may be examined as opaque objects. Observations so made simply confirm results previously obtained.

Specimens of S. costata *from the Wiltshire Greensand.*—Of this species I possess only one specimen (Pl. XXV. fig. 2); and it, in common with all others I have examined, has been infiltrated with silica to a much greater extent than the preceding specimens; and, as a consequence of this, the skeletal network is much better supported, so that Mr. Cuttell has been successful in obtaining a tolerably thin slice from it. In this section the structure has in many places been obliterated by mineral changes; but enough remains distinct to show that it possesses in all essential respects the same characters as the species we have already discussed.

Specimens of S. (Choanites) Königii *from the Chalk of Sussex.*—These have suffered greatly from mineral changes, the precise nature of which will be described in a subsequent paragraph (p. 817). Notwithstanding this, however, enough of the skeletal structure remains to determine its real character. The quadriradiate spicules, of the same form and size as in the other species, are united into a similar network; and there can be no doubt as to the Lithistid character of the sponge. The tubercular extremities are unfortunately not preserved so well; all one can say of them is that they were at all events confined to the ends of the spicular rays, and that what traces they have left behind accord best with an origin in tubercles of the same kind as those of other *Siphoniæ*. After a careful search through a beautiful series of *Choanites*, I have no hesitation at all in referring them to the genus with which they are here associated.

Structure of the Stem of Haldon Siphoniæ (Pl. XXVI. fig. 7).—The spicules which are exposed on the exterior of the stem of the Haldon specimens differ in an interesting way from those of the body, owing probably to physiological adaptation. The arms of these spicules are greatly elongated, and bent in a direction parallel with the long axis of the stem, and therefore with each other; or, at all events, those arms which do not take this direction remain short, whilst the produced ones always lie longitudinally. Again, all the spicular rays, whether bifurcated or not, appear, as far as one can see in unprepared specimens, to terminate in simple pointed extremities without forming clusters of botryoidal apophyses; hence the elongation of the spicules seems to be at the expense of the material of their articular processes. The shafts of the spicules are not seen, and may be inferred to penetrate the stem at right angles to its surface. As, then, the long rays all lie in the same direction (that is, with the length of the stem), and as the terminations of the spicules overlap one another by passing above and below those alongside them, and as the shafts appear to penetrate amongst the spicules of the interior, we may consider that the arrangement we have here is of the nature of a "plait," serving to keep the spicules in place, and yet not binding them together with the same rigid union which we find in the network of the sponge-body. From this results flexibility combined with security, the value of which will be understood when we remember that the *Siphoniæ* lived in a somewhat shallow sea (75 to 375 fathoms), and were exposed to currents which a flexible stalk would be better able than a rigid one to sustain.

Longitudinal Section of the Stem.—This does not expose any very clearly defined structure; but what there is to be seen agrees completely with the foregoing description.

Development.—Amongst the specimens from Haldon is a very small one (Pl. XXV. fig. 3), which I believe to be a young form, and which agrees in every particular with similar ones figured by Sowerby as the young forms of his *S. pyriformis* from Blackdown, near Cullompton. The body is somewhat fusiform, $\frac{7}{8}$ of an inch long and nearly $\frac{3}{5}$ of an inch broad; it is supported on a straight slender stem, the proximal end of which is broken off. At the apex of the body is a small conical depression produced by the oscular openings of some four or five excurrent canals, and very insignificant in size when compared with the rest of the body.

From this youngest known form the adults arise by successive coatings on the exterior, the coatings on the body being thicker than those on the stem. Each coating possesses all the characters which belong to *Siphonia*; and thus we have produced successive groups of longitudinal canals opening in a series of tiers vertically over one another in the cloaca or central cavity left in the axis of the body of the sponge. Thus, also, the longitudinal canals are axial in direction below the cloaca, and become more parallel with the curve of the existing exterior surface as they lie nearer to it, the successive groups of canals indicating, indeed, the successive surfaces of the sponge. Thus also arise the concentric rings of skeletal network seen in transverse section around the cloaca; and by the opening in different places of fresh radial canals for every fresh exogenous layer, the discontinuity of the radial canals when traced for any distance results. Fig. 1 *b* (Pl. XXV.) is a drawing of a section taken longitudinally from an adult *S. pyriformis*, Sow.: it is easy to understand how the series of changes just described would result in producing such a structure as this from the young form represented in fig. 3.

The differences presented in the surface of many fossil *Siphoniæ*, differences which have been held of specific importance by many authors, may be explained by reference to this kind of growth; for in cases where the last coating had grown so thick that a fresh set of excurrent canals was on the point of appearing in a new layer, but had not actually done so, it would require a considerable amount of attrition to reveal the outermost series of canals; and the chances are that the exterior of the specimen would be smooth, *i. e.* not grooved by superficial canals. If, on the other hand, a new set of longitudinal canals had just been produced, then the mere dissolution of the dermal covering of the sponge would leave them exposed as well-marked grooves proceeding from the rim of the cloaca for a variable distance down the sides of the body, as already described (p. 805).

4. States of Mineralization.

1. *Phosphatic Specimens from the Gault.*—The infilling material of these fossils is a brown substance composed of calcic carbonate and phosphate, clear and transparent in thin sections, especially in those parts where it fills the intermeshes of the skeleton, since in the canals of the sponge it is rendered more or less opaque by included earthy material, consisting partly of Gault clay and partly of various small foreign bodies, such as glauconitic granules, minute Foraminifera, as well as contorted fibres of the same kind as those figured in the 'Geological Magazine,' Decade ii. vol. iii. pl. xiv. figs. 8, 9, 10, as resembling contort spicules, and which I hope to show in a subsequent paper to be algoid growths, like that of *Saprolegnia*, that have infested the sponge subsequent to its death and during its decay.

The skeletal network in these specimens is generally transparent and colourless; it dissolves with effervescence in hydrochloric acid, and behaves with a power of 60 diam., under polarized light, as pure calcite, of which mineral we may therefore conclude it is mainly composed. When examined, however, with polarized light under a higher power, say 140 diam., small portions of some of the spicules, but not of all, give here and there the colours of quartz; and when such spicules are treated with hydrochloric acid an exceedingly small insoluble residue of a transparent mineral remains behind, which, when again examined with Nicol's prisms, turns out to be pure quartz. From this it is therefore evident that in some spicules a part, though a very insignificant part, possesses a siliceous composition, while on the other hand by far the larger portion of the skeletal network consists wholly of calcite. Now the skeleton of the Lithistidæ is siliceous; *i. e.* it consists of organic matter and silica in intimate combination; and since the skeleton of *Siphonia* is, as we have already shown on morphological grounds, that of a Lithistid sponge, it also must originally have been made up of organic silica, while its present calcareous state can only be due to a subsequent mineral replacement. In spite, however, of the fact that its original siliceous substance has been almost altogether exchanged for a crystalline calcareous one, and in some cases entirely so, it yet exhibits an anatomical structure so well preserved that we can trace it in nearly all its details, even to distinguishing the peculiar apophyses which terminate the ramifications of its spicules. So completely, indeed, has the original form of the spicule been preserved, that the hemispherical pittings, which generally excavate the walls of these structures in recent sponges after death, are to be observed in some cases on the surface of these calcareous pseudomorphs. Thus the fact that anatomical structure, and not mineral composition, should guide us in our investigations into the characters of fossil sponges, is here enforced afresh, upon evidence scarcely less striking than that which presented itself in the case of *Stauronema Carteri* *, a fossil sponge belonging to the order Hexactinellidæ. It will be noticed also that we have here another case of the conversion of colloidal silica into a crystalline state, so crystalline as to give colours with Nicol's prisms quite as brilliant as those of mineral quartz. Sometimes the spicules of the network are replaced by iron-pyrites, so that, seen by reflected light, they glitter like burnished brass.

Near the exterior of the fossil the spicules have sometimes wholly disappeared, and their places remain unoccupied as hollow casts; or more often these casts have become filled up with transparent "coprolite," which almost obliterates them, and is only prevented from quite doing so by the presence of a quantity of fine granular material along with it, which often collects into lines along the sides of the cast. Occasionally, also, an infiltration of glauconite accompanies the coprolitic infilling, so as to make it appear that the spicule has been replaced by that mineral, which, however, is not the case.

2. *Siliceous Specimens from Haldon.*—The internal canals in these remain to a great extent unoccupied, as mere hollow tubes, though here and there they have become partly filled in with crystalline silica; and very generally they contain a singular thread of silica, having very much the appearance of a thick bristle passed in to show the course of the canals; it lies in the axis of the canal containing it, and quite free from the walls, though sometimes it leaves this position and becomes attached to the side of the canal. The substance of the thread gives colours with polarized light; its exterior has a chalcedonic appearance; and it accommodates itself accurately to the course of its canal. From its irregular form, its position, and the entire absence of any such structure from the phosphatic specimens of the Gault, and in any known sponge, recent or fossil, I should say decidedly that it is not a spicule or any other structure proper to the sponge, but a subsequent formation produced during the mineralization of the particular specimens in which it occurs. Again, the position of the threads is sufficient to show that they cannot be of stalactitic formation; the running or dropping of water could never take place so as to form a thin axial thread extending throughout the length of a narrow, branching, and tortuous canal. On the other hand the connexion between the canals and their

* Ann. & Mag. Nat. Hist. ser. 4, vol. xix. p. 1.

fibres is too significant to be overlooked. A comparison of the two shows a correspondence of a very exact kind: wherever the canal expands, there the fibre becomes thicker; when the canal branches, the fibre bifurcates with it, and both undulate together in common curves: the two structures agree together, in fact, just like a mould and a cast which has contracted after its first formation. The explanation which therefore commends itself to my mind, and which at least satisfies all the facts of the case, is, that the silica of these threads infiltrated the canals while in the collodial state, and completely filled them up with a siliceous jelly; a subsequent and gradual loss of water of hydration caused this jelly to become dry and simultaneously to shrink till it attained its existing solidity and dimensions; finally, after a great lapse of time, the unstable colloid passed into the crystalline condition. The possibility of the latter transformation has been already proved by numerous observations on the existing crystalline condition of fossil siliceous spicules; and any one who has experimented with colloidal silica must have been struck with the wonderful amount of contraction which this substance experiences on desiccation, a contraction quite sufficient to account for the shrivelling of the silica in the canals of the Haldon *Siphoniæ.*

Network.—The interstices of the network are sometimes empty spaces, and sometimes occupied wholly or in part with crystalline silica. When empty, the spicules of the net retain their siliceous composition, but do not exhibit the central hollow canal, which frequently puts in an appearance in recent specimens of Lithistid spicules; they are solid throughout, and, since they give colours with polarized light, have evidently exchanged their originally colloidal state for the crystalline condition. In a single instance, to which I have not been able to recur, a spicule was observed in a section of one of these specimens with a smooth surface, and shining with a vitreous lustre, like the spicule of a sponge only just dead; but in all other cases the spicules are excavated all over with small hemispherical pittings, similar to those which Carter has described as affecting the deciduous spicules of recent sponges; they have a bluish opalescent appearance and a feeble resinous or gum-like lustre.

When the interstices are filled with silica, the spicules are represented by empty casts, the walls of which are coated interiorly with an opaque white substance, which appears black by transmitted light. Frequently the cast has entirely failed to preserve the original shape of the spicule, and the skeletal network presents the appearance of a number of fragments of moss irregularly scattered through a transparent ground of crystalline silica; these dendritic fragments, however, are, as we have already stated, not solid, as they appear to be by transmitted light, but merely hollow empty spaces.

The silica of the interstices presents a fibrous crystalline arrangement, the fibres generally radiating from the spicules, or what remains of them, in little tufts, each of which is defined at no great distance from the centre of crystallization by a curve concentric with it and normal to the direction of the fibres themselves: sometimes this curve is made more apparent by the presence of a number of accompanying minute granules; and it appears to indicate a line of growth. The fibrous tufts, or hemispherical bosses, do not, however, nearly fill up the whole of the interstice, but always leave a larger or smaller space in the middle, which is also filled with crystalline silica, giving either a granular colour-pattern with polarized light, or a fibrous one—but usually the latter, in which case these crystalline fibres are bolder than those of the hemispherical bosses. Here, when the fibres from two adjacent centres of crystallization meet and oppose one another, they terminate abruptly in a sharply defined straight line of demarcation; and if the adjacent and opposing groups be more than two in number, the respective lines of demarcation intersect each other at angles of 60°, and hence they may be regarded as sections of the sides of incompletely formed crystals of quartz. The fact that we find solid siliceous spicules in the uninfiltrated network, and mere empty spicular casts when the interstices are filled with silica, seems to me very significant, and certainly suggests the idea that the spicules have to some extent furnished the silica with which the sponge has become mineralized, and thus, up to a certain stage at least, the sponge has fossilized itself.

3. *Specimen of* S. costata *from Wilts.*—This specimen is solid throughout, the canals are filled with quartz sand, glauconite grains, and other foreign bodies, cemented together by crystalline silica. The interstices of the skeleton are filled up by transparent and crystalline silica; and the spicules have become absorbed, leaving only hollow casts in their place. These casts are lined internally by white opaque material, and frequently contain certain curious black linear bodies or acerate spicula, which, on treatment with nitric acid, lose their dark colour, turn faintly yellowish, and become perfectly transparent, while the resulting acid solution yields a blue precipitate with potassium ferrocyanide: their composition would thus appear to be mainly siliceous, while their black colouring-matter consists of some salt of iron. It is just possible that these spicules may be the remains of some *Cliona*-like sponge, which entered the *Siphonia* some time after its death, and specially inhabited the enlarged axial canals in the spicules of its skeleton.

The exterior of the arms of the skeletal spicules is sometimes covered with a number of hemispherical bosses, very regular in shape, and with a sharply defined contour. If these were integral parts of the original spicules, they would remove *S. costata* from its alliance with *S. pyriformis* and the recent species *Discodermia polydiscus*, and place it in some other group of Lithistids. I have consequently given great attention to their examination, and find, first, that they are inconstant: in some cases a group of spicules does not exhibit a single one; in others the spicules are covered with them, and occasionally so thickly that the bosses appear piled one on another in thick clusters. Next, the walls of the spicular casts are subject to other, though related, peculiarities, sometimes becoming slightly irregular or sinuous in outline, and at others bulging out all round into a large protuberance of no very precise form: these are certainly subsequent formations; and since, in character and position, they resemble some of the tubercular bosses, it seems probable that the latter are subsequent also. Finally, the bosses are hollow within, like the rest of the spicule, and the silica of the interstices radiates away from them in fibrous tufts; and thus we have repeated a structure and arrangement which I have before described in a very different sponge, viz. *Stauronema*, one of the Hexactinellidæ, and in which certainly they are the result of changes which have taken place during fossilization. The same holds good with the tubercles of the specimen we are describing; they are not proper to the original spicule, but have been formed as products of its fossilization. In both sponges, in *Siphonia* and *Stauronema*, the cast of the spicule has eaten its way outwards from its original position into a number of hemispherical tubercles; and these have served as centres from which a radiating crystallization of silica has been set up; in *Siphonia*, however, the spicular casts have remained empty, but in *Stauronema* they have become filled up with a crystalline carbonate of lime.

4. *Specimens of* S. Königii *from the Chalk*.—These exist in a great variety of mineral states; but in all the chief fossilizing agent is silica. In examining a common flint nodule which has been split open and found to contain a Choanite, we observe on the fractured surface, most exteriorly, a ring of opaque milk-white silica, excavated by a perfect network of empty spaces, on which apparently its white colour, to a great extent, depends; succeeding this, next interiorly, is a zone of dark transparent flint; and next to this, occupying the central area of the broken surface, is a white network, having its canals and interspaces filled with dark transparent flint, like that of the previous or middle zone. The central network is not, however, uniformly white and opaque, but portions of it are considerably more transparent than the remainder, the whiter and less white parts differing in appearance just as a piece of ordinary white paper differs from the same paper when impregnated with oil or grease.

The central network alone represents the original Choanite, the outer and middle zones having accumulated round it during its silicification. The outer zone, however, sometimes contains isolated Lithistid spicules, or, rather, the empty casts of such spicules; and similar casts sometimes project from the interior of this zone into the clear flint of the succeeding middle zone, wherein they appear as white and solid spicules, the true nature of which is at once revealed, however, by examining their extremities where they are intersected by the plane of fracture. Indeed I may here go so far as to state that whenever one sees a very white and opaque, solid-looking spicule imbedded in clear transparent flint, one may at once expect to find it just the reverse, as regards solidity, of what it seems.

The middle zone contains numerous transparent spicules of various kinds of sponges, various Foraminifera, and other included bodies.

which all appear to have been derived from the chalk-silt in which the Choanite was originally imbedded.

The central network, or the true Choanite, is of a mixed nature, consisting partly of the skeletal rete of the sponge and partly of a mineral incrustation. Thus one observes in it true, well-defined Lithistid spicules, composed of very dark and clear transparent silica, with a thin axial thread of whiter silica occupying the position of the axial canal, and a coating of white fluffy-looking silica surrounding them exteriorly like a growth of some kind of mould. Sometimes this fluffy material is so dense and abundant as to exclude the darker flint from the intermeshes of the network; and the central area then becomes very white and opaque; sometimes it loses its opacity, becomes less dense and abundant, and fades away into a whitish blue haze, as though permeated by more transparent material: and this produces the more transparent parts of the central area. From the nature of these changes we might conclude that the whiteness of the "fluff" is partly owing to the presence of small empty spaces within it, and that it is rendered more transparent by becoming filled with clear flint, by which its internal cavities are obliterated and the internal reflection of light prevented. In addition to this spicular network we meet also with some isolated hollow casts of quadriradiate spicules, white and opaque in appearance, and excavated with hemispherical pits so extensively as to have become almost entirely eaten away. These casts have in some places been filled in with transparent silica; and then they lose their whiteness and opacity and are converted into nearly invisible granular films. In some specimens, again, the silica of the transparent spicules of the network has been replaced by granular iron-pyrites.

In rare instances the whole specimen of the Choanite, excepting the cloaca and canals, which are filled up with opaque white material, is composed of colourless and transparent silica, and the white network is wanting. The spicules then exist as mere traces only, consisting of scarcely any thing more than the axial canal, which has undergone a slight enlargement, and become filled in with silica, which is only distinguished from that exterior to it by the presence of a few dark-coloured granules. In such a case we notice in the surrounding silica hemispherical bosses, with their rounded surfaces turned away from the spicule, and serving as centres from which a fibrous crystallization of silica radiates towards the centre of the intermesh in which they occur. This arrangement resembles that in *Stauronema*, where, likewise, the spicule has in places altogether disappeared, leaving only its axial canal, where also bosses have proceeded outwards from the site of the vanished spicule, and a fibrous siliceous crystallization has filled up the interstices surrounding it. This also appears to be the final stage of the process which led to the production of tubercles on the spicules of *S. costata* from Wiltshire.

Finally, in some Choanites the skeletal network, having its fibres simply incrusted with silica, forms the nucleus of an otherwise hollow shell consisting of the outer and so much as is present of the middle zone of flint which we described previously (p. 817). This appears to be a late stage of silicification in arrested development.

I have described the foregoing mineral changes in some detail and with great exactness, because I believe that the obscurity which prevails on nearly the whole subject of the mineralization of organic remains is, in great part, owing to our ignorance of the precise mineral replacements which have taken place, and consequently will not be dispelled till we have made ourselves masters of these. It is not part of my purpose now to theorize on the facts I have brought forward; that would require a paper to itself; and I shall content myself, therefore, with briefly summarizing in the following Table the various mineral changes which I consider I have demonstrated to have affected siliceous sponge-spicules in the course of their fossilization:—

Mineral changes of Sponge-spicules which were originally composed of Colloidal Silica in combination with Organic Matter.

1. Transformed into the crystalline state, with corresponding elevation of refractive index. Ex. *Stauronema*, *Siphonia*, &c.

2. Replaced by
   - *a.* Calcic carbonate (calcite). Ex. *Pharetrospongia*, *Siphonia*, *Stauronema*.
   - *b.* Ferric sulphide (iron-pyrites). Ex. *Siphonia*, certain spicules in Cambridge "coprolites."
   - *c.* Glauconite. Ex. *Ventriculites* and *Siphonia*, but merely as an accompaniment of a coprolitic replacement.
   - *d.* Phosphate and carbonate of lime (coprolite).

3. Dissolved, leaving empty casts. Ex. *Ventriculites*, *Siphonia*, *Eubrochus*, &c.

5. Classification.

The agreement in general and minute structure between the various species we have now described is so complete, that no one can doubt their generic identity. The genus to which they belong we have shown to possess a skeletal structure agreeing in all essential particulars with that of the Lithistidæ (O. Schmidt), or the Lithistina of Carter's Pachastrellidæ; and with this family group our *Siphonia* must consequently be associated.

We now proceed to a closer determination of the affinities of this genus. Amongst the various known Lithistids is one, *Discodermia polydiscus*, Bocage*, which is distinguished from the rest by the fact that the arms of its chief spicules remain short and round, whether bifurcated or not, till they break up into their terminal bunch of rounded apophyses, just as we described in the case of *Siphonia*. The two genera *Siphonia* and *Discodermia* thus show the same distinctive kind of spicule; and they so closely resemble one another in their other characteristics that a description of the

* Journ. des Sci. Math. Phys. et Nat. Lisbonne, No. iv. pl. xi. f. 1, 1869. This would belong to O. Schmidt's genus *Corallistes*, but differs from his *C. polydiscus*; Bowerbank erroneously includes it with *Dactylocalyx* as *D. polydiscus*, Bk. (Proc. Zool. Soc. Jan. 28, 1869).

one would apply very well to the other. Great interest attaches, therefore, to *Discodermia* as to the sole survivor of a once dominant race; and this seems sufficient to justify us in giving a short account of it. The figures 8 & 8*a* on Pl. XXVI., which have been kindly furnished to me by Mr. Carter, illustrate the inner and outer aspect of the single specimen of *D. polydiscus* preserved in the British Museum. It came from the island of St. Vincent. "All the *Lithistina*," Mr. Carter* remarks, "are short, sessile, or stipitate sponges which grow on rocks or attached to stones;" and this specimen is "in general form shallow, cup-like, with an equally short, stout, stipitate base. It is an inch in diameter and three quarters of an inch high." Thus its outward form is generally similar to that of some specimens of *Siphonia*; and we must also observe that its oscules are situate on the inside of the cup, just as they are in the interior of the cloaca of the fossil genus. As regards the arrangement of the canals in the recent specimen, we are without published descriptions; but Mr. Carter informs me that both they and the skeletal network are arranged in most Lithistids in very much the same fashion; we may therefore supply *this* gap by an account of what has been seen by Schmidt in a closely allied genus and species, viz. *Corallistes clavatella*, Schmidt†. This sponge is also stipitate; it is supported on a somewhat slender, not very short, pedicel, which enlarges above into an expanded head, on the flat superior surface of which the oscules are situated. Two sets of canals are observed, the longitudinal or excurrent and the radiating or incurrent ones, the latter reminding Schmidt of the canals and furrows of *Cnemidium*, a fossil genus which appears to me to be allied to *Siphonia*. Between the canals the spicules are arranged with the "coarser, smoothest, and short arms lying concentrically," and with their filigreed terminations lying in continuous bands parallel with the radiate canals, the whole forming just such a ladder-like arrangement as we have already found in *Siphonia* (Pl. XXVI. fig. 1).

This arrangement also, Mr. Carter informs me, is common to most Lithistids; and consequently our *Siphonia* resembles its existing allies not only in general form, but in the disposition of its canals and principal spicules as well.

To return to *D. polydiscus*. "Its structure internally consists of the filigreed spicules common to the Lithistidæ (but of a peculiar form, which will be mentioned directly), faced by a dermal layer of thin, smooth, subcircular disks, with more or less curvilinear or toothed margin, furnished respectively with a short, round, pointed shaft, which projects internally, and imbedded in a dermal sarcode densely charged with a minute, curved, acerate, microspined flesh-spicule. The peculiarity of the staple spicule of the interior is that it presents four *smooth round* arms, which, radiating irregularly from a central point, soon divide into two branches respectively that *termi-*

* Ann. & Mag. Nat. Hist. ser. 4, vol. xviii. pp. 460, 462.

† Grundzüge der Spongienfauna des atlantischen Gebietes, p. 23, Taf. iii. figs. 7, 7 *a* & *b*.

nate botryoidally, or in the form of a bunch of grapes, which unites or interlocks with that of the neighbouring branch, and thus the internal structure is formed, except at the surface, where the branches immediately under the dermal layer of disks &c. terminate respectively in flat filigreed or dendriform expansions, which do not intermingle with those of opposite branches."

Owing to the kindness of Mr. Carter, who has given me fragments of *D. polydiscus*, I am able to represent the "staple spicules" (Pl. XXVI. fig. 2) of the preceding paragraph side by side with those of *Siphonia*, so that any one who so wishes may judge of their resemblance for himself. In the same Plate (figs. 9 & 9 *a*) will be observed some of the "disciform spicules" from the dermal skeleton of *Discodermia*, specimens of which, judging from all analogy, we ought to find in connexion with *Siphonia*, more especially as Mr. Carter has found such spicules entangled in the interior of rolled, dead fragments of *Discodermia* dredged up on board the 'Porcupine' near Cape St. Vincent (*l. c.* p. 463). No endeavour on my part, however, to discover these, either on the surface or in the interior of my specimens of *Siphonia*, has met with success, which may arise from the extreme thinness and thus perishable nature of the disk. The nearest approach is the form represented on Pl. XXVI. fig. 11, a single specimen of which was found imbedded among the staple spicules just on the edge of one of the excurrent canals of *S. costata*. This form, however, more nearly resembles the dermal spicules of other Lithistids, ex. gr. *C. clavatella* (O. S.), and is most likely a stray waif washed in. Still it is quite possible that spicules with entire (Pl. XXVI. fig. 10) and with divided (Pl. XXVI. fig. 11) margins may exist together in the dermal membrane of the same sponge; and I believe that an instance of this has already been found.

True disciform spicules (Pl. XXVI. fig. 10), both with simple and sinuated borders like those of *D. polydiscus*, have been met with by Mr. Carter* abundantly scattered loose in the spicule-bed of the Haldon Greensand, and have been named by him *Dactylocalycites Vicaryi*; and I have myself obtained them in great numbers associated with pieces of Lithistid network of the *Discodermia* type from the Upper Chalk of Trimmingham, in Norfolk.

The coating of disciform spicules forming the dermal skeleton of *Discodermia* is readily separable from the internal network which it covers and conceals; the connexion between the two is, indeed, of the very slightest kind; and hence, if *Siphonia* ever possessed a similar coating of disk-like spicules, it would in all probability lose it after death and during decay; and the disk-like spicules separating from the sponge and from each other would be buried in the surrounding silt or sand, to be discovered subsequently as isolated spicules like those which have occurred to Mr. Carter in the Haldon beds and to myself in the Chalk.

Here I must quote the last paragraph in Mr. Carter's description of *Discodermia polydiscus* (Annals, *t. c.* p. 464); for it is evident tha

* Ann. & Mag. Nat. Hist. ser. 4, vol. vii. p. 123, pl. vii. figs. 1, 2, & 6.

another species has come to light from the Philippine Islands, vase-like in shape, similar to *Siphonia expansa* mentioned at p. 805, Mr. Carter says:—

"Schmidt's *Corallistes polydiscus* (Atlant. Spongienf. p. 24, Taf. iii. figs. 8 & 9) appears to me, from the form of its surface-spicules, to be a different species, according in this respect with a large vase-like specimen from the Philippine Islands that I have lately been examining, in which, however, there is, in addition to the acerate flesh-spicule, a small solid one of an elliptical form like that characterizing *Pachastrella abyssi*, while the acerate flesh-spicule in all is almost identical with that of *Macandrewia azorica*."

Now, as further on (p. 464), the latter is considered equal to *Corallistes clavatella*, Sdt., the close alliance of this Lithistid to *Discodermia*, which I have before noticed, is thus corroborated; and, as this would give a discoid spicule with *more indented*, *tooth-like* margin, then the finding of the one in *S. costata* just mentioned might be accounted for.

The previous existence of a dermal skeleton of some kind about the exterior of *Siphonia* appears probable also from the exposure of the outermost excurrent canals as grooves radiating from the cloacal tube of many Haldon specimens; these grooves must once have been covered in by a membrane of some sort in order to form completed tubes.

Two other forms of spicules also occur in *Discodermia*:—one the flesh-spicule already alluded to, so minute that it has little or no chance of surviving the changes of fossilization, and, indeed, is found to have already disappeared in recent deciduous specimens of *Discodermia* before fossilization has set in; this consequently we do not and cannot expect to find in *Siphonia*; the other, not mentioned by any preceding writer, is a long, straight, or curved acerate spicule*, 0·072 long and 0·002 diam. (Pl. XXVI. figs. 6 & 6*a*), and tolerably abundant in my pieces of *Discodermia*, and a characteristic spicule of our *Siphonia* (p. 808, Pl. XXVI. figs. 5 & 5*a*).

From the preceding comparison it will be seen that the very closest resemblance exists between the recent *Discodermia* and the fossil *Siphonia*. Not only in fundamental structure, but also in general form, and in the arrangement of the canals and elements of the skeleton, the two are, in a broad sense, the same. Thus the two puzzles of the Cretaceous sponges are now cleared up, the Ventriculites survive in *Myliusia Grayi* †, and the *Siphoniæ* in *Discodermia polydiscus*.

* This spicule, Mr. Carter tells me, is equally common in the British-Museum specimen and in that from the Philippine Islands, also in the Lithistids *Theonella Swinhoei* and *Azorica Pfeifferæ*; it runs throughout the whole group of the Lithistina, and may, as Mr. Carter proposes, be conveniently termed the "beam spicule." Bocage figures from *D. polydiscus* another large form of spicule (*l. c.* pl. xi. figs. 1*d* & 1*e*), which, however, differs from the beam spicule in being entirely superficial in position, and in having one end rounded off. Owing to its superficial position it would almost certainly be detached from the sponge before fossilization; and hence we cannot hope to find its representative in *Siphonia*.

† Ann. & Mag. Nat. Hist. ser. 4, vol. xix. p. 121, pl. ix. figs. 8–17.

The distribution of the Lithistid sponges is of interest as resembling and throwing light on that of the *Siphoniæ*: bathymetrically they range from 75 to 374 fathoms (*Carter*), or 152 to 270 (*Schmidt*); geographically they are found in the Atlantic, about the West Indies, Madeira, the Azores, and the coast of Portugal. The *Siphoniæ* similarly occur most abundantly in Greensand-beds, which were laid down not very far from the shore-line of the Cretaceous sea, and at not excessive depths from its surface. Here then is another link between the modern and the Cretaceous Atlantic. The specimen of *S. piriformis* described by Goldfuss, from the Jurassic, I must leave to Sir Wyville Thomson and his supporters.

Class SPONGIDA.

Order HOLORHAPHIDOTA.

Family PACHASTRELLIDÆ.

Group LITHISTINA.

Genus SIPHONIA.

Synonyms: *Caricoïdes*, Guettard; *Hallirhoa* et in parte *Jerea*, Lamx.; *Polypothecia*, pars, Benett; *Choanites*, Mantell.

Sponge. Consists of a head or body of variable shape supported on a longer or shorter stem, by which it is attached to some foreign body, or without a stem and anchored by a number of diverging rooting fibres which penetrate the silt in which it is imbedded.

Canals of two kinds, *excurrent* and *incurrent*, the former longitudinal, opening distally in oscules situated on the walls of a central cloaca, or upon a plane surface at the summit; the latter radiating, opening externally in pore-areas, and internally into the excurrent canals.

Skeleton siliceous; *spicules* (1) staple, quadriradiate with four diverging arms, all of which are smooth and round, bifurcating near their extremities, and terminating in a number of rounded apophyses with intervening concavities. Combined into a rigid network by the interlocking of their apophysial endings, and arranged in bands parallel to and chiefly about the radiating canals, the smooth arms lying concentrically, and their terminations forming a series of radiating bands of filigree. (2) Smooth acerate spicules, lying parallel with the series of staple spicules. (3) Flesh-spicules (?), (4) Dermal spicules (?), not found attached to the sponge, but occur in association in the Haldon Greensand.

Formation. Cretaceous and Jurassic.

Locality. England—Haldon, Blackdown, Wilts, Isle of Wight, Sussex, Yorkshire (?); Germany—Coesfeld, Quedlinburg, Borzen, Kutschlin; France—Cognac, Tours, Honfleur, Rouen, Havre, St. Aignan, Saumur; Russia—Bouchevoë (near Moscow).

Species. *S. pyriformis*, *costata*, *Webtsteri*, *Königii*, and *arbuscula*.

Note, October 1877.

It may not be out of place if I indicate here the kind of plan which I have set myself to follow in making a study of the fossil sponges. First, then, I wished to begin by publishing as exhaustive a description as I could of a number of single species of fossil sponges, each to illustrate a well-marked structural type, and having done this, to determine how far the various existing fossil species could be referred to these previously ascertained types.

The first part of my plan is now nearly accomplished; descriptions of *Stauronema*, *Pharetrospongia*, and *Siphonia* have appeared to illustrate the Vitreohexactinellidæ, Renieridæ, and Lithistidæ respectively; while we may expect to be furnished shortly with a good example of the Sarcohexactinellidæ (*Acanthaspongia*, *Hyalonema*) by other observers. The abundant material which has been placed at my disposal by the great kindness of Mr. Woodward at the British Museum, and by Mr. Moore of the Liverpool Free Museum, has now given me the opportunity of proceeding with the second part of my plan, *i. e.* with the classification of the various fossil species. Already I find that the Lithistidæ are well represented in the fossil state by very numerous species of great diversity in form and structure; Miss Benett's forms, for instance, more nearly related than I had previously imagined, belong all, or nearly all of them, to various Lithistid genera, some having affinities to *Discodermia*, some to *Macandrewia*, and others presenting us with a new generic type. No less abundant are the fossil Renieridæ, all the sponges with reticulate calcareous skeletons from Faringdon, such as *Manon macropora*, *Jerea mutabilis*, *Scyphia foraminosa*, and others, belonging to this group, or being closely allied to it. The Hexactinellidæ have already been dealt with in a very full and complete manner by Professor Zittel.

Hitherto the fossil sponges have furnished me with no type which does not find its close representative in existing seas. The existence of extinct calcareous sponges with reticulate skeletons finds no support from a study of either fossil or recent sponges; it is the merest myth; and the classification of D'Orbigny and his successors, based on an assumption, may now be regarded as finally and completely disposed of. I had the honour to receive a separate copy of Professor Zittel's Monograph on the fossil Hexactinellidæ on the day after this paper was read. Our independent observations agree in a manner no less remarkable than satisfactory, due doubtless to our having both followed the same modern methods of research. The points of difference between us are but few. Thus Professor Zittel speaks of the existence of fossil calcareous sponges with a reticulate fibrous skeleton; but I have reason to believe that since the publication of my paper on *Pharetrospongia* he has abandoned all belief in such forms, and thus made criticism on this matter needless. Professor Zittel also seems to consider that I regard the genus *Stromatopora* as belonging wholly to the Hexactinellidæ: this has at no time been my view; I regard the genus *Stromatopora* as a heterogeneous mixture of very various forms, some of which belong to the Hydrozoa and are nearly allied to *Millepora* and *Hydractinia*, while some are true Hexactinellid sponges, as Mr. Carter himself now admits, and others finally fall into other groups, not yet determinable. All this, however, I hope soon to set forth in a paper devoted exclusively to this supposed genus.

In conclusion, I hope I may be allowed to congratulate Professor Zittel on what he has done by his valuable monographs to save palæontologists from the reproach which the fossil sponges have for so long a time been to them.

A List of all described Species which have been rightly or wrongly assigned to the genus Siphonia.

Species.	Author.	Date.	Reference.		Page	Pl.	Fig.	Formation.	Locality and Remarks.
acaulis (1)......	Mich.	1840–7	Mich. Icon. Zooph.		139	38	2	Cretaceous	Cap le Hève. Doubtful *Siphonia.*
			D'Orb. Prodrome.		186			U. G. S.	Havre, Villers.
			Pictet, Traité.		544			,,	
acaulis (2).........	Court.	1861	Court. Ep.foss. Saumur		16	25	3	Lower Chalk	Saumur.
acuta	,,	,,	,, ,,		15	22	2	,,	,,
agariciformis ...	Benett.	1831	Benett, Cat. Wilts foss.	(*Polypothecia*)	9	15	1, 2	U. G. S.	Wilts. True *Siphonia.*
ampullacea	Goldf.	1826	Goldf. Petref.		98	35	12	U. G. S.	
anguilla............	Lee.	1859	Lee, Mag. Nat. Hist.		12		5	Chalk	Yorks.
			Morris, Catalogue		30			Upper Chalk	,,
arborescens	Court.	1861	Court. Ep.foss.Saumur		16	24	2	Lower ,,	Saumur.
			Mich. Icon. Zooph.	(*Jerea*)	136	42	2	Cret.	Châteauvieux, St. Aignan, Tours. (Sussex, Berks, England.)
arbuscula	Mich.	1840–7	,, ,, ,,		139	33	2	,,	Tours.
			D'Orb. Prodrome		285			Lower Chalk	
			Court. Ep. foss. Sau.		14	18	3 to 5	,,	Saumur.
			Fromentel, Introd.	(*Polysiphoneudea*)	30	1	10		
astroides	Römer.	1864	Römer, Palæont. xiii.		28	10	6	Quader	Geröll, Ilsenburg.
biseriata	Reuss.	1845–6	Reuss, Verst. böhm. Kr. ii.		72	17	6	Conglomerate	Borzen, south foot of.
			,, Geogn. Skizz. ii.		172				

A List of all described Species (continued).

Species.	Author.	Date.	Reference.		Page	Pl.	Fig.	Formation.	Locality and Remarks.
brevicosta	Mich.	1840–7	Mich. Icon. Zooph.	(*Hallirhoa*)	127	31	2	Lower Chalk	Tours.
			D'Orb. Prodrome.		285			,,	
cervicornis	Goldf.	1826	Goldf. Petref.		{18 98	6 35	11 11	Chalk Marl	Westphalia.
			Blainv. Man. d'Act.		536				
			Morris, Catalogue.						England (?).
			Reuss, Verst. böhm. K. ii.		73			Low. Pläner	Schillinge, near Bilin.
								Pyropensande	Tržibletz.
			Römer, Verst. N. Kr.		5			Low. Chk. Ml.	Lemförd, Coesfeld.
			Römer, Palæont. xiii.	(*Jerea*)	34				Haldon.
cæspitosa	Court.	1861	Court. *l. c.*		16	23	2	Lower Chalk	Saumur. (*Jerea* id., Mich.).
cidoniformis	,,	,,	,,		15	21	4	,,	,,
clava	Lee.	1839	Lee, Mag. Nat. Hist.		12		2 to 4	Upper Chalk	Yorks.
			Morris, Catalogue.					,,	,,
clavata	Court.	1861	Court. *l. c.*		15	22	1	Lower Chalk	Saumur.
complexa	Benett.	1831	Benett, Cat. Wilts. foss.	(*Polypothecia*)	9	6	1	U. G. S.	Wilts.
compressa	Court.	1861	Court. *l. c.*		14	20	1	Lower Chalk	Saumur.
conica	,,	,,	,,		14	{20 21	3 to 6 1 to 2	,,	,,
coronata	,,	,,	,,		17	27	2 to 6	,,	,,
costata	Lamx.	1821	Lamx. Exp. Méth. Polyp.	(*Hallirhoa*)	72	78	1	Marne bleu	Vaches-noires.
			Benett, Cat. Wilts. foss.	(*Polypothecia*)	9	2 to 5	{1 to 3 1 to 2 1 to 2 1 to 3	U. G. S.	Wilts. This is Benett's *P. bi-* to *septem-loba.*
			Bronn, Leth. Geogn. Th. v.		74	27	19		This figure represents Mich.'s *H. brevicostata.*
			D'Orb. Prodrome, ii.		186			,,	Villers, Honfleur, Rémalard, Havre. D'Orb. includes *H. Tessonis*, Mich., with this.
			Mich. Icon. Zooph.	(*Hallirhoa*)	127	31	3	Cret.	Vaches-noires, Rémalard.
			Morris, Catalogue.		30			U. G. S.	Warminster, Wilts.
			Pictet, Traité.		544			,,	

curta	Court.	1861	Court. *l. c.*		14	18	2	Lower Chalk	Saumur.
cylindrica (1) ...	Römer.	1840–1	Römer, Verst. N. Kr.		5	2	1	Chalk Marl, Pläner	Steckelnburg, near Quedlinburg. Römer, Palæ. xiii. p. 49, refers this to the genus *Stellispongia*.
„ (2) ...	Court.	1861	Court. *l. c.*		14	18	1	Lower Chalk	Saumur. This appears to be a variety of *S. piriformis*.
„ (3) ...	Eichw.	1866	Eichwald, Lethæa Rossica, i.		329	22	12	Calcaire à Orthocératites	Zarskoje, near St. Petersburg. Questionable whether this is a sponge at all.
decipiens	Court.	1861	Court. *l. c.*		13	{ 16 17	1, 2 1 to 4	Lower Chalk Lower Chalk	Saumur.
·dichotoma	D'Orb.		D'Orb. Prodrome.		285				Tours. Non *P. dichotoma*, Benett.
			Mich. *l. c.*	(*Scyphia*)	142	28	5	Cret.	Tours.
difformis	Court.	1861	Court. *l. c.*		16	22	5, 6	Lower Chalk	Saumur.
elongata (1)	Reuss.	1845–6	Reuss, Böhm. Kr. ii.		72	43	1	Up. Pläner	Kutschlin, Hundorf, Radowissitz. This appears to be a true Lithistid, with the same difference between the spicules of the body and the stem which exists in *Siphonia*.
			„ Geogn. Skizz. ii.		171			Lower Chalk	Quedlinburg.
			D'Orb. *l. c.*		285			Lower Chalk	Honfleur, Ste. Ménehould,
			Mich. *l. c.*		134	34	4	Cretaceous	Monblaineville.
			Römer, Palæ. xiii.	(*Jerea radiciformis*)	34			Quader	Ihme, near Hanover. Identifies this with *Spongia radiciformis*, Phil. i. 9.
elongata (2)	Court.	1861	Court. *l. c.*		14	18	4	Lower Chalk	Saumur. A variety of *S. arbuscula* (Mich.).
			Pomel, Pal.d.P. d'Oran	(*Polysiphonia*)	124				
emarginata	„	„	Court. *l. c.*		14	18	3	„	Saumur. „

A List of all described Species (continued).

Species.	Author.	Date.	Reference.		Page	Pl.	Fig.	Formation.	Locality and Remarks.
excavata	Goldf.	1826	Goldf. *l. c.*		17	6	8	?	?
			Blain. *l. c.*		536				
			Br. Leth. Geogn. Th. v.		75	27	21	Cretaceous: Firestone.	Maestricht.
			„ Th. ii.		155				
			Eichw. *l. c.*		331			Orthoceratite limestone.	Zarskoje, Poulkowa, &c.
			Milne-Edwards, in Lamk. vol. ii.		614				
			Mich. *l. c.*	(*Jerea*)	135	33 39	3 2	Cretaceous	Includes both *S. excavata* and *præmorsa*, Goldf., in this species.
expansa	Benett.	1831	Benett. *l. c.*	(*Polypothecia*)	9	6	2	U. G. S.	Wilts.
ficus	Goldf.	1826	Goldf. *l. c.*		221	65	14	Quader	Quedlinburg.
			Bronn, *l. c.* Th. v.		72			PlänerQuader	Germany.
			D'Orb. *l. c.*		186			U. G. S.	Blackdown and Quedlinburg. Includes *S. pyriformis* of Sowerby, not of Goldfuss.
			Fromentel, Mém. Soc. Lin. Norm. vol. xi.	(*Siphoneudea*)	29	1	12 & 12*a*		
			Pictet, *l. c.*, vol. ii.		544				"*Ficus vel pyriformis* (Sow.)".
			Pomel, *l. c.*		124				
			Roemer, Nordd. Kreid.		4			Up. Chk. Ml. Pläner	Sudmerberg, near Goslar. Near Quedlinburg.
			„ Palæ. xiii.		27				
ficoidea	Mich.	1840–7	Mich. *l. c.*		139	29	5	Cretaceous	Poitiers.
			D'Orb. *l. c.*		285			Lower Chalk	
Fittoni	Mich.		Mich. *l. c.*		140	29	6	Cretaceous	Cognac, Loudun. Syn. given by Mich. *S. ficus*, Gdf. pl. lxv. fig. 14. *S. pyriformis*, Sow.
			Court. *l. c.*		15	21	3	Lower Chalk	Saumur.
			D'Orb. *l. c.*		285				Non *S. pyriformis*, Sow., nec *S. ficus*, Goldf.

globosa	Court.	1861	Court. *l. c.*		15	21	6	Lower Chalk	Saumur.
gracilis	,,	,,	,, *l. c.*		16	22	4	,,	,,
gregaria...........	,,	,,	,, *l. c.*		16	23	1	,,	,, (*Jerea* id., Mich.).
Goldfussii	Roemer.	1840–1	Römer, Nordd. Kreid.		4			L. Chk. Ml.	Near Coesfeld. Syn. *Manon pyriforme*, Gdf.
			Goldf. *l. c.*	(*Manon pyriforme*)	220	65	10	Cretaceous	Coesfeld.
			Römer, Palæ. xiii.	(*Jerea*)	33			Chalk Quader	Coesfeld. Schwiechelt.
hastata	Court.	1861	Court. *l. c.*		16	25	2	Lower Chalk	Saumur.
heterostoma	Reuss.	1845–6	Reuss, Böhm, Kreid. ii.		72	17	4 to 5	Hornstein congl. and chalk marl.	S. Borzen, S. Hradisst, Schellinge, near Bilin. A hexactinellid. Reuss states that it much resembles *Retepora crassa*, Mich.
hybrida	Court.	1861	Court. *l. c.*		17	27	1	Lower Chalk	Saumur.
incrassata	Goldf.	1826	Goldf. *l. c.*		17	34	5	U. G. S.	Coesfeld, Westphalia. *Carycoïdes aplati* of Guettard, Mém. Acad. iii. pl. i. fig. 3.
			Blainv. *l. c.*		536				
			D'Orb. *l. c.*		285			Lower Chalk	Includes in his "*S. lycoperdites*."
			Mich. *l. c.*		138	40	1	Cretaceous	Nogent le Rotrou, Tours, Rémalard, Coulonges.
			Pictet, *l. c.*		544			White Chalk	
			Pomel, *l. c.*		124				
			Römer, Palæ. xiii.	(*Jerea*)	32			Chalk	Coesfeld.
inæqualis	Pomel.	1872	Pomel, *l. c.*		124				
infundibulum ..	D'Orb.	1847	D'Orb. *l. c.*		285			Lower Chalk	This is Michelin's *Scyphia terebrata*, not Phillips's *Spongia* id.
			Mich. *l. c.*	(*Scyphia terebrata*)	141	29	4		Thinks may be identical with *C. Königii*, Mant.
intermedia	Court.	1861	Court. *l. c.*		14	19	1, 2	Lower Chalk	Saumur.

A List of all described Species (continued).

Species.	Author.	Date.	Reference.		Page	Pl.	Fig.	Formation.	Locality and Remarks.
Königii …………	Mantell.	1822	Mantell, Foss. South Downs	(*Choanites*)	178	16	19–21	Upper Chalk	Lewes race-course (Sussex).
			Bronn. *l. c.*		69	34	11		Ilsenburg. Gives as syn. *S. Konigii*, D'Orb., *S. terebrata*, Phill., *Scy. terebrata*, Mich., *Cn. pertusum*, Rss., *Scy. heteromorpha*, Gein.
			D'Orb. *l. c.*		285			Lower Chalk	Includes *Spongia terebrata*, Phill., and *Scyphia* (*Cnemidium*) *pertusum*, Rss.
			Mantell, Medals.		234	75			
			Pictet, *l. c.*		544				
			Römer, Nordd. Kreid.		8			Low.Chk.Ml.	Ilsenburg.
			Römer, Palæ. xiii.		27				Bilin (Bohemia). Includes *Cn. pertusum*, Rss.
lagenaria ………	Mich.	1840–7	Mich. *l. c.*		114	26	4	Oolite	Caen.
					250			Forest Marb.	
			Fromentel, Introd. Ep. foss.	(*Diseudea*)	28			Bathonian	Luc, Ranville.
lobata …………	Benett.	1831	Benett, *l. c.*	(*Polypothecia*)	9	2 to 5	numerous	U. G. S.	Wilts. This is *S. costata*.
			Mantell, Medals.	(*Siphonia*)	231	73	4		
lycoperdites ……	D'Orb.	1847	D'Orb. *l. c.*		285			Lower Chalk	Tours, Havre, Nogent le Rotrou, etc. *Alcyonium* id., Defr., *S. piriformis* and *incrassata*, Goldf., *S. pyriformis*, Mich.
			Pictet, *l. c.*		544				
lycoperdoides. …	Mich.	1840–7	Mich. *l. c.*		251	58	6	Forest Marb.	Ranville, &c. (Calvados).
			Lamx. *l. c.*	(*Hallirhoa*)	72	78	2		
minima …………	Court.	1861	Court. *l. c.*		15	21	7	Lower Chalk	Saumur.
Morrisiana ……	Mant.	1853	Mantell, Medals.		254	69	3	Upper Chalk	I. Wight and Brighton.

Morrisii			Morris, *l. c.*		30			Upper Chalk	I. Wight, Brighton. Alters the name of the preceding to "*Morrisii.*"
multiformis	Bronn.	1851–2	Bronn, *l. c.* Th. v.		73	27	20	"Glauconie"	
			D'Orb. *l. c.*		285			Lower Chalk	Hanover, Peine.
			Mich. *l. c.*	(*Jerea mutabilis*)	133	36	4	Cret.	Grandpré, Vouziers.
								Lower Chalk	Near Peine.
			Römer, Nordd. Kreid.		5				Vouziers.
			,, Palæ. xiii.	(*Jerea*)	33			Quader	Peine.
multioculata ..	Mich.	1841–7	Mich. *l. c.*		138	33	6	Cret.	Tours. States that the species is still living!
nuciformis.........	Mich.	,,	Mich. . *c.*		140	33	4	Cret.	Honfleur, Tours.
ocellata	Römer.	1840–1	Römer, Nordd. Kreid.		5	2	2	Cret.	Ilsenburg. This is *Jerea elongata*, Mich., 134, 39. 4.
			,, Palæ. xiii.	(*Jerea*)	33				
oligostoma	,,	,,	,, Nordd. Kreid.		5	2	3	Chk. Ml.	Ilsenburg.
			,, Palæ. xiii.	(*Jerea*)	33			Quader	Ilsenburg.
ovalis	Court.	1861	Court. *l. c.*		15	21	5	Lower Chalk	Saumur.
osculata............	,,	,,	,,		13	17	5	,,	,,
ornata	Römer.	1864	Römer, Palæ. xiii.		27	10	5	Quader	Sudmerberg.
parasitica	Court.	1861	Court. *l. c.*		13	17	7, 8	Lower Chalk	Saumur.
pirum	Eichw.	1866	Eichw. Lethæa Rossica, ii.		100	6	8	Neocomian	Mongilakowo, nr. Kowask.
pistillum	Goldf.	1826	Goldf. *l. c.*		17	6	10	Greensand	Courtagnon.
			Mich.	(*Jerea pyriformis*).				Firestone	Rethel, Vaches - noires, Courtagnon, Nogent-le-Rotrou, Coulonge, &c.
polycephala	Court.	1861			15	22	3	Lower Chalk	Saumur.
præmorsa	Goldf.	1826	Goldf. *l. c.*		17	6	9	?	
			Bronn, *l. c.* Th. ii.		154	27	21		
			D'Orb. *l. c.*	(*Jerea excavata*)	286				
			Eichw. *l. c.* Per. ancienne.		331			Orthoceratite Limestone	Zarskoje, Poulkowa, &c.
			Mich. *l. c.*		135	{33	3	Cret.	
						{39	2		
	,,	1826	Milne-Edw. in Lamk. ii.		614			,,	

A List of all described Species (continued).

Species.	Author.	Date.	Reference.		Page	Pl.	Fig.	Formation.	Locality and Remarks.
præmorsa	Goldf.		Römer, F., Bronn's Jahr. 1848.		684				
			Römer, F., Sil. fauna d. westl. Tennessee.	(*Astylospongia*)	8	1	1		
			Römer, F., Foss. fauna Sil. Dil.		10	2	6		
prolifera	Court.	1861	Court. *l. c.*		17	26	1 to 4	Lower Chalk	Saumur.
pyramidalis	,,	,,	,,		17	25	4	,,	,,
pyriformis.........	Goldf.	1826	Goldf. *l. c.*		16	6	7	Cretaceous	Chaumont.
			,,		97	35	10	Jurassic	Streitberg.
			Benett, *l. c.*	(*Polypothecia*)	8	1	3	U. G. S.	Wilts.
			Blainville, *l. c.*		536				
			Court. *l. c.*		14	18	6, 7	Lower Chalk	Saumur.
			D'Orb. *l. c.* (*piriformis*)		285			Lower Chalk	Includes this species in his *S. lycoperdites*.
			Mantell, Medals.		230	73	1 to 4	U. G. S.	
			Mich. *l. c.*		137	33	1	Cret.	Rouen, Havre, Tours, &c.
			Morris, *l. c.*		30			U. G. S.	Identifies Sowerby's with Goldfuss's *S. piriformis*.
			Passy, *l. c.*	(*Choanites*)				Upper Chalk	Eure. This is a small *S. Königii*. Reuss, however, adopts it as a different species; he finds it in the Upper Pläner Kalk, Kutschlin (*loc. cit.*).
			Pictet.		544				Adopts D'Orbigny's *S. lycoperdites*.
			Reuss, Böhm. Kreid. vol. i.		72			Up. Chlk. Ml.	Kutschlin.
			Römer, Palæ. xiii.	(*Polyierea*)	35			Quader	Kölhlerholz, nr. Ilsenburg.
			Sow. Trans. G. S. iv. ser. 2.		340	xv*a*	1 to 9	U. G. S.	Blackdown.

radiata	Fischer.	1830–7	Fischer, Oryct. Mosc.		178	48	3, 4	Upper Chalk	Bouschevoyé (Moscow).
			Eichw. *l. c.* vol. ii.		102			Cret.	,, ,,
radiciformis	Römer.	1864–6	Römer, Palæ. xiii.	(*Jerea*)	33				Ihme, nr. Hanover.
ramosa	Mich.	1840–7	Mich. *l. c.*		141	28	6	,,	Tours.
			Court. *l. c.*		16	24	1	Lower Chalk	Saumur.
rariosculata	Court.	1861	,,			20	2	,,	,,
rivuligera	Eichw.	1866	Eichw. Leth. Ross. ii.		101	6	7	Neocomian	Mongelakowo, nr. Kowask.
sphærica	Court.	1861	Court. *l. c.*		13	17	6	Lower Chalk	Saumur.
sphærocephalus .	Benett.	1831	Benett, *l. c.*	(*Polypothecia*)	9	1	2	U. G. S.	Wilts.
subrotundus	,,	,,	,,	(*Choanites*)	9	16	1 to 4		
ternata	Reuss.	1845–6	Böhm. Kreid. ii.		72	17	1 to 3	Lowest Pläner	Borzen, near Bilin; Tripelberg, nr. Kutschlin.
			Geogn. Skizz. ii.	(*Cnemidium*)	298				
			Römer, Palæ. xiii.	(*Tremospongia*)	40			Chalk	Bilin and Quedlinburg.
Tessonis...........	Mich.	1840–7	Mich. *l. c.*		128	34	1	Cret.	Vaches-noires, Villers-sur-Mer.
			D'Orb. *l. c.*		186			U. G. S.	Includes in *Siphonia costata.*
triloba	Court.	1861	Court. *l. c.*		16	25	1	Lower Chalk	Saumur.
tuberosa	D'Orb.	1847	D'Orb. *l. c.*		285			,,	Goslar. This is *Scy. tuberosa* (Römer), a true Hexactinellid.
			Römer, Palæ. xiii.		27				Goslar. Accepts here D'Orbigny's assignment of this species.
typum	Blainv.	1834	Blainv. *l. c.*		536	95	1	Living	Mediterranean (Sicily). This is a Renierid sponge.
undulata	Benett.	1831	Benett, *l. c.*		9	7	1	U. G. S.	Wilts.
Websteri	Sow.	1836	Sowerby.					U. G. S.	I. Wight.

EXPLANATION OF THE PLATES.

Plate XXV.

Fig. 1. Specimen of *S. pyriformis*, Sow., v. *S. ficus*, D'Orb., v. *S. conica*, Court., from the Haldon Greensand, lateral view. 1 *a*. Its apex, seen from above, showing the opening of its cloacal tube, and its exposed excurrent canals. 1 *b*. A longitudinal section of the same specimen, showing (*a*) its cloacal tube, (*e*) excurrent canals, and (*i*) incurrent canals. (All natural size.)

Fig. 2. Specimen of *S. costata*, Lamx., from the Wiltshire Greensand. 2 *a*. Longitudinal section of the same specimen. (Nat. size.)

Fig. 3. A young form of *S. pyriformis*, Sow. 3 *a*. Its apical end seen from above. (Nat. size.)

Fig. 4. Specimen of *S. pyriformis*, Sow., var., *S. cylindrica*, Court.; lateral view. 4 *a*. Its summit as seen from above, showing cloacal aperture and exposed excurrent canals. (Nat. size.)

Fig. 5. Part of a band of skeletal network of *S. Websteri*, Sow., from the longitudinal section fig. 7 *a*. (×60.)

Fig. 6. Specimen of *S. pyriformis*, var. *Fittoni*, Mich., lateral view. (Nat. size.)

Fig. 7. Specimen of *S. Websteri*, Sow., from the Gault of Folkestone. Lateral view. 7 *a*. Its longitudinal section. 7 *b*. A transverse section of the same species, but from another specimen. (Nat. size.)

Fig. 8. Specimen of *S. pyriformis*, Sow., with divided summit. (Nat. size.)

Plate XXVI.

Fig. 1. Part of a band of skeletal network lying between two of the excurrent canals of the specimen of *S. Websteri*, shown in pl. i. fig. 7, as seen in its transverse section, fig. 7 *b*. *a*. Section of the shaft of one of its component quadriradiate spicules. *b*. Sections of shafts. *c*. Three arms of a quadriradiate spicule, separated from the shaft by the plane of the section. (×60.)

Fig. 2. Single skeleton-spicule from the recent Lithistid sponge *Discodermia polydiscus*, Bocage. (×60.)

Fig. 3. Union of the two spicular rays by the interlocking of their tubercular extremities, taken from the skeleton of *D. polydiscus*. (×60.)

Fig. 4. A small part of the skeletal network of *S. pyriformis*, Sow., as exhibited on its surface by reflected light. (×60.)

Figs. 5 and 5 *a*. "Beam" spicules from *Siphonia Websteri*, Sow. (×60.)

Figs. 6 and 6 *a*. "Beam" spicules from the recent *Discodermia polydiscus*, Bocage. (×60.)

Fig. 7. Skeletal network of the stem of the *Siphonia*, as exposed on the surface of the specimen shown in Pl. XXV. fig. 3. (×60.)

Fig. 8. Specimen of the recent Lithistid sponge *Discodermia polydiscus*, Bocage, preserved in the British Museum. *o*. The oscules opening into the interior of the cup; internal view. 8 *a*. External aspect of the same specimen. (Nat. size.)

[Figs. 8 and 8 *a* are from sketches furnished me by Mr. Carter.]

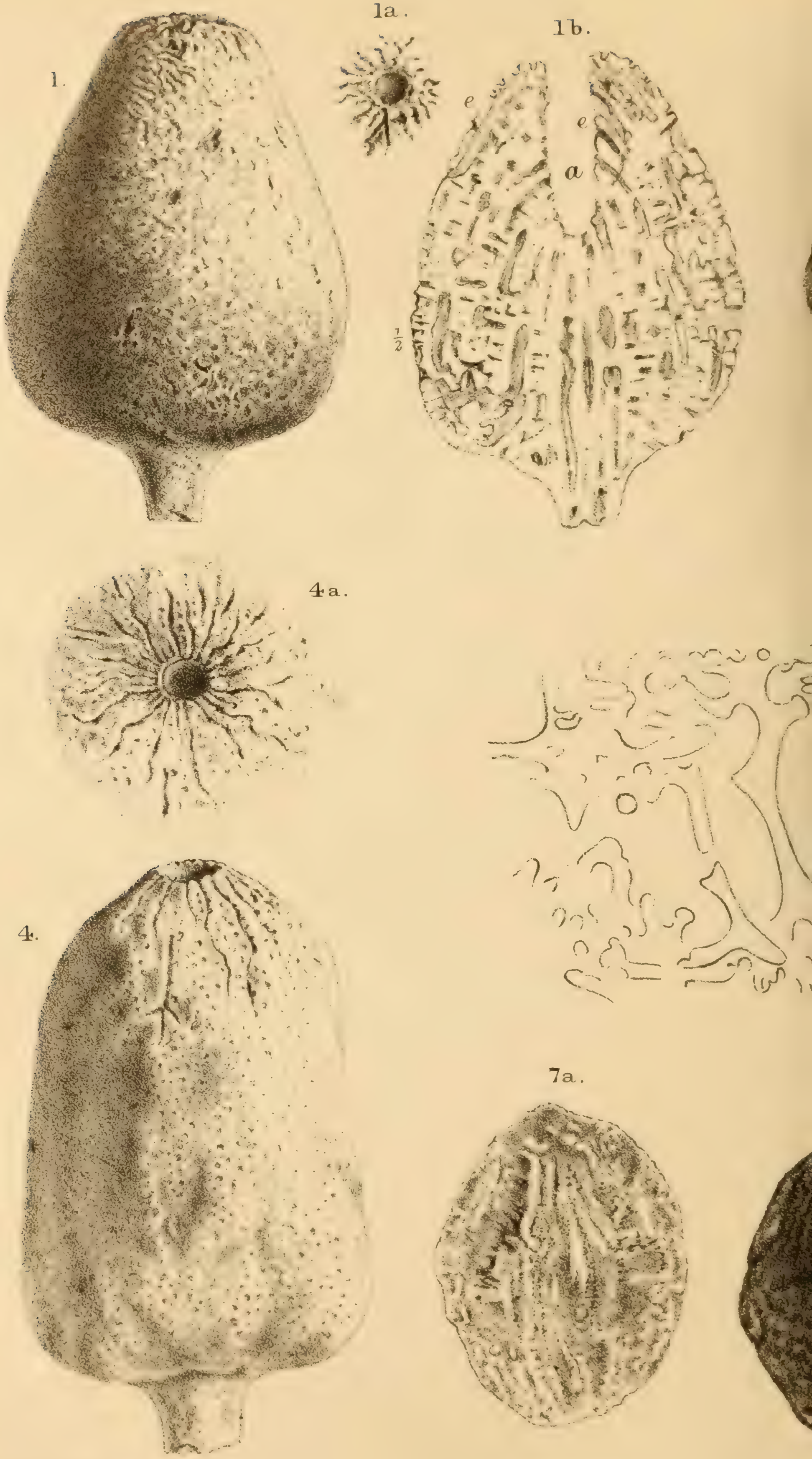
Fig. 9. One of the "dermal" spicules of the preceding, seen in place, exhibiting the characteristic central triradiate canal. 9 *a*. Profile view of the preceding. (×60.)

Fig. 10. Dermal spicule from the spicule-bed of the Haldon Greensand. (×75.) (After Carter, "Fossil Sponge-spicules of the Greensand compared with those of existing Species," Ann. & Mag. Nat. Hist. ser. 4, vol. vii. pl. vii. fig. 5).

Fig. 11. Dermal spicule from the network of *Siphonia costata*, Lamx. (×60.)

Discussion.

Mr. Charlesworth remarked that, if the consolidation of genera proposed by Mr. Sollas were satisfactorily established, it must be re-



A.S Foord del et lith.

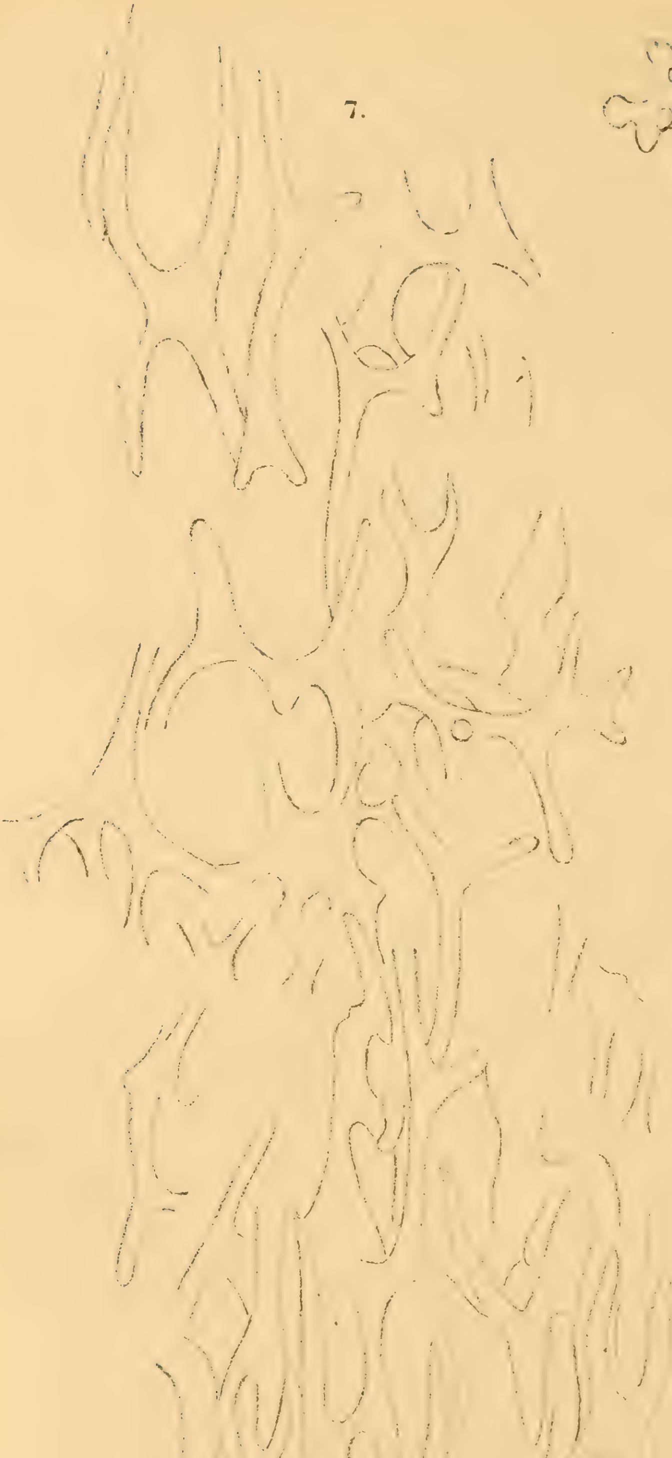
Mintern Bros. imp.

A.S Foord del et lith.

SIPHONIA.

Mintern Bros imp.

7.



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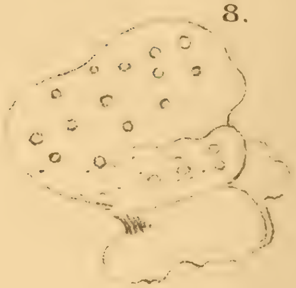

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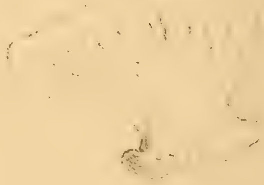

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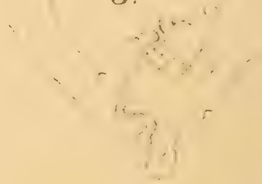

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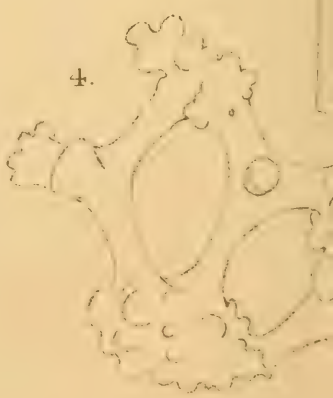
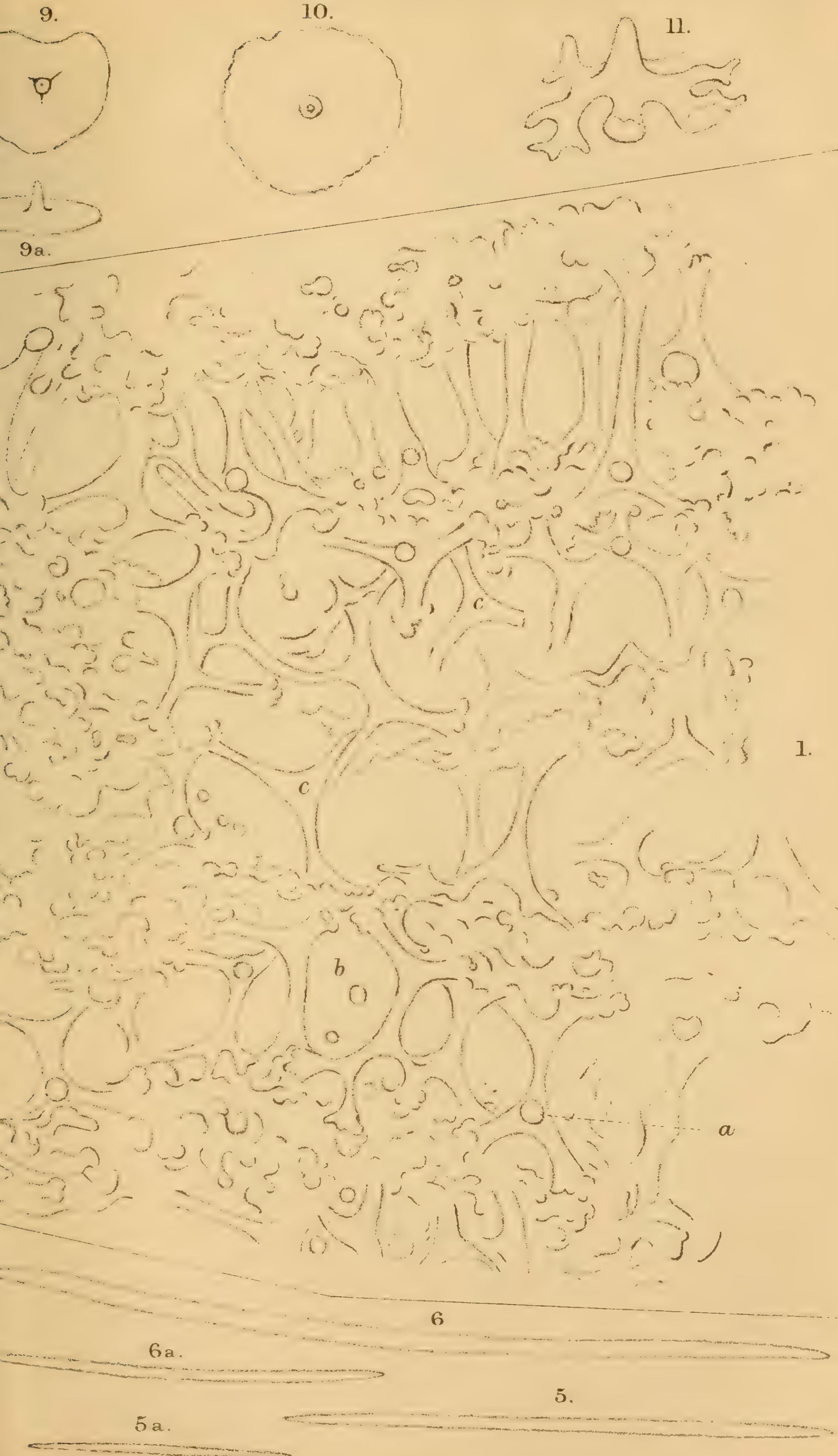
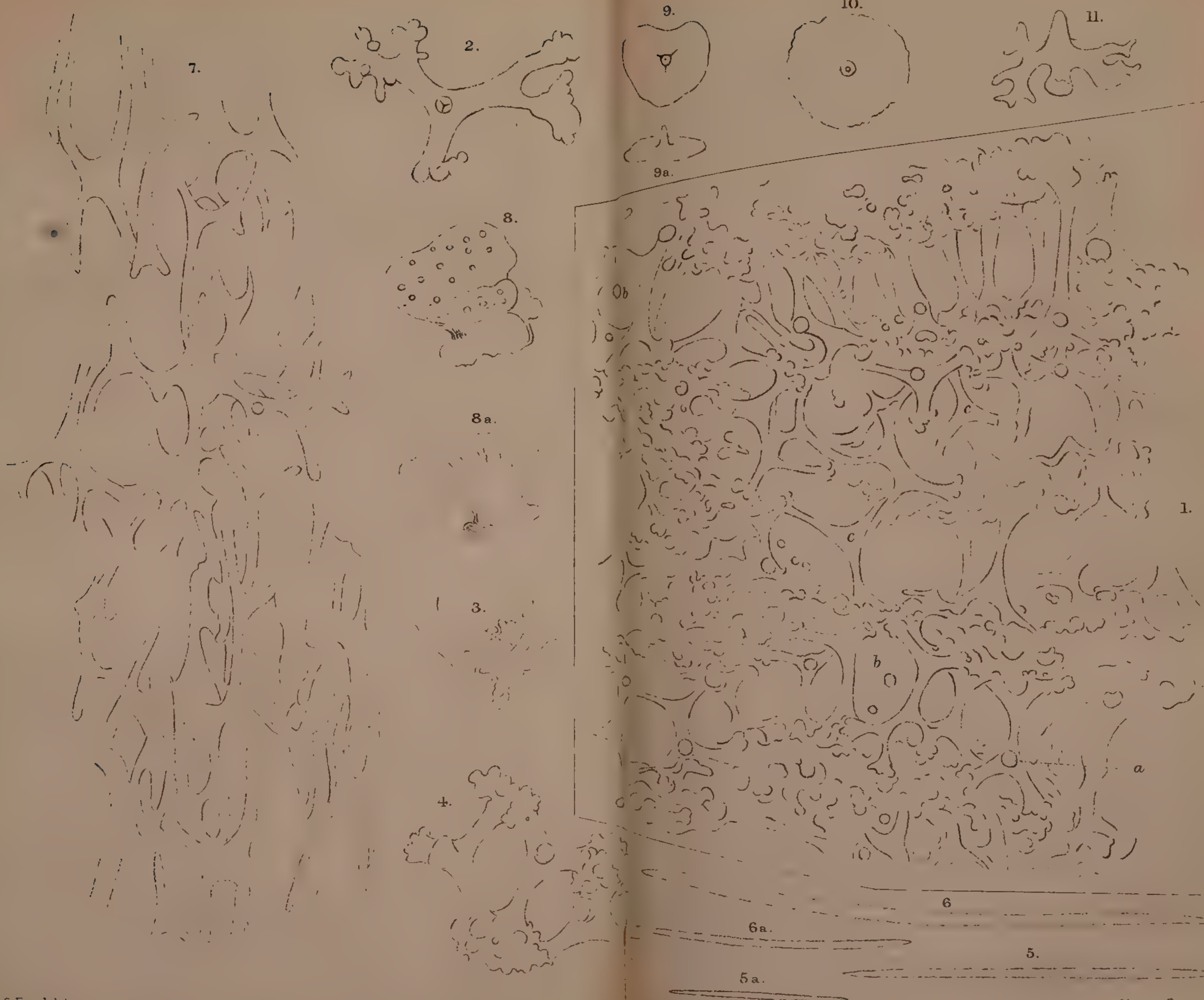


A.S.Foord. lith.



Mintern Bros. imp.



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garded as a great boon to palæontologists; but at the same time he thought there was some difficulty in ascertaining the structure, and in recognizing *Siphoniæ* by their structural characters. He inquired of the author what he regarded as the distinguishing characters of the genus *Siphonia*. He referred to the sponges of the chalk of Yorkshire, which he found to be siliceous by treating them with acid.

Mr. Hulke inquired of the author what was the nature of the triradiate cavity seen in the spicules with botryoidal branches.

Prof. Judd referred to the discovery of Radiolarians in Carboniferous rocks near Chester, and stated that, on dissolving portions of the rock which clearly show the Radiolarian structure, the latter entirely disappears, but at the same time the rock itself furnishes small crystals of quartz. This seemed to be confirmatory of Mr. Sollas's statements.

Prof. Tennant stated that the late Dr. Bowerbank's collection of fossil Sponges, including many microscopical sections, is now in the British Museum, and that a fine series of Greensand fossils, containing many Sponges, collected by the late Mr. Bensted, is in the Museum at Maidstone.

The President asked the author whether he knew of any other cases of replacement of silica by calcareous matter. He suggested that the supposed Radiolaria of the Carboniferous rocks of Cheshire might possibly belong to somewhat Radiolarian types in which the solid parts were calcareous instead of siliceous. So far as he knew, there were no instances of the replacement of silica by carbonate of lime in the Radiolaria of the Barbadoes earth.

The Author, in reply, said that the Yorkshire sponges mentioned by Mr. Charlesworth are often siliceous externally and calcareous within. The invention of their treatment with acid was rather an unfortunate one, as this treatment often removes delicate surface spicules, and thus modifies the external characters. The form of spicules which he had described as possessing three botryoidal arms were peculiar to the recent sponge *Discodermia* and to *Siphonia*, and would suffice to distinguish the genus. The triradiate cavity shown in the head of these spicules represents a triradiate canal. He stated that he had seen Radiolarian forms from the Carboniferous deposits of Scotland among the spicules which had been detected by Prof. Young. In *Stromatopora*, which he held to have been originally siliceous, the silica was converted into carbonate of lime, and similar crystals of silica to those already referred to were found here. The silica of the organism and that of quartz were in very different conditions as regards solubility; and the former contains organic matter. He thought that when remains were found presenting precisely the characters of living organisms we were bound palæontologically to regard them as of the same nature; and after referring to various instances cited, he said he thought the case of the substitution of siliceous by calcareous matter might be regarded as fully established.

44. NOTE *on a* SPECIMEN *of* DIPLOXYLON *from the* COAL-FORMATION *of* NOVA SCOTIA. By J. W. DAWSON, LL.D., F.R.S., F.G.S. (Read February 21, 1877.)

IN a recent visit to the South Joggins, with the view of further studying the fossils of that district, and more especially of searching for reptilian remains in any erect stumps of *Sigillaria* that might have been exposed by the action of the waves, I was zealously aided by my friend Mr. Albert J. Hill, Manager of the Cumberland Mine*, who, after my departure, determined to take down some erect trees occurring in beds lower in the section than those containing the reptilian remains. In pursuing this investigation he discovered an erect tree twelve feet in height, having the whole of its woody axis perfectly preserved, *in situ*, and showing structure. As this appears to me to be important with reference to questions now in discussion, I beg to present to the Society Mr. Hill's description of the specimen and some remarks on its structure and affinities.

Mr. Hill thus describes the mode of occurrence of the specimen:—

"The tree in question stood partially exposed near the top of a perpendicular cliff, one hundred and twelve feet above the beach (fig. 1). The means of reaching and successfully extracting it from the massive sandstone stratum in which it was still half imbedded, was a problem of no easy solution. The difficulty, however, was overcome by an adventurous workman, who undertook, by means of a ladder attached by a rope to a small tree upon the surface, to descend to a sloping ledge formed by the jutting-out of a coal-seam and superincumbent débris, and to form there a 'standage' from which subsequent operations could be carried on. Having successfully established himself in his eyry, the tree, which, from exposure to the weather and the action of the frost, readily divided itself into sections, was sent up piece by piece in safety to the surface.

"On removing the clay which covered the upper extremity of the stump, I was struck with the unusual appearance of a well-preserved stem or axis in the sandstone cast, and which exhibited structure in a remarkably distinct manner, though here from exposure it had become somewhat friable. Further down, however, it was perfectly calcified and showed its structure distinctly, except in the centre, which was occupied with a core of perfectly cylindrical form and consisting of grey sandstone. The outer surface of the axis is longitudinally striate, without joints, and occupies a position near the side of the cast, from which it is separated throughout by rather more than its own diameter, or about three inches.

* We were so fortunate as to find an erect *Sigillaria* containing the remains of no less than *thirteen* small batrachians, belonging to six species, two of them new. So soon as these can be worked out from the matrix, I hope to bring them under the notice of this Society.

Fig. 1.—*Surface of the Cliff, showing the position of the Tree.*
(From a sketch by Mr. Albert J. Hill.)

a, a. Coal-seams. *b.* Superficial Drift.

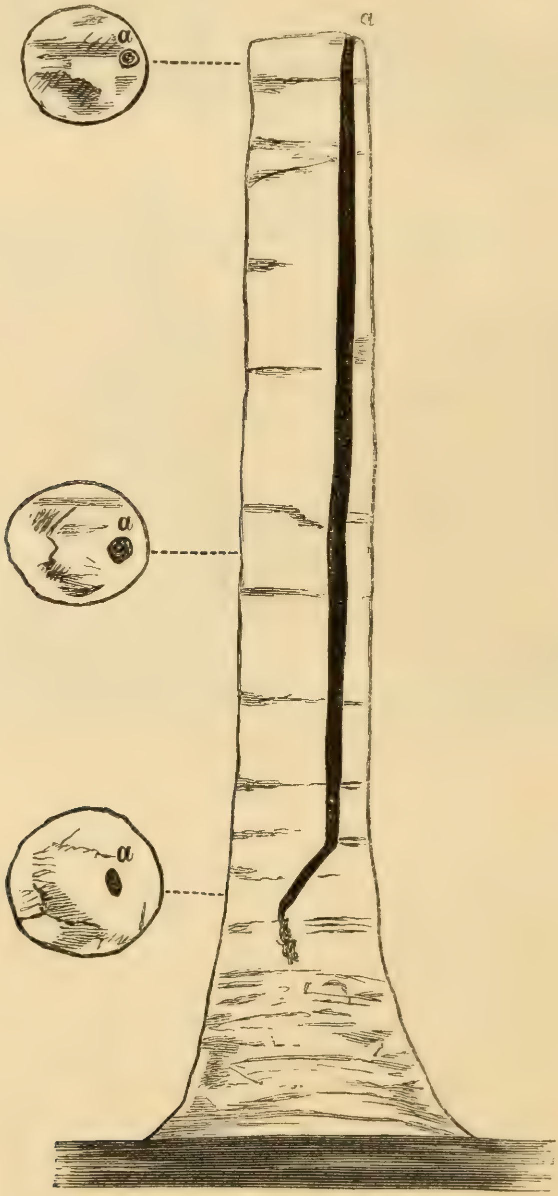
"The stump was found to originate in a six-inch coaly seam, thirty-five feet five inches below that worked in the Cumberland Mine in coal-group 29*a* of Dr. Dawson's section, or division 4, section xi. of Sir W. E. Logan's section*, and separated by an underclay of 3 feet 4 inches from the underlying seam of coarse coal in group 30. The downward termination of the tree exhibited spreading roots, which were, however, in a friable condition and not well preserved, but exhibited on the surface, inside the coaly bark, a fine transverse striation, scarcely visible to the naked eye. The surface-markings of the trunk are also indistinct; but it shows a coarse longitudinal striation and indications of broad flat ribs. The accompanying drawings (figs. 1 and 2) will illustrate the mode of occurrence of the tree in the cliff, and also the principal dimensions of the trunk and axis, with the position of the latter in the cast."

The axis of this remarkable stem is about six centimetres in its

* Acadian Geology, 2nd edition, p. 171.

greatest diameter, and consists of a central pith cylinder and two concentric coats of scalariform tissue (fig. 3). The pith cylinder is replaced by sandstone, and is about one centimetre in diameter. The inner

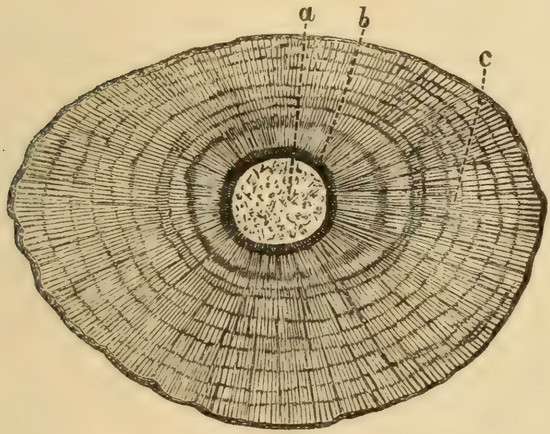
Fig. 2.—*Longitudinal and Transverse Sections of the Trunk, showing the position of the Axis.* (Scale 2½ feet to 1 inch. Drawn by Mr. Hill.)



a, a, a. Internal axis.

cylinder of scalariform tissue is perfectly continuous, not radiated, and about one millimetre in thickness. Its vessels are somewhat crushed, but have been of large diameter. Its outer surface, which readily separates from that of the outer cylinder, is striated longitudinally. The outer cylinder, which constitutes by much the largest part of the whole, is also composed of scalariform tissue; but this is radially arranged, with the individual cells quadrangular in cross section. The cross bars are similar on all the sides and usually simple and straight, but sometimes branching or slightly reticulated. The wall intervening between the bars has extremely delicate longitudinal waving lines of ligneous lining, in the manner first described by Williamson*, as occurring in the scalariform tissue of certain *Lepidodendra* (fig. 4). A few small radiating spaces, par-

Fig. 3.—*Axis of* Diploxylon, *as seen on weathered surface.* (Natural size.)



a. Medullary cylinder, filled with sandstone.
b. Medullary sheath of scalariform tissue.
c. Exogenous cylinder of scalariform tissue, radially arranged and with concentric lines.

Fig. 4.—*Portion of Scalariform Tissue.* (Magnified.)

tially occupied with pyrites, obscurely represent the medullary rays, which must have been very feebly developed. The radiating bundles passing to the leaves run nearly horizontally; but their structure is very imperfectly preserved. The stem being old and probably long deprived of its leaves, they may have been partially disorganized before it was fossilized. The outer surface of the axis is striated longitudinally, and in some places marked with impressions of tortuous fibres, apparently those of the inner bark. In the cross section, where weathered, it shows concentric rings; but under the microscope these appear rather as bands of compressed tissue than as proper lines of growth. They are about twenty in number. Though apparently of very lax tissue, the wood of the outer cylinder may, in consequence of the strength of the vertical rods and transverse bars of

* Monthly Microscopical Journal, August 1869.

ligneous lining, have been of considerable firmness, which would, indeed, seem to be implied in the manner of its preservation within the hollow bark.

No trace remains of the thick inner bark, which is represented by sandstone; and, as usual in these trees, the outer bark consists of structureless coal. The outer surface of the sandstone cast shows longitudinal striation; but the ribs, if present, are very indistinct; and only a few somewhat remote and indistinct depressions remain as indications of the leaf-scars. The roots, as stated by Mr. Hill, show a delicate transverse wrinkling, which may be an effect of pressure. In one small portion only could I recognize on them the remains of the stigmarioid areoles.

When treated with an acid, the calcareous matter is removed and the wood remains as a crumbling dark brown mass, which shows the structure very perfectly when diffused in water or Canada balsam. When this brown substance is ignited it burns with scarcely any flame, and leaves a reddish ash, in which the bars of the scalariform tissue are still quite apparent.

In some parts of the axis the medullary cylinder becomes reduced in size, and the inner scalariform cylinder proportionally thickened. Towards the top of the axis there is an indication of bifurcation, which may, however, be a deceptive appearance resulting from mechanical splitting due to decay.

The structures above described are obviously those of *Diploxylon* of Corda; and the tree may be regarded as a *Sigillaria* of this type, the only well-characterized one yet found in the Nova-Scotia coal-field. In comparison with the axes of *Sigillariæ* which I have described in former papers presented to this Society, it agrees in the general arrangement of the tissues, but differs considerably in their character. The pith cylinder is smaller and not Sternbergian. The scalariform tissue of the inner woody cylinder and medullary sheath is much coarser. The outer cylinder, instead of pseudo-scalariform and porous tissue, like that of Cycads, has coarse scalariform tissue. In these respects the trunk resembles those recently described by Williamson*, and is also like specimens from Arran shown to me some years ago by Mr. Carruthers. From the examples given by the former, I cannot doubt that such trees come within the limits of the genus *Sigillaria*, as determined by the markings of the bark; and that they belong to that low type of these trees in which the woody matter, while arranged in an exogenous manner, is wholly scalariform, and with the medullary rays little developed. As Williamson has shown, these trees approach closely to *Lepidodendra* in their structure. On the other hand, the *Sigillariæ* of the type of *S. elegans* of Brongniart, and of *S. spinulosa* of Renault and Grand'-Eury, have a somewhat higher organization, and point to the still more elevated type described by me in 1870. There would thus appear, as I pointed out in my paper on the structures of coal in 1859, and in that on the conditions of accumulation of coal in 1865,

* Transactions of the Royal Society.

and still more fully in that on *Sigillaria* and its allies in 1870*, several distinct types of Sigillarioid trees; though whether we can, as suggested in those papers, separate those with the *Clathraria* and *Favularia* styles of markings from the other *Sigillariæ*, is still doubtful. The French authors above cited regard their *S. elegans* and *S. spinulosa*, which are of the *Favularia* type, as true *Sigillariæ*, and hold that their woody cylinder, with its fibres in radial series and with medullary rays and radiating bundles proceeding from the inner cylinder, allies these trees with the gymnospermous exogens. Williamson regards his *Sigillariæ* of the *Diploxylon* type of structure as probably cryptogamous and allied to *Lepidodendron*, though maintaining that the structure of these stems is truly exogenous. There can scarcely be any doubt that the higher type of *Sigillaria*, which I described in 1870, and which, I think, represents the ordinary coarsely-ribbed species of the type of my *S. Brownii*, are allied to gymnosperms. Prof. Newberry and the writer have adduced strong circumstantial evidence to show that *Sigillariæ* produced the fruits known as *Trigonocarpa*, found so constantly with their remains. Goldenberg, on the other hand, has figured a sort of strobile as attached to *Sigillaria*. Williamson has figured fruit-scars, which he regards as attachments of cones. I have figured† well-preserved fruit-scars of two species which cannot have borne strobiles, but may very probably have borne *Trigonocarpa* or racemes of such fruits. These facts, I think, taken along with those of structure, tend to show that there may be included in the genus *Sigillaria*, as originally founded on the markings of the surface, species widely differing in organization, and of both gymospermous and acrogenous rank. This conclusion is further confirmed by the fact, which I have long ago amply demonstrated in my papers on the structures and mode of accumulation of coal, that in the great coal-beds tissues of gymnospermous character, but distinct from those of Conifers, exist to an enormous amount, while no other trees are found in connexion with these beds to which such tissues can be referred except the *Sigillariæ*.

Should this view be finally established, these trees will present an interesting link of connexion between the gymnosperms and the higher cryptogams. They connect the *Lepidodendra* with the Cycads and Conifers in the gradations of exogenous structure seen in their wood and bark, and also in the remarkable transitions which they exhibit between woody tissues of the discigerous type and those scalariform tissues which, though resembling scalariform vessels properly so called, yet in these plants are evidently arranged in the manner of woody fibres, and take the place of these in the construction of the stem.

The tendency of investigation of late has been to convey the impression that the Sigillarioid and Lepidodendroid trees of the coal-formation were of one somewhat uniform and monotonous type. On the other hand, the great number of species of these trees indicated

* Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 147.

† Quart. Journ. Geol. Soc. vol. xxii. Report on Fossil Plants of the Lower Carboniferous: 1873.

by external markings, the number of kinds of gymnospermous fruits and cryptogamous strobiles associated with them, and the great range of organization presented by their stems, indicate a considerable variety of generic and specific types, probably bridging over, by means of the class of Gymnosperms, the great gap at present existing between the Angiospermous and Acrogenous trees, and giving an amount of diversity to the forests of the coal-period of which we have as yet little conception. A further illustration of this is presented by the remarkable species of *Cordaites* recently described by M. Grand'Eury, and which furnish another varied series of Gymnospermous type.

45. *The* Steppes *of* Southern Russia. By Thomas Belt, Esq., F.G.S. (Read June 20, 1877.)

I first saw the steppes of Southern Russia in the spring of 1873, and under circumstances calculated to impress some of their peculiar features on my mind. I had, in company with a friend, crossed the Caucasus from Tiflis to Vladikafkas. We had travelled by the great military road through the pass of Dariel, and down the stupendously precipitous valley of the Terek. At Vladikafkas we came out on a vast plain, sensibly level as far as the horizon, and running in between and around the spurs of the mountains, like the sea around the headlands of a precipitous coast. I have since then travelled for thousands of miles over similar plains in Asiatic and European Russia; but the vividness of my first impressions of the steppe of Vladikafkas has not been dimmed, although my interest in the great plains has been increased by the personal experience I have since gained of their almost continental extent.

At Vladikafkas I saw no sections to a greater depth than 15 feet. These showed the upper surface of the plain to be composed of about 4 feet of black soil, resting on a fine grey loess-like clay, the base of which was not seen. I was only able to make a short search, and found no organic remains.

In 1875, and again in 1876, I travelled much in Southern Russia; and I propose to lay before the Society the information I have obtained respecting the extent, the constitution, the geological age, and the probable origin of the steppe-formations.

Very fine sections are to be seen around the shores of the Sea of Azof, where for many miles there are continuous cliffs, often more than 100 feet in height, composed almost entirely of the sands and clays to which the Russian geologists have given the name of "diluvium." The strata near Taganrog have been noticed by Sir Roderick Murchison in his 'Geology of Russia in Europe;' but the diluvial beds were not described in detail by him. Immediately below the town the beds are masked by débris; but after passing the mole there are fine sections several miles in length. The following sections (figs. 1 & 2), which I took on the coast, about two miles apart, give a fair representation of the general run of the beds.

Sarmatic, or Passage-beds.—The lowest beds seen are stratified limestones full of shells. The strata rise to about 10 feet above the level of the sea; and as they retain the same position for several miles along the shore, they must be nearly, if not quite, horizontal. Some of the beds are arenaceous; and the topmost are much decomposed, so that the shells can be picked out from the matrix. The commonest forms are *Mactra podolica*, *Tapes gregaria*, *Cardium plicatum*, and *C. obsoletum* amongst the bivalves, and *Bulla Lajonkairiana*, *Buccinum duplicatum*, *B. Verneuilli* and *Trochus podolicus* amongst the univalves. They are the "Passage-beds" of Murchison, and the "sarmatische Schichten" of Suess.

Fig. 1.—*Section ½ mile W. of Mole, Taganrog.* (Scale 50 ft. to 1 inch.)

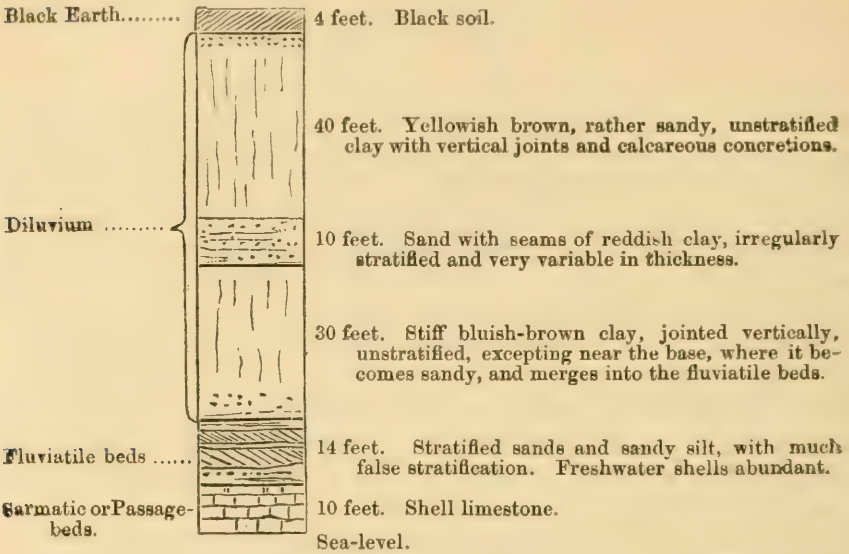
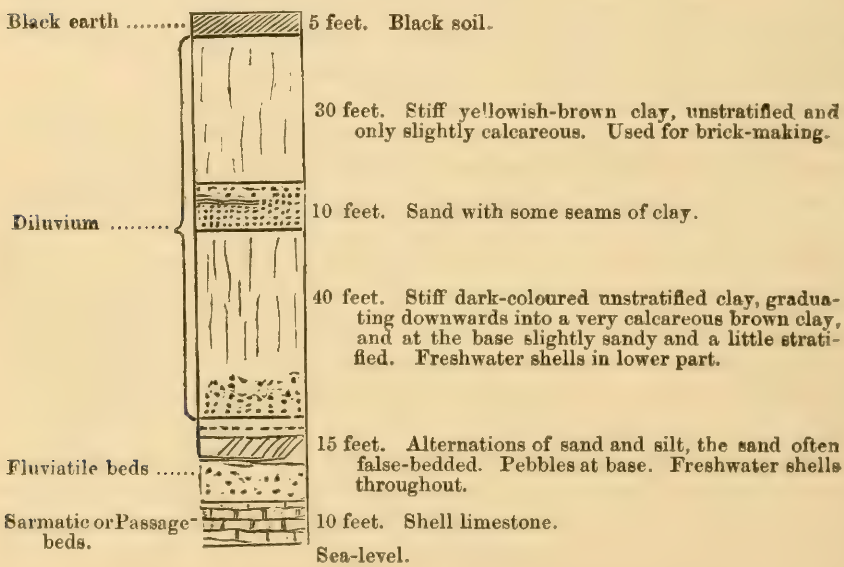


Fig. 2.—*Section 2½ miles N.W. of Mole, Taganrog.* (Scale 50 ft. to 1 inch.)



Fluviatile Beds.—Resting on the denuded upper surface of the limestones is a series of stratified sands and silts. The lowest bed is partly formed of broken pieces of the underlying limestone, and also contains pebbles of quartz, flint, and sandstone, amongst which are rolled shells of *Paludina* and *Cyclas*. Above this are strata of sand and silt, the sand often false-bedded. In some of the higher beds of sand there were groups of the shells of *Unio pictorum*, var. *elongatula*, with the two valves united, lying, as the mollusk had lived, with the smaller end of the valves pointing upwards. I saw as many as twenty individuals in some groups, all lying in the same position, and with even the ligament still preserved. Entire shells of a species of *Anodon* occurred in the same position, but singly in more silty beds; they were so tender and brittle that they fell to pieces when I attempted to extract them. Shells of *Paludina*, *Bithinia*, and *Cyclas* were very abundant, especially in the false-bedded sands; but they looked as if they had been drifted, and the valves of the *Cyclas* were never united. The beds upwards became more silty. In following the formation along the cliff, it was found to be very variable, and often contained no shells. Whenever the sands were false-bedded the drifted shells of *Cyclas* and *Paludina* appeared again. At the point where the section fig. 2 was taken, the beds graduated upwards into the diluvial clay, and in the upper part contained shells of *Planorbis complanatus*. In the more sandy layers I found a few fragments of *Adacna edentula* and drifted valves of *Dreissena polymorpha*. Dr. Jeffreys has found amongst the shells a single fragment of *Cardium edule*; and fragments of *Buccinum* and other shells from the underlying Sarmatic beds are not uncommon. I also obtained a few small pieces of bone *.

The molluscan fauna of the fluviatile beds, although separated from the present time by the whole period of the deposition of the thick and wide-spread diluvium, shows a remarkable resemblance to that of the present Sea of Azof. On the beach, thrown up by the waves, I found shells of *Adacna edentula*, *Dreissena polymorpha*, *Unio pictorum*, var. *elongatula*, and others, the same as those of the prediluvial sands. The principal difference in the fauna is, that the shells of *Adacna* and *Dreissena* are much more abundant on the present beach, and have their valves united, indicating, probably, that the water is now more saline.

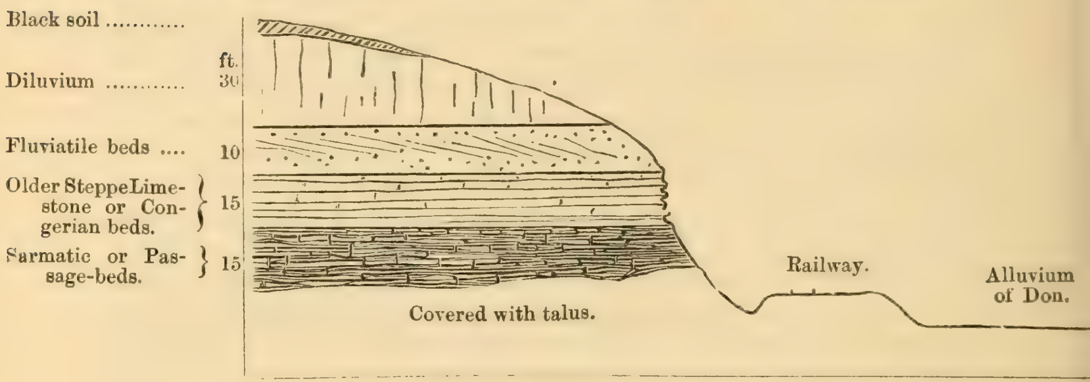
Diluvium.—Above the fluviatile beds lie thick deposits of clay and sand, which generally present three divisions, although the middle one is sometimes absent. The lowest of these is a stiff dark brown or bluish brown unstratified clay, often calcareous. In some parts it becomes a little sandy at the base, and graduates into the stratified beds below. At the point where the section fig. 2 was taken, I found shells of *Lithoglyphus*, *Bithinia*, *Fairbankia*, *Valvata*, *Planorbis*, *Succinea*, and *Helix* in the lower part, where it began to be obscurely stratified, and *Planorbis complanatus*, also, in the first six feet of the unstratified clay. The lower clay is succeeded upwards by irregular beds of sand, and these, again, by a thick deposit of yellowish-brown unstratified clay. In some places the upper clay contains numerous calcareous concretions; in others it is more arenaceous, and is then used for brick-making. This bed at the top graduates into the black earth, or "Tchornozem," which is merely a

* For a complete list of the shells, by Dr. Jeffreys, see the end of this paper.

surface modification of the fine diluvial clay, produced by the penetration of roots carrying down organic matter.

About eleven miles north-east from Taganrog, at the village of Siniafka, the following section (fig. 3) is exposed near the railway from Taganrog to Rostof.

Fig. 3.—*Section near Siniafka*, 11 *miles N.E. of Taganrog.*



The lowest strata seen at this place are thinly laminated beds of dark sandy silt, containing impressions of *Tapes gregaria* and a few other shells belonging to the Sarmatic or Passage-beds.

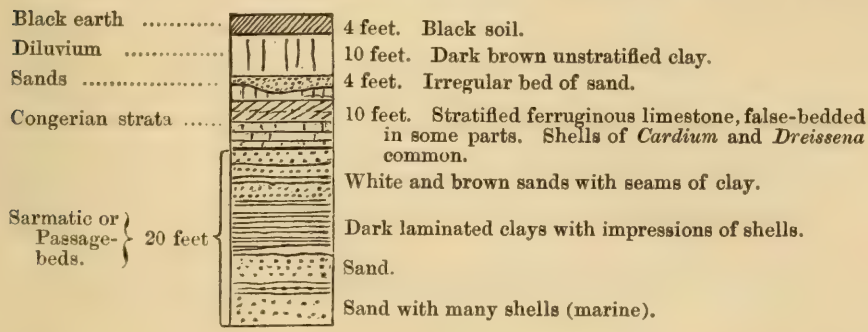
Above these lie about 15 feet of limestone, composed, in a great measure, of the shells of a species of *Dreissena*. Some of the lowest beds were entirely composed of these shells, held together by a little calcareous cement. The upper beds are sometimes concretionary, and resemble in appearance some of the magnesian limestones of the north of England. These limestones are the Older Steppe Limestone of Murchison, and the Congerian or Ingersdorf strata of the Austro-Hungarian geologists.

Above the limestone lies about 10 feet of yellow sand, which becomes a little loamy upwards. At the base I found fragments of limestone and pebbles of quartz and quartzose sandstone. I saw no shells; but fragments of bones and of tusks of the Mammoth were not uncommon. I picked several pieces out of the undisturbed sand; and the workmen employed in getting ballast for the railway had thrown on one side many others.

In ascending the estuary of the Don a similar succession of beds is often exposed, though one or more members of it are frequently absent through denudation; but everywhere the diluvium caps the series, resting sometimes on the Congerian strata, and sometimes on the Sarmatic beds. I sketched the following section (fig. 4) near Nova Tcherkask, the chief town of the Don Cossacks.

The cliff near Nova Tcherkask is mostly formed of the Sarmatic and Congerian strata, and there is a capping of only about 18 feet of black earth, diluvium, and sand; but the diluvium thickens inland, and forms hills rising more than 50 feet above the general surface. In the Museum at Nova Tcherkask I saw remains of the Mammoth and Irish Elk; and Captain Scariatine, to whom I must

Fig. 4.—*Section below Nova Tcherkask.* (Scale 50 feet to 1 inch.)



express my obligations for much kindness and information, ascertained for me that they had been obtained near the town in the lower part of the diluvial clay.

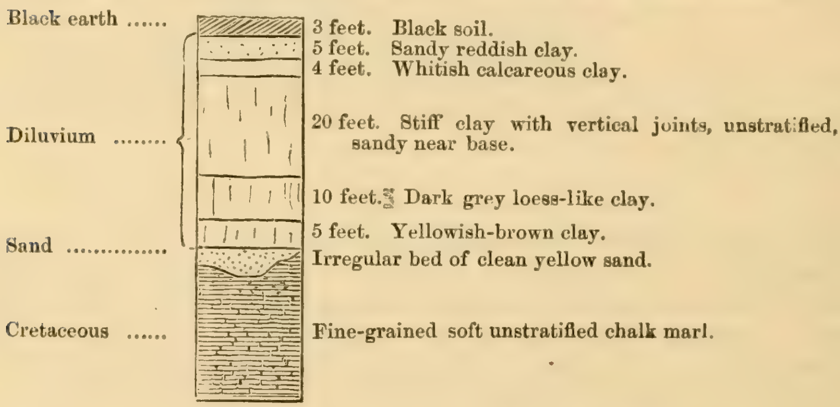
Going inland from Taganrog northward, along the line of the Taganrog-and-Karkov railway, the bed-rocks are at first completely concealed beneath the diluvial clay. Some of the sections in small valleys cut down through about 50 feet of it without reaching its base. Near Pokrofsky, about eight miles north of Taganrog, the Steppe Limestone comes in places nearly to the surface, and is exposed in the railway-cuttings and in the small valleys. The way in which the clay covers the limestone and fills up inequalities worn in it shows that the latter had been much denuded before the former was spread out. In some parts a knob of limestone reaches nearly to the surface of the level steppe, the flat character of which is entirely due to the diluvial clay. In others, some of the old valleys in the limestone have been partly opened out again in the clay that had filled them up. The old Aralo-Caspian sea, in which the limestones were deposited, had been lowered, and the strata subjected to subaerial denudation, before the diluvium was deposited and the irregularities of the older rocks levelled up to an even surface.

From Pokrofsky, the country on the line of railway gradually rises northward as far as Nikitofka, situated in the Donetz coal-field, where it attains a height of about 1000 feet above the sea. Up to 800 feet above the sea the diluvial clay is generally thick; but above that height in the coal-district it is thin and irregular, and often consists of not more than a few feet of the black soil. Eastward from Nikitofka the surface of the country rises still higher, and attains its greatest elevation near Evanofka, at a height of 1210 feet above the sea. The country here loses its steppe-like appearance, and the Carboniferous strata often crop up in long ridges. The slopes of the hills, however, are all covered with the diluvial clay, and most of the irregularities of the Carboniferous rocks levelled up by it.

Northward from Nikitofka the country gradually lowers again, and near the city of Karkov is only about 400 feet above the level of the sea. Below 800 feet it is thickly covered with the diluvial clay, and the bed-rocks are seldom seen.

Karkov is principally built on the alluvial plain of a tributary of the Don. The river has cut through the diluvium down to rocks of Cretaceous age. Two branches of the stream join at the city. On the hill between the two, extensive Government buildings were being erected when I was there; and in the excavations for the foundations of these and some adjoining sand-pits I obtained the following section (fig. 5).

Fig. 5.—*Section near Karkov.* (Scale 50 feet to 1 inch.)



From Karkov westward, all the way to the Russian frontier at Wolochisk, the traveller passes for hundreds of miles continuously over the diluvial beds, excpting when he crosses some of the valleys of the larger rivers, which have cut down through it to the older rocks. In going and returning between Wolochisk and Karkov, a distance of about 600 miles by railway, I passed one way in day-light much of that which the other I missed seeing in the night-time; and although I was constantly on the outlook, I only saw two exposures where the bed-rocks came to the surface, although cuttings through the rolling steppes were numerous. Whenever the older rocks were seen, as at Olviopol, on the river Bug, it was evident that they had been worn into valleys and hills before the outspread of the diluvium, and that the flatness of the country was due to the latter, the old irregularities having been filled up by it.

I found at Wolochisk, in some clay that was thrown out of a pit, which was being sunk in the diluvium for a well, some shells of *Succinea* and *Pupa*. They came from a depth of about 7 feet from the surface, and were imbedded in stiff yellowish-brown unstratified clay, throughout which were also scattered some small angular pieces of limestone. Wolochisk is situated on the high steppe which stretches away to the east in a great flat expanse of country.

To the west there is a descent into the valley of a tributary of the Dniester, on the other side of which is the Austrian frontier town of Podwolochisk. Westward from Podwolochisk the country gradually rises, and beds of limestone containing marine shells occasionally come to the surface, whilst the hollows between these knolls of the older rocks are filled with diluvial clay. The diagram, fig. 6 (p. 850), shows the position of the surface-beds at Wolochisk and Podwolochisk.

In rising from the alluvial plain at Podwolochisk westward some deep railway-cuttings had been made; and these were being widened at the time of my visit, affording me an excellent opportunity of examining the diluvial beds. At the point marked $\times\atop\times$ in the diagram I obtained the section, fig. 7 (p. 850).

The lowest bed of the diluvium seen here (marked 3 in fig. 7) is a yellowish brown fine clay, rather sandy, and breaking into irregular flakes, as if the pressure of the beds above had given to it a sort of slaty structure. Shells of *Helix hispida*, *Succinea oblonga*, and *Pupa marginata* were scattered through the upper part of the stratum. Above this lies about 20 feet of rather sandy clay, with obscure signs of stratification. I could find no shells in this clay; but this part of the section was much hidden by soil slipped down from above.

The topmost bed of the diluvium is composed of about 10 feet of yellowish-grey unstratified calcareous clay. Shells are abundantly scattered through it, the most common being *Succinea oblonga* and *Pupa marginata*. I also gathered *Helix hispida*, *H. minuta*, and *H. ericetorum*, var. *minuta*. It also contains fragments of Miocene shells and angular pieces of limestone.

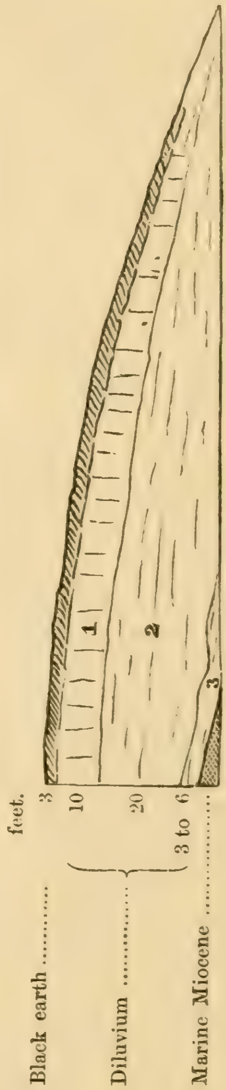
The resemblance of these clays to the beds of the Rhine and the Danube, both in their composition and fossil contents, is most remarkable. There is no question of this deposit being the diluvium of the south of Russia; and, as I have already mentioned, it can be followed continuously, excepting where cut through by the larger rivers, all the way to Karkov. Westward from Podwolochisk, through the province of Galicia, the same clay covers most of the country to a height at least of 1200 feet above the sea. Near Zloczou the black earth rests directly above shaly débris, and the country loses its steppe-like appearance, and is more broken up into hills and valleys.

In November 1875, I tried to trace the diluvium northwards from Karkov to its junction with or change into the northern drift that covers the north of Russia to similar heights as the diluvium further south. I found the country covered with diluvial clay all the way to the city of Orel, on one of the tributaries of the Oka, and near the top of the water-shed between that river and the Dnieper. At Orel the low hills bounding the valley are all covered with from 10 to 30 feet of unstratified yellowish brown clay, containing calcareous concretions; and here I got the first indications of the northern drift in a few pebbles of quartzite scattered through the clay.

Fig. 6.—Diagram Section at Podwolochisk.

a. Alluvium. 1. Diluvium. 2. Marine Miocene. ×, ×, ×. Places where land-shells occur in Diluvium.

Fig. 7.—Section west of Podwolochisk. (Scale 50 feet to 1 inch.)



For 70 miles north-westward from Orel the country is a great undulating plain, everywhere covered with clay; but unfortunately a snowstorm came on, and covered up the sections before I arrived at the first large boulders from the north. Between Smolensk and Orsha there are many huge northern blocks lying on the surface; but in consequence of the snow I could not trace their relation to the diluvial clay. Sir Roderick Murchison has, however, done so. In his 'Geology of Russia in Europe,' he has described the northern drift as extending all the way from the German Ocean, on the west, to the White Sea, on the east, a vast zone of country, nearly 2000 miles in length, and from 400 to 800 miles in width, more or less covered with drift, with colossal blocks of crystalline rocks, the whole of which have been brought from Scandinavia, Finland, and Lapland. This detritus has been borne southwards in long zones, often separated from each other by depressions, occasionally of great width, in which few or no blocks are discernible. Hills or slopes, 200 or 300 feet high, are covered with blocks, whilst the intervening valleys are free from them. The Valdai hills, which rise to over 1100 feet above the sea, are strewn with blocks of granite, gneiss, greenstone, and porphyry, which have come from Finland. Murchison traced these blocks as far southward as Voroneje, 700 or 800 miles distant from the nearest edge of their parent country. In the southern limits of this zone he found that the materials were reduced to small size, and mixed with local débris. He traced the drift southward merging into the diluvial clay, and considers the latter a deposit from the same water over which the northern blocks were borne on icebergs. He says, "Extending as far southwards as currents or icebergs would transport them, it is very natural to suppose that where the northern boulders ceased to advance, the bottom of the then sea, remote from any disturbing force, would become covered with fine silt or mud"*.

Whilst northward the diluvial clay merges into the northern drift, south-westward it bears the same relation to the loess of the valley of the Danube. Thus, if instead of going eastward from Balta, to which place from Karkov I have traced the diluvial clay without break, we go southward, we may follow it, again without break, to Odessa, where it occupies the same position as at Taganrog, and contains the remains of the Mammoth at its base. South-westward from Odessa it wraps round the end of the Carpathians into the valley of the Danube. Admiral Spratt, in his well-known papers, has described the steppes of Wallachia, Bessarabia, and Moldavia, as rising in a gentle slope northwards from the Danube, and ascribes their smooth and level character to the hollows of the older denuded surface having been filled up by the drift-deposit. He figures a section near Bolgrod, showing that the older beds (which, from their fossils, belong to the Congerian formation) have been denuded, and afterwards covered up with diluvial clay, just as around the Sea of Azof. He found the same characters in the deposits of the steppe at Galatz and near Ibrail, as well as more in

* See *op. cit.* pp. 510, 513, 519, 524, and 562.

the interior of Wallachia. On approaching the Carpathians the deposits became more gravelly. The lower part of the Dobrudscha is also covered with the same clay; and at Kustenjah it is 100 feet thick *.

Continuing westward, and still passing over the same diluvial deposits, we reach the great plains of Hungary, which stretch from the Danube to the flanks of the Carpathians, and are everywhere covered with the "diluvium" of the Austro-Hungarian geologists. Dr. Peters, of Gratz, correlates the drift-deposits of Hungary with those of Bessarabia †.

In Hungary the diluvial clay is sometimes termed the "loess," and is so known westward. In the Vienna Basin it covers the Congerian or Ingersdorf strata, exactly as the diluvial clay does in South Russia, and contains the bones of the Mammoth accompanied by those of the Woolly Rhinoceros, and the implements of palæolithic man at its base. Dr. Edward Suess, of Vienna, informed me that it extended to heights of 1300 feet above the sea in the upper parts of the valley of the Danube.

The parallel relations of the strata of the Danube and the south of Russia are shown in the following tabular statement:—

	Valley of the Danube.	Southern Russia.
Quaternary.	1. Loess of the Vienna basin and diluvium of the plains of Hungary and Wallachia. Bones of Mammoth at base.	1. Diluvial clay with land-shells in upper part, and freshwater shells and bones of Mammoth at base.
	2. Fluviatile beds of Valpuk, in Bessarabia, with freshwater shells.	2. Fluviatile beds with freshwater shells and bones of Mammoth.
	3. Clays with *Hydrobia*, *Bithinia*, &c., 180 feet below the beds of the Danube and the Theiss.	3. Freshwater beds 300 feet below the surface at Astrakhan on the Volga.
Miocene.	4. Freshwater beds with *Paludina* and *Melanopsis*, "Paludinen- und Melanopsis-Schichten" of the Austro-Hungarian geologists.	4. Possibly the *Cyclas* beds of Murchison.
	5. Brackish-water beds. "Congerien Schichten" of Austro-Hungarian geologists.	5. Brackish-water beds, Congerian strata, Older Steppe Lime stone of Murchison.
	6. Sarmatic beds.	6. Sarmatic beds, Passage-beds of Murchison.
	7. Marine Miocene.	7. Marine Miocene.

I shall refer very briefly to the Miocene strata, and only so far as their study throws light upon the conditions under which the Quaternary beds were deposited. When the marine Miocene beds were forming, the water of the Vienna basin was connected with the Mediterranean, and extended eastward over the present Black Sea, Caspian, and Aral areas, probably as far as Khiva. The characteristic mammals of this stage are *Mastodon angustidens* and

* Quart. Journ. Geol. Soc. vol. xiv. p. 203, and vol. xvi. p. 281.

† Geol. Mag. 1868, p. 63.

M. tapiroides. In the Sarmatic beds we have evidence of a great change in the conditions of the Vienna and Aralo-Caspian areas. The communication with the Mediterranean sea was interrupted, and an immense isolated basin formed, in which the Sarmatic fauna was developed. This change to an isolated area, and probably a slight freshening of the water of the basin, was followed by a great change in the molluscan fauna; and we have the unusual geological phenomenon presented of a nearly complete replacement of the species of mollusks, whilst the land mammals remained the same, the two species of *Mastodon* found in the marine beds continuing through the Sarmatic period.

The next stage shows a further great freshening of the water of the Aralo-Caspian area (including that of the Danube and the Black Sea), and another corresponding change in the fauna of the Great Lake. The more purely marine genera, such as *Mactra*, *Tapes*, *Buccinum*, &c., disappear, and *Dreissena* and abnormal forms of *Cardium* become the dominant groups, accompanied by freshwater genera, such as *Paludina*, *Cyclas*, and others. The abundance of the shells of *Dreissena* or *Congeria* has caused its deposits to be named the Congerian strata. It is the Older Steppe Limestone of Murchison; and its characteristic mammals are *Mastodon longirostris* and *Hippotherium gracile.* The same mammals also characterize the next stage, when the western part of the Aralo-Caspian area was entirely freshened, and the *Paludina*- and *Melanopsis*-beds were deposited above the Congerian *.

From the marine Miocene up to and including the *Melanopsis*-beds the strata follow each other conformably; but above the latter there is a great break in the succession. No representatives of our "Crags" are known in the Vienna basin or in the Aralo-Caspian area, nothing, indeed, that can be classed as Pliocene. The witnesses of the great interval of time between the Miocene and the Quaternary are not actual deposits, but the great denudation of the Miocene beds that took place during it. As during this time there was no intrusion of the Mediterranean fauna, it is probable that the great basin drained to the north, either to the east or the west of the Urals, through some channel now concealed beneath the diluvium.

And this channel appears to have been gradually deepened, so as to lower the surface of the lake, not only to the present level of the sea, but below it; for the early part of the Quaternary period is marked here, as it is in other parts of the world, by the rivers running at lower levels, and cutting their channels deeper than their present beds. Dr. Peters has informed me that between the Danube and the Theiss, clays, with freshwater shells, are found at a depth of 180 feet below the beds of these rivers; and Murchison mentions the occurrence at Astrakhan of freshwater shells of existing species 300 feet below the town †. I have followed Mr. Alfred

* Th. Fuchs, Band lxxiii. der Sitzb. der k. Akad. der Wissensch. 1. Abth., Jänner Heft, Jahrg. 1876.

† *Op. cit.* p. 573.

Tylor in ascribing this lower level of the rivers to a general depression of the surface of the ocean, caused in the Glacial period by so much water being locked up, in the form of ice, above the level of the sea.

The next stage represented is that of the fluviatile beds at the base of the diluvial clay, containing recent species of freshwater shells and the remains of the Mammoth. These beds at Taganrog graduate upwards into the diluvial clay, of which, indeed, they form the basement. Beds of similar age in Bessarabia are considered by Dr. Peters also to be truly intercalated with the loess. It will therefore be convenient to discuss the origin of the fluviatile beds along with that of the diluvial clay. It seems scarcely doubtful that the conclusion of Murchison is correct, that the diluvial clay is the continuation southward of the northern drift. Nor do I see how it can be disputed that it is also the continuation and equivalent of the loess of the Danube. The bones of the Mammoth and the Woolly Rhinoceros occur in each of the areas, and, in every case that I know, only in the basement-beds of the deposits that I suppose to be contemporaneous. We are assured, not only by the occurrence of these mammals, but by the transport of the erratic blocks of Russia, that the deposits belong to the Glacial period; and in considering the question of their origin we are able at once to show that some of the theories that have been proposed to account for the formation of similar diluvial beds in other parts of the world fail when applied to those of Russia. Thus the Baron F. von Richthofen has suggested that the loess-like clays of the north of China have been formed from clouds of dust blown by the wind*. In Russia, even if we could imagine a whole country to be covered by thick beds of clay formed of dust blown from some unknown region, we should still leave unexplained the transport of the northern blocks for hundreds of miles across the plains. Even for the formation of the loess of the Rhine and the Danube the theory is unsatisfactory; for the land-shells contained in it are generally those that belong to damp places and climates, and the species that frequent dry and sunny spots are scarce. Again, some geologists have ascribed the outspread of diluvial deposits to great floods, produced, according to Mr. Alfred Tylor, by more abundant rains than now occur, or, according to Dr. Dana and Dr. Haast, by the melting of the ice-sheet at the close of the Glacial period. But the diluvial clay of Russia extends from the Carpathians to the Urals, covers the watershed between the rivers that drain to the north and those that drain to the south, and is entirely independent of the great river-valleys. The northern blocks have also been carried in the opposite direction to the flow of the northern rivers, and stranded on the flanks of the Carpathians up to heights of 1200 feet above the sea, and even higher.

We thus have the question narrowed down to one of two issues only. We require a great sea of water for the flotation of the ice-

* Report on the Provinces of Honan and Shansi. 1870.

bergs that carried the northern blocks southward. That water covered the Valdai Hills, which are over 1100 feet in height, and rose on the flanks of the Carpathians to over 1200 feet above the present sea-level, and was therefore sufficient also for the distribution of the diluvial clay and the loess of the Danube. There is no occasion to look for any other cause; but the questions still to be determined are, whether the water was that of the sea, or, if not, how it was dammed up to such great heights and in such immense volume. Sir Roderick Murchison was of opinion that nearly the whole of Russia had been submerged beneath the sea. And, indeed, it seems most reasonable to conclude, when we take into consideration that some of the boulders have been carried more than 700 miles from their parent rocks, and that the diluvial beds cover nearly the whole country, and are absolutely independent of the lines of drainage, that there must have been a sea-like expanse of water; and in Murchison's time there was no other way known by which such a submergence could be produced, excepting by the sinking of the land below the level of the ocean.

Yet the objections that may be urged against a marine submergence are very strong. We have seen that from the time of the isolation of the Sarmatic sea there is evidence of successive freshenings of its water until, at the time of the deposition of the *Paludina*-beds, it appears to have become perfectly fresh, at least in the western part of the basin. The surface of the lake was then lowered; and when, after a long interval, during which the Miocene beds were greatly denuded, the water again began to rise and to regain some of its former extended limits, we find, from the fauna contained in the fluviatile beds, that it was still quite fresh. Then succeeds the diluvial clay, in the bottom part of which a few freshwater shells still occur, whilst in the upper portion only land shells are found. Surely if the sea had again covered this area, as it did in early Miocene times, it would have left some memorials of its presence. We are precluded from imagining that they may have existed, but have been destroyed, by the perfect preservation of the freshwater and land shells.

Dr. Dawson, who is the principal advocate of a marine submergence of the northern parts of the continents of America and Europe in the Glacial period, has fully perceived the importance of the absence of sea-shells from most of the areas that he supposes to have been beneath the sea, and has offered some reasons to account for it. The freshening of the sea by the entrance of large rivers, or by the melting of ice, may, he thinks, have prevented marine animals from existing. I do not know of any evidence showing that the estuaries of large rivers are not suitable for the abundant sustenance of animal life. Prof. Nordenskjöld has lately shown that even the Kara Sea, within the Arctic circle, and freshened by the immense volume of water brought down by the Obi and Yenissei, is rich in mollusks, crinoids, crustaceans, and other forms of animal life *; and with regard to the melting of ice, there are mol-

* Nature, vol. xv. p. 124.

lusks, such as some of the species of *Leda*, that appear to thrive best in water freshened by it. But even if these reasons were sufficient for some parts of the northern continents, they would not apply to the area in question. For when the country was almost entirely covered by the sea, there could be few large rivers flowing from it; and the melting of the northern ice could not cool water in the latitude of the south of France so as to make it unfit for animal life.

Dr. Dawson has also pointed to the evidence, obtained by the 'Challenger' Expedition, that in certain areas of deep water there is a possibility that an excess of carbonic acid may remove all trace of calcareous organisms. This, however, only applies to abyssal depths; and the water that covered the south of Russia nowhere reached 2000 feet, the extreme height that I can find anywhere in Europe for the diluvial waters being about 1700 feet above the sea. The preservation of the land and freshwater shells, as I have already urged, also forbids us to believe that marine ones have been destroyed.

All the evidence and every line of argument seems to point to the conclusion that the submergence was not marine, but that it was fresh water that covered Central and Southern Russia, and sent up a great arm into the valley of the Danube. In a former paper that I had the honour to lay before the Geological Society, I put forward a theory to account for the formation of a great continental lake or sea of fresh water, that is in singular harmony with the requirements of the present case*. It is that, in the Glacial period, the ice accumulated at the northern ends of the Atlantic and Pacific Oceans, and advanced southwards down the sea-beds, blocking up the drainage of the continents as far as it extended.

I shall not now enter on details as to the conditions under which the ice accumulated, or the method and reason of its advance, as I have already elsewhere treated these questions at length †; but I propose to show how far the theory explains the phenomena in the district under consideration.

From the north-east extremity of Asia to the Pyrenees there is a range of high land, continuous excepting for two interruptions. One of these is through the Bosphorus and Dardanelles; the other between the eastern end of the Pyrenees and the western spurs of the Alps. The latter, I suppose, was blocked up by ice in the Glacial period; the former not cut through until after the formation of the great lake. To the north of this ridge the diluvial beds are nearly everywhere spread out, up to heights of about 1200 feet above the sea, and reaching to an extreme height of about 1700 feet; to the south of it they are nowhere to be seen. According to my theory, the basin so bounded to the south was completed by the advance of the Atlantic ice on the coast of Europe, and by that of the Pacific on the coast of Asia. The ice of the Pacific would hem in the north-eastern outlet as soon as it advanced as far as the

* Quart. Journ. Geol. Soc. vol. xxxii. p. 80.

† Quart. Journ. of Science, January and July, 1877

mountains of Kamtschatka; but that of the Atlantic would, on the western side, have to reach the latitude of Northern Spain, and coalesce with the ice of the Pyrenees or of the Cantabrian range, to complete the basin on that side.

The ice, as it advanced on the coasts of Europe and Asia, would probably enclose to the north of the continents great areas of salt water, so that the lake at first would be saline, but continually freshening as it rose. This more or less saline water would first reach the Aralo-Caspian region up the depression or great river-valley by which the drainage of that area had flowed northward. It is probable that it was at this time and by this channel that the present arctic element in the Caspian fauna reached the Aralo-Caspian area. As is well known, the Caspian at the present time contains, along with many mollusks that appear to be the descendants of species of *Cardium* and *Dreissena* of the Congerian strata, from which a few of them can scarcely be distinguished, some vertebrates, crustaceans, and mollusks either identical with or very closely allied to forms now living in the northern seas. Thus the mammals are represented by a Seal (*Phoca caspica*) so nearly allied to the Common Seal (*Phoca vitulina*), that many naturalists consider them only varieties of the same species. Mr. Andrew Murray says that so nearly allied is *Phoca caspica* to *P. vitulina* that, excepting for their geographical position, no one would think of separating them *. Amongst the fishes of the Caspian there is *Coregonus leucichthys*, a species also living on the northern coast. Amongst the crustaceans there are many interesting relations shown with the fauna of the Arctic Ocean. Amongst these I may mention *Idothea entomon*, which abounds in certain parts of the Caspian, and is found in equal abundance in the Kara Sea to the north of Siberia. There is also the *Mysis relicta*, another species of the northern seas, and several other closely related species. Amongst the mollusks we must, I think, omit *Mytilus edulis*, as it is contained neither in Middendorff's nor in Grimm's lists, so that probably one of the forms of *Dreissena polymorpha* has been mistaken for it. There is no doubt, however, about the common Cockle (*Cardium edule*), nor of the variety *rusticum*, which is found on every coast of the Caspian, and is also abundant in the White Sea. The presence of these northern species has sometimes been appealed to as evidence of a marine submergence; but it is to be noted that they are all known to live in brackish water, and most of them thrive in waters less saline than that of the open sea.

To this period, the first stage in the rising of the waters of the great lake, I think the Newer Steppe Limestone of Murchison must belong. I have not had an opportunity of studying it; but Murchison states that it forms the low steppes to the north of Astrakhan, and that it contains the bones of the Mammoth.

The fluviatile beds at Taganrog, and similar beds in the Lower Danube, mark the continued rising and freshening of the water

* Geographical Distribution of Mammals, p. 662.

as the ice of the Atlantic and the Pacific more effectually blockaded the northern outlets of the basin. This stage is well marked in Northern Germany by the wide-spread sands, with freshwater shells, that lie at the base of the Lower Boulder-clay between the Oder and the Elbe.

The fluviatile beds gradually merge upwards into more silty strata, and finally into the unstratified diluvial clay. The waters were now charged with muddy sediment, the presence of which and its copious deposition probably caused the destruction of the freshwater mollusks over most of the area submerged. Another more important break in the succession of life is well marked in Russia. Both in the north and in the south of that country the bones of the Mammoth and its associates are found only at the base of the diluvial beds. In Western Europe they occur both in the same position and in the overlying "Middle Glacial Sands and Gravels." As when found in the latter formation they occur singly and are rolled or broken, it is probable that they have been washed out of the older diluvial beds. As palæolithic man was also the contemporary of these animals, there seems to be a broad foundation for the hypothesis I have advanced, that his disappearance from Europe, as well as that of the extinct mammals, was caused by the same event—the rising of the great flood that overwhelmed the whole of Northern Europe up to 1700 feet above the present level of the sea, whilst most of the higher land was covered with ice. Palæolithic man, according to my reading of the evidence, only lived in Europe in prediluvial times.

The sands that lie above the lower diluvial clay at Taganrog are, I think, the equivalents of the Middle Glacial sands and gravels of Western Europe, which are largely developed in the north of Germany and in our own country. They mark, I believe, the sudden and tumultuous discharge of the first great lake by the breaking away of the ice dam of the Atlantic, causing an enormous rush of water, that swept away much of the diluvial clay and boulder-beds, and rearranged the materials, including the implements of palæolithic man and the bones of the prediluvial mammals, in great sheets of gravel spread out over the lower ground *.

The outlet to the Atlantic must have been soon closed up again, and the great lake reformed. The deposition of the Upper Diluvial Clay of South Russia and the Upper Boulder-clay of Northern Europe then commenced. The immense mass of sediment carried as far as the Black Sea, and the distant transport of the northern blocks in the same direction, are strong evidences that the currents flowed that way, and towards the Straits of the Bosphorus. It is therefore probable that the waters were ultimately lowered by the excavation of a channel between the Black Sea and the Mediterranean.

* See Quart. Journ. Geol. Soc. vol. xxxii. p. 80. There is some evidence that the waters rushed across Languedoc to the westward, which probably indicates that the barrier of ice that gave way was that between the Alps and the Pyrenees.

The fact that the water that then covered so much of Europe carried such a quantity of mud in suspension for hundreds of miles is an additional argument in favour of the conclusion that it was not salt; for we know that sediment is rapidly precipitated from saline solutions. These turbid waters appear to have been unsuitable for living creatures; for the shells contained in the Upper Diluvial Clay are either those of land mollusks or of freshwater ones that live in marshy places or small pools. Their presence in the loess of the great valleys may be easily accounted for by supposing that they were washed down from the slopes of the hills by heavy rains; but their distribution over the plains near Wolochisk cannot be thus explained. As I found angular pieces of limestone in the same clay at Wolochisk that contained the shells, I think it likely that shore-ice breaking up in the spring, and carrying shells that had dropped off the reeds growing around the margin of the lake, may have been the agent of distribution, especially as the *Succinea oblonga*, which was likely to abound in such situations, is much the commonest shell in the clays of the Steppe.

We have still to inquire what became of the Aralo-Caspian fauna, and how it was preserved during the time of the deposition of the diluvial clay. It was certainly then banished from the areas of the Danube and the Black Sea, the water there being both too muddy and too fresh for its existence; but probably to the east different conditions prevailed. The currents from the north, carrying in suspension the fine detritus from the glaciers of Scandinavia and of Central Europe, would be all directed towards the outlet through the Bosphorus, and their muddy waters would not extend far to the east. We may suppose that somewhere around the southern shores of the Caspian, or still more to the east, the Aralo-Caspian fauna found a refuge. There are numerous salt springs now around the shores of the Caspian; and in areas thus made saline those species that require brackish water might be preserved.

Dr. Gwyn Jeffreys has kindly examined the shells I collected in the fluviatile, diluvial, and recent deposits, and furnished me with the following lists of the species. The recent ones from the river Bug and the sea of Azof are given for comparison with those from the fluviatile beds and the lower part of the diluvial clay.

No. 1. Upper part of Diluvial Clay at Podwolochisk:—

Succinea oblonga, *Draparnaud.*
Helix hispida, *Linné.*
Helix ericetorum, *Müller*; var. minor, *Jeffreys.*
Helix pulchella, *Müll.*
Pupa marginata, *Drap.*

No. 2. Lower part of Diluvial Clay at Podwolochisk:—

Succinea oblonga, *Drap.*
Helix hispida, *L.*
Pupa marginata, *Drap.*

No. 3. Picked out of rain-wash on talus-slope of Diluvial Clay at Podwolochisk, same as in No. 1, with the addition of

Vertigo edentula, *Drap.*

No. 4. Lower part of Diluvial Clay at Taganrog :—

Lithoglyphus naticoides, *Férussac.*
Bithinia Leachii, *Sheppard.*
Melania, sp. (fragment).
Fairbankia, sp.; allied to F. bombayana, *Blanford.*
Valvata piscinalis, *Müll.*
Valvata macrostoma, *Steinbuch.*
Valvata, sp.
Planorbis albus, *Müll.*
Planorbis spirorbis, *L.*
Planorbis complanatus, *L.*
Succinea oblonga, *Drap.*
Helix pulchella, *Müll.*
Helix, sp. (fragment).

No. 5. Sands below Diluvial Clay at Taganrog :—

Dreissena polymorpha, *Pallas.*
Sphærium rivicola, *Leach.*
Sphærium solidum, *Normand.*
Unio pictorum, *L.*; var. elongata, *v. Mühlfeldt.*
Unio crassus, *Nilsson.*
Anodon, sp.
Cardium edule, *L.* (fragment).
Adacna edentula, *Pall.* (fragments).
Lithoglyphus naticoides, *Fér.*
Paludina vivipara, *L.*
Paludina lenta, *Brander* = P. unicolor, *Olivi.*
Hydrobia, sp.
Valvata piscinalis, *Müll.*
Planorbis complanatus, *L.*

No. 6. Recent shells from sand taken out of the river Bug :—

Sphærium rivicola, *Leach.*
Unio pictorum, *L.*
Unio crassus, *Nilss.*
Unio batavus, *Nilss.*
Neritina fluviatilis, *L.*
Lithoglyphus naticoides, *Fér.*
Bithinia tentaculata, *L.*
Melanopsis Esperi, *Fér.*
Melanopsis acicularis, *Fér.*

No. 7. Recent shells from the beach of the Sea of Azof :—

Dreissena polymorpha, *Pall.*
Unio pictorum, *L.*; var. elongata, *v. Mühlfeldt.*
Anodon, sp.
Cardium edule, *L.* (valve).
Adacna edentula, *Pall.*
Paludina vivipara, *L.*
Limnea peregra, *Müll.*; var. maritima, *Jeffreys.*

Discussion*.

Mr. Drew said he should like to know by what marks Mr. Milne knew the effects of the coast-ice. He thought that Mr. Belt's theory was the same that that gentleman brought forward about three years ago; from the same data he had himself drawn very different conclusions. The supposed lacustrine deposits of Mr. Belt are formed, he thinks, by the damming up of an immense expanse of water by an ice barrier. Mr. Drew thought it was really fluviatile, and deposited by one or many rivers. The surface of the deposits in the plain of the Danube follows the river-valley at a higher level than the present bed; and it was formed by material brought down the slopes of the watershed. Mr. Drew illustrated his views by reference to the Punjáb and the plains of India.

Prof. Prestwich agreed with Mr. Drew in his explanation of the phenomena described by Mr. Belt, and said that, from what he knew of Western Europe he believed that all such deposits as those described by Mr. Belt may be explained by supposing them to be thrown down in old river-valleys. In England these fluviatile beds rise to 100 or 150 feet, and in France still higher. In the flat country dealt with by Mr. Belt the deposits would extend to a great distance.

Mr. Milne had described his ice-scratches as at right angles to the coast-line, but in most instances in inland striation the striæ were parallel to the coast-line. Had the rise of the land been very slow the marks might have been obliterated; but if the rise were rapid the marks would not be effaced.

Prof. Judd stated that he knew the beds referred to in the valley of the Danube, and that the phenomena as worked out by the native geologists gave great support to the explanation offered by Mr. Drew and Prof. Prestwich. The most remarkable individuality in the mud of each river-valley had been demonstrated.

Mr. Hicks compared Mr. Belt's sections with those of similar deposits in the east of England.

Mr. Whitaker said he had been for some years engaged in the detailed examination of comparatively small areas, in England, and sometimes had not been able to make up his mind as to the age of some of the Drift beds therein. There were glacial beds, postglacial beds, and beds of which no one can say whether they are or are not glacial. The difficulty thus experienced in interpreting a small area which had been almost exhaustively examined, made him suspicious of these broad generalizations from a few observed sections.

Admiral Spratt remarked that Mr. Belt's sections reminded him of many he had himself seen. The river-theory seemed to be plausible and good; but large rivers if ponded up make freshwater lakes. The sands and muds are very soft and fine, and would float to a great distance, like the Nile mud. False-bedding shows river-action in the lower beds or movement in shallow water. The shells found by him in Bulgaria were perfectly lacustrine in character; and

* This discussion applies also to a paper by Prof. John Milne, read on the same evening. See p. 930.

he found the *Dreissena* and a *Cardium*-like shell in lakes near the Danube.

Prof. Morris said, with reference to Admiral Spratt's remarks about the shells, that there were several distinct conditions to be considered, and especially whether the shells were those of inhabitants of lakes, rivers, or brackish water. The *Dreissena* and the *Cardium*-like shell referred to were modified brackish-water forms. Then he should like to know whether the specimens of *Planorbis* were mixed with the others, and, further, what were the relations of the shells found below the diluvium to those now living in the same areas.

Admiral Spratt stated that his *Planorbes* were certainly mixed with the others, and that the shells found below the diluvium seemed to him to be identical with those now living.

Mr. Belt, in reply, said that most of the arguments brought forward were already answered in his paper. From the marine Miocene beds there was a regular sequence up to the freshwater beds with *Paludina* and *Melanopsis*. Then there was a great gap; the waters of the old Aralo-Caspian sea were lowered, and the above-mentioned beds denuded. The next stage was the filling up of the basin again by the waters from which the diluvial beds were deposited, and a great destruction of life. He agreed in the main with Admiral Spratt's remarks, and had studied the beds referred to by Prof. Judd, which he considered were just such as would be formed at the mouths of streams emptying into a lake.

In regard to river-basins, he agreed with Prof. Prestwich that much might be said in favour of their agency in the deposition of the gravels and clays that fringe their valleys; but in Russia the diluvium covers the whole country, and extends across the watersheds. The northern blocks have been carried in the opposite direction to the flow of the northern rivers; and for their transport a wide sea-like expanse of water is required.

The President remarked that Sir Joseph Hooker, who first wrote on the Himalayas in connexion with the present subject, had stated that there is a complete absence of glacial striæ, which is, no doubt, due to rapid waste. For himself he had been startled by the amount of life proved to exist within 15° or 16° of the North Pole in shallow water; and Dr. Günther had recently described a species of Char from a lake which is frozen for many months in the year.

46. *On the* Occurrence *of a* Macrurous Decapod (Anthrapalæmon? Woodwardi, sp. nov.) *in the* Red Sandstone, *or* lowest group, *of the* Carboniferous Formation *in the* South-east *of* Scotland.

By R. Etheridge, Esq., Jun., F.G.S. (Read May 9, 1877.)

(Communicated with the permission of the Director-General of the Geological Survey.)

[Plate XXVII.]

1. Introduction.

I have had the honour on two previous occasions (with the permission of the Director-General of the Geological Survey) to bring under the notice of the Society two important additions to the Carboniferous fauna of Scotland, *Astrocrinites? Benniei* (mihi), and *Productus complectens* (mihi). Again the pleasure devolves upon me of calling attention to a further discovery of considerable palæontological interest—the occurrence of a Macrurous Decapod, probably referable to the genus *Anthrapalæmon*, Salter, in the basement beds of the Carboniferous formation, as developed in the neighbourhood of Dunbar.

To the prolific hammer of Mr. James Bennie, whilst engaged in his duties as one of the collectors of the Geological Survey of Scotland, we are again indebted for the valuable and unique fossil in question. The specimen, with its counterpart, was forwarded by Mr. Bennie as a Crustacean, amongst a collection of plants from the Red Sandstones of Belhaven Bay, near Dunbar. I at once saw that it was not only a Crustacean, but a member of one of the higher divisions of the class,—a fact of very considerable interest, in so far that it extends the range of the Macrura, if I am correct in so referring the fossil, downwards to a lower horizon than they have hitherto occurred at in this country. After a careful examination, I came to the conclusion that the form was closely allied to Salter's genus *Anthrapalæmon*, and, in the absence of any further evidence than is afforded by the specimen, must be regarded as a species of the latter; this I hope to prove in the succeeding remarks.

Following the plan adopted in my previous communications, I shall commence by giving an outline of the Bibliography not only of the Palæozoic Decapoda, but of the Malacostracous Crustacea generally of the older rocks, with the view of bringing forward any points which may tend to show an alliance of our fossil with any of the orders other than the Decapoda; secondly, a description of the fossil will be given; thirdly, its generic affinities will be dwelt on; and lastly, a few remarks on the geological horizon will be made. I have endeavoured to give as complete a Bibliography as possible. To those authors whose writings I have overlooked, my apologies are due for so doing; it will, however, be due to difficulties in obtaining some of the rarer works of reference.

2. Bibliography.

1820. Baron von Schlotheim appears to have been one of the earliest authors to describe an organism from Palæozoic rocks which could, with any thing like certainty, be referred to the higher Crustacea. Under the name of *Trilobites problematicus* he described a body from the "Cave-limestone" of Glücksbrunn, and placed it provisionally near the Trilobites *. As this form was afterwards more fully described by Baron von Schauroth and Mr. J. W. Kirkby, it need not be further referred to at present.

1839. Dr. Goldfuss described, in his "Beiträge zur Petrefactenkunde," the curious body to which he gave the name of *Bostrichopus antiquus* †. The body is here bilobed, separated into two halves by a constriction; the posterior half is elongated, and divided longitudinally by a groove. From the anterior half pass four appendages, the two hinder exceeding the anterior in length and thickness. From these feet stream out a number of threads or antenna-like jointed processes.

1840 (?). Professor (then Mr.) Prestwich described, in the explanation of the 41st plate illustrating his paper "On the Geology of Coalbrook Dale" ‡, a Crustacean from the Coal-measures of that neighbourhood as *Apus dubius*, regarded by Prof. Milne-Edwards as nearly allied to the recent *Apus corniformis*. The extinct species was afterwards redescribed by Mr. Salter, and referred to the genus *Anthrapalæmon*.

1844. Dr. W. Ick exhibited at a meeting of the Society, May 15th, 1844, casts of certain Carboniferous Crustaceans, one of which he compared with *Eryon* §. Mr. Salter afterwards showed that one of these specimens was none other than *Apus dubius*, Prest.; the other he referred to the later-described *Pygocephalus Cooperi*, Huxley.

1844. As *Astacus Phillipsii*, Prof. McCoy described an organism which he took to be the remains of the only Decapod then known from the Irish Carboniferous rocks ‖. We are informed, on the authority of Mr. Salter, that Prof. McCoy afterwards abandoned the notion of the Crustaceous nature of this fossil ¶.

1846. In his 'Grundriss der Versteinerungskunde,' Dr. H. B. Geinitz placed *Bostrichopus* with the Stomapoda **. He gives the Grauwacke slate of Dillenburg as the horizon and locality.

1847. The name *Gampsonyx fimbriatus* was assigned by Dr. H. Jordan to a Crustacean discovered by him in the Sphærosiderite of Laibach, at the ironworks of Herr Krämer, at St. Ingbert ††. It was

* Die Petrefactenkunde auf ihrem jetzigen Standpunkte, &c. 8vo, p. 41.

† Nova Acta Physico-medica Acad. Cæsareæ-Leopold. &c. 1839, vol. xix. p. 353, pl. 32. f. 6.

‡ Trans. Geol. Soc. 2nd series, vol. v.

§ Quart. Journ. Geol. Soc. 1845, i. p. 199.

‖ Synopsis Carb. Foss. Ireland, 1844, p. 159.

¶ Quart. Journ. Geol. Soc. xvii. p. 532.

** P. 197.

†† "Entdeckung fossiler Crustaceen im Saarbrücken'schen Steinkohlengebirge," Verhandl. d. naturhistorischen Vereins d. preuss. Rheinlande, vol. iv. 1847, p. 89, pl. 2.

considered to have the closest analogy with the Amphipoda, and is described as possessing a free head, and from twelve to fourteen body-segments, with fringed caudal appendages attached to the telson. The eyes are sessile; and there are two pairs of antennæ, an inner and an outer. The first pair of appendages preserved in the specimen is remarkable for strength and distinctness of the joints, which are apparently five. The structure of this Crustacean is described at considerable length.

1848. Dr. H. G. Bronn entered in his Catalogue the two following forms * :—

Apus dubius, *Prestwich*: p. 90.
Bostrichopus antiquus, *Goldfuss*: p. 172.

1848. Herr R. Richter described from the "Grauwacke" of the Saalfeld neighbourhood (? Upper Devonian), a badly preserved Crustacean, under the name of *Gitocrangon granulatus*, which, he considered, showed a transition from the Macrura to the Brachyura †. The carapace is divided into three chief regions by two transverse divisions, the foremost of which forms a deep sulcation backwards on the anterior part of the carapace. The posterior edge of the latter is excavated for the reception of the body-segments, which are seven in number. The telson (if the three longitudinal folds can be so called) is small and inconspicuous.

1848. In a review of Dr. H. Jordan's preceding paper, "Entdeckung fossiler Crustaceen im Saarbrücken'schen Steinkohlengebirge," the writer considers that the analogies of *Gampsonyx fimbriatus* should be sought for amongst the long-tailed Decapods rather than the Amphipoda ‡.

1850. Dr. H. G. Bronn, in a paper "Ueber *Gampsonyx fimbriatus* (Jordan) aus dem Steinkohlen-Formation von Saarbrücken und dem Murg-Thal" §, pointed out that the fore part of the body was segmented, and not coalesced into a cephalothorax, and that, irrespective of head and tail, there are fourteen segments. He considered this Crustacean to be an Amphipod or Isopod, but possessing more the characters of the former, whilst the five-lobed telson, amongst other peculiarities, points to the Macrura.

1852. Dr. A. Quenstedt, in his useful 'Handbuch der Petrefactenkunde,' gave a figure of *Gampsonyx*, and placed it amongst the Isopods ‖.

1854. In the second edition of Prof. Morris's 'Catalogue of British Fossils,' Mr. J. W. Salter summed up the known species of British Carboniferous Macrura ¶ as follows:—

Apus dubius, *Prestwich*, Geol. Trans. 2nd ser. vol. v. pl. 49. f. 9.
? Cancer, sp., *Ick*, Quart. Journ. Geol. Soc. 1845, i. p. 199.

* Index Pal. Nomenclator. 1848.

† Beitrag zur Paläontologie des Thuringer Waldes; Die Grauwacke des Bohlens und des Pfaffenberges bei Saalfeld. I. Fauna: 4to, p. 43, pl. 1. figs. 1-4.

‡ Neues Jahrbuch, 1848, p. 126.

§ Ibid. 1850, p. 575.

‖ P. 277, pl. 21. f. 7.

¶ P. 111.

1854. A celebrated paper appeared during this year by Drs. H. Jordan and H. von Meyer, on *Gampsonyx fimbriatus*—"Ueber die Crustaceen der Steinkohlenformation von Saarbrücken" *. They consider *Gampsonyx* to be an Amphipod with the characters of the Decapoda, especially of the subdivision Macrura. The normal number of somites is fifteen; and the antennæ four, an inner and outer pair, the former double, the latter simple and long. The first pair of feet are strong and longer than the others, and, instead of a chela, are furnished with a small claw-like process. The first pair of appendages is attached to the first or second somite, and the second pair to the third somite. Each of the following segments carries a pair, the fourth to the seventh and perhaps the eighth pair being, like the third, forked. The telson is terminated by two large subdivided caudal appendages.

1854. A further discovery of specimens resembling Schlotheim's obscure *Trilobites problematicus*, enabled Baron von Schauroth to propose for it a new genus, *Palæocrangon* †. He describes the cephalothorax, when divested of its outer integument, as divided into a "head-shield" and "breast-shield," the former being the smaller of the two, and overlapped by the latter, which is the largest of all the segments of the body. A smooth sharp keel occupies the median line of the head- and breast-shield; and the body-segments also show traces of it. The front of the head-shield is ornamented with knotty elevations, whilst the breast-shield is in places shagreened. On the posterior portion of the breast-shield there is a transverse swelling parallel to the first body-segment. The carapace (= head- and breast-shield combined) is somewhat triangular in profile, and on its outer surface is shagreened and besprinkled with tubercles. The body-segments are small, and are convex in their anterior half and concave in their posterior half. Von Schauroth considers that the general form, the median keel, and segmented body indicate an affinity with the Decapoda; the form and order of the body-segments remind one of the Isopoda. From the Zechstein dolomite of Glücksbrunn.

1854. Sir W. Trevelyan, in an Address to the Members of the Tyneside Naturalists' Field-Club, at their eighth anniversary meeting, announced the discovery by Mr. J. W. Kirkby of the tail of a Macrurous Crustacean in the Permian Limestone near Sunderland ‡.

1854. In the second volume of his 'Traité de Paléontologie' &c., Prof. F. J. Pictet, under the heading "Décapodes mal connus," places the Devonian *Gitocrangon granulatus*, Richter §. *Gampsonyx* was regarded by him as an Amphipod; and he remarks that, if Jordan's description is correct, it should be so regarded, or as an Isopod, and not as one of the Macrura, as placed by Bronn ‖.

* Palæontographica, Jan. 1854, vol. iv. pp. 1–16, pl. i.

† "Ein Beitrag zur Paläontologie des deutschen Zechsteingebirges," Zeitschrift d. deutschen geol. Gesellschaft, vol. vi. p. 560.

‡ Trans. Tyneside Nat. F. Club, vol. ii. 1851–54, p. 333.

§ 2nd edition, vol. ii. p. 461.

‖ Ibid. p. 464.

Apus dubius, Prestwich, is placed amongst the Phyllopods, with the remark that perhaps it belongs to the *Limulidæ*.

1855. In the 5th edition of Sir C. Lyell's 'Elements of Geology,' Mr. Salter figured one of Dr. Ick's before-mentioned fossils as *Glyphea dubia* *, and considered it identical with *Apus dubius*, Prestwich.

1855. An important paper was contributed by Dr. H. Burmeister on *Gampsonyx fimbriatus*, Jordan. According to this author the name *Gampsonyx* was in use by Swainson for a genus of Falconidæ before its adoption by Jordan for the above Crustacean; Burmeister therefore changed it to *Gampsonychus* †. A very full description is given in Burmeister's paper, accompanied by several figures. He took it to be a Stomapod approaching in some characters to the recent Schizopoda.

1856 (51–). In the 3rd edition of the 'Lethæa Geognostica,' Drs. H. G. Bronn and F. Römer place *Gampsonyx* among the Stomapoda, adopting Burmeister's name *Gampsonychus* ‡. They consider that this genus unites by its characters the Amphipoda and Decapoda, especially the subdivision Macrura of the latter. The distinct head and thorax without any coalescence into a cephalothorax recalls the Amphipoda; whilst the antennæ, appendages, and divisions of the telson are especially Macruran. *Palæocrangon*, v. Schauroth, is placed amongst the *genera incertæ sedis*, and the authors doubt the propriety of referring it to the Decapoda. The genus *Bostrichopus*, Goldfuss, is also placed here; indeed, so careful are the authors in this instance, that they merely call it a Crustacean §.

1856. In their useful and complete work, 'Die Versteinerungen des rheinischen Schichtensystems in Nassau,' Drs. G. & F. Sandberger adopt Burmeister's view of *Bostrichopus*, that it is an Isopod, and give a description and good figure of it ‖.

1857. The remains of the Macrurous Decapod mentioned by Sir W. C. Trevelyan as found by Mr. J. W. Kirkby, were referred by the latter to Schlotheim's *Trilobites problematicus* ¶; but instead of adopting for it v. Schauroth's name of *Palæocrangon*, Mr. Kirkby proposed a new one, *Prosoponiscus*. The author states that Mr. C. S. Bate referred the form to the Isopoda, and considered that in the position of the eye it differed from all larval and adult Isopods, but assumed rather the former than the latter character.

1857. When describing *Pygocephalus Cooperi*, Prof. Huxley ** stated his belief that in it we had the first certain evidence of the existence of the Podophthalmia at so early a date as the Carboniferous ††; it is probably allied to *Mysis*, and should be placed either amongst the lower Decapoda or Isopoda. "One end of the body is much broader than the other, and has the form of a semi-

* P. 388, f. 501.

† Abh. d. naturforsch. Gesellschaft zu Halle, 1855, vol. ii. pp. 191–200, pl. 10.

‡ P. 672. § P. 678. ‖ P. 2, t. i. f. 1.

¶ "On some Permian Fossils," Quart. Journ. Geol. Soc. xiii. p. 213.

** "Description of a New Crustacean (*Pygocephalus Cooperi*, Huxley) from the Coal-measures," Quart. Journ. Geol. Soc. xiii. p. 363, pl. 13. †† P. 369.

circular disk, . . . the opposite end has the appearance of a quadrate disk." Between these two disks "lies the central portion of the body, divided into a series of segments. Two pairs of appendages, one large and one small, are attached to the extremity of the quadrate disk, while a number of slender limbs are connected with the sides of the segmented part of the body."

1859. Mr. C. Spence Bate, in a paper "On the Fossil Crustacean found in the Magnesian Limestone of Durham by Mr. J. W. Kirkby"*, reconsiders the affinities of *Palæocrangon* (*Prosoponiscus*) *problematicus*, and refers it to the Amphipoda near to *Phædra antiqua*, S. Bate, rather than to the Isopoda.

1861. Attached to the Rev. T. Brown's paper "On the Mountain Limestone and Lower Carboniferous Rocks of the Fifeshire Coast"†, Mr. J. W. Salter gave a description and figure of a shrimp-like Crustacean, *Uronectes socialis*, found by Mr. Brown in the Ardross Limestone, near Elie, Fife, and considered it to be allied to *Gampsonychus fimbriatus*, Jordan, but with much fewer segments. There are seven body-rings and a minute telson, with a few scattered appendages. The head was elongated.

1861. A revision of the higher Carboniferous British Crustacea was given by Mr. Salter ‡, in which he established the genus *Anthrapalæmon* for a Crustacean from the Lanarkshire Coal-field, *A. Grossarti*, Salter §. The carapace is well marked, with a strong central ridge, projecting anteriorly into a thick spine; and the front margins are serrate. The outer antennæ have wide square basal joints. The abdomen consists of six somites, broad and short. A second species of *Anthrapalæmon* is figured ||, of a more elongated form, with a smooth carapace. Under *Anthrapalæmon* was established a subgenus, *Palæocarabus*, for the reception of *Apus dubius*, Prestwich¶. Mr. Salter further showed that one of the specimens exhibited to the Society many years ago by Dr. Ick was identical with *Palæocarabus dubius*, and that the other was the afterwards described *Pygocephalus Cooperi*, Huxley. Finally, for the shrimp-like Crustacean from the Fifeshire Lower Carboniferous beds (*Uronectes*? *socialis*), the name *Palæocrangon* was proposed**. The carapace is short and pointed, and the telson small, with narrow and obovate caudal appendages. The much smaller number of somites, 6 or 7, separates *Uronectes*? *socialis* from *Gampsonychus fimbriatus*, irrespective of other characters. With regard to *Gitocrangon* of Richter, Mr. Salter appears to have doubted its Crustacean character at all, and remarks of the Fifeshire fossil, that "no Decapod had up to that time been found in the lower shales of the Carboniferous."

1862. A second example of *Pygocephalus* was found in shale about three fathoms above the Hurlet or Nittshill Coal of the Lower

* Quart. Journ. Geol. Soc. xv. p. 137, pl. vi.

† Trans. Royal Soc. Edinburgh, xxii. p. 385.

‡ "On some of the Higher Crustacea from the British Coal-measures," Quart. Journ. Geol. Soc. xvii. p. 528.

§ *Tom. cit.* p. 530 & p. 531. f. 1–4.

|| P. 531, f. 5.

¶ P. 532 & p. 531. f. 6 & 7.

** P. 533 & p. 531. f. 8.

Carboniferous Limestone group near Paisley, and was provisionally described by Prof. Huxley as referable to his type species *P. Cooperi* *.

1863. From the Devonian beds of St. John's, Nova Scotia, Mr. Salter described a Crustacean, which he surmised might be a Stomapod, with an oblong-oval carapace rounded in front, a thorax of 9 (?) segments, and a semicircular tail-piece, as *Amphipeltis paradoxus* †. Another form, of which the carapace is unknown, is represented by five segments and a large triangular and spinous tail-piece, with two pairs of simple ovate appendages, for which is proposed the name of *Diplostylus Dawsoni* ‡. It appears to be an Isopod, allied to the recent *Sphæroma*, and also to the *Hyperina*-group amongst the Amphipods; it is from the Coal-measures of the South Joggins, Nova Scotia.

When proposing *Palæocrangon* for the Fifeshire *Uronectes*? *socialis*, Mr. Salter overlooked the previous adoption of this name by Baron von Schauroth for a distinct Permian fossil; he therefore, in the paper now under consideration, changed it to *Crangopsis* §.

1863. Mr. Salter, again, contributed another memoir towards our knowledge of the older higher Crustacea—"On a New Crustacean from the Glasgow Coal-field" ‖, in which was described *Palæocarabus Russellianus*, from the Palace-Craig Black-band Ironstone (Coal-measures)¶. *Palæocarabus*, previously described as a subgenus of *Anthrapalæmon*, was here raised to generic rank, and was distinguished from the latter by having a complete cervical furrow and ridge, as against a faint cervical furrow and incomplete ridge in *Anthrapalæmon*. In both the ridge is produced anteriorly into a thick serrated spine.

1865. In a "Notice of some New Types of Organic Remains from the Coal-measures of Illinois," Messrs. Meek and Worthen describe two genera which must be noticed here, *Acanthotelson* and *Palæocaris* **. In the former the thoracic and abdominal segments, except the last, do not differ materially in length, and each is shorter than the head. The telson is simple, long, and spiniform ††. In the second form the head is about as long as the first two abdominal segments, and the telson long, tapering, and horizontally flattened. According to Messrs. Meek and Worthen, *Acanthotelson* combines the characters of the Amphipoda and Isopoda, and should, perhaps, be placed in Dana's intermediate group the Anisopoda, amongst the Tetradecapoda. *Palæocaris* is also provisionally placed in the Tetradecapoda, although it may perhaps be a low type of the Decapoda. There is no trace of a carapace; the thorax is divided into seven segments, like those of the abdomen, and each is provided with a pair of legs.

* "On a Stalk-eyed Crustacean from the Carboniferous Strata near Paisley," Quart. Journ. Geol. Soc. xviii. p. 420.

† "On some Fossil Crustacea from the Coal-measures and Devonian Rocks of British North America," Quart. Journ. Geol. Soc. xix. pp. 75 & 79, f. 11.

‡ *Loc. cit.* pp. 77 & 79, f. 6.

§ Ibid. p. 80.

‖ Quart. Journ. Geol. Soc. xix. p. 519.

¶ Ibid. p. 520, f. 1 & 2.

** Proc. Acad. Nat. Sciences, Philadelphia, 1865, pp. 46 & 48.

†† Ibid. p. 50.

Under the Macrura the authors describe *Anthrapalæmon ? gracilis*, which differs from *A. Grossarti*, Salter, in the absence of the central spine and in the structure of the antennæ, although it possesses the serrated lateral border of the carapace. Prof. Dana, Messrs. Meek and Worthen tell us, considers *Anthrapalæmon* to be more nearly allied to *Æglea* and *Galathea* than to *Palæmon*. These forms are all from the base of the Coal-measures of Grundy County, Illinois.

1866. Messrs. Meek and Worthen again published descriptions of the before-mentioned fossils, but now accompanied with good figures and supplementary remarks bearing on them, in the second volume (Palæontology) of the Illinois Geological-Survey Report, as follows:—

Acanthotelson Stimpsoni, *M. & W.* p. 401, t. 32. f. 6, a–f.
,, inæqualis ,, p. 403, t. 33. f. 7.
Palæocaris typus, *M. & W.* p. 405, t. 32. f. 5, a–d.
Anthrapalæmon gracilis, *M. & W.* p. 407. t. 32. f. 4, a–c.

1867. Mr. H. Woodward follows Prof. Huxley in placing *Pygocephalus* near *Mysis* among the lower Decapoda, and does not consider it to have any affinities with the Stomapoda*. The cephalothorax has seven pairs of appendages, and two pairs of external mouth-organs. Each appendix consists of two parts—the limb proper, or endopodite, and a filamentous appendage, or exopodite. Both the antennæ and antennules have two basal joints, with a broad oval scale externally. The epimera of the abdominal somites are produced to a point. Mr. Woodward shows that there are no differences of generic value between *Anthrapalæmon* and *Palæocarabus*, as imagined by Salter, and that the latter must be reduced to a synonym of the former.

1868. In a "Supplementary Note on some of the Grundy-County Crustacea, &c., formerly described" †, Messrs. Meek and Worthen give some additional information on the genera *Acanthotelson* and *Palæocaris*, and propose a new species of the former genus, *A. Eveni*.

1868. The third volume of the Illinois Geological-Survey Report contains further notes and figures of the curious Crustaceans of Grundy County, Illinois ‡, including a figure of the new species *Acanthotelson Eveni*. The sum of the evidence at the disposal of Messrs. Meek and Worthen appears to be that *Acanthotelson* "approaches some of the lower types of the macrural *Decapoda*;" but they leave it with doubt in the "Isopod group of the *Tetradecapoda*." As to *Palæocaris*, there appears to be some diversity of opinion. Prof. Dana and Dr. Stimpson believe "that it is a low embryonic type of the Macrura, in which the carapace is not developed." The authors themselves consider that it exhibits a combination of Decapod (Macruran) and Tetradecapod characters, having "the caudal appendages, anteriorly directed thoracic legs, the antennæ and general aspect o a Macruran, with the distinct head, divided thorax

* "On the Crustacea from the Glasgow Coal-fields," Trans. Geol. Soc. Glasgow, vol. ii. p. 240, pl. 3.

† American Journ. Sc., 2nd series, vol. xlvi. p. 28. ‡ Pp. 549–555.

(without a carapace), and seven pairs of thoracic legs of a Tetradecapod." They further consider that it has an analogy with *Gampsonychus*. Other specimens of *Anthrapalæmon gracilis*, M. & W., show that it departs further in its structure from the type species than was at first supposed.

1868. Dr. Dawson refigured *Diplostylus Dawsoni*, Salter, and *Amphipeltis paradoxus*, Salter *.

1870. Some remains of great interest were described by Mr. H. Woodward as indicating a gigantic Isopod in the Old Red Sandstone allied to the living *Arcturus* (*Idotea*) *Baffini*, Westwood. To the remains in question, consisting of body-segments ornamented with large tubercles, and portions of appendages, the name of *Præarcturus gigas* was given †.

1870. To Mr. Woodward's intimate knowledge of all that is Crustacean we are also indebted for the solution of some additional obscure remains from the Lower Ludlow, described in a paper by that author, "On *Necrogammarus Salweyi*, an amphipodous Crustacean from the Lower Ludlow of Leintwardine" ‡. This species is represented by "three laterally compressed and thin crushed somites," with the base of a limb attached to one of them. *Necrogammarus* is probably allied to the existing *Gammaridæ*.

1872. In his "Fifth Report on Fossil Crustacea," Mr. H. Woodward considers that representatives of both the Isopoda and Amphipoda will doubtless be found plentifully in our Palæozoic rocks §.

1873. Dr. O. Feistmantel recorded the occurrence of *Gampsonychus fimbriatus* in considerable quantities in the gas-shale of Nürschen, and gave figures of the specimens ‖.

1877. Dr. Dawson has lately described another species of *Anthrapalæmon*, under the name of *A.* (*Palæocarabus*) *Hilliana*, from a band of black bituminous limestone in the middle division of the S. Joggins Coal-measures. It possesses a short rostrum and large spines at the anterior angles, although there is a reduction in the total number of these when compared with previously described species. There are, in addition, two spines placed in front of the cervical groove ¶. This paper is accompanied by a note by Mr. H. Woodward on the genus *Anthrapalæmon*.

Addenda to Bibliography.

1854. Von Schauroth, in the paper previously referred to, "Ein Beitrag zur Paläontologie des deutschen Zechsteingebirges," describes

* Acadian Geology, 1868, 2nd ed. p. 207, f. 49; p. 523, f. 180.

† "On the Remains of a Giant Isopod from the Old Red Sandstone, &c.," Trans. Woolhope Club, 1870, p. 266.

‡ Ibid. p. 271.

§ Brit. Assoc. Report for 1871, p. 54.

‖ "Ueber den Nürschener Gasschiefer, dessen geologische Stellung und organische Einschlüsse," Zeitschr. deutsch. geol. Gesellschaft. xxv. p. 593, t. 18, f. 9–11.

¶ "Note on two Palæozoic Crustaceans from Nova Scotia," Geol. Mag. Dec. 2, iv. p. 56, f. 1.

a depressed hemispherical body, having an externally granulated shell, under the name of *Hemitrochiscus paradoxus* *. He was unable to state any thing definite as to the affinities of the fossil, but provisionally regards it as the shell of a Crustacean from the Zechstein dolomite of Pörsneck.

1861. Dr. H. B. Geinitz refigured *Hemitrochiscus paradoxus*, Schaur., and referred it to the Decapoda Brachyura †. His figures are much more intelligible than Schauroth's. Geinitz likewise describes *Palæocrangon* (*Prosoponiscus*) *problematicus*, Schaur., and refers it to the Isopoda. He adopted the generic name *Prosoponiscus*, Kirkby, in preference to *Palæocrangon*, Schaur., apparently without any very well-defined grounds; but at the same time he remarks that *Palæosphæroma* would have been a more appropriate name than either of the foregoing ‡.

1871. Mr. F. B. Meek published a paper in the Proceedings of the Academy of Natural Sciences of Philadelphia for this year, in which he established the provisional genus *Archæocaris* for a shrimp-like form of doubtful affinities §. Prof. Dana considered that it had some relation with the recent genus *Cuma*. From the Waverly group, Danville, Kentucky.

1875. In the second volume of the Ohio Geological-Survey Report, *Archæocaris vermiformis* is figured ‖. It is referred to the Tetradecapoda.

The following Table (p. 873) will show at a glance the genera enumerated in the foregoing bibliography, their authors, orders, geological horizons, and chief localities.

3. Description of the Specimen.

The remains of this interesting Crustacean are scanty in the extreme. We at present possess only those of two individuals, one of which is a film-like impression and its counterpart, compressed laterally (figs. 1 & 2); and the other is a portion of the carapace and body-segments of another individual flattened from above downwards (fig. 3), both in the same ironstone nodule.

The more perfect of these, that seen in profile (Pl. XXVII. figs. 1 & 2), measured as nearly as possible 7 lines long by $3\frac{1}{2}$ wide, taken across the carapace. The length of the carapace is equal to, if not somewhat greater than, that of the abdominal somites. The latter are narrow and probably six in number (*a*, figs. 1 & 2), irrespective of the telson (*b*, figs. 1 & 2). The thoracic appendages are certainly six, and, if I mistake not, seven in number (*c*, figs. 1 & 2); but any abdominal appendages that may have existed have quite disappeared. The telson and its caudal appendages (*b*, figs. 1 & 2) were evidently a well-marked feature in the organism.

To enter more minutely into the structure of this Crustacean, it may be observed that the carapace is somewhat elongately quadran-

* Zeitschr. deutsch. geol. Gesellschaft, vi. p. 558.
† Dyas, oder die Zechsteinformation und das Rothliegende, p. 28.
‡ P. 29. § P. 355. ‖ T. 18. f. 7.

Genus.	Author.	Order.	Horizon.	Localities.
1. Acanthotelson	*Meek & Worthen.*	Isopoda? (Anisopoda, *Dana*).	Coal-measures.	Morris, Illinois.
2. Amphipeltis	*Salter*, 1863.	Stomapoda?	Devonian.	St. John's, N. Brunswick.
3. Anthrapalæmon =Glyphea, *Salter.* =Palæocarabus, *Salter.*	" 1861.	Macrura.	Coal-measures.	Coalbrookdale, Goodhock Hill, Lanarkshire.
4. Bostrichopus	*Goldfuss*, 1839.	Stomapoda?	Devonian.	Herbarn, &c.
5. Crangopsis =Uronectes, *Salter.* =Palæocrangon	*Salter*, 1863. *Salter* (non Schauroth).	Macrura.	L. Carboniferous.	Ardross, Fife.
6. Diplostylus	*Salter*, 1863.	Amphipoda? or Isopoda?	Coal-measures.	S. Joggins, Nova Scotia.
7. Gampsonychus =Gampsonyx	*Burmeister*, 1855. *Jordan*, 1847.	Stomapoda? or Amphipoda?	" "	Saarbrück.
8. Gitocrangon	*Richter*, 1848.	Macrura.	Up. Devonian.	Saalfeld.
9. Necrogammarus	*H. Woodward*, 1870.	Amphipoda.	L. Ludlow.	Leintwardine.
10. Palæocaris	*Meek & Worthen*, 1865.	Isopoda?	Coal-measures.	Morris, Illinois.
11. Palæocrangon =Trilobites, *Schlotheim* (pars). =Prosoponiscus, *Kirkby.*	*Schauroth*, 1848.	Amphipoda.	Permian.	Glücksbrunn.
12. Præarcturus	*H. Woodward*, 1870.	Isopoda.	Old Red Sandstone.	Rowleston, Herefordsh.
13. Pygocephalus	*Huxley*, 1857.	Decapoda?	Coal-measures.	Manchester, Kilmaurs.

gular; but as the anterior part in front of the cervical furrow (*d*, figs. 1 & 2) is much mutilated, it is difficult to speak with certainty on many essential points in its organization. The posterior margin, which, on the other hand, is well defined, is concave in the median region, and the lateral angles apparently pointed (*f*, fig. 3). The carapace was occupied in the median line by a cephalic ridge (*g*, figs. 1, 2, 3), continuous from the cervical groove to the posterior margin. I feel convinced that this was produced anteriorly into a rostral ridge, perhaps slightly interrupted by the cervical furrow, but to all intents and purposes forming a continuation of the cephalic ridge. Placed at equal distances, on each side of the latter, is a lateral ridge (*h*, figs. 1, 2, & 3), nearer to it than to the lateral margin (*i*, fig. 3); both these appear to commence at the cephalic groove, thence proceed backwards, as in the case of the median ridge, and, like it, terminate at the posterior margin of the carapace. So far as can be seen, the lateral margins of the carapace are entire, without any trace of serration. In the specimen seen in profile (figs. 1 & 2) the carapace is bent almost, but not quite, along the median line, a little more on one side the median ridge than on the other. Anterior to the cephalic groove the fore part is so confused that no definite characters are traceable; still it is quite evident that appendages did exist, probably representing the antennæ and antennules. In fig. 2, at *k*, there is an indication of an appendage in what would be the position of the antennæ, which may, indeed, so far as we can judge from the indistinct outline preserved, be the basal scale of one of them. The cephalic groove itself (*d*, figs. 1, 2, & 3) is broadly V-shaped; and at it stop short the two lateral lines or ridges; but the central one is continued in front of it, and forms the rostrum (*m*, figs. 1 & 3). No trace of eyes, either pedunculated or sessile, can be made out. The abdominal somites, as before stated, are six in number, irrespective of the telson. They are narrow, and apparently possessed pointed pleuræ (*l*, figs. 1 & 2). The appendages, as preserved, are all thoracic (*c*, figs. 1 & 2), and seven in number on each side; at any rate there are certainly six; and I believe, seven. There is no appearance of a division into endopodite and exopodite. The individual seen in profile (figs. 1 & 2) demonstrates that the caudal appendages were probably two on each side, or four in number (*b*, figs. 1 & 2). Surface ornamentation is not discernible on any part of the specimen.

4. Affinities and Systematic Position.

Had the eyes been preserved, a difficulty which meets us at the outset would be avoided, and the considerations as to the systematic position of this interesting Crustacean much abbreviated. As it is, we can only conjecture its relation to the Podophthalmata from general analogy and the protection of the anterior portion of the body by a carapace. If the presence of a well-defined carapace without the actual observation of stalked eyes be accepted as sufficient evidence of Podopthalmatous affinity, we then have a choice of orders limited to the Stomapoda and Decapoda. The same character would indicate the latter of these as the proper resting-place for the present form, whilst, from the number of ambulatory feet, *seven pairs*, as I believe, there appears to be a transition towards the Stomapoda. On the whole the Decapoda Macrura have perhaps the strongest claim, especially when we take into consideration the well-developed abdominal somites, the telson with its caudal appendages, and the forwardly directed appendages.

If we pass in review the thirteen genera enumerated in the foregoing Bibliography, it is evident that some of them may be at once eliminated as possessing little or no relation to the present form. Thus, referable to the Amphipoda are *Diplostylus*, Salter, *Necrogammarus*, H. Woodward, and *Palæocrangon*, Schauroth. The first is represented by a few somites and a peculiarly distinctive telson; the second by three somites with the feet articulated along the border, which Mr. Woodward attributed to a Crustacean allied to the Gammaridæ of the Amphipods. The last, although approaching nearest to our fossil, possesses sufficiently distinctive characters to separate them. Passing to the Isopoda, we have *Prœarcturus*, H. Woodw., *Acanthotelson*, Meek & Worthen, and *Palæocaris*, M. & W. The fragmentary remains referred to under the name of *Prœarcturus* require, I think, no comparison with the present fossil. In both the American genera the absence of a carapace, the division of the somites into thoracic and abdominal, and the character of the telson at once serve as points upon which to base a separation.

Of the Stomapoda, we have *Amphipeltis*, Salter; *Gampsonychus*, Burmeister; and ? *Bostrichopus*, Goldfuss. Again, in the case of the last, I think, no comparison is necessary; whilst in *Amphipeltis* the form of the carapace and number of the somites (9) posterior to it will separate the two forms. As to *Gampsonychus*, the somites are still further increased, and there is no coalescence into a cephalothorax, although in the telson there is some resemblance. We are now left with four genera, which have been referred by their respective describers to the Decapoda:—*Crangopsis*, Salter; *Gitocrangon*, Richter; *Pygocephalus*, Huxley; and *Anthrapalæmon*, Salter; and with these a more minute comparison is necessary.

First, in *Crangopsis* the carapace is short and pointed; here it is oblong and broad; the telson is small; in our specimen it is large; the caudal appendages are obovate; here, however, they are broad, and apparently double on each side. Secondly, in *Gitocrangon* the carapace is transversely segmented, the somites are seven, and the telson is inconspicuous; still it would be well if a more satisfactory comparison with this genus could be made; unfortunately little appears to have been written about it. Thirdly, with regard to *Pygocephalus*, we fail to notice any separation into the semicircular and quadrate disks of this genus in the present fossil, although there appears to be a closer relationship with *P. Huxleyi*, H. Woodw., than with *P. Cooperi*, Huxley.

Lastly, we have for consideration the genus *Anthrapalæmon*, of which, I believe, our fossil is a species. In this genus the carapace is provided with a strong central ridge, separated into two parts by the cervical groove, and projecting anteriorly in the form of a strong spine. The abdomen consists of six somites with pointed pleuræ, exclusive of the telson, which has double broad caudal appendages.

All these characters, or at all events traces of them, are discernible in our fossil. On the other hand, one which was assigned by Mr. Salter to his genus as particularly distinctive, viz. the serrated front margins of the carapace, is not present here. Taking all things into consideration, I think no better reference can be made than to *Anthrapalæmon*.

Mr. Woodward has shown that no generic difference exists between *Anthrapalæmon Grossarti* and *A.* (*Palæocarabus*) *dubius*, as surmised by Mr. Salter. In the former of these species there is a central ridge on the carapace (irrespective of other characters) which does not reach the posterior margin, and no lateral ridges. On the other hand the central ridge in *A. dubius* does so, and on each side of it there is a lateral furrow, between it and the margins of the carapace. I have shown that on the carapace of the present fossil there is a central ridge extending from the cervical groove backwards to the posterior margin, flanked on each side by two parallel lines, which may represent either two ridges or two grooves. Whichever they may be, they are sufficient to show, I think, a closer affinity with *A. dubius* than with *A. Grossarti*.

I propose to associate with this interesting fossil the name of my friend Mr. H. Woodward, F.R.S. (*Anthrapalæmon? Woodwardi*), to whom I am indebted for much kind assistance and advice in palæontological questions.

5. Geological Position and Locality.

The Calciferous Sandstone, or Lower Carboniferous series, is divisible into two groups, as now adopted by the Geological Survey—an Upper or Cement-stone group, and a Lower or Red-Sandstone group resting on the Old Red Sandstone. At Belhaven Bay, near Dunbar, whence *A.*? *Woodwardi* was derived, the lower group consists of red and white sandstones and marls, "probably not far from the top of the Old Red Sandstone"*, and immediately under "great masses of igneous rock, in the form both of ash and felspathic trap . . . . These piles of volcanic material lie about the middle of the Calciferous Sandstone series"†.

A.? *Woodwardi* is preserved in an impure ironstone nodule from a bed of red and mottled shale, according to Mr. Bennie, about 15 ft. thick. The associated nodules contain a Modioliform bivalve in abundance; and the enclosing shale a similar mollusk, with the remains of *Stigmariæ*, *Lepidodendra*, some curious Ferns, and an *Estheria* in great abundance, which Prof. Rupert Jones, F.R.S., cannot distinguish from *E. Dawsoni*, Jones ‡, of the Lower Carboniferous of Horton Bluff, Nova Scotia. The same bed, in its lower

* A. Geikie, Mem. Geol. Survey, No. 33, Scotland, 1866, p. 30. † Ibid.
‡ Etheridge, Geol. Mag. Dec. 2, 1876, vol. iii. p. 576.

part, yielded a few specimens of *Bellerophon,* and one or two crushed Orthoceratites.

Locality.—Shore east side of Belhaven Bay, near Dunbar, Haddingtonshire; red and mottled shale of the Red Sandstone, or lower group of the Calciferous Sandstone series.

Collector.—Mr. James Bennie.

6. Concluding Remarks.

If truly a macrurous Decapod, *Gitocrangon*, Richter, is without doubt the oldest genus of its order (grauwacke of Saalfeld, ? Upper Devonian). Next to it in age, previous to the discovery of *A.? Woodwardi,* comes *Crangopsis socialis*, Salter. This little crustacean was found by the Rev. T. Brown, M.A., at Ardross, Fifeshire, in beds which, according to the mapping of the Geological Survey *, are in the Cement-stone group, or upper division of the Calciferous Sandstone series—but according to Mr. Brown †, in the true Carboniferous Limestone, 1400 feet above the division between the two series. From whichever point of view we regard the geological position of *C. socialis*, it is quite clear that the horizon of *A.? Woodwardi* is defined, and that it must take precedence of *C. socialis* in antiquity, and rank next to *Gitocrangon.*

I have to return my best thanks to my colleagues Messrs. B. N. Peach and R. L. Jack—the former for drawings of *A.? Woodwardi,* and the latter for much literary assistance.

EXPLANATION OF PLATE XXVII.

Anthrapalæmon ? Woodwardi, *R. Eth. jun.*

Fig. 1. Side view of one half the specimen, in which the thoracic appendages (?) are in relief. Considerably enlarged.
Fig. 1 *a.* The same. Natural size.
Fig. 2. Corresponding view of the other half, in which the thoracic appendages (?) are in cast only. Similarly enlarged.
Fig. 3. View of the pressed-out remains of another individual. Considerably enlarged.
Fig. 3 *a.* The same. Natural size.

a. Abdominal somites.
b. Telson.
c. Thoracic appendages (?).
d. Cervical groove.
e. Middle of cervical groove.
f. Lateral angles (posterior) of carapace.
g. Median ridge of carapace.
h. Lateral ridges.
i. „ margin of carapace.
k. Indication of appendage.
l. Pleuræ of abdominal somites.
m. Portion of rostrum.

(*N.B.* The letters refer to the same parts in all the figures.)

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* Sheet 41, Scotland.

† Trans. Roy. Soc. Edinb. vol. xxii. p. 391.

Discussion.

Mr. H. Woodward expressed his gratification at the discovery of this interesting Crustacean by Mr. Etheridge, but could not feel sure that it was a new species, although it may be so, as it occurs so much lower down than any of those hitherto found. The most interesting point in this specimen is the exposure of the gills by the removal of the carapace, showing clearly its affinity to the highest forms of Crustacea, in which the respiratory organs are entirely removed from the feet and enclosed in special cavities.

Fig. 1.

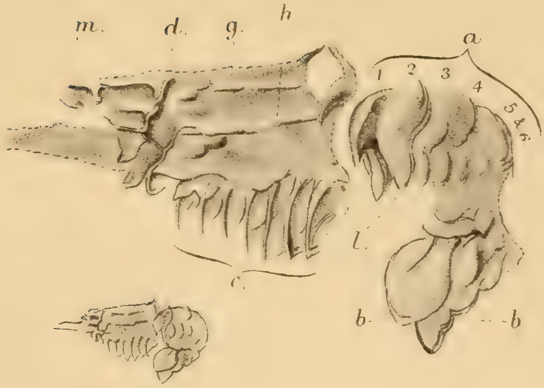


Fig. 1a.

Fig. 3.

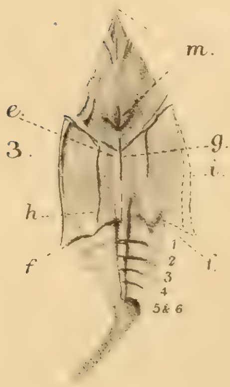


Fig. 3a.

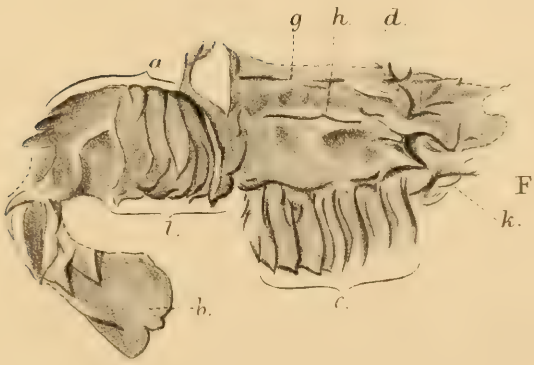
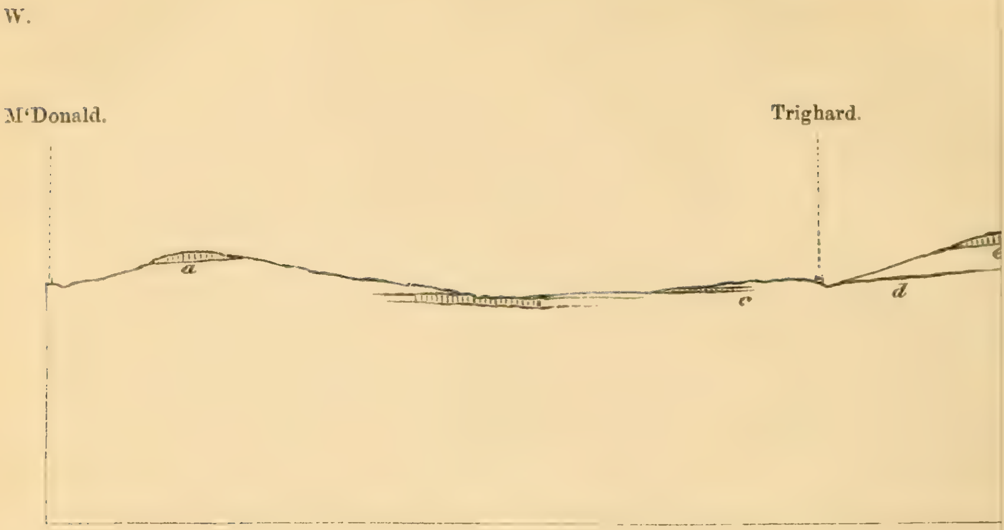


Fig. 2.

B N Peach del. C L Griesbach lith. Mintern Bros. imp.

ANTHRAPALÆMON? WOODWARDI.

Fig. 1.—*Section through th*



a. Quartz rock.
c. Amygdaloid (agates).

d. Fine pink sa
e. Hard brown

Fig. 2.—*Section of a Gold-claim (Lawrence's), Pilgrim's-Rest Creek, Transvaal.*

7. Further Notes *on the* Diamond-fields *of* South Africa, *with* Observations *on the* Gold-fields *and* Cobalt-mine *in the* Transvaal. By E. J. Dunn, Esq. (Read June 21, 1876.)

[Communicated by Prof. A. C. Ramsay, F.R.S., F.G.S.]

I. Diamonds.

A visit made to the Diamond-fields in December 1874 enables me to make some additions to, and corrections of, my previous paper, read before the Geological Society in 1873*.

At De Beer's, mining-operations have clearly established the fact that the "pipes" are more recent than the sheets of dolerite and other intrusive rocks surrounding them; for on the east side of the mine the rudely tabular dolerite, forming the wall of the "pipe," is tilted at an angle of about 40° (fig. 7.) Included masses and nodules of dolerite occurring in all the pipes hitherto opened, help to confirm this view.

In no case are the "pipes" traversed by dykes of hard rock; and the only instance of dykes of any description intersecting the material forming the "pipes" is at De Beer's, where, at a depth of 100 feet from the surface, and at the east side of the mine, long, narrow, dyke-like masses, from 2 to 5 feet wide, vertically cut through the soft diamond-bearing rock; one having the latter width runs for about two hundred yards in a straight line. These dykes (?) are lighter in colour and somewhat harder than the bounding rock, but earthy in texture and so much altered that specimens sent to the British Museum were undeterminable, though evidently quite distinct from the surrounding soft rock. The general opinion of the miners who have these dykes (?) cutting through their claims, is that they contain no diamonds.

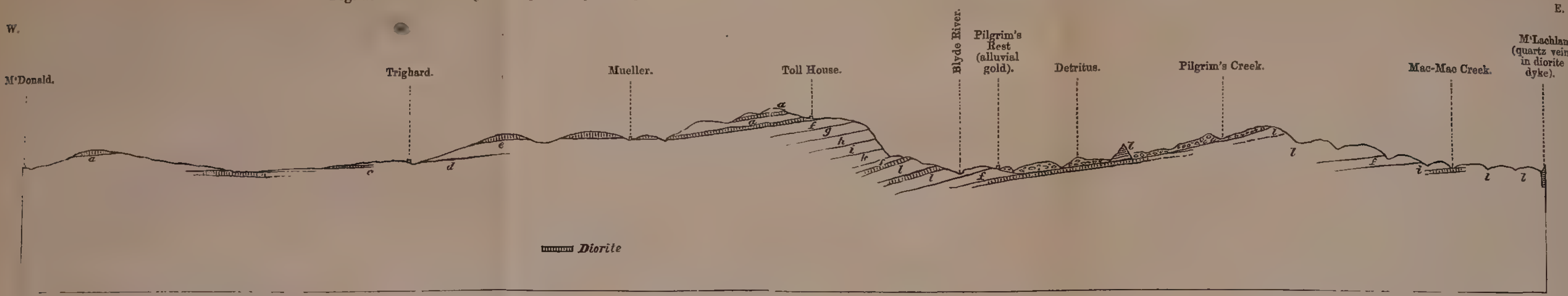
The wall of De Beer's Mine, except on the north side, which is shale, is formed by the sheet of dolerite (?) that commences near Kimberley Mine, and continues on past Du Toit's Pan. Within this mine, on the west side, an extensive crescent-shaped mass of shale is exposed; it is interpenetrated by the decomposed rock that fills the "pipe" (probably it formed part of the wall at a higher level, but, being undermined by the intrusive rock, fell in bodily); the adjacent wall is of dolerite (the miners call this a "reef").

Kimberley Mine (Colesberg Kopje, fig. 6) is entirely bounded by shale, though a sheet of intrusive rock occurs within about 300 feet of the edge of the mine. The shales lie nearly horizontal as a rule; they are faulted on the north side.

Du-Toit's-Pan Mine is bounded by the same sheet of intrusive rock that forms the wall of De Beer's. Shale forms the wall on the south.

* Quart. Journ. Geol. Soc. vol. xxx. p. 54.

Fig. 1.—*Section through the Lydenburg Gold-field.* (Horizontal scale 4 miles to 1 inch; vertical scale 4000 feet to 1 inch.)



a. Quartz rock.
c. Amygdaloid (agates).
d. Fine pink sandstone.
e. Hard brown sandstone.
f. Fissile sandstones.
g. Soft pink sandstone.
h, i. Pink, blue, grey, and brown fine sandstones (much jointed).
k. Cherty limestone.
l. Limestone.

Fig. 2.—*Section of a Gold-claim (Lawrence's), Pilgrim's-Rest Creek, Transvaal.*

a. Limestone. *b.* Mass of rock. *c.* Decomposed Diorite.

Fig. 3.—*Section of Cobalt-mine near Nazareth, Transvaal.*

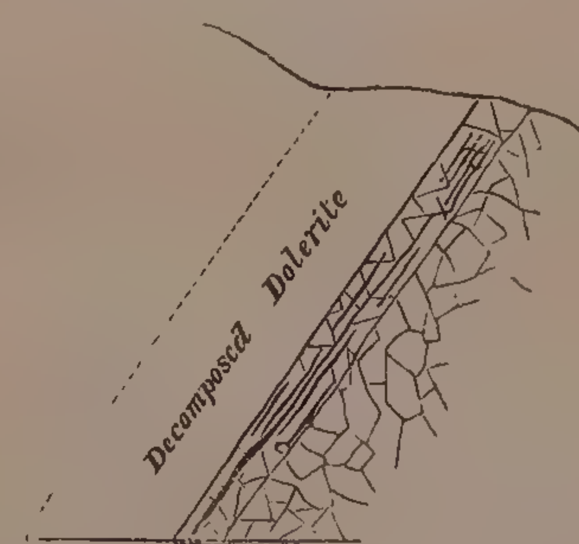
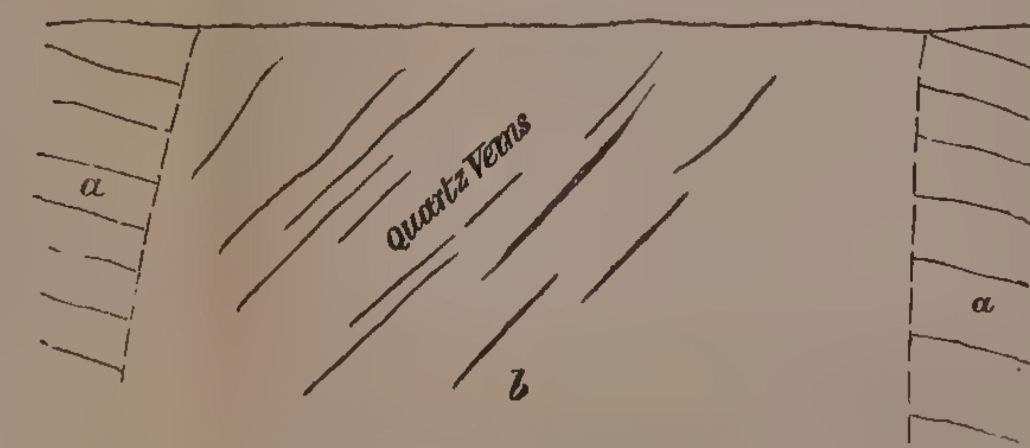
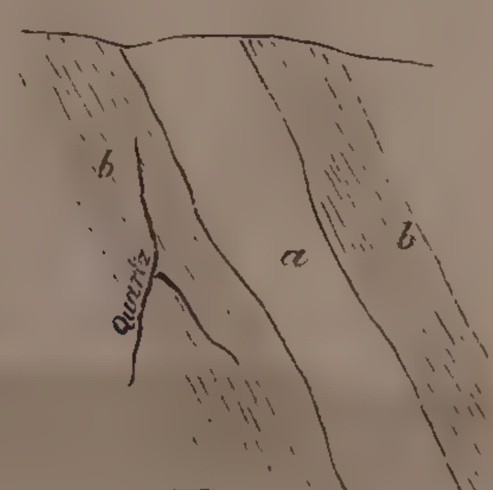


Fig. 4.—*Section of Diorite Dyke with veins of quartz carrying iron pyrites and traces of gold.*



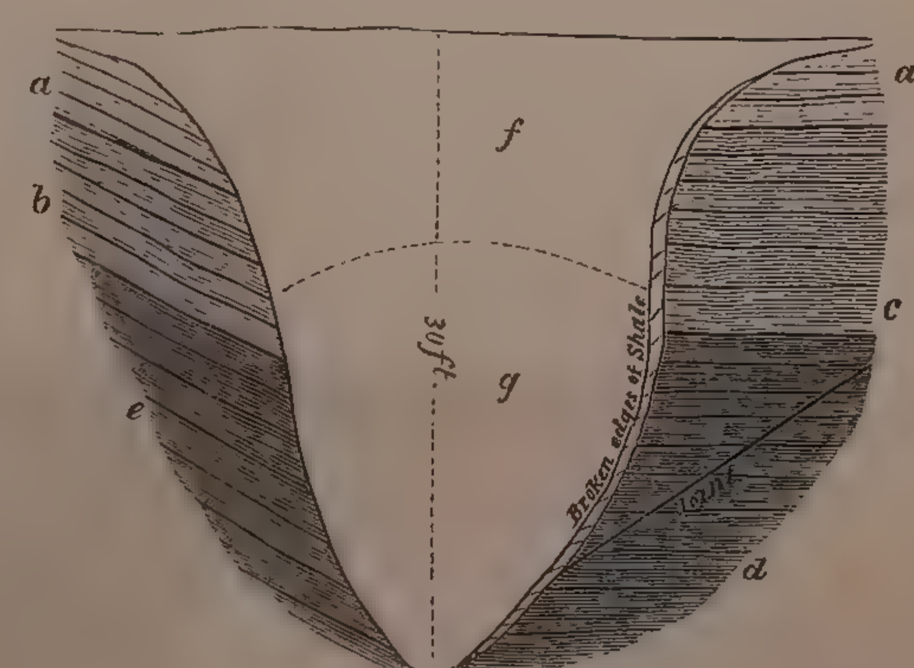
a. Soft pink sandstone, very fissile.
b. Decomposed diorite with quartz veins.

Fig. 5.—*Section of Natalia Reef, Eersteling, Transvaal.*



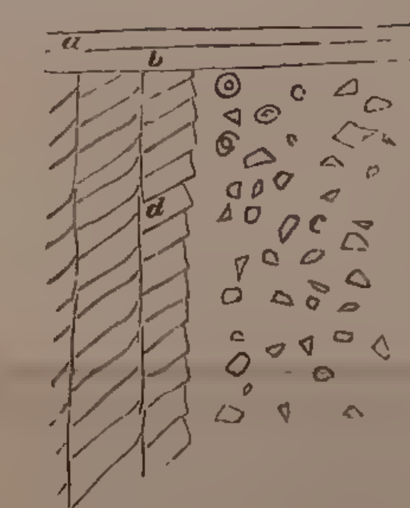
a. Quartz reef, about 4½ feet thick.
b. Steatitic schist.

Fig. 6.—*Vertical Section of East End of Kimberley Mine.*



a. Shale with lime (tufaceous).
b. Blue-grey shale.
c. Ditto, much broken.
d. Yellowish-brown shale.
e. Hard brown shale.
f. Red sand, loose above, and cemented with lime below the dotted line.

Fig. 7.—*Tilted Dolerite (?), De Beer's Mine, Diamond-fields.*



a. Red sand.
b. Calcareous layer.
c. Soft euphotide.
d. Tabular dolerite.

Now that the mines are well opened out, they disclose a form less circular than at first they appeared to possess.

Kimberley Mine is elongated in an E. and W. direction, De Beer's in a N.W. direction, and Du Toit's Pan in a S. direction (towards Bultfontein, with which it may be connected by a fault). Sufficient work has not yet been done to prove the extension of these elongations for any considerable distance; but present appearances suggest that the first effect of the disruptive force was to cause a rent in the rocks, and that the sides of this rent were torn away in the weakest part by the intrusive rock until the present form resulted.

In a few places mining-operations have pierced through the "floating shale" so abundant in the southern portion of Du-Toit's-Pan Mine; and the usual soft rock is met with below.

Under extensive areas of shale, the depth at which the dark compact rock occurs is less than where no such protection exists; this would lead to the inference that the "cores" or "pipes" have decomposed from the surface downwards, and that, in all probability, the rock will become more compact and less altered as depth is gained.

In all the mines the dark-coloured and less-decomposed rock occurs at depths varying from 80 to 100 feet from the surface, and always nearer the surface at the sides than at the centres of the "pipes."

At a depth of 120 feet, in Kimberley Mine, several small fresh-water shells were discovered in what appears to be undisturbed material. A specimen of mineralized charcoal was unearthed in the same claim.

Mode of Working.

At Kimberley the ground is picked and blasted at the bottom of the mine (a huge pit about nine acres in area, according to recent surveys), broken into small pieces, and brought to the surface in buckets running on wire ropes that stretch from the brink of the pit to each claim; on reaching the surface the tough decomposed rock is spread on the ground and exposed to atmospheric action, water being occasionally sprinkled over it to assist disintegration; subsequently it is dry-sorted (with sieves) by the old method, or, what is much more efficacious, washed.

The usual machines used for washing are:—(1) a small description of puddling-machine, specially adapted for this work, as the material cannot be reduced and run-off as slime or "sludge," but must be got rid of in fragments about the size of disintegrated granite (this process gives good results); and (2) a trough, with cross ripples, and rakes moving from side to side: the puddled material, with sufficient water, flows through it, leaving the heavy substances at the ripples; results uncertain, but still superior to the dry method.

The heavy sand obtained by the above processes, consisting mainly of garnet and ilmenite, with the diamonds, is taken from the machines and washed in sieves, in the same manner as tin-ore is separated from iron-sand &c.; and the diamonds are picked out.

Throughout the finest of this heavy sand minute diamonds occur, some so small that they are only recognizable by the aid of a lens.

As an instance of the yield of diamonds from Kimberley Mine, I may state, on good authority, that two claims, measuring together 60 × 30 feet, and worked to a depth of 150 feet, yielded 28,000 carats of diamond, or 2·8 carats per cubic yard of ground.

The claims on the boundary of the pipe at Kimberley are worked at a depth of 200 feet from the surface; those in the centre have been mined with less spirit, as they are considered less productive. The water met with, though comparatively insignificant, costs a large sum to get rid of, in consequence of the inefficient machinery employed and the absence of system in draining the mine; it is now utilized at the surface by washing-machines. Another heavy expense in working is caused by the ever-increasing liability of the unsupported sides to fall into and bury the claims.

"Trap Conglomerate" is mentioned in my former paper; and that occurring near Pniel is classed with the rock thus named by Wylie, which occurs along the edge of the Karoo Beds. Microscopic examination proves them to be quite distinct; and the manner of occurrence of the latter in Natal* shows it to be of sedimentary origin, while that mentioned as existing at Pniel is certainly intrusive, and of more recent date than some of the amygdaloids.

II. Gold.

Gold is mined for at Lydenburg and Eersteling, in the Transvaal Republic.

Lydenburg Gold-field is situate in a mountainous tract of country (lat. 25° S., long. 31° E.), the highest peaks of which rise fully 7000 feet above sea-level. The geological disposition of the rocks gives a peculiar character to the physical geography of this district. The rocks strike about N. and S., and dip at an angle of about 15° to the W.; in consequence the E. sides of the mountains are abrupt, while on the W. the slopes are gentle (see fig. 1).

This region, and a considerable portion of the Transvaal Republic, are occupied by beds of sandstone, mudstone (sometimes thinly laminated), white and red quartz rock, cherty and crystalline limestones (the cherty limestone thickly seamed with small veins of chert and quartz lying in the planes of bedding), thin beds of black calcareous sandstone, quartz-breccia (a rock resembling quartz rock that has been shattered and the cracks filled with vein-quartz &c.). Intercalated sheets of diorite are numerous; and dykes of the same occasionally intersect the stratified rocks. Massive diorite occurs about forty miles to the west of Lydenburg; and probably from it the sheets lying between the stratified rocks have been supplied.

Quartz reefs occur throughout the area occupied by the above rocks; they are generally barren-looking, and vary much in strike.

Diorite on the W., and gneiss on the E., appear to be the underlying rocks of this formation. The age of this series is unknown,

* Quart. Journ. Geol. Soc. vol. xxvi. p. 516.

as no fossils have been discovered by which to identify it; probably it is Silurian or Devonian.

The alluvial gold at Lydenburg Diggings has doubtless been supplied from two distinct sources, as gold occurs, associated with iron- and copper-pyrites, calc spar, &c., in the flat leaders and strings of quartz in the limestone-beds, and also with iron-pyrites in small lenticular veins of quartz in vertical dykes of diorite. An instance of the former occurs about one mile north of Mac Mac, where a "flat leader" of quartz, about 4 inches thick, has been opened out in calcareous rock; specks of gold are visible in the cavernous quartz. About two miles south of Mac Mac, near M'Lachlan's house, is a large dyke of diorite, in which are short narrow veins of quartz thickly studded with iron-pyrites and containing traces of gold (fig. 4). Very little has been done towards prospecting this dyke; but, from its resemblance to diorite dykes in Australia that have proved highly auriferous, it deserves careful examination.

Pilgrim's-Rest Creek has supplied most of the alluvial gold of this district; it is about thirty miles nearly due east of Lydenburg, about three miles in length, and flows to the westward, falling into Blyde River.

In its course it cuts through sandstones, thick beds of limestone seamed with veins of quartz and chert &c.; for a considerable portion of its length its bed is diorite, generally soft. There are two descriptions of drift worked:—that occupying the present bed of the watercourse, which is from 5 to 12 feet in depth, fine alluvium at the top, then clay and pebbles of sandstone, quartz, chert, &c., with about a foot of auriferous drift lying on the bed-rock; and that known as "terrace claims," worked at various levels above the creek-bed, where the base of the moraine-like mass of débris that forms a talus to the mountains is exposed resting on the bed-rock. The gold is all within a few inches of the bed-rock; where soft diorite formed the floor many of the claims were very rich. The heaviest nuggets were found where hard irregular blocks of diorite contract the creek-channel (fig. 2).

The gold is coarse and nuggetty, as a rule well rounded, and generally coated with oxide of iron. Lumps up to 10 lb. weight have been found; it is of good quality, worth from 76*s.* to 80*s.* per ounce.

Sluice-boxes and cradles are used to separate the gold from the drift. The supply of water is abundant, and greatly facilitates mining. The principal impediment is the enormous size of the angular and subangular blocks of quartz-breccia that have to be removed; they are from 5 to 20 tons in weight, and appear to have fallen from the adjacent mountain-sides. The interstices between these blocks are filled with boulders and drift.

Mac Mac is on the east side of the ridge from which Pilgrim's-Rest Creek flows; the drift is formed of shingle of slaty sandstone, quartz, &c. There is an absence of the large boulders so common at Pilgrim's Rest; the gold is also finer, but inferior in quality.

At Eersteling, near Marabastadt (lat. 24° 5′ S., long. 29° 45′ E.), auriferous reefs are worked. The containing rock is steatitic and chloritic schist, dipping at a angle of about 80° to the northward. This series rests on gneiss, and is overlain unconformably by the group of beds in which gold occurs at Lydenburg. The principal reef worked is called the "Natalia," about 3 feet wide in places, dipping about 80° to northward (fig. 5); some very rich patches have been met with in it; and a fair sprinkling of gold runs throughout the stone; it is in the solid quartz as well as in the cavities. Dykes of diabase run east and west, parallel and close to the reef; cross dykes of dolerite intersect it.

Numerous other reefs run parallel and at right angles to the "Natalia." Some of them are auriferous; but so far none of them have been sufficiently explored to determine their value. Extensive crushing-plant has been erected at Eersteling; the yield from the main reef has been less than 1 ounce of gold per ton of quartz.

At Marabastadt the schistose series includes beds of green talcose schist, quartz rock, and felspathic schist, standing at high angles. Veins of quartz bearing N.E. run between the bedding; much of this quartz is cherty in appearance, and looks more like quartz rock than vein-quartz. Several of these veins contain gold in the heart of the quartz, but nothing payable has been discovered. Outliers of schist, containing reefs of quartz, crop out in several places over the gneiss-country, N. of 24° S. lat. Gold is reported as occurring in some of them.

III. Cobalt.

Smaltite and erythrite occur in the Transvaal, at a locality situated about six miles from Oliphant River, on a small stream named Kruis River. Middleburg is about thirty-six miles south.

The rock in which the cobalt-ore occurs is very fine-grained felsite, much shattered. The hanging wall of the mineral-yielding portion is formed by a large dyke of very fine-grained dolerite. There is no defined lode; but about 18 inches of the felsite rock, in contact with the dyke, carries small threads and lenticular veins of the ore, running parallel to the dyke (fig. 3); the widest vein of solid ore was 8 inches thick, but soon thinned out all round. The solid rock near the contact is mineralized; specks of ore are sprinkled through it. The mineralized part strikes E. 10° S. magn., and dips 55° southward. Beryls and millerite occur at the east end of the present workings; and the locality is one likely to prove rich in other minerals. To the east and south is an extensive area of diorite, amygdaloid, &c. More than 100 tons of ore have been sent to London.

48. *On the* Serpentine *and* associated Rocks *of the* Lizard District.

By the Rev. T. G. Bonney, M.A., F.G.S., Fellow, Lecturer in Natural Science, and late Tutor of St. John's College, Cambridge; *with Notes on the Chemical Composition of some of the Rocks of the Lizard District*, by W. H. Hudleston, Esq., M.A., F.G.S. (Read May 23, 1877.)

Contents.

Literature of the Subject.

The following papers occur in the 'Transactions of the Royal Geological Society of Cornwall:'—

"Sketch of the Geology of the Lizard District," by A. Majendie, i. p. 32.

"Hints on the Geology of Cornwall," by Sir H. Davy, i. p. 38.

"On the Serpentine District of Cornwall," by the Rev. J. Rogers, ii. p. 416.

"Contributions towards a Knowledge of the Geology of Cornwall," by H. S. Boase, iv. p. 160.

The subject is also treated in the following works:—

"On the Physical Structure of the Lizard District," by Professor Sedgwick (Trans. Cambridge Phil. Soc. i. p. 291).

"Report on the Geology of Cornwall and Devon," by H. T. De la Beche (published 1839).

"On the Serpentinite of the Lizard," by Profs. W. King and T. H. Rowney (Phil. Mag. ser. 5, vol. i. p. 280).

In the last of these papers the authors maintain the metamorphic character of the serpentine, but consider it probably an altered pyroxenic rock, like that of Bufaure in the Fassa-Thal. The paper appears to have been mainly written with the view of calling attention to imitative organic, especially Foraminiferal structures. So far as my experience goes, any thing of this kind is very rare.

The great work of Sir H. De la Beche, and the shorter paper of Professor Sedgwick, are models of careful observation; and several things mentioned hereafter have been already noticed by them. The former author strongly inclines to the belief that the serpentine is of igneous origin, though he admits some difficulties. The latter is of the same opinion, but suggests that the gabbro, greenstone (including some of what we now should call hornblende schist), and serpentine may be portions of the same igneous mass, which varied in mineral composition. As neither of these works is now very readily accessible, and I wish to make my paper as complete as possible, I have occasionally described phenomena noticed by them, although it has added slightly to the length of the communication. The microscope has, I hope, enabled me to explain several of those phenomena with which the appliances at their command could not deal. Where I differ from them, as I do occasionally, it is with diffidence, and only because, after careful consideration, I am unable to adopt any other conclusion. The remaining works are generally too vague in their terminology to be of much use at the present day*.

For the general features of the Lizard peninsula I must refer, for the sake of brevity, to Sir H. De la Beche's admirable memoir; suffice it to say here that the district of which I more particularly treat may be described as a plateau, partly cultivated, partly wild moorland, which, as a rule, descends precipitously to the sea, except where it is furrowed by small coves and gullies. The cliffs often rise vertically from 100 to 200 feet above the sea; of beach beyond the high-tide mark there is but little, the base of the cliffs being then often washed by the waves for hundreds of yards together. In not a few places the cliffs are totally impracticable from above, and could only be examined (without a hope of landing) from a boat below in the calmest weather. This, of course, adds greatly to the difficulty of investigating the district; for, even at low water, progress at the base of the cliffs, where possible, is often laborious, and the state of the tide has to be carefully watched.

The district described in this paper forms the southern part of the Lizard peninsula. I have examined the coast of this from Lizard Head to Mullion Cove on the west side, and from the same to Manacle Point on the east, as carefully as circumstances admitted, and have also traversed the interior in two or three directions.

The following rocks, the positions of which may be seen on the geological map, occur in the above district:—(1) hornblende schist; (2) serpentine; (3) gabbro; (4) granite (restricted, as will be shown, to the west coast); (5) greenstone, *i. e.* dark augitic or hornblendic traps, described hereafter in detail, restricted, so far as I know, to the east coast.

The most convenient arrangement will be to commence with a few remarks on the hornblende schist, next to describe the petrology and stratigraphy of the two coast-sections in detail, and then the inland sections, reserving to the end all details of the microscopic structure of the serpentine.

The Hornblende Schist.—Under this title are included an extensive group of rocks which I do not profess to have minutely investigated, as I was chiefly occupied with the rocks of presumed igneous origin. The following description, however, will be fairly accurate:—This

* Mr. Smyth, in his Presidential Address, Quart. Journ. Geol. Soc. xxiii. p. lxiii, calls attention to a distinct case of intrusion of the serpentine, and doubts the evidence of a passage into gabbro. He also mentions some interesting facts supporting the theory of a peridotic origin for the serpentine.

rock varies in the hand specimen from a black, schistose, but not very fissile rock, which appears to consist mainly of hornblende, to a dark greyish granitoid rock, in which the hornblende is not conspicuous, and the prevailing minerals are quartz and felspar in variable quantities, so that the rock sometimes might almost be called a quartzite; at others it resembles a vein granite. The more schistose hornblendic varieties, on a closer examination, show, generally, fine white specks of felspar. Now and then we find porphyritic varieties, sometimes with felspar crystals about $\frac{1}{4}$ inch long, sometimes with hornblende about the same size; occasionally also the rock appears to contain a talcose or chloritic mineral in large quantities, especially when it shows signs of decomposition. I have examined microscopically three varieties of this rock—one (1) a typical specimen of the prevalent black hornblende schist*, another (2) a dark grey granitoid variety, and the third (3) a greyish quartzo-felspathic rock, very difficult to distinguish from true vein granite.

1. About two thirds or more of the field is occupied by crystalline grains of hornblende of rather irregular outline, with very characteristic cleavage, of a green colour, and strongly dichroic. There are many small rounded or vermicular grains of a black mineral, probably magnetite, often included in the hornblende, occasional small rounded or subangular grains of clear quartz, and a few small acicular hexagonal crystals, probably apatite. The rest of the field is occupied by a kaolinized or altered felspathic mineral, which seems, in parts, as if it had never been perfectly crystallized.

2. Taken from a junction with a gabbro vein, and shows traces of foliation parallel to the common surface. Exhibits an imperfectly crystallized and decomposed groundmass, as in the last, though much more abundant, as well as numerous fairly defined felspar crystals, generally plagioclase; quartz rare; magnetite less abundant than in the last, as is, of course, the hornblende; the crystals of this are also more irregular, with less-distinct cleavage-planes, often somewhat acicular, platy or fibrous. There are microliths—some, probably, apatite; others, shorter and strongly dichroic, may be tourmaline.

3. A rarer variety, closely resembling a vein granite, being highly crystalline, and consisting of quartz, felspar, and a little mica. A microscopic description of one of these will be given further on.

In general the hornblende schist, except in the darkest and most compact varieties, shows distinct signs of stratification; sometimes thin felspathic (or quartzose) and hornblendic bands alternate, occasionally exhibiting current-bedding; and sometimes quartzo-felspathic strata, from an inch to a few feet thick, alternate with more hornblendic, chloritic, or earthy layers. Epidote is occasionally present in minute quantities; and veins of quartz, felspar, and ferruginous matter occur. Foliation seems generally almost, or quite, parallel with the stratification; there are many extremely beautiful small contortions. The rock is rather sharply jointed, and weathers into bold headlands, dark in the wash of the waves, grey and lichen-covered where exposed to the blasts.

* See Mr. Hudleston's analysis, p. 928.

At the south-west corner of the Lizard peninsula is a mass of talco-micaceous shales, described by De la Beche (p. 29), and separated in his map. As far, however, as I can make out, they only form a zone with some slight lithological peculiarities in the hornblendic schist, into which they seem to pass almost insensibly. These may be well studied in the descent to the shore at Polpeor, and in the base of the cliffs there.

The Western Coast.

Following the cliffs from Polpeor for about a mile in a straight line, we come to the first junction with the serpentine, at the south end of the narrow strip of sand called Pentreath Beach; a little chine runs almost along the line of junction. To make out the relations of the two rocks here is no easy task; both are extremely decomposed for some yards, and traversed by numerous cracks, which are filled with calcite, often stained red with hæmatite, and project like a network from the weathered ground. The rocks are thus almost brecciated *in situ*. The difficulty is caused by the close resemblance of the two rocks in their extremest decomposition, so that it is sometimes almost impossible to separate them. After two or three visits and a most minute examination, I think I have succeeded. The cliff on the north bank of the little chine is all serpentine; on the south the headland is all hornblende schist; but after a few yards the serpentine rises from the shore and forms the lower part of the cliff, its boundary curving gradually upwards. Thus there is not really a passage from the one rock to the other here, or a faulted junction, but the serpentine is intrusive. The serpentine then forms the cliffs as far as they can be followed; above them, near the upper end of the beach, and some 50 feet above it, a granite vein breaks in two or three places through the serpentine, which is cracked and altered at the junction; the granite is finely crystalline, chiefly composed of quartz and felspar, with only a little mica; it is of a pinkish grey colour, becoming red and friable in weathering. One mass has carried up some irregular fragments of hornblendic schist. Close by is another mass of hornblendic schist, included in the serpentine, possibly forced into it by the granite; and another included mass may be seen on the beach below. On the hillside, a short distance beyond, is a serpentine-quarry. Two of the varieties of the rock obtained here are very pretty (no. 1 *):—one, of a dull red colour, irregularly mottled with a waxy-looking dull green mineral, with occasional flakes of greenish bronzite †, rather hard and irregular in fracture; the other, a dull purplish red, veined with greyish green, the latter generally fringing a thin dark line, like a crack, and forming a sort of polyhedral network. It is probably only the result of decomposition, but produces a very pretty effect. At the north-east angle is a bifurcating granite vein, about

* These numbers are for reference in the microscopic descriptions.

† Until I come to the microscopic examination of the serpentine, I shall use this term as generic, to include either metalloidal diallage or enstatite.

a foot wide, colour and texture much as before; the serpentine adjoining is much baked. In a small excavation on the east side of the quarry, a piece of hornblende schist may be seen included in the serpentine.

Passing on northwards we find a granite vein exposed on the north side of the little cove just before reaching Kynance, and another at the zigzag of the road descending to that cove. Serpentine forms the cliffs on the mainland, the large island, the Steeple rock, and some of the smaller skerries; it is generally of a dull red, mottled with dark green, which often coats the joints (no. 2). Much of it shows the sharp but rather irregular jointing so common in the Lizard serpentine; one of the nearer skerries, however, exhibits a very distinct jointing in a series of parallel curves, such as we not seldom see in igneous rocks. But three or four of the reefs that rise from the sandy spit joining the island to the mainland are highly crystalline hornblende schist; and about the same number are little bosses of vein granite: two small bosses of this also lie just opposite to the opening of the cove. Of this there is a larger boss in the middle of the serpentine, above the "Drawing-room" cave, and another on Asparagus Island, just beyond and above the "Post Office;" these two bake and crack the adjoining serpentine, and resemble that already described.

By scrambling over the boulders along the beach to the north of the Steeple rock we come (in about 100 yards) to a most interesting and difficult section. At first sight it seems rather to confirm the idea of a passage from hornblende schist into serpentine, the two rocks being apparently interstratified, almost vertically, in a low terrace-like step at the foot of the cliff which is of serpentine. As we face this, we have on the south (1) serpentine, (2) a mass of grey, rather sandy "hornblende schist," about 8 feet thick, with apparently many thin laminæ of red serpentine, (3) red serpentine (no. 3), rather fissile in structure, two and a half feet, (4) a dark brownish grey rock with crystals rather resembling diallage, two feet, (5) red serpentine, four and a half feet, divided by a thin band of the schist (2), then (6) bedded schist like (2), with the apparent layers of serpentine, for about six feet. Here a branching granite vein breaks very irregularly through the schist on the top of the terrace, and shows again in three places in the shore just at the foot. When we examine carefully the back of this terrace, we see that all this schistose mass is really included in the main mass of serpentine. A great fragment of schist has been caught up by that rock when molten; some of the beds composing it have been forced asunder and parted by tongues of serpentine. The apparent interstratification of schist and serpentine on a smaller scale is due to the fact that a serpentinous mineral has been deposited by infiltration in the schist (as is commonly the case near a junction); and, further, the staining of certain layers by red peroxide of iron makes them simulate a rather decomposed serpentine. In two or three cases these *may* be the ends of thin tongues of intruded serpentine; but in most the red streak is certainly not true serpentine. Finally, a granite vein has cut irregularly through all these rocks.

The rock (4) is not easy to determine; its texture is coarser on the face of the crag than it is along the outcrop a few feet back; I have had slides prepared from each part. The finer variety consists of an interwoven mass of rather acicular crystals of hornblende (actinolite), in a clear base, which, with crossed prisms, either remains dark or exhibits an obscure microcrystalline structure. This in parts seems to resemble steatite; in others it is more like one of the pseudomorphic products after felspar, which will be noticed below. Granules of magnetite* are scattered about; and there are some very irregular grains or plates of a brown hornblende, full in many parts of a black dust. This mineral appears, from its cleavage, to have a platy structure. In the coarser specimen there appears still more actinolite, and the brown hornblende grains are much larger; they appear in some cases to have been broken or partly destroyed after they had been formed. The mineral to the eye has a clove-brown colour; it much resembles anthophyllite, but is certainly not an orthorhombic mineral; probably it is the variety of hornblende noticed by Rosenbusch (Mikr. Phys. p. 264). I believe that this rock was originally a hornblende schist, that its entanglement with the intrusive rock affected it to some extent, and that since then it has undergone further changes, chiefly by the action of water.

Nearly above this place, at the top of the cliff (the Rill), is a landslip, or a deserted quarry, of considerable size. Here are two granite veins in the serpentine—one about 4 feet wide, forming a curved dyke running up the face of the higher cliff, the other showing in it a short distance towards the south. Both are much decomposed and of a red colour; they crack the serpentine in contact considerably; and in places it is so much altered that for a few inches it might be taken for a talcose schist. We have thus an irregular line of veins and small bosses of granite extending pretty continuously over more than half a mile. The serpentine forming the cliff just mentioned is compact in texture, of a dull purplish colour; the bronzite crystals are few and small (no. 4). When examined carefully the rock shows a sort of parallel streaky structure, indicated by darker lines; the faces of the joints are coated by films of green or whitish steatite; and old surfaces weather dark rusty brown. The parallel structure becomes much developed by the weathering, and might easily induce the supposition that the rock was really stratified. It is particularly well exhibited along the down to the north of Kynance Cove, though it may also be observed to the south of it, as in other places. In the coarser varieties the structure appears to be formed by bronzite crystals, which have resisted weathering better than the matrix in which they are imbedded.

* To save time, I shall use this term for the opaque mineral, obviously an oxide of iron, common in many of the rocks described below. As, however, it generally occurs in small rounded grains, I cannot be sure that it is always magnetite, since it may be ilmenite. Chromic iron has been found in serpentine near Cadgwith (Trans. R. G. S. Corn. ix. 99).

We pass now along the edge of the cliffs northward; these are not seldom so precipitous as to make a close examination impossible. The serpentine varies in character, being sometimes dull and compact, sometimes redder in colour, and containing larger bronzite crystals. The headland called the Horse is remarkable for the boldness of the jagged rocks that form its crest, which in form, colour, and even in aspect, recall memories of the gabbro of the Cuchullin Hills; the rock, however, is an ordinary serpentine.

Nearly a mile in a direct line north-west from Kynance is a cove called Gue Graze. A gully on the north side exhibits a granite vein; it resembles that already seen*. On descending to the beach we find the serpentine is in places much brecciated and cemented by steatite, which is here abundant. Much of the serpentine on the beach is rather peculiar in appearance (no. 5), being of a dull red colour, with obscure dark greenish lines, a slightly rougher fracture, and (under the lens) more granular texture than common; it is also remarkable for hardness and the absence of conspicuous bronzite. In many places it is sand-polished. The joints are often coated, as usual, with films of green steatite.

Returning to the higher ground and passing Vellan Head, we continue to observe the apparently stratified structure in the serpentine, which sometimes even seems to mimic current-bedding. Near the Head its dip is fairly persistent, about 50° south; but this does not continue for long; I observed, however, that it was often parallel to one of the leading systems of joints; and hereabouts fairly defined tabular jointing is not unusual. The end of the serpentine is reached at a spot called Ugethawr, on one side of George's Cove, to the south of the place where a well-marked valley descends to the sea; thus the breadth of this practically uninterrupted tract of serpentine, measured in a straight line from sea to sea, is about $2\frac{1}{4}$ miles. I could not find the actual junction of the hornblende schist and serpentine on the rocky slope; but it is possible to scramble down to the water's edge, and there it can be discovered in a little sea-cave. It is in many respects an interesting one. The hornblende schist is rather compact and very dark; so also is the serpentine, especially near the junction—so compact, dark, and hard†, indeed, and with so conchoidal a fracture, that at first sight it might readily be mistaken for Lydian stone; it overlies the hornblende schist, which here dips rather evenly about 60° W.N.W., and seems to be closely welded to it. One or two thin *tongues of serpentine are thrust into the schist* within a foot or two of the junction. The serpentine is therefore

* The granite of Gue Graze may be regarded as fairly typical of the veins on the west coast; so that it is the only one which I have examined microscopically. It consists of quartz and felspar, both orthoclase and plagioclase. There is a scale or two of magnesia mica, a good many small clusters of minute granules of magnetite, with some fine needles and asbestiform fibres, some of which I think are tourmaline. There is an orthorhombic mineral of secondary origin here and there in the felspar, probably prehnite. One rather abundant microlith seems to be apatite; but there is probably another mineral also present. Altogether there are a good many included microliths and some minute cavities.

† Its hardness varies slightly, but is about 5.

intrusive; but the junction is a remarkably clean one, and the close correspondence in colour adds to the difficulty of seeing it. The serpentine, in places, near the junction exhibits very regular, thin, parallel bands, of a greyish green mineral, and of very lustrous chrysotile, and is in all respects a remarkable variety (no. 6).

The serpentine is not again seen on the coast till the other side of the bold headland of Pradanack Point, rather more than a mile away in a straight line. The boundary line between it and the hornblende schist, according to the geological map, curves inland, the greatest distance from the sea being a good half mile. I have not traced it, but have examined the serpentine in a small pit, not far from the boundary, on the left bank of the valley mentioned above. Here the rock is rather decomposed and traversed by many joints, coated by a white steatitic film; in parts it shows some indications of a streaky structure; the colour is a dull earthy red to brown. The rock is full of minute scales, of a talcose aspect, which gives a glimmering lustre to the broken surfaces. Fracture rather uneven (no. 7).

The dark crags of hornblende schist which form the northern side of Pradanack headland are singularly grand, as are the cliffs of the next mass of serpentine. The junction here is difficult to examine. A small gully seaming the face of the cliff marks it, as is often the case; but though we spent some time in careful search over the accessible parts, we could find no actual contact, though we traced the two up to within a yard of each other. This mass of serpentine is also dark; a specimen obtained a few yards from the gully is of a dull olive, approaching black (streaky structure clearly indicated by paler lines), rather unequal fracture, and lustreless surface; joints coated with paler greenish films. The hornblende schist is much broken and disturbed near the junction, and looks as if in the vicinity of an intrusive rock. The dip, in a glen a little south of the above spot, was 55° E.N.E.

The celebrated Mullion Cove is the end of a valley which very nearly defines the northern limit of this mass of serpentine; it is, however, cut everywhere through the hornblende schist. The actual junction is masked by débris; so this also is inconclusive.

The serpentine at the northern end varies: most of it is dark dull green to black; but in one place it assumes a redder tint. A common variety has a dark, almost black, matrix, full of small scales of glittering mineral, similar to, but darker than, those at Pradanack (no. 8). A fine sea-cave here well repays a visit.

A very short distance beyond the cove is another mass of serpentine, not marked in the map, dull in colour, streaky in structure, resembling that in the southern part of that which has just been mentioned. There is sometimes a little difficulty in tracing the exact junction of this and the hornblende schist; but there can be no doubt that the serpentine is intrusive; on the northern side, against the cliff, is an included fragment of the schist. Again, the headland to the west of the above is serpentine, with two included fragments of schist by the track which ascends it; the adjoining islands appear to be one serpentine, the other schist.

The hornblende schist on each side of the cove has a fairly regular strike, of about S. 23° W., running straight at the main mass of serpentine, and dips at a high angle (about 86°) on the western side; north of the above spot I could not find any more serpentine.

The Eastern Coast.

(*a*) *The Coast to Coverack.*—The sections on this coast are, on the whole, more complicated than those on the western. Commencing at the narrow cove of Perranvose near Landewednack, we find this cut down to the shore through hornblende schist; but by turning aside along a track before the steepest part of the descent, we are in a few minutes brought to a serpentine-quarry at the top of the cliffs above the sea.

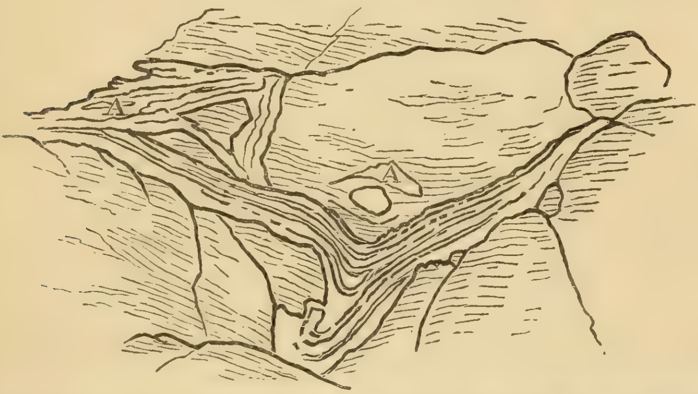
By the side of the road leading into this, the junction of the serpentine with the hornblende schist is well seen. The former overlies the latter, following very nearly the plane of its bedding, which here dips at about 40°. The last foot or so of the serpentine is extremely rotten, crumbling into dust under the fingers; the hornblende slate is also rotten, and stained red; hence, as is often the case, the junction may be easily overlooked. Its nature, however, is clear; for careful search will detect two small tongues of serpentine a few yards distant in the hornblende slate—the larger about 2 feet in diameter. They are extremely rotten, but undoubtedly are serpentine.

The quarry furnishes some handsome varieties of this rock, generally a compact purplish or reddish brown groundmass, mottled and veined with pistachio green, in which are small groups of bronzite crystals of greenish hue and submetallic lustre, and sometimes veins of brightish red hæmatite (no. 9). Some masses are almost wholly of a grey-green colour; but this is only the result of decomposition; in some, minute crystals of magnetite are common. The lower part often exhibits a curious fissile structure, the cracks being filled by calcareous films. Sometimes the latter are about $\frac{1}{4}$ inch thick and the mineral is aragonite.

By descending the "tip" of the quarry to the beach and walking to the end of a little headland, we have further proof of the intrusive character of the serpentine. The headland consists of hornblende schist, resting on serpentine which forms a little isthmus; the slope on the south of the "tip" shews hornblende schist with intrusive tongues of serpentine; then two or three more masses of hornblende schist crop out in the slope; and finally there is a small headland of that rock. On the other side, beyond the débris, is serpentine curving round to another little headland of the same rock.

Rounding this, we enter a second little recess, and passing two fragments of schist included in the serpentine, come, on the opposite side, to a third of the most singular shape. Any one looking at the outline only, would take it for a dyke (see fig. 1). The bedding however, and mineral character of the rock are perfectly distinct. Other smaller masses, included in the serpentine, will be noticed on the shore, in some cases indicating by their peculiar jointing that they

Fig. 1.—*Irregular Strip of Hornblende Schist caught up by Serpentine.*

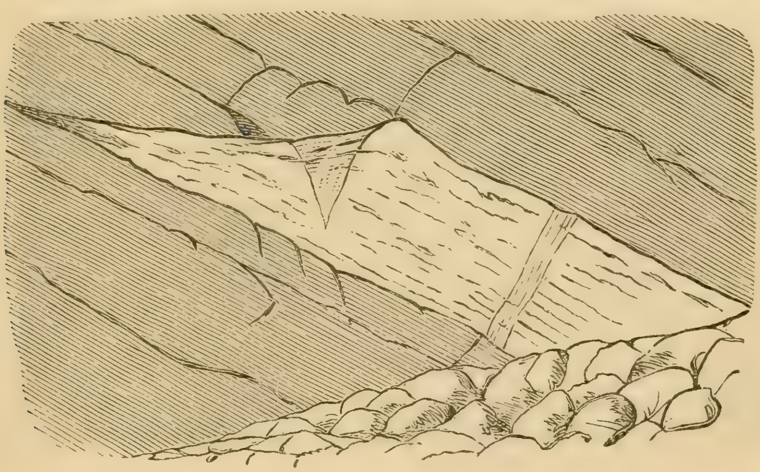


A. Hornblende schist. (The parts shaded by fine lines are serpentine.)

have been subjected to heat. Clambering on at the base of the serpentine crags, we enter a small bay with a narrow shore, almost divided into two by a slight projection. Soon after entering the nearer of these we pass, at the base of the cliff, two small intrusive gabbro veins, the nearer at most about two feet thick and branching, the other about half as much. The rock is dark in colour, partly owing to staining from the serpentine, and rather coarse. This bay also exhibits well the relations of the schist and serpentine. The luxuriant herbage generally masks actual junctions, except in one place near the base of the cliff, where the serpentine may be seen gradually passing across the broken ends of the beds in the schist; but without this evidence the relations of the schist and serpentine in the cliff cannot be wholly explained by faults.

A gabbro vein in thehornblende schist should be noticed; it is about half a yard thick, and in form a rude rhomboid (fig. 2). It exhibits a

Fig. 2.—*Foliated Gabbro Vein in Hornblende Schist at the Balk.*



marked foliated structure, the felspar and the pyroxenic constituent being to a great extent separated, and the latter running in seams roughly parallel to the longer sides of the vein, except towards the top, where it tends to become parallel to the upper surface. This structure is more conspicuous near the lower surface. The felspar, at any rate on the exterior, is a dull yellowish white ; the other constituent, as is very common here, is chiefly made up of minute crystals of hornblende, which, as will presently be explained, have almost entirely replaced the diallage. Some six feet above the end of this vein a tongue of serpentine, about 1½ foot wide, is exposed in the schist.

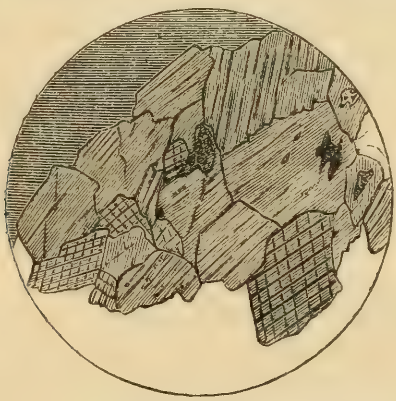
The bay is bounded by a small headland ; and the shore is strewn with fallen blocks of schist and coarse gabbro. I will first describe their general relations, then discuss their lithological character.

The gabbro and hornblende schist are here mixed up in the most extraordinary way ; the gabbro has penetrated again and again through the latter, crumpling up pieces of it in places so much that it is difficult to believe they come from a sedimentary rock. The best example of this intricate intrusion can be seen from a narrow track just above the headland. Here some of the veins of gabbro are only an inch or two wide and about a quarter thick ; they thin away to mere strings, but remain rather coarsely crystalline to the last. This seems to indicate that the whole mass of the rock was at a pretty uniform high temperature at time of the intrusion. The so-called granite vein is a grey bed of a highly altered rock : a crystalline granular compound of quartz, felspar, and a little mica or hornblende. At the base it is most difficult to distinguish from vein granite. Still, after several very long and careful examinations of this part of the coast, I am quite convinced that it is merely a case of extreme alteration, and that there is no granite here. Below this is another intruded mass of gabbro, terminating in a broad broken tongue, the root of which rests upon a prominence of serpentine. Hence both these rocks are here intrusive in the schist. On the northern side of the headland we have a large mass of gabbro intrusive in and enclosing blocks of hornblende schist—and three masses of serpentine, one of large size.

The hornblende schist is here rather variable in character, having much less hornblende than in the ordinary black variety, and a considerable quantity of felspar and quartz. The gabbro usually consists of an opaque white or pale cream-coloured mineral of rather granular fracture, and of diallage which is often replaced wholly, or to a great extent, by a green mineral, something like chlorite. The former under the microscope appears irregular in outline, partly semitransparent, partly occupied by more or less opaque dotted aggregates of dark grey dust. Indications of cleavage-planes may be sometimes traced in this, shewn by fine parallel more transparent lines. With crossed prisms this mineral is, as might be expected, almost, or quite, dark, the clearer portion appearing as an aggregate of minute crystalline granules and microliths of ill-defined form showing faint colours, with occasional small irregular interspaces of a pale translucent bluish grey. Now and then there is a portion still showing the colour and striping of plagioclase felspar. This alteration is very common in the gabbros of this district. Some from Coverack Cove, which I shall presently describe, show it in an early stage; some from Karak Clews in a later; a specimen also from this very headland, cut to shew the junction of the gabbro with the hornblende schist, still retains its plagioclase in many parts unaltered. A similar alteration has taken place in a gabbro which I have collected from Mont Colon, in the Pennine Alps; and I have observed it in not a few other cases. I regard the mineral therefore as a kind of pseudomorph, the result of the alteration of labradorite or some plagioclase felspar. It is the mineral often called saussurite, and is quite as hard as, sometimes a little harder than ordinary felspar *.

The other mineral is sometimes diallage †, but in others a rather dark green mineral, something resembling chlorite at first sight; microscopic examination proves this to be hornblende. The larger patches are found to be composed of irregular aggregates of small prismatic crystals and grains (or possibly occasionally folia) of that mineral; these are generally pale green in colour, fairly dichroic, changing from a strong dull green to a sort of straw-green, and now and then showing very distinctly the characteristic cleavage along ∞P (fig. 3). On examining a series of specimens, both macroscopically and

Fig. 3.—*Hornblende in Gabbro Vein from the Balk.*



The part left white is altered felspar

microscopically, this change, which we shall find to be very common in these Cornish gabbros, is seen to take place as follows:—The aggregated hornblende crystals form as a kind of border to the diallage (fig. 7, p. 912), when the latter generally becomes rather opaque under the microscope and loses its brilliant colours with polarized light, and its metallic lustre with reflected light, assuming a greenish colour and silky aspect. Small crystals of hornblende also appear here and there in the body of the crystal, inserting themselves, as it were, between

* See Mr. Hudleston's analysis, p. 927.
† See Mr. Hudleston's analysis, p. 927.

the planes of principal cleavage; until at last the whole crystal is converted into an aggregate of small crystals of hornblende. From the general appearance of the mineral I take it to be actinolite, which as a non-aluminous variety of hornblende would most readily be formed from ordinary diallage. In many cases it is almost fibrous in structure; then it is paler in colour and feebly dichroic. The specimens which I have examined have not shown me any olivine; yet, as we shall presently see, this mineral abounds in the gabbro further north. This absence seems strange: I have, however, some reason to think that it, too, in this case, has been replaced by actinolite*.

The "granite vein" headland is a prominence on a rather larger one; beyond this is a little chine and another small headland. Over this space serpentine predominates; but fragments of hornblende schist are included, and intrusive dykes and veins of gabbro are common. Every step shows something new and interesting. At one place the gabbro on the left, and the serpentine on the right, make an almost vertical junction in the cliff. The former includes a long strip of hornblende schist in an upright position; the latter assumes near the junction a rather fissile character. Often it would be hard to say whether the serpentine or the gabbro were the intruder; but here and there may be found conclusive evidence that the latter is the newer. The gabbro is coarse, the diallage crystals being sometimes very large, one composite specimen being about $6'' \times 2'' \times 2''$. The foliated structure mentioned above is often seen; and I observed that, as a rule, it was best developed where the gabbro intersected the hornblende schist, especially where it had passed between two masses along the plane of bedding. As the whole mass cooled, these already solid schists would doubtless produce a definite pressure on the crystallizing rock between them at right angles to their bounding surfaces, and so determine its structure. I have seen the mica crystals in a granite vein which had broken through angular fragments of a schist lying at right angles to normals from their surfaces, and have often observed that on the outside of a granite vein the mica plates tend to lie parallel to the surface.

The next headland exhibits both serpentine and gabbro intrusive in schist, with a large felspar vein. But it is needless to carry these details further; so I will select one more section for description, the last which can be reached from the shore. Here a lofty cliff of serpentine is shattered by veins of gabbro, one of which, about ten

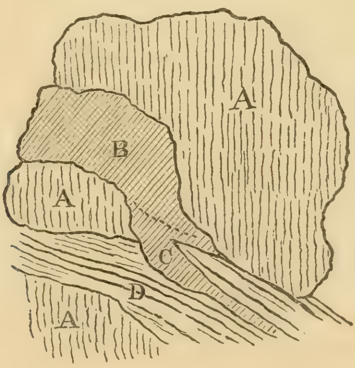
* I have good reason to believe that this replacement of augite or diallage by a form of hornblende has taken place in several of the Welsh "greenstones." It is not precisely a paramorphic process like the formation of uralite, nor a pseudomorphic, because the form of the original crystal is often lost, but a replacement of a mineral by another, which, if not really a dimorphous form of the first, is very closely allied to it. I conceive the change to have been mainly brought about in the "wet way." I have seen the same change in the gabbros from Mont Colon (mentioned above), and the Matterhorn, also in the hypersthenite of Penig (Saxony). MM. Poussin and Renard have observed it in the Ardennes rocks (Roches Plutoniennes de la Belgique, &c. p. 69).

feet thick, forms a sort of terrace, some height above the shore, which can be reached with a little difficulty; the gabbro is extremely coarse, the diallage crystals being often two or three inches long; and some of the largest occur in a vein only a few inches thick. Just on the left there appears to be a small fault in the serpentine; on the right is a large included mass of schist forming a headland, down to which descends a dyke of dark compact trap about a foot wide. This can be seen to cut through two sheets of gabbro and the serpentine between them, and ends abruptly against the schist. The examination of this part of the coast leads to the following conclusions:—

1. That the serpentine is an intrusive rock.
2. That probably the hornblende schist was metamorphosed prior to its intrusion.
3. That the gabbro was probably intruded when the serpentine had arrived at its present condition.
4. That the black trap dyke was intruded last of all.

Under the microscope the trap is found to consist of a groundmass generally microcrystalline, consisting probably of some pseudomorphic

Fig. 4.—*Gabbro intrusive in Serpentine and Hornblende Schist north of the Balk.*



A. Serpentine. C. Gabbro showing a foliated structure.
B. Gabbro. D. Hornblende schist.

product after plagioclase, with perhaps minute crystals of actinolite enlarged, and a large number of small hornblende crystals, merely rather platy in structure, but varying from the normal to the actinolitic form. There are, as usual, grains of magnetite, and a number of microliths, sometimes acicular, sometimes rather irregular in form, which are commonly included in the larger hornblende crystals, lying with their longer axes in the planes of principal cleavage. I have not been able to satisfy myself as to the nature of these. At present we must call the rock a diorite; but whether it has always been hornblendic is by no means certain.

From the above headland a walk of about a quarter of a mile along the edge of the cliffs leads to Polbarrow Cove. The cliffs, which appear impracticable, consist of serpentine; but some of the jutting reefs below resemble hornblende schist.

Descending into Polbarrow Cove by a narrow track, we find that the southern part of it consists mainly of hornblende schist; but there are intrusive veins of serpentine in it close to a natural arch, as well as in the little ridge of schist, on the middle of which stands a small boathouse. Serpentine may also be seen in a quarry above the cliff south of the boathouse. Just north of this is a junction of the schist with the serpentine, which runs obliquely in this direction up the cliff. It now continues for some time; but two low headlands which bound the cove are capped by hornblende schist; and the next one to north is wholly of that rock. There is a gabbro vein in the schist, near the junction with the serpentine, about on a level with the boathouse, and another much higher up the cliff in the latter rock.

Returning to the cliff we come to a small quarry showing a junction of hornblende schist and serpentine. The former rock dips about 27° E.N.E., and in 1873 could be seen to be overlain irregularly by the serpentine. In one part of the quarry a piece of the schist was intercalated between serpentine. In 1876 the relations were less clear. The schist is very dark and full of hornblende. The specimen described above was collected here. The cliffs, as may be seen from the geological map, consist of hornblende schist from this spot to near Cadgwith, when we come to another junction in the celebrated Devil's Frying-pan, obviously an old sea-cave whose roof has fallen in.

The relations of the serpentine with the schist, as seen by descending into this hollow, leave no doubt that the former rock is intrusive. On reaching the shore we find ourselves at the bottom of a funnel-shaped pit communicating with the sea by a natural archway. This, and the greater part of the two adjoining sides, is of hornblende schist, which dips westward at an angle of 40° to 50°, increasing gradually to about 70° towards the west on the southern side, and rolling over considerably on the northern. The remaining side is serpentine.

The junction at the S.W. corner is masked by débris; but on the other it is clearly an intrusive one, a large fragment of schist being entangled between two masses of serpentine. I think that the present summit of the entrance archway also marks a former junction with the serpentine; for the schist of this looks much disturbed and slickensided, and has a "junction" aspect. Also an overlying block apparently *in situ* is serpentine. The serpentine is dull mottled blackish brown and red in colour, full of small glittering scale-like crystals with a rather silvery lustre, as at Mullion and at Pradanack Quarry.

After climbing back to the pathway leading to Cadgwith, the descent into that village is mainly over serpentine. But the rocks exposed in the little cove forming the harbour are very characteristic hornblende schists, dipping about 35° N.N.W.

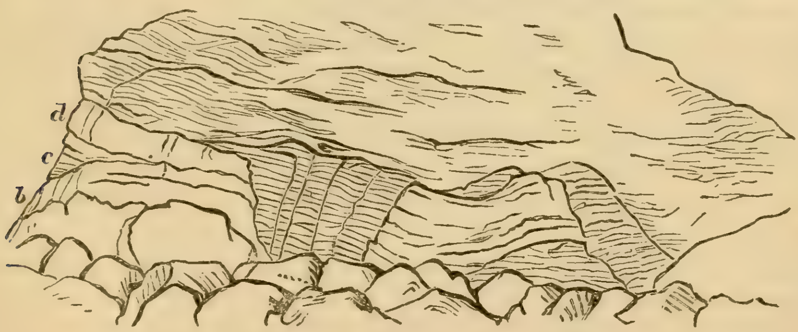
On reaching the summit of the steep ascent which leads from

Cadgwith village to the level of the main plateau above the sea, we again find the serpentine. A quarry here (in 1876) showed the junction with the schist very well. The former rock overlay the latter (which had a dip of some 30°) with a rather irregular junction; but here, as in other cases, it seems to have generally forced its way fairly evenly along the plane of bedding. The serpentine (no. 6) is very compact in texture, and varies from a claret-colour to an olive green, both varieties being veined and mottled, the former with dull green and bright red, the latter with a purplish tint; occasional layers of greyish-green steatite occur.

The serpentine in the cove beyond is mottled light and dark green. This rock now continues to form the cliffs above the sea for some distance. About half mile from Cadgwith (measured in a straight line) the shore is strewn with huge boulders and overhung by cliffs of a dark serpentine. This rock is almost as black and compact as that of George Cove; but the surface is varied by a vein-like mottling of very dark olive-green, and by bronzite crystals about 0·2 inch wide with a bright submetallic lustre (no. 10); it weathers a dull earthy green.

Some 100 yards from this spot, along the shore, we reached an apparently faulted junction of the serpentine and hornblende schists. Directly after, the serpentine sets in again, overlying the other rock, following nearly the plane of bedding. The hornblende schist is extremely altered; some bands in it are in colour and texture very like ordinary vein granite; but, after most careful examination, I feel convinced there is no true granite here. The ends of the strata are bent over on the southern side; and in the lower part a coarse breccia of schist and serpentine separates the two masses of these rocks. There is a similar breccia, though less irregular, on the other side, where the base of the serpentine is greatly decomposed, the rock assuming an earthy aspect, of a mottled dull greenish or reddish grey colour, veined with indian-red, having scarce any resemblance to normal serpentine. A little further on are four masses of hornblende schist, one after another along the shore, caught up in the serpentine (fig. 5). Parts, again, of these are

Fig. 5.—*Masses of Hornblende Schist included in Serpentine.*



(The serpentine indicated by fine wavy lines.)

b. Schist, bedding nearly vertical. *c.* Tongue of serpentine.
d. Schist, bedding nearly horizontal, highly altered.

curiously like vein granite; but I am convinced all is metamorphic rock. The serpentine near the junction is, as usual, much decomposed; a line of breccia either of schist or altered serpentine extends from the top of the first to the second. The northern end of the third piece all but joins the fourth; and the beds in it are absolutely squeezed together by the pressure which they have undergone. Then we pass another small fragment, and after about a hundred yards come to two or three more, all highly altered. Another, chiefly on the shore itself, occurs after about fifty yards; and they are common for the next hundred yards or so. A fragment occurs just at the angle where the cliff turns inland towards the serpentine-works in Caerleon Cove. Following this for a short distance we come to a remarkable "greenstone" dyke at the foot of the low cliff. It is from 4 to 5 feet wide; the sides for about 6 to 10 inches are very dark and compact, and so platy in structure as to be almost undistinguishable from some specimens of the hornblende schists. This structure is lost rather suddenly; and the rock assumes the ordinary aspect of an igneous rock, consisting of a finely crystalline mixture of white felspar and dark hornblende, with porphyritic crystals of the former as much as $\frac{1}{4}$ inch long.

I have had a section made of the heart of the dyke; and my friend Mr. Allport has kindly lent me two of his own cutting, one being from the outside. The former shows that the rock consists of a much decomposed plagioclase felspar in long narrow crystals. The interstices are occupied by a pale-coloured (generally greenish) hornblende of rather fibrous or filmy aspect. There is also some magnetite. The aspect of this rock is so like a typical dolerite, and so unlike a diorite, that I suspect the hornblende to be a secondary product, as in the gabbro. The other section is totally different, and closely resembles the hornblende schist above described. I examined the rock at the time to see whether a piece of schist had been caught up; but if it was, I failed to detect it.

Some of the quarries belonging to the Poltesco works are up the valley inland; but these I have not been able to visit. From Caerleon Cove a steep ascent leads us up again to the main plateau.

Hornblende schist may be seen on the shore of the next little cove, and on its left bank, above the path, intrusive gabbro*, coarse, but showing a rather foliated structure, may be seen on the rough grassy slope. I observed three exposures; near to the furthest there appears also to be a little schist, the rock generally on each side of Caerleon Cove being serpentine.

This rock, on the beach beyond the next headland, includes many large fragments of quartzose rock, some of which very closely resemble granite veins. After careful examination, however, I am of opinion that they are only bands in the schist. The more quartzose and harder layers have been forced among the softer, so as to mimic intrusion.

Beyond this, in cliffs of a dark serpentine, is a greenstone dyke,

* Analyzed by Mr. Hudleston, see p. 927.

the lower part of which bifurcates; and just beyond this is an included fragment of schist of singular form. The dyke in the mass has a slightly serpentinous aspect. It is a finely granular, almost compact, very dark grey rock, faintly variegated with minute white specks. Under the microscope its appearance is as follows:—There is a tolerably clear homogeneous-looking base containing a large number of small prismatic crystals and folia of greenish hornblende with fairly marked dichroism, and a good many small grains of magnetite. With the two Nicols the base exhibits the microcrystalline pseudomorph after felspar, and the hornblende shows brilliant colours. A little has a rather fibrous structure, and on rotating the stage behaves as an orthorhombic mineral; it is strongly dichroic, showing a brown tint (? anthophyllite); there is, however, not enough to enable one to be certain about it. A vein is filled by asbestiform mineral, possibly a variety of chrysotile.

Proceeding along the shore we pass in quick succession some other narrow dykes (three, I think) of very similar appearance. The last but one (2 to 3 feet thick) cuts through a vein of coarse gabbro about 10 inches thick, which shows again in one or two places in the face of the cliff. A little to the north it is apparently cut by another dyke; but after carefully examining the latter, especially where it is exposed on the shore, I believe it to be only an included fragment of a peculiar compact variety of the schist, highly altered. About 30 yards to the north is another included mass of the schist, standing upright in the serpentine cliff so as to look wonderfully like a dyke.

Just where the sandy beach of Kennack Cove commences is another large mass of included schist, occasionally resembling vein granite, which may be traced some way inland. Two or three intrusive tongues of highly decomposed serpentine may be seen in this mass.

Kennack Cove is a sandy tract at the embouchure of two flattish valleys, divided by a low headland of serpentine. In this is a small dyke about a foot (or rather less) thick, closely resembling those described above, but perhaps even more compact.

Crossing the second stretch of sand we come again to cliffs of dark serpentine, and find almost at the first point a dyke, generally from 4 to 5 feet thick, which bifurcates above. The appearance of this rock is very similar to those already described. Under the microscope it is found to consist of longish, rather irregularly outlined, plagioclase crystals, and a quantity of aggregated grains or imperfectly shaped small crystals of hornblende, green-coloured, strongly dichroic, and showing bright colours with polarized light. There are also some irregular grains of magnetite and a few needles of apatite.

A short distance further along the shore a mass of rock, forming a group of low reefs, bears, at first sight, a close resemblance to a granite vein. This is heightened by the extraordinary way in which, in one place, it inserts itself in thin tongues into the adjoining rock, which is a crumbling, dull, greenish to reddish substance, not unlike a decomposed serpentine. Careful examination, however, shows that we have here, highly metamorphosed and entangled in the serpentine, another mass of sedimentary rock, which has once consisted of lenticular bands of a more sandy character, in a mud whose mineral composition somewhat resembled that of hornblende.

The first stage has been the conversion of the former into a kind of granulite, the latter, probably, into a hornblende schist. Torn off and squeezed by the igneous mass (now serpentine), the harder bands have been crumpled up, and in some cases forced into the softer, which at last, by slow action of water, have been converted into a rotten chloritoid and rather serpentinous schist. The serpentine around is also rotten near the junction. In some places the two rocks are so altered by addition and subtraction of mineral constituents that it is almost impossible to fix their precise boundary; still I am convinced that the above explanation is the correct one.

I have examined a slice from the most granitoid part of this rock; and, though highly altered, it quite confirms my view. It consists of quartz, felspar, orthoclase, and some plagioclase, with a little of some variety of magnesia mica. The felspar is full of microlithic alteration products. In the quartz are a good many minute cavities and shapeless microliths—also some microliths of larger size, which may be apatite. Here and there a piece of the felspar (it is not very characteristic) is full of minute branching empty cavities or microliths (I rather think the latter), which would certainly be quoted as canal systems by the opponents of *Eozoon*. I have seen something similar in a granitoid rock from Holsteinborg (Greenland), but at present can do no more than record the occurrence, hoping to return to the subject on a future occasion. It is the nearest approach to an organic structure that I have ever seen*.

From Kennack Cove we proceeded along the cliffs to the headland of Karak Clews, about a mile distant. So far as I saw, serpentine continues all the way; and just before reaching the point called Carn Sparnack a small quarry affords some very pretty varieties (no. 11)—one a rich red mottled with dark olive green, the other claret-colour with similar markings, both containing in the green part small crystals of greenish bronzite with a submetallic lustre. Karak Clews is a bold headland formed by the extremity of a great elongated mass or broad dyke of coarse gabbro, which, according to the map, is about two miles long and a furlong broad. The headland terminates in a narrow ridge leading down to a precipitous mass of rock running some little way out to sea; the general direction is nearly N. and S., the mass further inland for most of its course having a N.W. strike.

There are very few places more instructive than this to the student of igneous rocks. Broadly speaking, the ridge consists of gabbro, in which so many pieces of serpentine are entangled that it would

* Perhaps the structure erroneously described as a Laurentian organism, 'Nature,' xiv. 8, 68, may have been this.

often be easy to suppose the latter intrusive in the former. Careful examination, however, will show that there is no doubt as to their true relations. The serpentine is generally much decomposed.

On the western side of the headland the gabbro extends for some distance along the shore. I was unable to examine closely its junction with the main mass of the serpentine; it appeared, however, to be, as usual, intrusive. A small shallow gully just on this side of the actual headland affords the best study of the gabbro, which might be mistaken for a metamorphic rock. The schistose structure strikes about N. and S., extending in considerable perfection over a space about 5–6 yards broad, and dips to the eastern side at an angle of about 80°. It is, however, quite impossible to draw any line of demarcation between the foliated and the ordinary (rather coarsely) crystalline gabbro. This consists of a purplish-grey plagioclase felspar, probably labradorite, often mixed up with a dead-yellowish-white felspar (the saussuritic variety already mentioned), which of course predominates on exposed surfaces, crystals of brownish diallage, often about $\frac{1}{2}$ inch across, and having a metalloidal lustre, and a considerable, but variable, quantity of the minute rather dark green hornblende already described. In short, the process of alteration from an augitic to a hornblendic rock has taken place here as at the Balk; and specimens may be found in almost every stage. Not seldom the diallage seems to be entirely replaced by these pseudomorphs. In some of the most schistose varieties the dark "eyes" of this hornblende remind one in appearance of the spots in the *Knotenschiefer*.

The two minerals (the felspar and diallage, or hornblende) are often quite separated in alternating bands, those of felspar being from nearly $\frac{1}{4}$ inch downwards to mere lines. Not seldom the diallage predominates, felspar only occurring in very thin threads, with occasional "eyes" as described above. From such specimens we pass to normal coarse gabbro—a variety in which the plates of the diallagoid mineral are wavy in outline, and tend to be parallel, being very common.

Among the most schistose varieties lenticular pieces and long slab-like masses of included serpentine are very abundant, and may not improbably have contributed to the development of the structure, as at the Balk.

I have had two sections cut from the gabbro of Karak Clews. The normal rock consists now chiefly of short broad rather irregular crystals of partly altered plagioclase, with numerous microliths and aggregated small crystals of pseudomorphous actinolite. Here and there, however, portions of plagioclase crystals still remain but little altered, as well as crystals of diallage in which the change to hornblende has not been completed. Every stage of the change from plagioclase to the saussuritic mineral can be traced in various parts of the slide. There are occasional microliths and larger grains of magnetite; and one or two of the diallage crystals are filled with an opaque black dust, the result of decomposition. These have some resemblance to certain hypersthenes; but the mineral does not belong to the orthorhrombic system. There is a general banded structure shown in the arrangement of the minerals.

The second slide is cut from a pale-coloured, apparently imperfectly crystallized rock, consisting chiefly of two minerals—the principal a whitish or pale pinkish felspathic one, the other a pale green mineral. The former, under the microscope, when examined with polarized and analyzed light, assumes the characteristic granular aspect of the saussuritic pseudomorph after plagioclase. The other mineral appears to be an almost colourless augite, containing a large number of very minute microliths. There are but slight indications of secondary hornblende. Some small roundish white specks, just visible to the eye, in the felspathic portion of the rock, appear, under the microscope, as rather oval blotches, often opaque and brownish, but in other cases showing aggregate polarization of a somewhat fibrous mineral, with colours from a rather orange yellow to a purplish blue, probably one of the zeolites. This rock also shows a banded structure.

On the eastern side of the headland we come at once on the serpentine as the predominant rock, though it is broken through by many veins of coarse gabbro. The mineral composition of these resembles that just described. Some are of considerable thickness; but others die away as mere strings. The material of the gabbro, therefore, must have been injected in a very fluid condition, and, as even the strings are coarsely crystalline, must have made its way into rock of high temperature, and have cooled down very slowly. The larger masses more frequently exhibit a schistose structure than these finer veins, though they are sometimes quite without it. Every stage may be noticed here as on the other side of the headland. Here, also, the "eyes" of hornblende are frequently seen in the schistose varieties.

Between the headland and Lankidden Cove are several gabbro veins. The serpentine is a red variety, much resembling one presently to be described. On approaching the Cove two or three narrow greenstone dykes are seen in the cliffs, and one in a skerry projecting from the sand. These cut both the serpentine and the gabbro, and closely resemble those already described near Kennack Cove. A section from one exhibits plagioclase felspar in fair preservation (the crystals commonly five or six times as long as broad, characteristically twinned, and mostly well defined), augite (often well preserved), and some magnetite. Besides this there is in the interval of the larger plagioclase crystals, a good deal of an aggregate of a fibrous transparent mineral, changing, with polarized light, from bright blue to yellowish or occasionally pinkish colours—doubtless a pseudomorph after felspar, perhaps replacing a magma. Here and there the augite changes to pale green rather fibrous hornblende, showing marked dichroism, and rather rich colours with analyzer and polarizer. There is also a brown dichroic mineral: some of this is probably little more than a ferruginous staining; but in one case it is certainly a distinct mineral, probably an iron-mica. There is no unaltered olivine; but I think I have detected a few pseudomorphs. This rock, then, is a basalt only slightly altered.

The gabbro veins continue to the eastern side of the cove. One, which shows a marked schistose structure, contains, as usual, many long strips of serpentine. Close by it is another gabbro vein, only a few inches thick, but quite unique in character. It consists mainly of felspar, a whitish to bluish-grey labradorite, with crystals often from an inch to an inch and a half long, in excellent preservation. In the interstices of the felspar are aggregated minute crystals of a dull green mineral. The latter under the microscope proves to be actinolite. The aggregated clusters of crystals are very beautiful objects with polarizer and analyzer; and the felspar crystals (which are a little decomposed) contain, especially near their edges, many small acicular crystals of the same mineral.

Close to this vein is a small dyke (6 to 12 inches wide) of a very slaggy-looking, compact, dark rock, which, I have no doubt, is an old basalt. Some of the serpentine near this weathers to a dull green colour, and contains distinct crystalline grains of magnetite. Beyond this point is about a mile of coast, coloured as serpentine in the map, which I have had to pass over almost unvisited; and the steep cliffs will, I think, render detailed examination no easy task.

(*b*) *Coverack Cove.*—We then come to Coverack Cove, one of the most interesting localities on the coast. Without a regular survey and large-scale map it is not possible to give very precise details; but the following general description may render clearer those which I can furnish.

The cove terminates in a widish valley. On the right bank is a headland of serpentine, on the left the great gabbro mass which rises from the sea to the upland of Crousa Down.

The village stands on a low cliff (a raised beach, traces of which are also conspicuous along the edge of the gabbro mass) on the right bank of the cove. Beneath it is a rocky foreshore.

The principal rock beneath the village is serpentine; but this is broken up by a network of dykes and intrusive veins. As will be seen from what follows, we have here the following association of rocks in order of age:—

(1) Serpentine (no. 12).

(2) A gabbro, generally of a dull reddish green colour, which I shall refer to as the Older Gabbro.

(3) A gabbro of more normal aspect, which I shall call the Newer Gabbro.

(4) Some dark trap dykes, similar in general appearance to those described at Kennack and Lankidden.

At the eastern end of the village is a small harbour bounded by a pier, which starts from a little headland. I commenced my examination on the further side of this. The rock here is serpentine, much jointed and cracked, and often rather decomposed. This is also found on the other side of the harbour, where at the base of a high wall a vein of gabbro is exposed, about 4 feet thick and with a schistose structure. The top and bottom of the rock shows the usual mineral changes. The serpentine in contact is much cracked and burnt. The projection of rock, which forms the western limit of the port is cut by a dyke of newer gabbro; and the same rock, a few yards further on, appears at the base of the cliff on which the village stands; an isolated patch also breaks through the serpentine on the shore. A few yards from this is the first patch of the older gabbro. This older gabbro forms the base of the cliff for a short distance, while the shore consists mainly of newer gabbro, veins of which cut the older. Just where a projecting angle of the cliff begins is an interesting junction. The older gabbro is cut by a dyke of newer gabbro about 18 inches wide, and both again cut by a dark trap dyke about 12 inches wide (fig. 6). The two intrusive dykes are displaced by a fault of a few inches. This last dyke (1) may be traced for some distance towards the sea; its general direction is N.N.E.–S.S.W. At the angle named above, serpentine replaces the newer gabbro, both on the shore and in the cliff, and on the whole is continued to beyond another small projection.

Here another trap dyke (2), generally about 5 inches wide, may be traced about 20 yards along the shore in a northerly direction. Beyond this veins of the newer gabbro break repeatedly through the serpentine. Then comes a dyke of compact trap (3), about 4 inches wide, cutting into the cliff and running N.N.W.–S.S.E. Beyond we find serpentine with intrusions of newer gabbro, till we again find the older gabbro beneath the cliff, broken into by the newer, and both cut by another compact trap dyke about 1 foot wide. A few yards further, over serpentine and newer gabbro, is another trap dyke cutting both, exposed up the face of the cliff for 7 or 8 feet. It is about 3 feet wide, and rather coarser in texture than the others. Well-marked horizontal joints give it a slightly columnar aspect. The shore for some little distance further consists of serpentine with some intrusive newer gabbro, and at least one more dyke of compact trap.

It will now be convenient to describe more precisely the lithological characteristics of these rocks, omitting at present the serpentine.

The Older Gabbro.—This might easily be mistaken for a mere variety of serpentine*. It has a compact, dark, dull red or purple groundmass, often mottled with a brighter red, in which are imbedded crystalline grains of a greyish white felspar, perhaps about 0·2 inch in diameter, and some rather smaller crystals of diallage, generally about $\frac{1}{4}$ to $\frac{1}{3}$ inch apart. The matrix for a quarter of an inch square or more is often unbroken by any crystals visible to the eye; occasionally, however, the felspar predominates. The rock does not vary much in texture, the smaller veins being about as coarse as the larger masses. One small boss has the groundmass a dark green instead of red. It is, however, the same rock, though as a rule it is rather more finely crystallized than the average of the

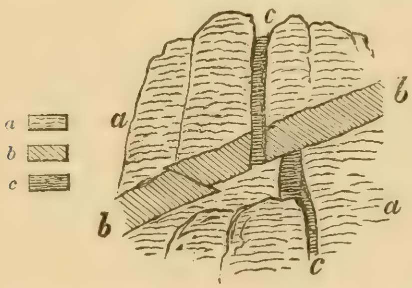
* As it is described by most writers who have noticed it.

red variety; for towards the outside it exhibits perfectly the change into the red variety. I have specimens about 4 inches long, red at one end and green at the other. Hence the alteration may not be so deep-seated as from its uniformity I should have supposed.

I have examined three slides of the red, cut from slightly different varieties of the rock, and one of the green. I will refer to them by numbers, taking the most normal specimen first.

On placing slide I. beneath the microscope, we find it to consist of colourless or nearly colourless felspar, in rather irregular to roundish oblong grains, occasionally showing lines indicative of twinning, traversed often by cracks and in places partly kaolinized. Associated with this, in about equal quantities, are a large number of irregular grains of olivine; these in parts are almost unaltered, in other parts entirely converted into serpentine. This is occasionally translucent and of a greenish yellow, occasionally opaque, from the presence of a muddy brown peroxide of iron, and showing every grade of intermediate staining. The process of conversion of the olivine into serpentine will be described below.

Fig. 6.—*Shore below Coverack Cove.*



Newer gabbro intrusive in older gabbro, and both cut by dyke of dark trap.

a. Older gabbro. *b.* Newer gabbro. *c.* Dark trap.

With polarized light (crossed prisms) the felspar is seen to be crystallized in irregular grains, many of which show characteristic plagioclase twinning; bright colours, however, are rare, shades of light and dark milky grey being commonest. In parts the felspar is almost opaque from decomposition; in other parts it presents the usual finely granular "saussuritic" aspect. The olivine, when unchanged, shows its characteristic rich colouring. The process of conversion into serpentine, best examined by rotating the polarizer, is as follows (see figs. 8 & 9). In the cracks of the olivine a dark ferruginous stain is deposited; then on either side of this a layer of fibrous serpentine of pale golden colour (probably chrysotile) is formed; thus the olivine grains seem traversed by an irregular network of associated dark and light strings. The interspaces then seem to be attacked; and they also are converted into serpentine; but in them the mineral is usually in an isotropic or noncrystalline state, and the peroxide of iron either forms a dark clot in the middle (sometimes rendering nearly the whole opaque), or clouded granules disseminated in various ways. At last when the whole grain is converted into serpentine, the black strings marking the original cracks become less definite, being interrupted and disturbed, probably from the action of molecular forces, so that their significance might readily be overlooked. The chrysotile strings also become less conspicuous; but still they may often be traced when the prisms are crossed. It is worth noting that, as a rule, the formation of chrysotile appears to proceed from the surface of a crack inwards, and is generally arrested at a fairly constant distance from the outside; but the conversion of the remainder of the grain into non-crystalline serpentine appears to be nearly simultaneous over the whole. The process very closely corresponds with that which I have already described in the Ariége lherzolite* (see fig. 9, p. 916), except that here, as the olivine is apparently ferruginous, there is a more marked discoloration. The augitic constituent is less abundant than the other two minerals. Most of it is diallage; but grains, and sometimes even parts of a crystal, seem rather to be normal augite. Occasionally the serpentine appears to have been deposited in a crack in them; but as a rule there is not the slightest advance towards a conversion of these minerals into serpentine.

The diallage occasionally assumes a dusky, finely granulated, stained aspect along the principal cleavage-planes, which I have observed in cases where a change to hornblende is commencing; and one crystal is bordered by an aggregate of minute crystals, which I fully believe to be actinolite. There are few included microliths, excluding these ferruginous clots; but there seem to be one or two grains of magnetite, and in one of the diallage crystals are two needles which I think are apatite.

Slide II. (cut from a rather duller-coloured specimen) does not materially differ, except that the iron stains in the olivine are more uniformly dark. Some of the diallage (which mineral is fairly abundant in this specimen) contains small opaque belonitic microliths lying parallel to the plane of principal cleavage.

In slide III. the felspar decidedly predominates over the other minerals, the olivine coming next. Some of the grains here are wholly converted into serpentine; one shows, with polarized light, a single speck of the original mineral alone remaining in a good-sized grain. There are both diallage and augite; and here, as in the other slides, there are appearances of a passage from one variety to the other. One crystal shows in parts the ordinary imperfect cleavages of augite parallel to ∞P, with an occasionally marked clino-diagonal cleavage; then, in places, the last cleavage dominates over the other, forming very definite parallel lines of weak cohesion; and, lastly, the inner (and major) portion of the crystal is filled by a fine parallel cleavage, giving it an almost granular-linear aspect, in which, I think, occasional cracks indicate traces of a cleavage parallel to ∞P. The absorptive powers of the two minerals seem to differ. By rotating

* Geol. Mag. Dec. 2, vol. iv. p. 59.

the stage the unaltered part of the crystal becomes (with crossed prisms) as nearly as possible black after it has been moved through $29\frac{1}{2}°$ from parallelism with a vertical line; but the other part offers no approach to complete darkness, and, though darkest when near the above position, is not all uniformly at its darkest then. This, however, may be only due to imperfect cohesion of the cleavage-planes.

Slide IV. is cut from the green-coloured variety of the older gabbro. The principal differences of this from I. and II. are:—that the conversion of the olivine is about as complete as in III., but is unattended by any red colour; the serpentine is of a pale yellowish-green tint; the dark dust is formed in the cracks of the olivine, as described above, but appears to recombine, or in some way or other is made partially to disappear at a further stage of the process; for some of the most completely changed greenish grains are very fairly clear. The augite or diallage is scarce, and, as a rule, occurs in very small grains. The resemblance of this rock, macroscopic and microscopic, to the troktolite of Volpersdorf is very remarkable, the only difference being that the felspar in the latter shows brighter colours and the serpentinous part is a shade darker in its green. The cracks traversing the felspar in all these rocks are noteworthy, as they appear to radiate from the serpentinized olivine granules and to imply some strains caused by them in the process of alteration. I may also call attention to the fact that the pyroxenic constituent seldom, if ever, shows any signs of being converted into serpentine.

The Newer Gabbro.—This is generally much coarser in texture than the others, and more decomposed. It pierces the adjacent rock with very irregular veins, which sometimes thin away to mere strings not half an inch thick, but are fairly coarse to the last. The plagioclase, often in crystals nearly an inch across, varies from a dull purplish tint to white. The diallage crystals are frequently from $\frac{1}{2}$ to $\frac{3}{4}$ inch across. In places red spots may be observed; these are evidently altered olivine, as in the last rock, but they are often larger, more friable, and irregular in their occurrence. Included fragments of serpentine are also seen. Spots of the green hornblendic mineral are frequent towards the exterior. As might be expected the weathered surface of the coarser varieties is much rougher than in the older gabbro. The latter rock also has a perfectly close junction with the serpentine, as if it were welded to it; while between that and the newer gabbro is more or less of a crevice.

The result of microscopic examination of a slide of one of the dark purple and green specimens is interesting. It contains abundant plagioclase, apparently labradorite, resembling that in the other gabbros, in fair condition but dull in colour, which here and there seems partially replaced by a clear isotropic pseudomorph. The green spots prove to be altered diallage: here and there small portions of the original mineral with characteristic cleavage &c. remain, but the greater part is converted into a mass of pale green actinolite, the crystals being crowded together like interlacing leaves, and sometimes forming fringes almost like tufts of grass; they make their way sometimes up cracks in the felspar, and appear even to form as endomorphs. The difference in dichroism between these and the yet unchanged diallage is well exhibited on rotating the polarizer without the analyzer. I find no olivine or grains of serpentine; but a speck here and there resembles the latter; the outline, however, of some of the bunches of actinolite resembles rather that of olivine than diallage. As there certainly has been olivine in the rock, this confirms my suspicion that this mineral sometimes, instead of forming serpentine, contributes to the actinolite. When the latter mineral is formed, it is remarkable how greatly the cohesion of the constituents of the rock seem to have been disturbed; for it not only invades the edges of the felspar in needle-like fringes, but also occurs in blades and tufts anywhere in the heart of that mineral. In fact, where this process has been carried far, it is only now and then that the outline of the original crystals can be traced.

Lastly, as to the trap-dykes, I regret to say that I cannot give precise information with regard to all of these, as I have found it difficult in one or two cases to identify those which I had observed in different visits. The notes made in 1873 and 1875 were taken with a rising tide; and so, as other matters were of still greater interest, I rather hurried over these dykes. In 1876 the tide was very favourable, and I observed more dykes than I had noticed previously; but still, as there was so much to do that I did not collect a specimen from every one, I have a little difficulty in identifying those collected on former occasions with the dykes noted on this. However, the following results are fairly correct. There are two varieties of rock in the dykes:—one, coarse enough to be obviously a crystalline rock, much like an anamesite; the other very compact, of a dark purplish colour, looking almost like a dull serpentine. Thin veins of serpentine often show in the latter; and films of the same not seldom coat joint-faces. The dyke seen in the cliff may be taken as a type of the former. On microscopic examination it proves to be a felspar basalt,—the plagioclase being, as a rule, clear, though with polarized light dull in colour, the augite little changed, and dull green spots replacing probably the olivine. There are also grains of magnetite, with brown stains from one of the other ferric oxides; and cracks are overspread by an infiltrated serpentinous mineral.

The second specimen (collected in 1873 from a dyke "cutting gabbro and serpentine") is quite different. It has an isotropic matrix, which remains black, with crossed prisms, as the stage is rotated, full of rather acicular crystals of actinolite, very pale clear green with ordinary light, slightly dichroic with the polarizer, and often showing brilliant colours with the analyzer. Here and there are patches of the brown hornblende granulated with magnetite (?), like that described from the shore north of Kynance (p. 889). Some of these occur in such a way as to produce a strong impression that they too have been partly replaced by actinolite. One or two portions of unchanged plagioclase crystals remain in the matrix; and probably some of the microliths in it are the pseudomorphs already mentioned. As a type of the other variety, I take a specimen from a dyke about four inches wide (just opposite the north end of a row of white cottages), which cuts through two rather thin veins of newer gabbro to a slight hummock of serpentine (I believe, no. 3 in my description above). A hand specimen might very easily be taken for a dull-coloured serpentine, were it not for its greater hardness and its behaviour under the hammer. Microscopic examination shows it to be an altered basalt, infiltrated here and there with serpentinous veins, full of minute crystals of plagioclase (or probably a pseudomorph after it), occasionally about 0·02 inch long. Here and there occur pale brownish films replacing the ordinary dusky granulated matrix. Examination with polarized light shows that actinolite is present here; and minute bright specks over the whole slide suggest the presence of the same mineral. The grains of magnetite (perhaps also of ilmenite) are much decomposed. Here, then, is a basalt, probably a magma basalt, greatly altered, but still not in any true sense of the word converted into serpentine. Another specimen, broken in 1873 from a very similar dyke, shows a still greater change, the felspar crystals being still just discernible, but the actinolite more characteristic and perfectly formed.

Near the western end of the village, in the little open glen which comes down to the cove, and about 100 yards from the sea, is a quarry in serpentine. This (no. 13) is rather a dull dark variety of an aluminous aspect, and is much cracked and jointed. This is probably due to some small gabbro veins (coarsely crystalline and much decomposed) which have been exposed in opening the quarry. On the shore, east of a small row of houses, a mass of the newer gabbro is exposed, very schistose in the upper part. Gabbro veins may be seen on the hill-side behind the village.

Proceeding onwards, we observe that the shore, where free from sand, consists of serpentine with intrusive veins of the newer gabbro. These become more numerous as we approach the main mass of gabbro, which is reached about a quarter of a mile from the end of the village. In plan this is an irregular oval, a little more than four miles long and two wide, which forms the elevated upland of of Crousa Down, some 300 feet above the sea. The line of the raised beach is well marked by a low cliff, and in one place by a projecting rocky plateau of considerable extent a short distance above sea-level. The rock at the southern edge of the *massif* varies greatly in texture, being sometimes moderately coarse (often, owing to the prevailing greyish-blue tint, seeming from a short distance quite compact), sometimes very coarse, with crystals of felspar and diallage nearly an inch across. In the latter the felspar generally weathers to a dull white; the diallage is more or less metallic, commonly with a greenish tinge. Some of the more compact varieties also weather to a decided mottled white and dull green, like the gabbro of Mont Colon and the Matterhorn (Pennine Alps); but others (for what reason I cannot say) assume a slightly rusty tinge on their surface as the felspar weathers out, leaving the diallage crystals projecting, as happens with the gabbro of the Cuchullin Hills, Skye. I have had slides cut from one of the dark bluish unweathered specimens, and from one of the exterior white and green. The former shows the rock to be an olivine gabbro. There is plagioclase felspar, generally in rather short irregularly oblong crystals, showing bright colours and twinning. Some of these exhibit a peculiar strongly marked cleavage (or minute twinning, with one set of crystals dominating), which gives them a general resemblance to the structure of diallage. The felspar is in places rather decomposed. There is a fair amount of diallage, and a few crystals of common augite. These with ordinary light are as nearly as possible colourless, and are in good preservation. The olivine is rather rough in texture and much cracked; the cracks are marked out by a deposit of granular opaque mineral, probably magnetite, which in some cases appears to penetrate the intermediate spaces (which are commonly fairly translucent), rendering them almost opaque; now and then it assumes a browner tinge, as from hæmatite or limonite, and the grains are slightly stained with brown or green. Most of the olivine grains have a finely granulated aspect at the edges, and are sometimes bordered by a finely fibrous mineral, probably serpentinous and a secondary product; the grains, however, show very little trace of conversion into serpentine. Except the minute granules described above, there is very little magnetite or other iron-oxide visible. The above appearance would lead us to conclude that the olivine is a rather ferruginous variety. The other slide (fig. 7),

Fig. 7.—*Diallage partly altered into Hornblende, from outer part of the great Gabbro mass at Coverack.*

A. Decomposing felspar. B. Diallage. C. Hornblende.

cut from a somewhat weathered mass, which in appearance closely resembled that of the veins, exhibits plagioclase felspar beginning to pass into the saussuritic mineral, and diallage, more or less converted into minute hornblende, but no olivine or serpentine that can be recognized—the slide on the whole being remarkably like one cut from a vein on the shore at Coverack. On closely examining the replacing hornblende, there appears some little difference in the various aggregates—some (and these show no signs of diallage) being more " matted " in texture, if I may use the phrase, than others, and showing here and there a little of a non-doubly refracting mineral rather like serpentine. It can hardly be supposed that one part of the same mass of gabbro would be rich in olivine and another at no great distance entirely without it; hence I conclude that sometimes the olivine in a gabbro, instead of changing to serpentine, becomes converted into hornblende: the requisite silicate of lime must be supplied by the neighbouring felspar—a thing not impossible when we see how it is often penetrated by these new acicular crystals.

There are some dykes in this mass of gabbro. Soon after getting on it we come, as we clamber along the shore, to two small dykes, running rather irregularly, of a sharp-jointed, rather splintery, very compact dull-greyish or greenish rock, of a rather serpentinous aspect, the larger generally about 18 inches, and the smaller about 15 inches wide. I have had a slide cut from the former. It proves to be a basalt, chiefly consisting of small crystals of plagioclase and augite, both rather altered, and rather poor in magnetite. I suspect that much of the plagioclase is now a pseudomorph; we have the irregular low-tinted granular aspect in part of the field. A good deal of the augite has undergone change, and should, perhaps, rather be called uralite; but that the rock has been a basalt I have no doubt. There is a little apatite. A short distance further is a dyke from one to four yards wide, which forms a little headland. This is in parts very like an ordinary basalt or anamesite, with a glistening surface and weathering brown. Parts of it are rather porphyritic, having very white felspar crystals up to about $\frac{1}{4}$ inch long. I have had slides cut from this; and on examination it proves to be a basalt, the plagioclase being fairly well preserved, the augite sometimes very characteristic, and a good deal of olivine with a granulated dusky aspect like (though on a smaller scale) that described above; there is also a fair quantity of magnetite. The most porphyritic variety of this rock, macroscopically, so closely resembles the most porphyritic variety of the " diorite " at Poltesco, that the specimens might easily be confused.

Beyond this I observed two other dykes:—one resembling a basalt, not more than a foot wide, in a little headland; the other some quarter of a mile further on, also like a basalt, very compact, splintery in fracture, much cracked and jointed. The above-described dykes lie well in the first mile of the gabbro. After following the shore for about that distance—a slow and rather laborious process—I was obliged, by want of time, to take a path along the low cliff above, as I was anxious to examine the greenstone of St. Keverne.

This I was not able to do as completely as I had hoped; for where from the map I had expected to come well into the mass (here coloured over a space nearly half a mile across), I was still on gabbro, pierced by frequent veins of greenstone; and I had not time to go as far as Manacle Point, a promontory, according to the map, formed of the greenstone. This rock is, in the veins, very compact, of a dull greyish green colour, extremely hard and tough, weathering brown; in general appearance it is not unlike the 18-inch dyke described above. Under the microscope it is found to be a finely crystalline rock, closely resembling the aforesaid specimen—the augitic constituent now appearing generally as a pale greyish or brownish rather fibrous mineral, very feebly dichroic, changing with polarized and analyzed light from a pale or golden yellow to a blue or puce-brown tint. The felspathic constituent also only alters from light to dark milky grey; hence I have no doubt that it too originally was a finely crystallized basalt.

To the north of this there is a little serpentine associated with gabbro (schistose in places), in the neighbourhood of Polkerris Point. These have been briefly described by Prof. Sedgwick and Sir H. De la Beche; and I have examined specimens in the Woodwardian and Mr. S. Allport's collections, but have not yet been able to visit the district. I hope, should they prove of sufficient interest, to make them the subject of a future communication.

Some Inland Sections.

In conclusion, I must briefly mention two places inland where I have more particularly examined the serpentine:—one, at its first appearance, on the road from Helston to Llandewednack. Here, so far as I know, the junction is concealed by vegetation; but a little stream running through a ravine must be very close to it. On the north side of this is seen altered Devonian rock, apparently shattered and baked. On the south the serpentine rises in some picturesque knolls by the roadside. It is a dark-coloured homogeneous rock (no. 14), resembling that at the south end of the Mullion mass, weathering a brownish grey, and showing, more especially in the weathered surfaces, the banded structure already noticed.

The other instance is on Goomhilly Downs, on the road from Helston to Coverack Cove. In the first serpentine-pit which I passed (about half a mile beyond Sir L. Vyvyan's lodge), that rock is found to be dull and dark in colour (no. 15.) with but few bronzite crystals, homogeneous in aspect, but showing the banded structure remarkably well, so that on weathered surfaces it quite mimics stratification. Another quarry, to the right of the road, about seven miles from Helston, shows a similar structure; but here the serpentine varied much in different parts of the pit, some specimens barely indicating it. Many of the latter were extremely compact in texture, almost conchoidal in fracture, and very beautiful, having a dull-reddish to greenish groundmass, with veins of bright red and of yellowish steatite; the bronzite crystals are small and inconspicuous. The serpentine weathers a brownish grey, often with a very rugged surface.

Summary of Inferences.

From the details, somewhat lengthy I fear, given above, we are, I think, entitled to draw the following conclusions:—

(1) That the serpentine of the Lizard was originally an intrusive igneous rock.

(2) That its intrusion was posterior to the metamorphism of the hornblende schist, the fragments of that rock included in it not differing materially from the main mass, though, of course, a little more altered.

(3) That on the western coast the serpentine has been broken through by several granite dykes.

(4) That on the eastern coast it has been broken through by the following igneous rocks:—

(*a*) Gabbros, which at Coverack Cove are certainly of two very distinct dates; and the later are most probably of the age of the great gabbro mass of Crousa Down. Similarity of mineral character would lead me to regard all the east-coast outbreaks as far as the Balk as of the same date, viz. that of the Crousa-Down *massif*.

(*b*) Certain dark trap dykes found, like the gabbros, only on the east coast, having much the same range, and the latest of all in date.

(5) That the gabbros appear liable to three forms of mineral change.

(*a*) The gradual conversion of their felspar into a microcrystalline saussuritic mineral.

(*b*) The conversion of their diallage into hornblende by pseudomorphism, or rather by a recrystallization, not generally by paramorphism, and that in certain cases some olivine disappears in this process.

(*c*) The conversion, more or less complete, of the olivine into serpentine, in which case the diallage appears little changed.

(6) That these trap dykes were very probably once all dolerites or basalts, and that the hornblende, which undoubtedly characterizes many of them, is a secondary product due, as above, to metamorphism of the original pyroxenic constituent.

(7) That the metamorphism of the serpentine was probably complete before the intrusion of any of the above rocks.

(8) That the serpentinous aspect of a rock is often rather illusory, being due to the presence of an extremely small proportion of that mineral; hence that statements about the conversion of ordinary pyroxenic or hornblendic rocks into serpentine require confirmation from microscopic examination.

Microscopic Examination of the Serpentine.

With the view of ascertaining, if possible, the original character of the rock which now constitutes the serpentine of the Lizard, I have had altogether twenty-one slides prepared from different localities* ; and Mr. S. Allport has kindly permitted me to use others from his collection, admirably cut by himself. I have also procured, for comparison, several others from foreign serpentines. A suspicion of the true nature crossed my mind in 1874, when examining a slide from the black serpentine near Cadgwith (no. 10). A specimen collected in 1875 at Coverack Cove rendered the conjecture a certainty ; and a further confirmation was given by my visit to the Ariége, and by specimens collected at other Cornish localities, in 1876. In the following description I shall not take the slides in the order in which their localities are mentioned above, but group them so as best to tell their story.

Coverack Cove (no. 12).—This serpentine is often considerably decomposed ; but my slide was cut from a well-preserved specimen. To the eye it is a dull mottled red-and-green rock, with ill-defined flakes in the latter part of a silky bronzitic mineral. With the microscope, we see that about two-thirds of the rock consists of a clear transparent mineral of a texture rather like frosted glass, traversed by reticulated veins of a golden-coloured (varying to greenish and reddish-brown) serpentine. These serpentine veins run together sometimes like matted roots, and apparently coalesce like the pseudopodia of foraminifera (fig. 8). As described in the gabbro above,

Fig. 8.—*Portion of a Slide of Serpentine from Coverack Cove.*

Fig. 9.—*Portion of a Slide of Lherzolite* (*Etang de Lherz, Ariège*), *showing the formation of Serpentine.*

The granulated part unchanged olivine ; the rest rather fibrous serpentine. (Magnified 50 diameters, about.)

there is the same deposit of iron peroxide (here reddish) parallel to the sides of the fibres, which in the larger patches of serpentine seem either to disappear or to be aggegated in dusky patches. On applying

* These, with the others used in this paper, have been excellently prepared for me by Mr. Cuttell, 52 New Compton Street, Soho.

polarized light, the clear mineral filling the interspaces of the serpentine network proves, as we should anticipate, to be olivine, often very well preserved, and showing brilliant colours, while the serpentine (with crossed prisms) is dull milky white, with an indistinct fibrous structure in the strings, and often almost or quite dark in the larger patches. The other mineral, which is colourless with ordinary light, is now seen to be of more than one species. One part exhibits the characteristic cleavage of augite; this occurs in somewhat rounded grains; very thin veins of serpentine frequently traverse the crystal, following the lines of its cleavage-planes. This mineral does not seem the result of change of the augite, but to have formed in the cracks; and the generally open condition of the cleavage-planes rather bears out the idea. The colours of the augite are generally dull; but parts of a crystal occasionally show the usual rich colours, as if the present low tints were due to some subsequent chemical change. The other mineral, also colourless, and showing much the same tints with polarized light, has a peculiar silky aspect, and one well-developed set of close and slightly wavy cleavage-planes. I was at once struck with the resemblance of this mineral to the enstatite in my specimens of lherzolite, and on testing it find it to be orthorhombic, and so true enstatite. I found, however, a crystal or two of ordinary diallage. Besides the above ferruginous microliths, doubtless secondary products, there are a few larger opaque grains of iron peroxide, probably original constituents. I searched the slide for picotite, but could not be certain of any specimen, though one or two grains resembled an opaque variety of this mineral. One or two cracks, filled with fibrous serpentine, traverse the slide.

Mullion Cove (no. 8).—With transmitted light the slide appears to be composed of a great number of small subangular grains of a clear mineral, often associated with aggregated black or brownish dust, and generally clear, rather irregularly oblong crystals, about ·02 inch in greatest length, showing a prismatic cleavage, one set of planes being rather strongly developed, all lying in a base of yellowish green serpentine. On applying polarized light we find that, as before, the grains are olivine, only that the process of conversion has here advanced a stage further than in the last slide. The other crystals show moderately bright colours: many of them are rather dusky in parts, as if somewhat decomposed; and the patchy change of the colours with polarized light confirms this. As in the last slide, they seem to have been cracked after crystallization, as though they had been subjected to a strain; and serpentine has been deposited in the cracks. Some specimens resemble normal augite; others are nearer to diallage; other small crystals are enstatite. This quite bears out the macroscopic appearance of the rock, which is full of a mineral with a rather silvery lustre, but not exactly like ordinary diallage. Here, too, a few small grains very much resemble picotite. In the augitic mineral the planes of principal cleavage are approximately parallel in many of the crystals, and there are other indications of a flow or pressure structure. This is still more conspicuous in two specimens lent to me by Mr. Allport, one of which is cut transversely to the streaky structure. From these, especially the latter, it is quite clear that the structure is produced, not only by a general parallelism in the longer diameters of crystals of a prismatic outline, but also by a partial separation of the constituent minerals—the augitic constituent, the olivine with strings of serpentine, and the magnetite being each more abundant in particular layers.

Gue Graze (no. 5).—The greater part of the slide closely resembles that of no. 8, except that there is a slightly larger proportion of serpentine, and the rock has not been quite so coarsely crystalline. The augitic constituent, however, is less conspicuous, and there are a number of small patches of a semitransparent, rather earthy-looking mineral from about ·01 to ·03 inch in greatest length, most of which seem to be coated externally by a reddish film of iron peroxide. The augitic constituent appears, as at Coverack, to be partly normal augite, with some diallage, and partly enstatite. The crystals, however, are much smaller here; so that it is more difficult to determine them. The granular mineral, with polarized light, very closely resembles the pseudomorphic product after the felspars of the gabbros described above; and on close examination, some indications of an irregularly oblong crystal-like form may be detected. This rock, therefore, probably differs from the others in containing a small quantity of felspar; and I may state that it is the only case in which I have detected that mineral in the serpentines of the Lizard*.

Lower Pradanack Quarry (no. 7).—The slide from this quarry, as might be expected from the general resemblance of the rock, corresponds very closely with that described above from Mullion Cove; the olivine is in much the same condition of conversion into serpentine. It contains also little dark brown and greenish brown semitransparent grains, which I feel certain are picotite. Here also a banded structure is indicated by a partial separation of the component minerals; enstatite, however, in this rock, rather predominates over the augitic constituent.

Rill Quarry (no. 4).—This slide shows a number of subangular transparent grains, generally edged with black, of clear, colourless, and rather fibrous crystals of longish oblong outline, and of scattered granules of magnetite, set in a very pale yellowish green serpentine, now and then stained brown. A few larger, irregular, imperfectly transparent granules seem to be picotite. On applying polarized light the subangular grains prove to be olivine, and the fibrous crystals enstatite (lengthened in the direction of the macrodiagonal). There is also a crystal about 0·2 inch long, of rather rhomboidal shape, which proves to be this mineral; it exhibits the usual clea-

* My friend Mr. Main, our Lecturer in Chemistry, kindly ascertained for me the amount of Al_2O_3 in this rock, and informs me that the amount is only 0·4 per cent. This would mean rather more than 1 per cent. felspar; but then this amount of Al_2O_3 might be present in the pyroxenic constituents. So the determination is uncertain.

vages, and is rather cracked and separated along those parallel to ∞P. This rock contains small quantities also of an augitic mineral, but much less than the other.

Helston Road (no. 14).—This slide shows a very pale greenish serpentine, here and there a little clouded with a pale olive tint, with colourless granules of olivine, a good deal of a rather fibrous mineral in irregular aggregated grains, granules and dust of magnetite, and larger grains of dark picotite. One or two pale brownish grains show dichroism and a cleavage like that of hornblende.

On applying polarized light the serpentine shows the usual arrangement of doubly refracting meshes on an isotropic ground, not much of the unchanged olivine remaining to show colours. By testing the fibrous-looking mineral I have found some to be enstatite; but with the greater part the optic axial plane seems certainly not to coincide with the plane of principal cleavage, but to make an angle of about 10° with it; I believe it to be hornblende, not diallage. The bedded structure is indicated by a tendency to a banded arrangement in the component minerals and a frequent approach to parallelism in the longer diameters of prismatic-shaped crystals, and of the principal cleavage-planes. Part of the slide is traversed by an irregular vein filled with a steatitic mineral, which is almost transparent with ordinary light, and with crossed prisms shows a feebly doubly refracting granular structure. I regard it as a secondary product.

Goomhilly Downs (no. 15).—Another dull-coloured serpentine with a decided banded structure. Groundmass of very pale light-greenish serpentine, with numerous small angular or subangular grains scattered in it rather irregularly, many aggregated dusky clots, streaks and grains of magnetite, several clear brown crystals with a prismatic cleavage rather like hornblende, in parts somewhat dusky, with several semiopaque dusky patches of greyish and also greenish colour. Small grains of picotite occur, dull olive-brown and subtranslucent. With crossed prisms the field appears partly dark, partly occupied by a slightly fibrous, feebly doubly refracting variety of serpentine, of a dull bluish-grey colour,—chrysotile or some allied variety. The grains of olivine show the usual clear bright colours; the hornblendic mineral is not brilliant; and enstatite is seen. The dusky spots show a granular structure, something like the felspar pseudomorphs described above; but of their true nature I cannot be certain. The streaky structure is indicated both by a tendency to grouping in parallel bands on the part of the minerals, and by a parallelism in the longer diameters of the prismatic crystals and the streaks of magnetite.

Kynance Cove (no. 2).—A fine specimen kindly lent to me by Mr. Allport, intermediate in character between that of Gue Graze and Mullion. Some unaltered olivine, a good deal of augite or diallage (it seems generally, as at Mullion, nearer the former) and perhaps a little enstatite; there are also a few semi-opaque patches which *may* be altered felspar as at Gue Graze. With ordinary light the serpentine is of a yellowish colour; and there is a good deal of staining with a dark ruddy-brown iron peroxide. There is a steatitic band containing enclosures of a doubly refracting variety, some of which are more like the pseudo-organic forms of Messrs. King and Rowney than I have elsewhere seen, and many augitic crystals.

Serpentine from Quarry behind Coverack Village (no. 13).—This rock, as might be expected from its appearance, is, when examined microscopically, a peculiar one: rather clear strings of pale gold chrysotile, including not unfrequently small granules of magnetite, divide the field into a number of irregular grains; each of these is subdivided by a network of yellower strings of the same mineral; these are crowded with an exceedingly fine black dust composed of microliths of various forms, mostly rather granular; and the interspaces, often roughly quadrangular, are occupied by a colourless mineral also partly filled with dust, probably magnetite. This, commonly, is aggregated, as described above, on the outer edge of the interspace; also, by bisecting the string, it often shows the position of the original crack. There is no enstatite or diallage recognizable; but some fair-sized scales of a very dark brown and all but opaque mineral, whose cracks are filled by colourless serpentine, may have been some such mineral. With crossed prisms the larger strings vary from opaque to a pale milky grey; the smaller, commonly, have a distinct golden tinge, and the interspaces are dark or very pale dull milky grey.

Dyke of Serpentine, base of Cliffs north of Kynance (no. 3).—This may be regarded as an exceptional condition of the serpentine of this district; it is very compact in structure, streaky, and red. On placing it under the microscope we find that the slide consists partly of roughly parallel wavy branching bands of nearly clear serpentine, with a number of roundish grains, something like the eyes in a piece of knotted wood, of a ruddy brown tint, inclining now and then to purple; there appears to be little or no unaltered olivine, but a fair sprinkling of magnetite. On examining it with the two Nicols, we find that the clearer serpentine is the feebly doubly refracting variety described above, and that in most cases the browner spots are slightly doubly refracting. Hardly any of the olivine has escaped alteration; but any one who has made himself familiar with the other slides will have no difficulty in recognizing the characteristic structure in the replacing serpentine. I have no doubt the rock shows a true flow structure.

Specimen from Junction near George Cove (no. 6).—This is also an exceptional variety, characterized by its exceeding compactness and parallel bands of chrysotile. Under the microscope both this mineral and the serpentine appear nearly colourless; but the latter contains many streaks and fibre-like aggregates of magnetite, while the former has only occasional minute microliths included between the fibres of chrysotile, and so roughly at right angles to the sides of the bands. Some dark brown subtranslucent grains are probably picotite. In one band of the slide these are rather abundant. The banded structure, very conspicuous throughout this specimen, is parallel to the junction-face of the rock; and I regard it, like that in the Karak-Clews gabbro, as a pressure rather than a flow structure.* On applying the two Nicols, the major part of the slide is seen to consist of the usual bluish-grey fibrous mineral; and the only difference between that which makes up the mass of the rock and that in the pale golden band is the greater regularity of crystallization in the latter. A few minute crystals show a more brilliant tint.

Carn Sparnack (no. 11).—Obviously an altered olivine rock, though but little of the olivine remains unchanged; the general aspect of the groundmass resembles no. 3, except that there is no tendency to a parallel structure, the irregular network of fine serpentine strings with the granules bordered within by iron peroxide being very distinct. The olive-green mineral, with submetallic lustre, which forms the green marbling, is all or almost all enstatite, though here and there probably is a little diallage; but alterations and staining make it difficult to be sure.

Black Serpentine from near Cadgwith (no. 10).—The ground of the slide is a pale green serpentine, traversed by numerous strings forming the usual network; these are colourless, except that they are often darkened by the abundant deposit of fine magnetite dust. Several small grains of picotite occur, and a good many crystals of rounded exterior and platy structure—the same which is so conspicuous to the eye by its bright metallic lustre. The rock is clearly an altered olivine rock; and on applying polarized light we see that a few grains of that mineral yet remain unchanged. The metallic mineral is all or almost all enstatite, though part of it is rather altered, and converted into a kind of serpentine; and on comparing some of the specimens with that which I have described in lherzolite from Sem (Ariége), one cannot fail to be struck with the correspondence.†

The Balk Serpentine (no. 9, two varieties).—These have the same general character as the Carn-Sparnack rock, both being mottled with olive-green; but the ground of the one is more or less red, of the other rather pale claret-colour. A detailed description is needless; both obviously are altered olivine rock, the chief distinction being that in the former the iron occurs rather in little patches and lines, often fringing the included grains (which are clear but isotropic, and so serpentine also), and is the red peroxide; while in the other it is more generally disseminated, giving a dusty look to the slide, and appears to be mostly the black oxide, while the grains are generally a dull pale green: both contain some picotite. The green mineral

* It is obvious that very similar structures may result from tension and pressure; thus the fissile structure of certain igneous rocks (as I have shown in Quart. Journ. Geol. Soc. xxxii. p. 140) is like true cleavage. Professor J. D. Forbes regarded the banded structure of glacier-ice as the result of differential motion, like that of slags. Professor Tyndall considers it a pressure structure; while in some igneous rocks a pseudo-foliation seems to result, now from pressure, now from tension.

† See Mr. Hudleston's analysis of this rock, p. 925.

in both is wholly or almost wholly enstatite, though often a little altered into a serpentinous mineral.

Mr. Allport has lent me two specimens from the Balk, collected from a lower level than my own: one shows the banded structure very well, and contains many augitic crystals, with one which I think is certainly enstatite; the other has some olivine still unchanged, and a good deal of enstatite partially converted into serpentine.

A Specimen from the Quarry, south of Kynance (no. 1).—The dull claret-coloured rock with many greenish grey strings, can be now identified as an olivine rock, though very highly altered, and much more difficult to recognize than the others. The metamorphic process has been carried very far; the grains between the strings are stained a very pale greyish brown; and there is a faint concentric banding like that of agate. Some of the iron remains as black dust; the rest is the red peroxide. The enstatite or diallage (in small crystals always) is almost replaced by an opaque brown mineral deposited between its cleavage-planes, probably some oxide of iron. Polarized light, as usual, shows the strings to be doubly refracting, the grains isotropic.

I possess four other slides, cut from specimens from the east coast, two from the Balk and two from near Poltesco; of the precise localities I am less certain than in the case of the above. It is, however, needless to describe them, as they would add nothing to the above evidence, being more highly altered than the majority. Still it is clear they have been olivine rocks; and the glistening mineral also appears to be enstatite*.

That the Lizard serpentine is an intrusive rock I have already shown in the earlier part of this paper; the microscopic examination confirms the idea, which both *à priori* chemical considerations and the general aspect of the rock suggest, that it is an altered olivine rock. The process, as is shown by what we have seen above and what I have described in my paper on the "Lherzolite of the Ariége," apparently consists in the gradual decomposition of the olivine by the action of slowly infiltrated water, during which the hydrous compound serpentine is formed, and the iron thus liberated is thrown down as either Fe_2O_3 or Fe_3O_4, commonly the latter. Mr. Macpherson† considers the reaction as a "loss of one fourth part of its (magnesia) base.... replaced by two molecules of water," a reaction which can be expressed by the formula

$$(4MgO\,2SiO_2) + 2HO = 3MgO\,2SiO_2 + 2HO + MgO.$$

The magnesia he conceives to have been removed. He does not,

* It may be interesting to mention that I have had a fragment sliced from that very dark serpentine with calcareous veins called Genoa marble, which has been used in the decoration of the Hall of the Fitzwilliam Museum, Cambridge. It, too, is a highly altered olivine rock, with small crystals of rather altered enstatite, and veins of dolomite (?).

† "On the Origin of the Serpentine of the Rhonda Mountains," Ann. Soc. Espan. Hist. Nat. vol. iv. pt. 1.

however, take account of the iron, which must have entered into the composition of the original olivine, replacing some of the magnesia; as this seems to remain, all that would be required would be the decomposition of the original mineral, and hydration of some of its constituents. Mr. Macpherson's paper, which I did not see till I had nearly completed my own, quite confirms my observations; and some of his figures might have been taken from my Cornish slides, so great is the resemblance. As, then, the Lizard serpentine also contains enstatite *, an augitic mineral, and even picotite, all constituents of typical lherzolite, we are, I think, justified in regarding it as the result of an alteration (by the action of water, not necessarily at a high temperature) of a great mass of that rock †.

The results of my examination of the older gabbro and dark trap dykes of Coverack, and of these Lizard serpentines, render me rather suspicious of the common statements about the metamorphism of ordinary pyroxenic and hornblendic rocks (*i. e.* those also containing a fair proportion of felspar) into serpentine. An olivine constituent, as a rule, changes readily into that mineral; enstatite also alters, though more slowly, as we have seen, and as is shown in Brögger and Vom Rath's description of the great enstatite crystals from Norway (Monatsber. d. k. Akad. der Wissensch. Berlin, 1876, p. 549). The augite yields also, though, I think, generally subsequently to the enstatite; but if it is an aluminous variety, I believe the silicate of alumina remains to form the rather shapeless dirty-looking microliths which I have often noticed under these circumstances. To remove a felspathic constituent of a rock or convert it into a magnesian pseudomorph would, I think, not be a common operation in nature.

In conclusion we may ask the question, Is there any clue to the age of the various igneous rocks noticed above? From what has been stated, we are, I think, justified in concluding:—

(*a*) That the sedimentary rock had been metamorphosed before the intrusion of the lherzolite.

(*b*) That the lherzolite had become serpentine before the intrusion of the gabbro and of the granite.

(*c*) That the dykes of dark trap are the latest rocks in this part of the peninsula.

I am not aware that there is any proof whether the granite or gabbro is the older rock. Sir H. De la Beche (Report, pp. 99, 173) speaks of the granite as cutting the gabbro; but, as the only evidence seems to be the supposed vein at the Balk, which I am convinced is

* From what has been said it will be seen that most of this is the variety with a metallic lustre, or *true* bronzite, though it has often been somewhat altered by the action of water, and is now a hydrous bronzite. I have never seen true bastite in the Lizard serpentine, but believe I have detected it in the Clicker-Tor rock.

† In addition to the rocks mentioned above, the change of olivine into serpentine is well exhibited by the serpentine of Elba. One also, a serpentine with bastite from Sta. Catarina, is very like the Clicker-Tor rock described by Mr. Allport, Quart. Journ. Geol. Soc. vol. xxxiii. p. 422.

not true granite, but only an altered sedimentary rock, we have, so far as I know, no clue.

The sedimentary rocks of the Lizard peninsula are probably about Lower-Devonian age. The great granite masses further north are probably late Carboniferous, or at any rate pre-Triassic. Doleritic outbreaks, such as might have been fed by the great gabbro *massif*, the form of which seems to suggest the probability that it was once deep below a volcanic cone, occur both of Devonian and Carboniferous age; and the latest known igneous action in "West Wales" is recorded by the Triassic basalts in and about Exeter. We may then venture to conjecture that the intrusion of the lherzolite was of later Devonian age, and that both the gabbro and the granite may belong to some part of that immense period when the Coal-measures of Central and Northern England were being deposited and afterwards denuded before the "New Red" series was formed. Possibly the dark traps may record the slight sporadic igneous action indicated by the Exeter basalts, and so be of Triassic age. The aspect, however, of some of these seems indeed to suggest that they solidified at no great distance from the surface, and so under conditions not very different from those at present existing. Hence it is possible that these veins, together with the phonolite of the Wolf Rock, are remains of a yet later period, the Miocene, during which volcanic action was so rife in Scotland, Central France, and Germany.

Notes on the Chemical Composition *of some of the Rocks of the Lizard District.* By W. H. Hudleston, Esq., M.A., F.G.S.

These rocks may be roughly divided into four principal groups (without enumerating others of less importance), viz.:—

1. The Serpentines.
2. The "Greenstones" in the Serpentine.
3. The Hornblende Schists.
4. The Gabbros.

Features in common.—In all specimens of the above rocks examined by me, alkalies are extremely scarce, if not altogether absent in most cases. They are all basic, rarely containing as much as 50 per cent. of silica.

Differences.—Chemically they divide themselves into two groups:— Group A (poor in lime and alumina) includes the serpentines; Group B (rich in lime and alumina) includes the "greenstones," hornblende schists and gabbros—rocks which, however much they may differ in appearance, have considerable resemblance in their fundamental constitution.

Group A. The Serpentines.

These rocks, as usual, present an infinite variety as regards external appearance; but there is considerable resemblance in their chemical composition. A specimen has been selected for careful analysis.

Black Serpentine from "near Cadgwith."—Black to greenish black, opaque; fracture splintery; charged with numerous crystals of a highly cleavable mineral of a pale brass-colour and metallic lustre. Sp. gr. of the mass 2·587. Freed as far as possible from the crystals, the black matrix yields a greenish-grey powder, which adheres in considerable quantity to the magnet. Composition:—

Dried at 100° C.

Silicates &c. undecomposed by HCl	1·37
Iron bisulphide	0·41
Water (including traces of CO_2 and C ?)	12·35
Silica (pulverulent) traces of Ti O_2	38·50
Alumina	1·02
Ferric oxide	4·66
Ferrous oxide	3·31
Oxide of nickel	0·59
Lime	1·97
Magnesia	36·40
Sulphuric acid	traces
	100·58

Two or three kinds of crystalline fragments are noticeable in the undecomposed residue; one is probably enstatite.

As the amount undecomposed is so small, the quantity of unaltered augite, diallage or enstatite, must be very trifling. Any olivine still existing would of course be dissolved; but the quantity of water found, and the fact that no gelatinous silica is noticeable, preclude the possibility of there remaining any considerable amount of this mineral *.

The quantity of ferric oxide is probably wholly in combination as normal magnetite; this would absorb 2·09 out of the 3·31 of ferrous oxide, leaving 1·22 ferrous oxide for the hydrous silicate which forms the bulk of the mass. There exists, therefore, in all probability, 6·75 per cent. of normal magnetite disseminated as a fine powder throughout the mass, causing the blackness and opacity for which this serpentine is remarkable.

The undoubted presence of nickel is interesting in connexion with these magnesian rocks; it may exist partly as nickeliferous pyrrhotite, and partly as a base of the hydrous silicate. It has been

* The amount shown by the microscope is extremely small (see p. 921).—T. G. B.

calculated as an oxide. Sterry Hunt had previously detected it in the serpentines of Cornwall, Banffshire, and the Vosges, but states that none exists in the ophiolites of the Laurentian rocks of Canada*.

Red Serpentine from the Balk quarry.—Dull purple, ground streaked with green, and containing crystals somewhat similar to the last, but of a green colour and more blended with the general mass. Sp. gr. 2·561.

Though so different in appearance, this rock is in composition singularly like the preceding one.

The undecomposed silicate is less in amount, and the water is greater (13·28); the relative proportion of silica and magnesia about the same; but there is only 1·37 per cent. of ferrous oxide, the total iron remaining nearly the same. The bulk of the ferric oxide occurs probably as hæmatite, dispersed in fine powder through the mass, just like the magnetite in the last example †; in this case the powder does not adhere to the magnet. There is about the same quantity of nickel, rather more alumina; but, on the whole, we have every reason to suppose that we see here a rock whose original composition was very close to that of the black rock. The gradual oxidation of the magnetite into hæmatite, and a slightly more complete hydration of the original basic minerals, constitute the real difference between them.

The Brass-yellow Crystals.—These lose 9 per cent. in ignition (dried at 100° C.), and, although composed principally of silica and magnesia, contain more alumina and lime than the matrix, and much less iron. Their chemical composition is similar to that of bastite; and they are probably the result of the hydration of a variety of enstatite ‡.

Group B.

The following are very rough analyses of some of the rocks associated with the serpentines, and which, as before stated, present such a remarkable contrast to them in the amount of lime and alumina which they contain. This is due to the presence, in all or nearly all of them, of a kind of alumina-lime felspar (?), whose varieties may be grouped under the general term "Saussurite." The amount of alkali in those specimens examined appears to be so small that it has been queried in some cases when making up the total constituents.

One of the most interesting rocks is a peculiar gabbro occurring near Caerleon Cave §. This gabbro is remarkable for crystals of diallage of great size, associated with an opaque white mineral mass,

* Dana's 'Mineralogy,' p. 468.

† This is confirmed by microscopic examination (see p. 921).—T. G. B.

‡ See the description of the microscopic appearance, p. 921.

§ Mr. Hudleston's specimen is very similar to some of the varieties found at the Balk, so this may be taken as a type of the "Saussurite" in this series of gabbros.—T. G. B.

representing the "Saussurite." The external portions of this latter contain much carbonate; but the central mass, or core, consists of a bluish-white compact silicate, or mixture of silicates which, omitting small quantities, has the following composition:—

I. "Saussurite" of the newer Gabbro.

Dried at 100° C.

Ignition (water with traces of carbonic acid)	4·80
Silica	45·70
Alumina	23·00
Oxides of iron	·50
Lime	19·30
Magnesia	4·75
Alkali and loss	1·95
	100·00

The compound has more affinity, as regards its percentage of silica, with anorthite than with labradorite; but the presence of so much magnesia and its poverty in alkali must lead us to regard it as a mixture rather than as a mineral species worthy to be classed with the felspars *.

II.

The diallage associated with the above is a well-defined mineral, and but slightly affected by ignition or acids. Subjoined is a rough analysis:—

Dried at 100° C.

Ignition (water)	1·30
Silica	50·10
Alumina	6·77
Oxides of iron	6·90
Lime	17·46
Magnesia	17·47
	100·00

No alkali was found in the specimen examined. The amounts of lime and magnesia, being so exactly equal, indicate a mineral which, in its chemical aspect, is almost equally allied to the augites and the hornblendes †.

* See p. 895 for the history of this mineral. Perhaps the magnesia may be accounted for by the presence of pale-coloured hornblende, which, though almost microscopic, is often present in considerable quantities.—T. G. B.

† This may explain the extreme facility with which this diallage is replaced by hornblende, see p. 895.

III.

Analysis of the Carnpersack Rock (p. 902).—A very hard tough variety, poor in diallage, occurring in the great dyke-like mass of gabbro which comes down to the sea at Karak Clews. The analysis therefore represents the condition of one of the more "saussuritic" varieties of the last rock.

Dried at 100° C.

Ignition (chiefly water)	1·13
Silica	49·50
Alumina	18·75
Oxides of iron	1·50
Lime	20·62
Magnesia	8·00
Alkali (?) and loss	·50
	100·00

IV.

The hornblende schist of the Lizard presents many varieties, which, on analysis, would differ materially as to quantities. The following is from a variety of high specific gravity occurring near the lighthouse. About one fourth of the rock is soluble in acid. It contains a noteworthy amount of pyrites and phosphoric acid.

Dried at 100° C.

Ignition (water)	1·30
Silica	47·40
Alumina	19·30
Oxides of iron	11·40
Lime	11·80
Magnesia	7·75
Alkali (?) and loss	1·05
	100·00

(*For the Discussion on this paper see p.* 460.)

49. *On the* Action *of* Coast-Ice *on an* Oscillating Area. By Prof. John Milne, F.G.S., of the Imperial College of Engineering, Tokio, Japan. (Read June 20, 1877.)

[Abridged.]

[In this paper the author commenced by discussing those theories which have been proposed to account for glacial markings by the assumption of a polar ice-cap. He argued that even if such vast sheets of ice as are accepted by many geologists could have produced the grooves and other markings, and the drift deposits ascribed to their agency, the action of the sea during subsequent submergence and upheaval of the regions where these phenomena are displayed would certainly have effaced all such traces of ice-action. Other objections might also be raised to the hypothesis of great ice-sheets; and he thought it desirable to consider fully "whether other agents may not have shared the work with which they have been credited." He proceeds as follows:—]

Excepting glacier-action, which will generally have taken place in elevated regions, I think it can be shown that the modelling and scratching has in many instances been produced by an agent the existence of which is certain, and which acted under conditions favourable to the preservation of its work. Such an agent is coast or floe-ice acting on a rising area.

Examples of the work done, and being done, by such an agent under the stated conditions I shall take from Newfoundland, Labrador, and Finland. Every year the shores of these countries are surrounded by a fringe of ice. During the process of freezing and at other times, by various causes, such as tides, currents, wind, the driving in of pack-ice from the sea, this is forced up and down upon the shore on which it rests. By actions such as these, which extend sometimes 100 yards back above high water, the shore line is scratched, scoured, and rounded. Boulders and angular stones travel along the coast, and are often deposited in banks and lines far removed from the cliffs or mountain masses from which they were originally detached. These actions are perhaps best seen upon the small islands which form archipelagos along the shores of all those countries to which I have referred.

Lying well out from the east coast of Newfoundland there is an island called Funk Island, which, through the action of the floe-ice by which it is annually invaded, has, I believe, received not only the ordinary marks due to the moulding of ice, but also its contour as a whole. It is about half a mile in length, very low and flat, and is situated right in the stream of arctic ice coming south from Baffin's Bay and Labrador. The northern end of this island, which has every year to face the pressure of the vast fields of ice which are borne down upon it, is visibly worn down and covered with erratic boulders, whilst the opposite extremity is a low but abrupt cliff.

Passing by this extreme case, and considering the generality of islands as exhibited in these three districts (but more especially perhaps those of Finland) with regard to the way in which they are acted on by ice, I divide them into the following three groups:—

1. Rocks which at high water are hidden from view, but at low water appear as small islands.
2. Those small islands which are always above sea-level, but yet are annually covered with ice, which is driven up their sides and over their summits by outside pressure.
3. Those islands whose summits are beyond the influence of ice. The tops of these are generally covered with trees and vegetation, whilst others, which are usually not so high, have only a black colour, probably due to a growth of lichen.

Islands emerging from an ocean, as these appear to be doing, must successively pass through the stages I have enumerated. During the first two of these stages they are wholly within the influence of coast-ice, as may be clearly seen from those islands on the Finnish coast, which have not only been moulded, but are kept of a whitish colour by the scouring they continually undergo. This latter character is especially noticeable in the islands of the third class, the upper parts of which have been raised so high that they are now beyond the influence of the scouring agency; these parts are black with a growth of lichen, whilst those at a lower level, which are annually invaded by the ice, are kept of a whitish colour. Now, between the dark upper parts of such islands as I have classed in this last group and their lower parts, so far as I could see, *there is a continuity in contour between the undulations and curves along the margin of the water* (*which I know to have been produced by coast-ice*) *and those which lie at higher levels.* From this it seems to me an inevitable conclusion that the upper mouldings were produced in the same way as those below, and have since been raised to their present position.

Should two or three, or, still better, a whole archipelago of these islands slowly rise to unite and form a continuous land surface, I do not think it would be unlike many parts of Finland.

Turning from the islands to the adjoining mainland, it seems natural to conclude that the actions which produced the features in the one were identical with those producing the features in the other.

In these arguments it must be remembered that not only does the action of coast-ice upon an oscillating area explain many phenomena of ordinary occurrence, but it also readily explains some phenomena, such as the appearance of erratics at levels higher than the parent rock from which they were derived, which would be difficult to account for by either the action of sheets of ice or of glaciers.

Icebergs I have not considered, because, both from my own observations and more especially from the observations of those whose labours lie amongst them, I believe them, as compared with all other forms of ice, incomparable as transporters of material, and, from mathematical considerations of their flotation, incapable of producing any great effect in grinding the shoals on which they may occasionally ground.

Many of the phenomena presented by our northern countries and attributed to ice-action are readily explained by the supposition of coast-ice acting on a rising area, but only with difficulty when either glaciers or ice-sheets are supposed to have been the grinding agents. In such cases, all that I ask is that coast-ice may have its due.

Cosmical changes, or even changes in the geography of land and sea, I think have been sufficient to bring coast-ice as far south as any of the low-lying regions which exhibit traces of ice-action. These changes may also on the higher ground have given rise to glaciers which ground out lake-basins and moulded valleys; but that these changes produced large ice-caps, filling oceans and covering countries, I do not see that we are justified in supposing until there is a greater convergence of such evidence as can be brought to bear upon the subject.

If we take a map of Northern Europe on which are indicated the general direction of ice-markings, any inference which can be drawn from such directions, *which all point more or less at right angles to the sea-coast*, is as favourable to the view that they were produced by coast-ice acting on a rising area as it is to the fact that they point out the direction in which the great ice-sheets travelled.

In conclusion, I will say that one thing appears to me certain—namely, that, even if we accept the most favourable views of large ice-caps, the appearances presented by many countries, which have hitherto been ascribed to their action, ought rather, for reasons already stated, to have been accredited to the action of coast-ice on a rising area.

(*For the Discussion on this paper, see p.* 861.)

50. *On* Coal-pebbles *and their* Derivation.

By H. K. Jordan, Esq., F.G.S.

[Abridged.]

The author commenced by referring to the discovery by the late Sir William Logan, as early as 1840, of a pebble of cannel coal in a layer of indurated clay at Penclawdd, and of coal-pebbles interstratified with the Pennant Sandstones in considerable abundance (Proc. Geol. Soc. vol. iii. p. 276). The late Sir Henry de la Beche also discovered coal-pebbles in several areas of the coal-field both in Monmouthshire and Glamorganshire (Mem. Geol. Surv. vol. i. pp. 193, 194).

The author noticed the division of the coal-bearing strata of the part of the Welsh coal-field east of the Vale of Neath into two groups. The higher, consisting of the sandstones known as the Pennant Grit, with comparatively few coal-seams, varies from 3000 feet in thickness at the Vale of Neath to 900 feet at its eastern outcrop near Pontypool; the lower, consisting chiefly of argillaceous shales with numerous seams of coal and ironstone, is about 1600 feet thick to the lowest workable coal-seam. According to his observations, coal-pebbles are not found in the shales of the lower group, but they occur towards the base of the Pennant Sandstones, sometimes associated with granite pebbles.

Sir W. Logan's pebble of cannel-coal was found in a layer of indurated clay overlying a seam of ordinary coal; and it was supposed to have been derived from a coal-seam about 2000 feet lower in the series. This view the author regards as untenable, as it would imply the elevation and denudation of the lower seams in some adjoining area of the original coal-field before the deposition of the higher Coal-measures—an assumption which is negatived by the structure of the district. His own opinion is that the pebbles are derived either from the seam of coal above which they are found, or from the destruction by erosion of a seam of coal which once existed approximately in the position where they are found, the erosion in either case being effected by the strong water-currents which distributed the grains of sand and other material upon the coal-seam.

The author instanced the sandstone forming the roof of the "Rock Fawr" seam near Bridgend as containing in some areas very large quantities of detrital coal and coal-pebbles up to the size of a hen's egg; and these pebbles, which consist of the same coal as that in the seam below, have their angles but slightly rounded. In some seams the coal is overlain by thin beds of shale, coal, and fireclay, upon which the roof of the seam reposes; but in places these overlying beds disappear, sometimes from large areas, bringing the sandstone roof into direct contact with the coal, which is generally thinner at these parts; and the author concludes that this lesser thickness of coal, and the disappearance of the shales, &c., are due to the erosive action to which he ascribes the origin of the coal-pebbles.

When these "coal-conglomerates" are found without any coal-seam immediately beneath them, the author infers that the seams from which they were derived have been entirely broken up, and converted into pebbles and fine detritus, the characters of the pebbles and the friability of the material of which they are composed being, he thinks, incompatible with the notion of their having been transported from a distance.

The greater frequency of coal-pebbles in the south than in the north and east parts of the coal-field he attributes to the occurrence of stronger water-currents, probably resulting from more rapid subsidence, in the former—in support of which he instances the increase which takes place in the thickness of certain strata in a south and west direction.

With regard to the occurrence of a pebble of cannel-coal at Penclawdd above a seam of bituminous coal, as recorded by Sir W. Logan, the author remarks that several seams of coal in South Wales have for their upper layer a thin bed of cannel-coal; and he infers that the Penclawdd seam was of this kind, and that its original superficial layer of cannel-coal was broken up and eroded as above suggested.

As an example of the effects of a water-current, the author stated that at a colliery in the Forest of Dean the "Coleford-Hill-Delf" seam, which had a thickness of about 5 feet, was in one part of the colliery found to be entirely "washed out," the sandstone roof resting directly upon the underclay. In an adjoining area the coal was from 8 to 12 feet thick; and the author was of opinion that the coal, after its formation, but before the deposition of the roofing sandstone, had been entirely removed from one locality and piled up in the other by the action of a strong current of water. The thick coal, although unusually friable, was free from any admixture of roof-material.

From the preceding considerations the author infers that, previous to the deposition of the roof-material, the coal was to a great extent consolidated, although perhaps only partially indurated; and he points out further that the hardness of coal is not, as sometimes supposed, dependent upon pressure, as hard and friable coal may be found in contiguous beds of the same seam, and the highest seams in the South-Wales Coal-field yield harder coal than others 3000 feet lower in the series.

Discussion.

Mr. Moggridge stated that he was well acquainted with the district referred to, and had always thought that these pebbles resulted from beds broken up and much rolled. There is a bed of good cannel-coal in the district, four miles from and at a higher elevation than Penclawdd, so that pebbles from it might have been deposited at the latter place. Thus we should not have far to go for the source of the pebbles.

Prof. Morris remarked that the subject brought forward by Mr. Jordan was one of great interest. He thought there might be three sources for these pebbles:—first, floating wood encased in sandstone and carbonized; secondly, the breaking up of submerged forests, when the fragments became imbedded in sands and clays; and, thirdly, the breaking up of old coal-beds, and the distribution of the fragments through younger deposits.

The Author, in reply, stated that he could not accept Mr. Moggridge's explanation, because the difference in the level of the deposits referred to was due to changes subsequent to the formation of the beds containing coal-pebbles. Nor could he adopt the explanations suggested by Prof. Morris, because, had the pebbles been so derived, it would be reasonable to expect their occurrence, more or less, throughout the entire series of Coal-measures, whereas they they were found associated only with seams of coal which had coarse sandstone roofs.

GENERAL INDEX

TO

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[The fossils referred to are described; and those of which the names are printed in italics are also figured.]

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