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OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

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

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ERRATA ET CORRIGENDA.

In Vol. XL. of the Quarterly Journal of the Geol. Soc.

Page 166, line 4, *for* "480" *read* "380."

Page 176, line 17, for "*Haliophyllum*" read "*Heliophyllum.*"

Page 176, line 18, for "*Acanthocænium*" read "*Acanthoconium.*"

Page 177, line 13, for "*Triplasma*" read "*Tryplasma.*"

Page 177, line 14, for "*Scarithodes*" read "*Acanthodes.*"

Page 177, line 9 from bottom, for "*porcatus*" read "*præacutus.*"

Page 332, line 10, *for* "in the fossil state" *read* "in the Mesozoic Rocks."

Page 492, line 7 from bottom, *for* "Lincolnshire" *read* "Leicestershire."

Page 508, lines 6 and 7 from bottom, *for* "by those who have, of recent years, devoted all their time" *read* "by all those who have, of recent years, devoted their time."

[*To be substituted for the list given in No.* 160.]

A. S. Foord, lith. Mintern Bros, imp.

STRUCTURE IN CLIFF, TORCROSS.

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

Vol. XL.

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1. *On the* Geology *of the* South Devon Coast *from* Torcross *to* Hope Cove.

By T. G. Bonney, D.Sc., F.R.S., Sec. G. S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read November 7, 1883.)

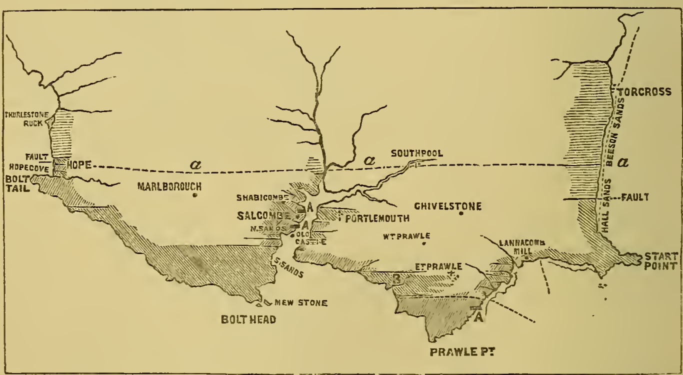
[Plate I.]

Contents.

1. *Introductory.*

The wild and picturesque coast which fringes the most southern part of Devonshire has already attracted the notice of not a few geologists. As, however, a detailed list of their writings, carried up to the year 1879, will be found in a valuable paper by Mr. Pengelly, published in the 'Report and Transactions of the Devonshire Association for the Advancement of Science, Literature, and Arts' (vol. xi. p. 319); and as no material addition to our knowledge, so far as I am aware, has since been made, it is needless for me to burden the pages of our 'Journal' with a copious history of the literature of the subject. Suffice it to say that the geology of this district is described in the paper of Sedgwick and Murchison "On the Stratified Deposits of Devonshire" (Trans. Geol. Soc. ser. ii. vol. v. p. 633), and in the "Report" of Sir H. De la Beche. In these two works, which after the lapse of more than forty years are still of the greatest value, the stratigraphy of South Devon is excellently sketched, and the main problems relating to it are clearly enunciated. Briefly stated, the latter amount to this: Does this district indicate a progressive metamorphic action, which increases in intensity as we proceed southwards? or do we find here two distinct and independent series, the southern, a group of highly metamorphosed rocks, true schists, the northern, slates, such as are common elsewhere in Devonshire, with no signs of a transition from the one to the other? Sedgwick and Murchison, if I understand them rightly, incline to the latter view; Sir Henry De la Beche inclines, though hesitatingly, to the former, which appears generally to have found favour with later writers, including Mr. Pengelly himself*. Accordingly the schists of the southern part of this district are regarded simply as altered Palæozoic rocks, possibly of Devonian age, whose upheaval is connected with the series of

Fig. 1.—*Sketch-map of the South Devon Coast from Torcross to Hope Cove.* (Scale about 3 miles to 1 inch.)



a. Slaty Series.

b. Mica-schist.

c. Chloritic schist.

A A. Bands of Mica-schist interstratified with lower parts of Chloritic schist.

a a. Boundary in the Survey Map.

B. Axis of Chloritic schist.

post-Carboniferous disturbances which have affected the south-west of England, and whose metamorphism is probably due to some proximate protrusions of igneous rock, analogous to those yet visible

* This opinion is also adopted, with some hesitation, by Dr. H. B. Holl, in his invaluable paper "On the Older Rocks of S. Devon and Cornwall," Quart. Journ. Geol. Soc. vol. xxiv. p. 400.

in the granite bosses of Dartmoor and of sundry districts of Cornwall. All these observers, however, had been obliged to labour without the aid of the microscope; yet it appeared to me from their statements that the question was one in the settlement of which that instrument would be of exceptional value. Accordingly, last Easter I spent a week in examining the coast section from Torcross to the eastern side of the Salcombe estuary, as far as Portlemouth, and from some distance north of the town of Salcombe on the opposite shore round by the Bolt Head and Bolt Tail to Hope Cove (see Map, fig. 1). Favoured by exceptionally fine weather I had time enough to traverse some of the more difficult parts of the coast section three or even four times, and to collect a considerable series of specimens, the more important of which have been subjected to microscopic examination. The results of these studies I now lay before the Society. As will be seen, there are several matters relating to the stratigraphy of the district upon which I have not been able to come to a satisfactory conclusion. Still I hope to have succeeded in clearing up some difficulties, in narrowing the issues involved, and incidentally in throwing light upon one or two difficult general problems *. In excuse for the incompleteness of some parts of this paper, I may plead that the region presents unusual difficulties. The magnificent cliffs sometimes render a close scrutiny impossible, and their bases are unapproachable except in a boat, and in the calmest weather; while in the neighbourhood of Salcombe, for a considerable distance, the gardens and enclosures around houses make the shore difficult of access. Further, the indubitably metamorphic series exhibits but little variety; it consists of a thick mass of a chloritic rock, overlain and perhaps underlain by a dark mica-schist, and these are bent into such sharp folds that when the green rock and the dark schist emerge from the sea, it is difficult to say which is the upper of the two. Nature, in fact, if I may be allowed the expression, seems to have taken a pleasure in puzzling the geologist by placing the rocks at critical sections, in a nearly vertical position, or by bringing together on opposite sides of a fault rocks, which, though really very different in the amount of metamorphism which they have undergone, to the unaided eye bear a very close resemblance one to another. I may say, however, that I had no hope of clearing up my difficulties by any moderate increase of the time allotted to my work in the field, and am therefore compelled by various duties to leave to others the final settlement of some of the questions proposed in this paper.

2. *Torcross to the Start Point.*

The little village of Torcross, sheltered from the southern gales by a rocky headland, stands on the margin of a singular sheet of water called the Lee †. This is one of those freshwater lakelets

* The nature of these has rendered necessary the occasional repetition of details of stratigraphy already given by earlier authors.

† There is another example (completed, however, by the intervention cf man

which have been formed by a bar of shingle and sand damming up the streams issuing from one or more valleys. It is, however, on an exceptionally large scale, and is worthy of more attention from physical geologists than it seems to have received. In the headland bounding the northern side of this sheet of water grey satiny slates, not unlike those in the mid-Devonian series of the northern part of the county, are exposed *. The headland immediately south of Torcross consists of dark slaty and fine gritty beds thrown into great folds with many minor contortions. On its southern side is a thick mass of dark glossy slate, which is quarried for roofing-purposes. All these rocks have undergone little alteration other than mechanical. They are distinctly cleaved, the planes dipping, usually at high angles, to the N. or slightly to the W. of N., and the strike both of the cleavage and the bedding being not far away from E. and W. The petrology of this group is interesting in more than one respect; but this I shall reserve for a separate section (No. 7), in order not to interrupt the description of the general stratigraphy of the district. South of the slate-quarry just named is another valley, now occupied by a small 'Lee,' and at the end of the bar and shore called Bossons Sand comes another headland, on the northern side of which nestles a hamlet bearing the same name. Here, according to the map of the Geological Survey, begins the tract of metamorphic rock which occupies the remaining part of S. Devon, the boundary of this and of the unaltered region running nearly due west by South Pool and Marlborough, until it finally reaches the sea at Hope Cove. At first sight there seems good reason for putting the boundary here on the eastern coast, and much evidence in favour of those who maintain that the rocks between Torcross and the Start Point exhibit progressive metamorphism. Indeed, on my first traverse of the ground, I inclined to the same view; but after carefully reexamining the section from Bossons Sands to some distance south of the village of Hall Sands (similarly situated at the next opening in the uplands), I observed that the rocks in the headland between these two valleys, though locally they might assume the macroscopic aspect of schists †, reverted again and

within the last few years) in the next valley to the south. The Loe Pool, near Helston, is another; and it is possible that the Chesil Bank at Portland may be the remains of a like phenomenon. I think it probable that these shingle beaches are memorials of a period when the coast was depressed slightly below its present level, and thus are bars once formed at the mouths of estuaries and since elevated.

* Dr. Holl (Quart. Journ. Geol. Soc. vol. xxiv. p. 400) considers the whole series of this Torcross district as higher in position than the Plymouth Limestone, and thus equivalent to the upper part of the middle and lower part of the Upper Devonian of the north.

† Throughout this paper I apply the term "schist" (as is my constant practice) only to *foliated* rocks, in accordance with the limitation insisted on by the late Professor Jukes. The lax use of the term by many continental and some English petrologists (by whom it is made to include not only highly metamorphic rocks, but also some where the chemical and mineral changes are but slight) causes much confusion, both in description and (as I have observed) in reasoning.

again to the slaty type, while south of the valley the characteristics of a schist are seen on closer examination to be not only more distinctly marked, but also permanent. Thus in the very first craggy boss N. of the valley at Hall Sands, after a few yards of rock so much decomposed and cut up by quartz veins as to be incapable of giving testimony, we come to a true slate. This can be split up into thin quadrangular or polygonal plates, whose upper and under surfaces have a glimmering satiny lustre, crumbling, or rather cracking and splitting up, when manipulated, after the manner of the fine-grained less flinty slates; while in all the rocks south of the valley, beginning with the very first crag, the surfaces are more waved, and have a more silky mica-like lustre; the thinner edges of fragments can be split up by the knife into rather translucent wavy folia; in short the demeanour of the rock is in all respects that of a micaceous schist.

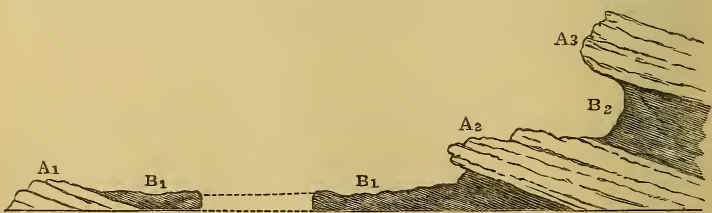
I examined the crags beneath the hamlet of Hall Sands, until a reef, which projected into the sea, compelled me to mount above them. The rock is fairly uniform in character, being commonly a dull greenish schist, often marvellously corrugated, with "eyes" of quartz and with innumerable quartz-veins, the latter often being best developed in the loops of the corrugations, and seemingly produced by mineral segregation from the darker bands. Sometimes, however, these veins are on a large scale, and traverse irregularly the mass of the rock. They also are frequently crumpled and corrugated to an extraordinary extent, the dip of the schist, if we may trust the alternation of the finer quartzose and micaceous laminæ (*i.e.* the foliation planes) as indicative of bedding, is to N.N.W. and is high, being perhaps on the average from 66° to 70°; but the crumpling and zigzagging of the layers is such that it is most difficult to estimate the dip, though there is a fairly clear intimation of a general E.N.E. strike. Mica-schists (often greatly crumpled and corrugated), varying from a dull greyish green to a leaden or brownish colour, are traversed by the path leading to the Start lighthouse and the rock. About the buildings is a mica-schist, which reminded me of those which so commonly occur on the flanks of the higher ranges in the Alps. Everywhere the schist, in addition to the ordinary aspects of a foliated rock, has a peculiar slickensided look, as though it had been subjected to great compression long after it had become a normal mica-schist.

3. *Prawle Point and the adjacent Coast.*

Instead of continuing the section westward from the Start lighthouse, it will, I think, save time to describe next the rock which forms the fine headland of Prawle Point, and then to follow the coast back to the Start, on the eastern, and to Portlemouth on the western side. The first rock seen after quitting the village of East Prawle for the Point, is a mica-schist presenting a general resemblance to that at the Start. It forms a sort of scarp running westward, on the southern slope of the hilly upland. Apparently emerging from beneath this mica-schist comes the mass of rock which forms the headland of Prawle Point, and is exposed in the grand cliffs for a considerable distance on either side. This latter rock varies in colour from a dull green to a light yellowish (epidote) green. Sometimes rapidly alternating bands of different tint appear to indicate a very distinct bedding, at others it is more massive and homogeneous. Generally it has a somewhat decomposed aspect; in the latter case it is often very rotten, passing into a crumbling earthy or sandy material, sometimes of a rusty colour, and forming a pitted carious-looking surface, the rounded hollows being occasionally several inches in diameter and three or four inches deep. It frequently reminded me of a rotten "greenstone tuff;" and now and then I could have supposed myself to be looking at a decomposed diabase. In two or three places I fancied I detected a slightly fragmental aspect, but could never satisfy myself that this was more than an accidental resemblance. In other places, however, the banding of the rock is very distinct, and it has more the aspect of an ordinary schist, though the foliation is seldom or never of a kind that renders it conspicuously fissile. Still, though rightly classed among the metamorphic rocks, it may be well to keep in view the possibility of this having once been a fine basic tuff. As will presently be seen from examination of the microscopic structure, it is rather difficult to give this rock a name. We may continue to call it "chlorite rock," with De la Beche, or adopt "chloritic schist" as being slightly less definite as to its mineral character, remembering that it occasionally becomes rather massive. The dip indicated by the banding, which I think can only result from bedding, at one place rather to the north-west of the Point, was about 45° towards a point between N.N.W. and N.W. At the Signal House it is about 45° or 50° to N.W., or even slightly to the west of this.

The steep cliffs on the eastern side of the Point rendered examination difficult; but, so far as I could see, the general character of the rock for about three quarters of a mile is similar to that already described. I then descended to the shore, the chloritic schist con-

Fig. 2.—*Section on shore E. of Prawle Point.*



A_1, A_2, A_3. Bands of Mica-schist. B_1, B_2. Bands of Chloritic schist..

tinuing to form an inland line of crags; the reefs by the water afford the section given in the diagram (fig. 2). Three bands of mica-schist are intercalated in the chloritic schist, the lowest forming a skerry insulated at high water, the other two exposed on the face of a rocky mass on the shore. The lower of these is about four feet at its thickest part; but both are rather lenticular in form, and in one place the chloritic schist appears to be nipped between two beds of mica-schist. The latter is banded with thin quartzose laminæ, and has a more gneissic aspect than the rock at the Start *. I also observed that it was more corrugated than the interbedded chloritic schist. The dip varies from about 20° to 30° to N.N.W., or a few degrees more to the north. These interstratified schists, so far as I can ascertain, are the lowest rocks exposed in this district. I followed these associated schists for some distance, the rock at one place being much contorted and cut by quartz veins several inches thick. Then I ascended the inland cliff, which consists of chloritic schists with one or two bands of mica-schist. After this, keeping along the coast, which now trends nearly N.E., I continued to traverse interbedded chloritic and mica-schists, sometimes much rolled about, but generally striking not far from E. and W., and with the prevalent dip on the northern side at a rather low angle, until (I omit details of minor importance) I lost the chloritic schist on reaching a headland projecting from the Start promontory towards the south. The last band of the chloritic schist appears to strike out to sea, so as to pass beneath the lowest rocks of the Start. My examination of this part of the coast, especially about Lannacombe Mill, and to the east of it, led me to the conclusion that the mass of chloritic schist probably thins, and is certainly split up by bands of mica-schist as it is traced eastward.

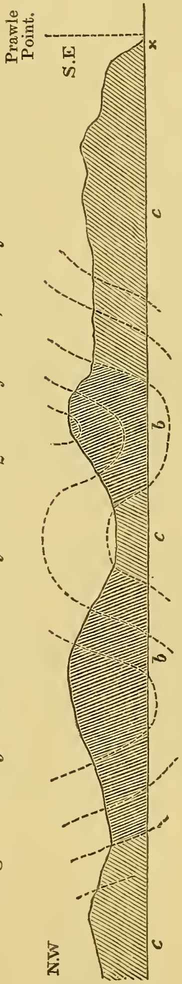
Returning to Prawle Point, we can follow the chloritic schist already described along the limit of free cliffs for a distance of nearly half a mile to a projecting headland †. The evidence as to the dip of the strata is sometimes obscure, sometimes variable; but on the whole the dip seems to be high, perhaps about 60°, and the inclination slightly to the W. of N. Beyond the headland the readings are discordant, the beds in one place appearing to plunge to the S., in another to the N.E. The strike, however, seems generally to be about E. and W., and folds are very probable. A short distance to north of the headland the chloritic schist is replaced by mica-schist (the prolongation of that already mentioned as forming the ridge just below Prawle village), the line of junction being almost vertical (fig. 3). The latter is rather greener in colour than usual. In the cove beyond we again find chloritic schist, but on the further side mica-schist occurs again. The latter is wonderfully gnarled and quartz-veined, the zigzagging bands appearing generally to be almost vertical. The former also indicates great disturbance, though

* Probably this is the rock spoken of by De la Beche as "gneiss;" but I should agree with Sedgwick and Murchison in preferring to call it a mica-schist.

† Here I may venture to call attention to the coast scenery. Rarely, except in the recesses of the Alps, have I found a spot so perfect in its solitude or so impressive in its grandeur as on the crags of this headland.

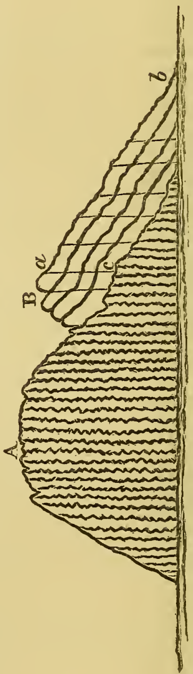
at one place on the southern side the beds dipped pretty clearly to the south. By following these along the shore I could come to no satisfactory conclusion as to the relative position of the two schists, but afterwards, by traversing the little glen which leads down to

Fig. 3.—*Diagrammatic Section of about $1\frac{1}{2}$ mile of coast, west of Prawle Point.*



b. Mica-schist. *c*. Chloritic schist.
× Approximate position of bands of lower mica-schist.

Fig. 4.—*Chloritic and Mica Schist on shore south of Portlemouth.*



A. Mica-schist, foliation nearly vertical, with many minute crumples.
B. Chloritic schist, with distinct bedding parallel with *a b*, and slight indications of vertical cleavage, *a c*.

the cove, I found that I only lost sight of the mica-schist beneath the turf for a very short distance, and have no doubt that the rock exposed in the headlands on either side of this cove belongs to the same bed, and that the sea has cut across the crown of a sharp arch which brings up the underlying chloritic schist (fig. 3).

This second mass of mica-schist forms a considerable headland, which descends in steep crags to the sea. The rock is much "gnarled," and is slightly greenish in colour, the strike being very nearly E. and W., but the dominant direction of the dip is very uncertain. In the next cove, on the S. side of a small stream which here descends to the sea, we again meet with the chloritic schist. Here also the junction appears to be nearly vertical, but in the cove itself a sharp N.N.W. dip may be noticed in the last-named rock, which is, I think, the lower of the two. Hence, for some distance along the shore, bands of mica-schist occur in the chloritic rock, the former being always the more corrugated and having more quartz-veins. The dips which I observed were now less steep, first to W.S.W., then to S.W. at about 45°, the latter being near the westernmost angle of the coast. The trend of this is now a little E. of N., and we pass over chloritic schist till in a little sandy cove we find a darkish mica-schist pretty clearly underlying it. The annexed diagram (fig. 4)' roughly illustrates the relation of the two rocks, and indicates that here, at any rate, the foliation-planes of the mica-schist cannot be trusted as evidence of bedding: for they make a considerable angle with that (indicated by marked mineral changes) in the chloritic schist, and correspond with a faint imperfect cleavage in the latter. Hereabouts the rocks evidently are greatly folded, but the dark mica-schist is pretty clearly shown to be the lower of the two.

Mica-schist, with its foliation-planes generally dipping northward at a high angle, continues as far as the ferry at Portlemouth; and the same rock can be traced for a considerable distance inland up the hill, at least as far as the church; but a little beyond the ferry the chloritic schist seems to set in again and to continue along the shore for some distance. The mica-schist at Portlemouth is evidently thick, and the evidence just mentioned would naturally lead us to place it below the chloritic schist: still after consideration of the whole question, I doubt whether this is not another repetition of the upper schist, the apparent infraposition of that in the cove being due to the folding over of a banded part at the top of the chloritic schist. I was unable, for want of time, to examine the coast north of Portlemouth.

4. *Salcombe to the Bolt Head.*

The ramifications of the coast and the numerous houses and enclosures cause this district to present even greater difficulties than the former. I visited the junction between the true schist and the slaty rock laid down on the geological map to the north of Salcombe, and by making use of a boat, formed some idea of the stratigraphy of the very irregular coast-line between this locality and the town. Landing a little north of the spot where the junction is indicated, I found the rock very imperfectly exposed; but satisfied myself that though, as at Bossons Sands, it occasionally assumed a schistose character, all is indubitably slaty, the cleavage-planes dipping apparently to points between N. and N.N.W. I place the actual junction, which I have no doubt is a faulted one, about 200 yards S. of where it is drawn on the Geological map; for I succeeded in tracing the slaty rock almost to this point *, and then after a few yards' interval (the rock hereabouts being very imperfectly exposed) found an indubitable mica-schist of rather chloritic aspect. Beyond this, at a slight headland, is a very "gnarled" greenish schist, and at the headland bounding the little bay chloritic schist appears to rise from below the mica-schist.

Along the shore of the inlet leading to Batson, which cuts obliquely across the above-named beds, we have chloritic schist more or less banded with mica-schist, and at last, near the inlet leading to Snapes Farm, these appear to be overlain by a considerable thickness of darkish mica-schist †.

The town of Salcombe is scattered over a headland formed of chloritic schist (fig. 5), of which rock many exposures will be found by searching; but a band of mica-schist occurs near the base, as may be seen in an alley not far from the ferry; and at the upper part of the hill is found a considerable mass of mica-schist, resembling that already described, and clearly overlying the chloritic schist. This is, in all probability, continuous with a mica-schist exposed in a quarry to the west of Shabicombe, on the road to Marlborough.

From Salcombe to North Sands the coast, for the reasons given above, is generally difficult of access. So far as I could ascertain, the rocks are chloritic schist, but in one or two places I observed bands of mica-schist underlying the basal part of the former rock. In the southern flank of the hill, forming the northern boundary of North Sands, the chloritic schist, here pretty well banded, is quarried. The dip is steep, approximately to S. The same rock forms the headland dividing North Sands from South Sands; but by the roadside, low down on its southern face, we find a darkish mica-schist and on the shore at its base chloritic and mica-schists are interbedded and, I think, repeated by minor flexures. The general strike is about E. and W., but it is difficult to say whether the dominant dip is northwards or southwards. On the south side of the little bay called South Sands is a darkish mica-schist, the commencement of the great mass which forms the Bolt Head. The rock is greatly disturbed and "gnarled." At first I inclined to the view that the whole rose up steeply from beneath the chloritic schist, but on repeated examination I fancied I could detect some indication of bedding which gave a southerly dip, and after studying specimens with the microscope, and a review of the whole evidence, I think it more probable that the Bolt-Head mica-schist is only a repetition of the upper schist of the Salcombe hill and is thus a continuation of that already noticed on the eastern side of the estuary. The Bolt Head, so far as I could see, is a mass of darkish mica-schist, the general strike of which appears to be a few degrees

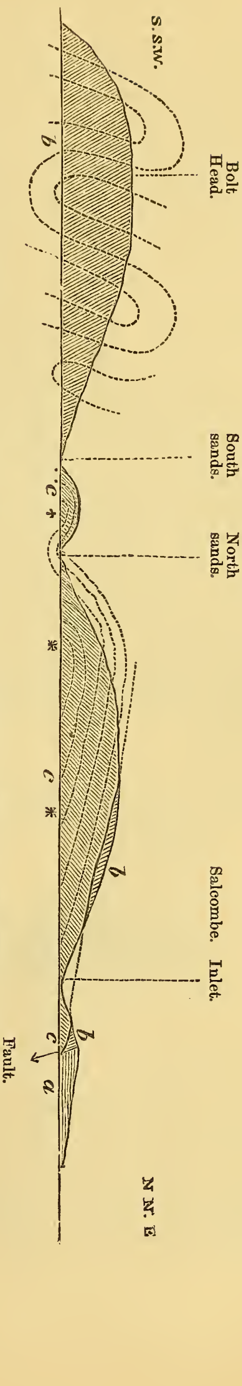
* About 80 yards from a gate, opening from the shore into a field.
† The tide was falling, and mud prevented me from landing.

N. of E. The foliation-planes seem generally to incline rather to the southern side, but the thinner quartz bands among the micaceous laminæ are intensely "gnarled," and the quartz veins, by which the rock is often traversed, are commonly completely smashed. I do not think that we can rely much upon the evidence of the minor features of this mass: but the general aspect of the crags—of marvellous wildness and beauty—produced upon me the impression that the headland consisted of a series of grand folds, the loops of which had their axes in a nearly vertical position.

5. *The Bolt Tail and the neighbouring Coast* (fig. 6).

At the Bolt Tail we have, as at Prawle Point, a great mass of chloritic schist. The coast between the Head and Tail may be dismissed in a few words, though the walk from the one to the other is rather a long one (more than four miles as the crow flies, and over very broken ground). As a rule, it is not possible to descend the cliffs to the water's edge; but we can see clearly that the rock is very uniform in character, a dark mica-schist, the interlaminations of quartz being very thin, often barely perceptible, while the mass is frequently traversed by quartz veins. There can be little doubt that the general strike is to the east, and the bedding (if we can trust the indications) dips at a high angle to the south. We do not touch the chloritic schist until we reach a spot almost due south of Hope village, where it is seen to rise abruptly from the

Fig. 5.—*Diagrammatic Section near West Side of Estuary, Salcombe.* (Horizontal scale 2 inches to 1 mile.)



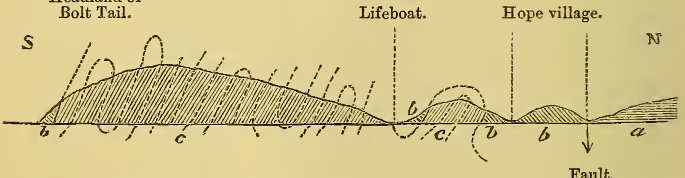
a. Slaty rock.
b. Mica-schist.
c. Chloritic schist.

* Bands of lower mica-schist seen on shore.
† Much rolling evident on shore.

sea in the face of a precipitous headland, difficult of approach, and impossible to descend. The two rocks strike a little S. of E., and the mica-schist, so far as can be seen from above, appears to plunge at a very high angle beneath the chloritic rock, but not more than would be perfectly consistent with a slight overthrow in the folding. As we proceed towards the "Tail," the strike becomes E. and W., and about a furlong from the junction the dip is distinctly about 60° N. We see no more of the mica-schist until, as we proceed from the Tail to Hope village by the path along the northern margin of the headland, we note some outcropping beds of it in a cove below; and then, beyond another little cove, where the coast-line bends sharply to the north, we find in the crags of a headland first mica-schist, then chloritic schist, and lastly mica-schist, all seemingly dipping at a high angle to the south. The last-named mica-schist also forms the little "look-out" headland, which divides the two coves, between which extends the village of Hope. It is rather dark in colour and marvellously gnarled and broken, but the foliation-planes are often vertical.

We have only to traverse the rocky shore in the northern cove at Hope for a very short distance to be convinced that, as is indicated in the map, we have returned to the slaty series. Here again the mimicry of foliation, and the other results of the tremendous pressure which the beds have undergone, make it difficult to fix the exact position of the junction, but after repeated examination on more than one occasion, I came to the conclusion, fully confirmed by subsequent microscopic examination, that the beds outcropping on the shore were never more than schistose, while those in the headland itself, wherever I could get at the crag (rendered difficult each time by the state of tide), were true schists, so that the fault has probably determined the northern face of the headland.

Fig. 6.—*Diagrammatic Section near Bolt Tail.* (Horizontal scale 3 inches to 1 mile.)



a. Slaty rock. *b.* Mica-schist. *c.* Chloritic schist.

In the floor of the cove the newer series exhibits considerable variety of mineral character; but in the crags beyond, dark slaty rocks predominate, bearing a general resemblance to the series in the headland between Hall Sands and Bossons Sands. In the distance, beyond Avonmouth, the peculiar sheen of the cliffs recalls to mind the satiny slates seen at Slapton on the east coast, and at Kingsbridge at the head of the estuary.

I postpone the full consideration of the facts recorded in the above descriptions until I have given the results of the microscopic examination of the rocks, merely remarking that the evidence obtained in the field leads us to the following conclusions:—(1) that the foliated and slaty series are quite distinct rocks, the one much older than the other, so that very possibly the foliation of the former was anterior to the deposition of the latter, and that their junction is a faulted one; (2) that both have subsequently been subjected to tremendous lateral pressure, which has bent them into huge folds, cleaving the newer and producing marked effects on the older rock.

6. *Microscopic structure of* (A) *the Foliated Series*, (B) *the Slaty Series.*

(A.) Regarded lithologically, the foliated series may be divided into two groups, the mica-schists and the chloritic schists, of which the former are decidedly the more fissile, the latter being occasionally almost massive. Macroscopically the mica-schists do not materially differ; they are of a dull lead-colour, sometimes rather dark, but often relieved by minute spangles of silvery mica, sometimes distinctly laminated with quartz; but not seldom the latter mineral is inconspicuous. The surface often weathers to a rusty brown. The rock, almost everywhere, appears to have been much squeezed after it had assumed its present mineral character. Sometimes it has a peculiar slickensided look, as near the Start; sometimes the surface of the foliation-planes is traversed by minute wavelike wrinklings; sometimes, as especially about the Bolt Head, it is so crumpled as to break up under the hammer into rude prisms with irregularly fluted sides.

Microscopically examined, the differences are merely varietal, and so slight that one description will suffice for the predominant characters of the specimens which I selected for cutting. The chief constituents are quartz, mica, and a variable amount of a minute black mineral.

Quartz.—This occurs in granules variable in size. These are sometimes at least as old as the time when the foliation was produced; at others they have a chalcedonic aspect, as if a secondary product, in interstices due to subsequent disturbance. Cavities, especially in the former, are rather numerous, but extremely minute, so as to require for examination a magnification of at least from 300 to 400 diameters. Some are rounded in outline, some vermiform, a few are irregular, and may possibly be films of some micaceous minerals. Bubbles are extremely rare. Sometimes the cavity is slightly darkened as if by the internal deposit of a ferruginous coating.

Mica.—Of this mineral there appear to be three varieties—(*a*) a colourless mineral in flakes rarely exceeding ·01″ in length, exhibiting with the polarizing apparatus a satiny chromatic polarization, the tints of moderate brilliancy, varying from pale green to pink, and extinguishing when the cleavage-planes are parallel with the vibration-planes of the crossed nicols; probably a hydrous potash or soda-mica; (*b*) a dark brown mica, associated with, and often rendered almost opaque by, the black dust named above, probably akin to biotite, or a hydrous variety of it; and (*c*) a pale olive-green slightly dichroic mineral in rather smaller flakes which seems not to extinguish in quite the same positions as the first mineral, and so may be rather a chlorite than a mica.

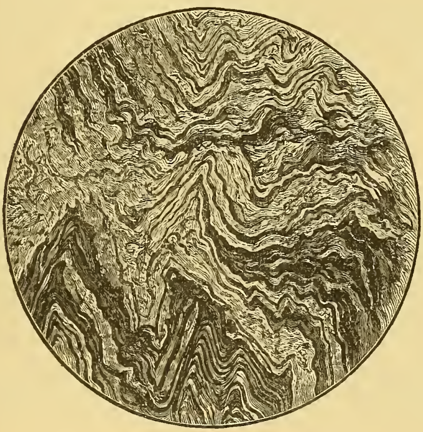
The white and the dark mica are closely interbanded, sometimes the former, sometimes the latter predominating, in which case the slides become locally only very feebly translucent. The crumpling of these interlaminated minerals is often singularly beautiful, equalling the most complicated arrangements of banded agates (see fig. 7). In this case I have observed that the white mica, when seen with the polarizing apparatus, assumed a peculiar granular aspect, as if the mineral had been somewhat "crumbled" *in situ*. The microscopic structure fully confirms the conclusion, formed in the field, that after the rock had assumed its present mineral character, it was subjected to great lateral pressure, often crushing the minuter laminæ of quartz as well as the larger veins of the same mineral, and abruptly bending the more yielding laminæ of mica, which were now and then somewhat broken.

The Black Mineral.—This is generally associated with the darker mica, occurring in minute specks, vermicules, and rods, forming fine black bands and streaks, which under a low power are often almost wholly opaque. Among the quartz occasional specks and rare larger grains occur; but even in the latter anything like a definite crystalline outline is wanting. Mr. J. J. H. Teall has kindly undertaken some investigations, experimenting with much care both on prepared slides and on a specimen of the rock powdered, with the results (i) that the colouring matter is principally iron-peroxide, but that there is probably a small amount of carbonaceous matter, and (ii) that the rock contains about 6 per cent. of combined water. Besides the above there is often a little iron-glance, limonite, and a grain or two which we may regard as impure epidote.

Fifteen specimens have been examined, on which I will make a few remarks. One, from the first rock visible on the north of Hall-Sands village (p. 5), *i. e.* from the first outcrop of true schist on the east coast, though much affected by crushing and decomposition (as its macroscopic aspect led me to expect), appears to me to be a true foliated rock. Another specimen, from near a fissure about 100 yards further south, is a mica-schist, like several of those following, but extraordinarily crumpled. A specimen taken from a greenish band in this neighbourhood has, as we might expect, more the aspect of the slides of the chloritic schist presently to be described, but it contains some mica and a fair amount of calcite. It has, as is common with the chloritic schists, a rather "fragmental" look; but this I believe to be the result of subsequent crushing.

Two specimens from different parts of the Start headland call for no special remark. Three specimens, one from the schist to the west of Prawle village, the others from the two principal masses further west, selected to see if they were microscopically as well as macroscopically identical, agree in all essential particulars with one another and with the last two; so also do three from the Bolt Head, one from a quarry just inside the grounds, another from the eastern face of the Head, and a third from near the Mewstone, except that in these, perhaps, there may be a little more of the black mineral. There is therefore nothing to be discovered under the microscope which forbids us to consider all the thick masses of mica-schist one and the same rock. I figure a portion of one from the Bolt Head

Fig. 7.—*Section of Mica-schist fom the Bolt Head* (× 50).



(fig.7), to give an idea of the general structure and the extraordinary corrugations. I examined slices from the bands (A_1 and A_2 of fig. 2) which are undoubtedly below the main mass of the chloritic schist, in the hope of finding something that would characterize a lower mica-schist, but without success. They contain a few grains of a mineral which also occurs in the chloritic schist, and rarely in the ordinary mica-schist; as I shall presently explain, this may be a felspar, but I have doubts as to its nature. I have also examined one of the lower schists from the northern side of South Sands, but it does not help in our attempts at differentiation. Hence, as might be expected, the microscopic evidence as to the position of the mica-schist is inconclusive.

The macroscopic aspect of the chloritic schist has already been described (p. 6). Seven specimens have been cut for microscopic examination. In these three minerals predominate:—(1) the most abundant, a laminated yellowish green mineral occurring in isolated folia, in grains exhibiting a marked scaly cleavage, and in felted aggregates. Viewed with the polarizer alone, it is seen to be moderately dichroic, a dull green when the lines formed by the cleavage-planes are parallel with the vibration-plane of the transmitted beam, and yellow-green when they are perpendicular to it. We may safely regard this mineral as a species of the chlorite group. (2) A granular mineral, often dusty-looking, giving, when clear, fairly bright tints with the two nicols. This I have no doubt is epidote. (3) Quartz in rather irregular granules, frequently containing microliths of a pale green mineral; some of these, I have little doubt, are flakes of a chlorite, but others appear to be belonites, minute elongated prisms. The comparative thickness of the including quartz grains renders it most difficult to examine their optical characters; but I think that the greatest extinction is when the belonite forms a small angle with the vibration-plane of one of the crossed nicols, so that they are probably hornblende. The quartz also contains numerous extremely minute cavities; these generally seem to be empty, but in a very few I have detected little moving bubbles. (4) A mineral in grains of moderate size, present, but in variable amount, in most of the slides. It has one well-marked cleavage, and another making with it an angle not far from 90°. It may be orthoclase, but I should have expected this under the circumstances to show more indication of decomposition, and I should consider that a few earthy-looking grains occasionally present are more likely to represent a felspathic constituent. The present mineral has considerable resemblance to my specimens of kyanite, which would be a mineral very likely to occur in a rock of this nature. Calcite, grains of iron

Fig. 8.—*Section of Chloritic Schist from the west side of Prawle Point* (× 50).

peroxide, and ferrite stains are occasionally and variably present. The quartz granules often have a very clastic aspect, but as they contain frequent microliths of the green constituent, I consider this illusory, the result of subsequent pressure. It will be remembered that the chloritic schist exhibits less marked crumpling than the mica-schist. The more granular and uniform character of its constituents probably allowed of their being compressed into a smaller space, while the platy laminæ of the mica were necessarily folded by a transverse pressure. It is rather difficult to obtain thin slices of this chloritic schist. Seven slides have been prepared, one from the rock by the signal-house on Prawle Point, another from the cliffs on the west side, and a third from the beds associated with mica-schist on the east (p. 6, in fig. 2). There is nothing in these calling for special remark, except that the belonitic character of some of the microliths is very conspicuous; they pierce the grains of quartz (and of felspar ?) like pins in a cushion; there are also bands of secondary quartz, probably filling interstices produced by crumpling. A slide from the quarry near North Sands (p. 10) shows, more than any other, quartz grains like original clastic constituents, and contains some calcite; but, as already stated, I believe the structure to be due to unequal pressure. One from the other side of North Sands, and one from near the Signal on the Bolt Tail, call for no special remark; that from the headland south of Hope, has the felspar-like mineral in greater quantity and in larger grains than is usual.

B. *The Slaty Series.*

Of this group I have examined, microscopically, eight specimens, the majority being selected from critical positions. As an example of one of the normal rocks of the district, I take the silky slate from the quarry on the south side of the Torcross headland. This, cut perpendicular to the cleavage-planes, exhibits a moderately clear, finely granulated ground-mass, divided into minute lenticular streaks by dark lines of variable thickness—the usual aspect, in short, of a fine-grained blackish slate; the dark lines which are parallel with the cleavage-planes are due to the presence of carbonaceous matter, perhaps graphite, with probably some iron oxide. The clearer interspaces (not seldom minutely granulated with similar minerals), when magnified 300 or 400 diameters, appear to be composed largely of very minute scales, rather irregular in form, of a filmy mineral, which on applying the nicols gives pale colour tints; these are probably one of the hydrous micas which seem to be common to many slates, especially the more 'satiny' varieties, and to the phyllites; with them are associated extremely minute granules of (apparently) quartz. The slide, as a whole, is darkest when the cleavage-lines are parallel with the vibration-planes of one of the crossed nicols.

A specimen of a slaty rock collected a little to the north of the marshy valley at Hall Sands (just to the north of a stone building), and so one of the nearest to the metamorphic rocks south of the valley, exhibits a structure generally similar to the above, except that the rock has evidently been much crumpled. A sharp zigzag fold traverses the slide, and some of the bands have been broken across, and one part of the fold thrust over the broken ends of the other, so as to exhibit a structure in one part of the slide which might readily be mistaken for false-bedding *.

A specimen from the curiously corrugated rock at the headland north of the last locality (p. 4) shows a similar mineral structure, but one more conspicuously banded, the slide having been very skilfully cut from the apex of a fold. In this, however, the micaceous constituent occurs in slightly larger flakes. Still, notwithstanding the presence of a hydrous mica, which perhaps we may venture to designate sericite, these rocks differ widely from the normal foliated rocks and, if we restrict the term schist to the latter, they have no claim to that title. These filmy minerals appear to be very readily formed under pressure from damp argillaceous material in a fine state of division, and rocks in which they occur alone differ widely under the microscope, and usually to the naked eye, from the true mica-schists. I call special attention to this because I have noticed in some authors a tendency to confuse these two generally well-defined and widely separated groups of rocks.

A specimen from a rather gritty-looking band in the cliffs south of Torcross shows a minutely granular, somewhat streaky structure, and appears to consist of quartz, white mica, a dusty mineral, probably kaolin, perhaps a little calcite, with ferrite, opacite, and a filmy mineral belonging to the chloritic group. Bands of secondary quartz associated with some of the last-named mineral traverse the slide. Another somewhat similar rock, in which scales of silvery mica are distinctly visible to the eye, from south of Bossons Sands, exhibits a coarser texture under the microscope, consisting chiefly of grains of quartz and flakes of white mica with streaky ferrite and opacite; the quartz is rather full of minute cavities, bubbles being very rare, if not absent. The rock has evidently been much compressed, and some slight amount of mineral change has taken place. I have little doubt that the more conspicuous quartz grains and mica flakes are derivative and indicate the destruction of a gneiss or mica-schist.

Specimens of the greyish, greenish, and blackish rocks from near the fault in the Hope Cove have also been examined; but a very minute description does not seem to me necessary. They are clearly not foliated rocks, though they have been much compressed, and consist of fine aluminous sediments of rather varied nature, associated with some quartz, calcite, and numerous microlithic minerals which it is hopeless to identify with precision. For my present purpose it suffices to say that I have no hesitation in classing these with the slaty group, not with the true schists of South Devon.

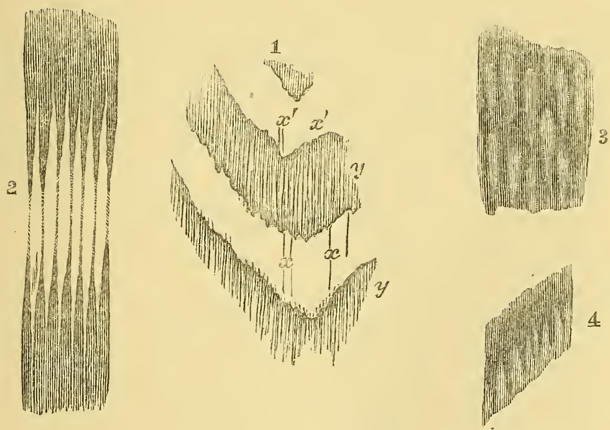
7. *Peculiarities of Structure in the Slaty Series.*

I have already called attention to the remarkable corrugations and schistose structure locally exhibited by members of the slaty

* This structure is described by Prof. Lapworth; Geol. Mag., Dec. ii. vol. viii. p. 343.

series; but there is one case which appears to me so interesting and suggestive that I have reserved it for a separate notice. This is exhibited in the rocky headland upon whose northern slope the village of Torcross rests, and the most striking examples are exhibited in the smooth face of a low cliff rising from the shingly beach within a two minutes' walk from the hotel door. The rock appears originally to have consisted of alternating layers of fine dark mud and silt. The former predominate; the latter, though differing so little in mineral composition or texture as to be with difficulty visible on a freshly broken surface, are more distinct on a weathered one, as their colour changes to a lighter grey than the former. The beds are much folded, and so are inclined at various angles to the direction of pressure. Where this has been normal to the bedding, the different layers have evidently been much compressed, the stripe is remarkably clear and sharply defined, cleavage corresponding with bedding; but in other parts, where the angle between the direction of pressure and the normal to the surface of the bed has been a fairly large one, the results are very remarkable. The stripe is obscured or obliterated, and a new and often more conspicuous structure produced, which is parallel to the planes of cleavage.

Fig. 9.—*Diagrams of Pressure Structure in Banded Rock.*



1. Banded gritty (x, x') and slaty (y, y') rock, cleavage parallel with x, x'. Gritty band about 4 inches thick.
2. Enlarged drawing of part of gritty band between $x\,x'$.
3. Study of a portion of rock, about $1\frac{1}{2}''$ by $1''$, where these gritty bands, which have lain diagonally, have been squeezed out by a nearly horizontal pressure.
4. A small diagonal band of gritty rock squeezed out on one side only.

An examination of Plate I.*, which represents a small portion of the cliff face, aided by the smaller diagrammatic figures (fig. 9), may, I hope, render intelligible the following extract from my note-book, and thus render a lengthy description unnecessary. "The whole of this bedded mass exhibits a cleavage-structure, and the more gritty bands are squeezed out into long lenticular streaks, as if the bedding coincided with the cleavage. Where the gritty bands are broadest, there the ends are all 'frayed out' (fig. 9, no. 2); where the banding has been fine and rather close, there it has been entirely obliterated and replaced by this new structure of parallel lenticular streaks or elongated 'eyes' (fig. 9, no. 3). Round these the darker part of the rock bends, just as the folds of mica in a gneiss pass round the lenticular patches of quartz and felspar. Occasionally, perhaps where the materials of the gritty band have been coarser than usual, rather larger lumps have been formed, like the 'eyes' in an augen-gneiss. These are 'drawn out,' as it were, into long flame-like ends, with more distinctly indicated central eyes. They vary in length from about 1 to 3 inches, and in breadth from $\frac{1}{8}$ to $\frac{1}{4}$ inch. In some cases I noticed that the thinner bands were much more squeezed out on one side than on the other, like the feather of a pen, when the pinnules are a little separated (fig. 9, no. 4). Commonly, during the latest stage of the squeezing-out, there appears to have been a slight slipping of one part over another, and a thin film of the darker material has been either infiltrated or dragged in between; this aids greatly in obliterating the traces of the original bedding and in simulating the aspect of a schist." I may also note that in one or two of the coarser gritty bands in this neighbourhood (not "teazed" out as above described) I noticed indications of stratulæ, which might readily be taken as marks of ripple-drifts. I came, however, to the conclusion that these were more probably indications of a rude cleavage—minute splits along which perhaps a slight infiltration had taken place; they made an angle of about 15° or a little more with the well-defined and level surface of the bed. It may be well to bear this instance in mind, for the structure might easily have been mistaken for one of the cases of ripple-drift noticed by Dr. Sorby †.

The peculiar structures described above are, I think, interesting as illustrating some of those seen in foliated rocks. Though the Torcross rock is in no true sense of the word foliated, yet it is often an excellent model of one that is foliated. In regard to rocks of the latter class it is often difficult to say whether foliation corresponds with bedding or is transverse in direction to it, whether it is independent, or only a further development of cleavage; further, an arrangement of the minerals in lenticular streaks with their longer axes parallel is common, especially in gneisses. If the action

* Copied from a photograph. For this I am indebted to my brother, Mr. F. Bonney, who kindly undertook a journey to Torcross to make it. Shingle thrown up by a recent storm had buried the best example, but the one which he secured is nearly as good.

† Quart. Journ. Geol. Soc. vol. xix. p. 401.

of heat, pressure, and alkaline water on these slaty rocks of Torcross had been sufficiently prolonged, we can hardly doubt that the darker laminæ would have been converted into bands of mica, the greyer streaks into lenticular aggregates of quartz and felspar. All trace of the original bedding might thus have been lost, and the presumption from the general aspect of the foliation would have been that the original stratification had been parallel to it. Certain portions also of the rock would have closely resembled an augen-gneiss.

In offering these suggestions, I wish to guard myself against being supposed to put forward a general theory of foliated rocks. I merely mention these as a possible explanation of certain cases of foliation, and certain cases of "eyed" structure. I am only prepared to make one general induction, namely, that a lenticular structure in a foliated rock is probably an indication that it has been subjected to pressure in a definite direction, which, though making a fairly large angle with, is not at right angles to, the dominant mineral banding. From what I have seen of foliated rocks in a rather wide experience, I am convinced that very commonly their characteristic structure, speaking in general terms, is parallel with the original stratification, and that there are many augen-gneisses to which the above explanation does not seem to be applicable *.

8. *Conclusions as to the Relations of the various Rocks in the above District.*

From the foregoing remarks it is evident that in this district of South Devon two questions especially present themselves for consideration:—one, the relation of the foliated to the slaty series, the other, the mutual relation of the members of the former series. As regards the former question, we have to decide whether we find in the sections above described—a case of progressive metamorphism, so that we pass in descending order, from true slates to true schists—or two distinct groups, of which the lower was probably metamorphosed before the upper was deposited.

The facts mentioned above in detail prove, I think, that there is no valid evidence of a passage from schist to slate. While I cannot assert that there is a conspicuous fault, as in the Lizard district †, yet the transition from the one class of rock to the other is so abrupt as to be incompatible with the idea of progressive metamorphism, while at Hope Cove and to the north of Salcombe the chloritic schist appears to approach much nearer to the slaty series than at the Start; but apart from the former of these considerations—that we pass from slates and phyllites (to use the strongest term that can be applied to them), from rocks in which the metamorphism can at most be called incipient, to true schists, too rapidly for us to regard

* I may refer in connexion with this subject to a paper read before our Society by the late Mr. G. Poulett Scrope on May 12, 1858, and published, with an admirable illustration, in the 'Geologist' for 1858, p. 361; a paper replete with valuable suggestions, which, as it appears to me, has not attracted the notice which it deserves.

† Quart. Journ. Geol. Soc. vol. xxxix. p. 1.

the change as resulting from an action which has affected both masses to a different extent—there is another which to my mind is conclusive. All the rocks of this region—slates as well as schists—have been greatly folded and bear unmistakable indications of lateral compression. In those which some observers might call phyllites, those which, as described, at first sight resemble schists, the aspect of the rock leads us irresistibly to the conclusion that to this compression is due such modification in mineral structure as they have undergone; but the contrary is the case with the schists, and especially the mica-schists. Folded and corrugated schists are far from uncommon in nature. In some cases the structure of the crystalline constituents indicates that the folding has been the first stage in the process of metamorphism, and that the chemical or mineral change has been subsequent to the mechanical one. In others the former appears in immediate connexion with the latter, subsequent to it, indeed, but in such connexion that the mineral constituents, owing to the plasticity of the mass, were capable of change of position mutually without visible rupture of continuity or sign of crushing; but in a third case it is obvious that the rock, when compressed, was substantially the same that it is now. In the first and second cases we find that the rock does not separate along the different mineral layers, where corrugated, more readily than where these are level; pieces may be struck off from it upon whose broader faces sections of many corrugations of the mineral layers are exhibited. Not so, however, when the lateral compression has been long subsequent to the metamorphism. Then not only do we find evidence of brecciation in the laminæ and veins of quartz &c., but also the arched bands of different minerals fall readily apart, and the rock, when hammered, demeans itself in a wholly different manner.

We also meet with abundant confirmatory evidence of the above view in examining the microscopic structure of the rock. The mica-layers have evidently been bent into zigzags subsequently to their crystallization. Sometimes they have gaped, and the aperture has been filled by infiltrated quartz or other minerals: sometimes there is distinct brecciation of the mineral constituents and the like*. Now in the case of these metamorphic rocks of South Devon—the chloritic rock, with its frequent clastic aspect, especially as regards its quartz, the mica-schist with its wrinkled surface, and, especially at the Bolt Head, its peculiar fracture into prisms with corrugated sides, and its wonderful microscopic structure—there is, to my mind, every sign that the metamorphism and the great lateral compression of the rocks were wholly distinct, and the latter long subsequent to the former; and I believe that any petrologist, accustomed both to handle rocks in the field and to examine them with the microscope, will be led irresistibly to the same conclusion.

* I only mention two or three of the most obvious signs. There are others familiar to me which I do not mention, because they would require too long a digression, in order to convince any but the very few who have made a special study of these questions.

I incline further to the opinion that the fault at the junction of the two groups is a considerable one, and that the slaty series of Torcross and Hope Cove was not deposited in immediate succession to the southern schists. The former are generally composed of extremely comminuted materials; even fine grits are not common, conglomerates I never saw. Now the mica-schists especially abound in quartz-veins, and contain layers with fair-sized plates of mica. The former would furnish pebbles of white quartz, the latter mica flakes, not comminuted, because they would be carried for considerable distances without much attrition. Hence, if the slaty series derived much of its materials from the neighbouring schists, I should expect occasional conglomerates of rolled quartz, not unfrequent micaceous grits, and abundant scales of the latter mineral in the muddy beds. Yet in only one of the specimens examined (p. 18) have I found distinctly fragmental quartz and mica, and the micaceous constituents of the most satiny slates or phyllites are so minute as to render it very possible that they are endogenous rather than exogenous*.

The absence of fossils makes it difficult to fix precisely the age of the slaty series of South Devon. Dr. Holl regards the Torcross group as newer than the Plymouth Limestone, and so fairly well up in the Devonian series; but, at any rate in Cornwall, we can trace unmetamorphosed rocks at least as far back as the Ordovician series; so that we may fairly assume any metamorphic rock in a district so near to be considerably earlier than this geological period. I think therefore that we may safely regard the South-Devon schists as Archæan, and as a prolongation of the *massif* so distinctly indicated in the Lizard, to which also belonged the gneiss of the Eddystone † and those granitoid rocks which furnished the pebbles in the conglomerate at the Nare Point.

The physical history of the district of which the south-west of England is a fragment seems then to be identical with that of many other regions which have undergone great disturbance from lateral pressure. The first stage—a very remote and doubtless very long one—was the formation of a great mass of more or less crystalline rock, in which perhaps we may discover the usual progression from a basal group of granitoid gneisses through more distinctly foliated gneisses and strong schists, to a well-bedded and more variable series, in which felspar is comparatively rare. The next stage, an uplifting and denudation of this mass; the third, a long period of depression and deposition of sediment; and the fourth, a period of continued lateral pressure, folding, cleaving, and otherwise modifying the rocks affected by it. To this has of course succeeded, as usual, another period, characterized chiefly by denudation, which has lasted down to the present time. A physical history this, which, with

* It will be remembered that in the slaty series of the district N.E. of the Lizard, fragments of metamorphic rocks are found in the associated conglomerate. Quart. Journ. Geol. Soc. vol. xxxix. pp. 9, 10.

† See for indications of the occurrence of crystalline rocks in the bed of the Channel, papers by Mr. A. R. Hunt, in Trans. Devon Assoc. vols. xi., xii., xiii.; also by Mr. Pengelly, in vol. xi. p. 319.

more or less complication, we find in the Scotch Highlands, in North and in South Wales, in the Alps, the Pyrenees, and other mountain chains.

The question as to the mutual relation of the members of the presumed Archæan rocks of South Devon may be quickly dismissed. We have simply to decide whether the chloritic schist is interbedded between two great groups of mica-schist, or whether there is only one thick mass of the latter, with some thin bands of the same rock in the lowest visible part of the chloritic schist. For the reasons given above I consider the latter view to be the more probable, and regard even the mass of the Bolt Head as simply the upper mica-schist repeated by an extremely sharp fold, or rather series of folds.

If I were to attempt to correlate the South-Devon rocks with others of Archæan age, I could only say that they cannot, in my opinion, be referred to the earlier portion of it. In all Archæan rocks which I have examined, where there is any thing like a full development, the rocks become, broadly speaking, more distinctly bedded, more variable in their mineral character, more markedly foliated as we ascend. The threefold division mentioned above (I do not say that further subdivision is not possible) is very recognizable in the Alps; and this—into the group of granitoid gneisses, the group of more fissile gneisses and strong schists, and the group of variable well-bedded schists—suffices for my present purpose. The rocks of South Devon remind me most of members of the last group. I cannot find an exact parallel to them elsewhere in England; but so far as lithological evidence (and we have no other obtainable) avails us, I should consider them to belong to this third group, to be not very far away in geological position from the schists of the Lizard, but, if any thing, a little more recent.

The above conclusions, if established, suggest one or two inferences of a more general nature. One as regards the physical history of a large adjacent area of country. I have indicated the successive changes which the rocks of South Devon have probably undergone. The great period of disturbance—the formation of the boundary fault, followed by the folding and the various results of lateral compression, including, in all, a long series of events—was doubtless subsequent to the deposition of the Carboniferous series as a whole. The flexures &c. of South Devon form parts of the great series of flexures, affecting all rocks, belonging and prior to that age, which can be traced from Belgium to the South of Ireland. It would seem to have been a wrinkling of the earth's crust, scarcely less important than that to which the existing Alpine chain is due. We can hardly help associating with its phenomena the great granitic intrusions and the other igneous masses of Cornwall and Devon, which fringe the north of the most highly compressed area, much as granitic and felsitic bosses now stud the southern margin of the Alps *. In short,

* It may be worth noting the apparent absence of intrusive igneous rocks in the district described in this paper. There is a greenstone dyke near Torcross; but I found no igneous rock in any other place to the south of it. Yet in the Lizard district, where the beds are less sharply folded and there is less evidence

as perhaps will have been inferred from some of my preceding remarks, the phenomena of the district described in this paper are eminently those indicative of a mountain chain*. They record more than one chapter in the history of mountain-making. I can hardly understand the production of those great parallel flexures which affect all south-western England, and especially this district—flexures whose undulations become broader and flatter as we trace them northwards, without assuming the existence to the south of them of a great axial mass of much harder rock, to the pressure of which these sharper crumplings are due. On comparing a section of South Devon with a series of sections across the Alps we cannot fail to be struck with the resemblance between them, except that in the former we do not find the crystalline nucleus rising up as the central mass of the chain, often overtopping and apparently overlying the later deposits. But when we look to the south, beyond the South-Devon and South-Cornish schists, we find at the Eddystone—we find probably in the shallower parts of the neighbouring sea—we certainly find yet further south in the Channel Islands and on the adjoining coast of France—large masses, projecting from the ocean, of much more coarsely crystalline rock. Is it possible that these may be the foundation-stones of a great mountain region, of whose outer zone South Devon and South Cornwall are the last remnants—the relics of a long-vanished highland region of Archæan rock? If so, the mountain-making—at any rate that with which we are now concerned—occurred after the Carboniferous, and prior to the Triassic epoch,—was, in short, one of the closing incidents of the Palæozoic volume of geological history. Yet the Channel sea now occupies the place where this range was upraised, and of its ruins some fragments only remain *in situ* †. These remarks may seem to belong rather to the poetry than to the prose of science; but I think that any one who will spend a few years in studying the structure of rocks and of mountain-masses will see that the idea conveyed by them is something more than a baseless flight of imagination ‡.

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of compression, intrusive igneous rocks abound. This is, of course, what was to be expected.

* See also in illustration of this the sections in Dr. Holl's paper, especially fig. 1, p. 409, and fig. 5, p. 438.

† A thorough study of the rocks composing the Triassic conglomerates of Devonshire would give, I am sure, most interesting results. Whoever undertakes it must be a resident in Devonshire; for the field-work will take no little time; he must be a skilled petrologist, or his results will be worse than useless; and he must have a special knowledge of the rock masses of Devonshire and Cornwall. Among the many excellent geologists and enthusiastic students of the West of England is there no one to undertake this task, and endeavour to replace the covering which has been stripped from the granitic bosses, and rebuild the hills which the sea has destroyed?

‡ There is another more general conclusion to which I may call attention, namely, the importance of pressure as modifying rock structure. Rocks subjected to much pressure, folded, and squeezed out of shape, appear to undergo more micro-mineralogical change than similar rocks when not so maltreated. Perhaps it is hardly too much to say that the difference between a satiny slate or phyllite and an ordinary shale is due even more to the action of

EXPLANATION OF PLATE I.

Structure imitative of foliation produced by pressure on a stratified rock without important mineral change.

The mass of rock figured is about four feet high. The cleavage-structure is vertical; the beds (of alternating dark mud and paler silt) are bent into rather irregular curves pointing downwards, and are separated as described in the text. The paler parts of the figure represent the 'streaks' and 'eyes' of the silty rock, made sometimes more distinct by aggregations of quartz.

Discussion.

Mr. J. Starkie Gardner stated that the Eocenes of freshwater origin of the south of England were formed from granitic materials, and not from flints, the Chalk not being then upheaved; and these facts seemed to lend support to the author's conclusions.

Rev. G. F. Whidborne said that somewhat similar beds at Hope Nose contained the fossils of the Middle Devonian. He asked if the rocks dredged in mid channel by Mr. Hunt at all resembled those of the coast.

Rev. E. Hill asked if the gneiss mentioned by Sir H. de la Beche resembled any rock of the Lizard. He agreed with the author that the lenticular structure described is such as would be produced by the oblique crushing of a mass. He stated that in the Channel Islands none but the most highly metamorphic rocks occur.

Prof. T. McK. Hughes pointed out the close resemblance of the gnarled beds of Prof. Bonney's post-Archæan slates to the gnarled beds of Amlwch, which he (Professor Hughes) had described as not truly metamorphic, but only mechanically altered rock. He thought that the lowest Archæan of Britain and France was sometimes granitoid rock, sometimes schist, and that they alternated and passed into one another, so that no general order could be established between granitoid rock and the lowest schists. In Brittany he had observed such alternations, especially in the remarkable sections along the river Rance, near Dinan.

He called attention to the thickening of sediment from north to south, *i. e.* towards the English Channel, in the two groups which next succeeded the Archæan, viz. the Lower Cambrian and the Devono-Carboniferous, and thought that these facts must be taken into consideration when speculating upon the probability of the

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pressure than to mineral composition or geological age. Such rocks as the phyllites of the Ardennes and of the Alps, not to name others, have, as a rule, little claim to be classed with the true schists—the foliated rocks. They have, indeed, taken a step in that direction, but it is only a small one, and their alteration should be classed with the phenomena of mechanical rather than of chemical metamorphism, although the latter has operated to a slight extent. Still, though pressure is an important agent, it is not, as these words imply, the only agent; and when marked regional metamorphosis prevails, when we are considering great masses of truly foliated rock (gneisses and schists), we seem to require something more. Are we justified in asserting that the other necessary agencies operated more freely in Archæan times than they have subsequently done?

former existence of Archæan mountain land over the area now occupied by the Channel.

Dr. Hicks objected to Prof. Hughes's view that schistose rocks such as those exhibited alternate with the granitoid series. He agreed with the author in referring the Devonshire rocks to the newer of the Archæan series. The same succession had been described by Barrois in the North of Spain.

The Author agreed with Mr. Starkie Gardner that many of the materials of the Eocene and also of the Mesozoic rocks were derived from granitoid materials. In reply to Mr. Whidborne he stated that the rocks dredged by Mr. Hunt in the Channel were generally of a much older type than those of South Devon. The so-called gneiss near Prawle Point did not resemble any rock at the Lizard. In reply to Prof. Hughes he stated that he had never seen schists of the type now described by him alternating with granitoid rock, and that the two varieties of rock in South Devon, so much alike to the eye, yet really so different, formed a good parallel to the cases in Anglesey which had so misled Prof. Hughes.

2. Notes *on* Brocchi's *Collection of* Subapennine Shells. By J. Gwyn Jeffreys, LL.D., F.R.S., V.P.G.S. (Read November 7, 1883).

Having lately passed through Milan on my way to Venice, I took the opportunity of examining the collection of fossil shells made by Professor Brocchi and described in his classical work 'Conchiologia fossile subapennina'. That remarkable work was published in 1814, when the study of palæontology was almost in its infancy. It was based on the Linnean system and nomenclature.

Giovanni Battista Brocchi was not only a celebrated geologist but also a botanist, an entomologist, and an antiquary. His first essay was on Egyptian sculpture, and was published at Venice in 1792, when he was only 20 years old. His other works on different subjects were about fifty in number. In 1802 he was appointed to the chair of natural history at Brescia, and he afterwards became Inspector of Mines in Lombardy. He died in 1826, at the age of 54.

The first volume of the 'Conchiologia' contains an interesting introduction, an elaborate treatise on the progress of the study of fossil conchology in Italy from 1300 to 1811, and geological remarks on the Subapennine and adjacent formations. The second volume is devoted to the enumeration and description of the fossil shells, and is illustrated by 16 well-executed copper plates. The 'Conchiologia' is a monument of careful and conscientious labour, and is invaluable to every palæontologist.

The collection was shown to me, in the absence of Professor Stoppani, by Signor Francesco Molinari, an assistant at the Civico Museo of the Reale Istituto, whose courteous attention I am glad to acknowledge. I was informed that the collection had been presented to the Museum after Brocchi's death, and arranged in 1870 by Emilio Spreafico, an engineer who had been the author of a geological chart of the Ticinese Canton. Such an arrangement of any typical collection evidently leads to occasional misplacement and mistakes. Even Linné's collection of shells, now in the possession of the Linnean Society, was said not to have been kept intact after its presentation to the Society by Sir J. E. Smith, and it therefore cannot be implicitly relied on for the identification of some species.

There is no question that the study of fossil in comparison with living forms is indispensable to a thorough knowledge of any branch of zoology in which the remains are preserved, especially as regards the Mollusca, Polyzoa, Crustacea, and Testaceous Annelids. I fear sufficient attention has not been paid to this study in the case of the last-named two departments of the Invertebrata.

In offering the following observations I will refer to the "Catalogo ed illustrazione delle specie" in the second volume of the 'Conchiologia' and to the pages there given.

Page 257. Patella sinuosa.

This is the type of Bronn's genus *Brocchia.* The specimens in the collection clearly show that they belong to *Capulus hungaricus*, Linné, and that they had been originally attached to a species of *Cassidaria* (*echinophora* or *tyrrhena*) and had thus taken the impression of the ribs which ornament the latter species. The spire and apex are precisely the same as in *C. hungaricus*; and although the minute sculpture of that species is indistinct, sufficient traces of it remain on some of the fossil specimens. Similar cases of moulding occur in *Anomia ephippium* (as is implied by its specific name), *Calyptræa chinensis*, and other quasi-parasitic shells. Several other species of *Brocchia* have been made by modern palæontologists out of *C. hungaricus* in consequence of their having been attached during their lifetime to various shells which had a different kind of sculpture. Professor Biondi described and figured as many as twelve species in his 'Monografia del genere *Brocchia*,' 1864.

P. 258. Patella cornucopiæ.

A conical variety or form of *Capulus hungaricus.*

P. 262. Dentalium sexangulum.

A variety of *Siphodentalium tetragonum*, Brc.

P. 264. Dentalium coarctatum.

A testaceous Annelid.

P. 277. Bulla convoluta.

A poor and worn specimen of *Cylichna umbilicata*, Montagu, and not *C. cylindracea*, Pennant, with which Brocchi's description and figure evidently agree. Possibly replaced by a specimen not from the collection.

P. 297. Nerita helicina.

Small specimens of *Natica catena*, DaCosta.

P. 304. Helix nitida.

Not *Eulima nitida*, Philippi (*E. intermedia*, Cantraine), but larger, thicker, and more convex.

P. 305. Helix subulata.

One specimen shows the coloured bands. Brocchi does not seem to have known Donovan's work on British shells, in which the same name had been previously taken for this species of *Eulima.*

P. 319. Voluta buccinea.

Includes *Ringicula auriculata* of Ménard and *R. ventricosa* of J. Sowerby.

P. 339. Buccinum asperulum.

Nassa incrassata, Müller.

P. 351. Trochus cingulatus.

A broken specimen of *T. zizyphinus*, L.

P. 353. Trochus turgidulus.

Comprises two species, the smaller of which is *T. Montacuti*, W. Wood.

P. 353. Trochus miliaris.

A broken specimen of *T. millegranus*, Phil.

P. 354. Trochus crenulatus.

T. exasperatus, Penn.

P. 354. Trochus obliquatus.

Not Gmelin's species of that name, but *T. turbinatus*, Born.

P. 355. Trochus cinerarius.

Not the Linnean species, but a variety of the last.

P. 358. Trochus agglutinans.

Several specimens under this name, including *Solarium mediterraneum* of Tiberi. Some of these, especially younger specimens and one adult, are umbilicated; this is not a good character to distinguish species of *Solarium*, any more than those of *Trochus*. Brocchi's variety of *T. agglutinans* (p. 360) is a different species.

P. 359. Trochus pseudo-perspectivus.

Certainly not (as Brocchi supposed) *T. hybridus* of Gmelin, which is a very different species of *Solarium* or of an allied genus.

P. 366. Turbo exoletus.

Not the Linnean species, but a variety of *Turritella triplicata*, Brc.

P. 367. Turbo duplicatus.

Same remarks.

P. 368. Turbo acutangulus.

P. 369. Turbo spiratus.

Both are the same species, the latter being the young.

P. 374. Turbo tricarinatus.

The slender variety (*gracilis*) of *Turritella terebra*, L.

P. 376. Turbo plicatulus.

Comprises 5 different species of the *Turbonilla* or *Chemnitzia* section of *Odostomia*. One is *O. rufa*, Phil., var. *fulvocincta*.

P. 378. Turbo clathrus.

Represented by 3 different species of *Scalaria*.

P. 381. Turbo pusillus.

A species of *Rissoina*.

P. 382. Turbo gracilis.

Two species of *Odostomia*, allied to *O. lactea*, L., and having the tooth-like fold of the typical form.

P. 383. Turbo terebellatus.

Includes two species of *Odostomia*.

P. 385. Strombus pes-pelecani.

Mixed with *Aporrhaïs Serresianus*, Michaud.

P. 420. Murex vulpeculus.

Three species of *Pleurotoma*, intermixed. One is *P. costata*, Don.

P. 422. Murex squamulatus.

Apparently *Trophon muricatus*, Mont.

P. 423. Murex echinatus.

A well-known and living species of *Defrancia*, which is generally called *reticulata* as of Renier; but Renier never described that or any other species named in his 'Tavola alfabetica delle Conchiglie Adriatiche.' *Murex reticulatus* of Brocchi (p. 435) is another species of *Defrancia*, although unknown as living; and in strictness the name *echinata* ought to be applied to the living species.

P. 430. Murex oblongus, var.

Defrancia gracilis, Mont.

P. 435. Murex turricula.

A species of *Pleurotoma*, but not *P. turricula* of Montagu, which has priority. The difficulty as to this specific name is removed by adopting *contigua*, by which Brocchi described (p. 433) the same species as his *turricula*.

P. 437. Murex gracilis.

The young of *Aporrhaïs pes-pelecani*, as corrected afterwards in the appendix.

P. 449. Murex granulosus.

Triforis perversa, L.

P. 459. Anomia ephippium.

Represented by eight so-called species. One of them (*A. pellis-serpentis*) had been moulded on a specimen of *Cassis undulata*, and had appropriated its markings.

P. 465. ANOMIA STRIATA.

P. 466. ANOMIA ORBICULATA.

Both are *A. patelliformis*, L.; but *A. striata* (p. 471) is a species *Terebratula.*

P. 478. ARCA NODULOSA.

Not Müller's species, but *A. lactea*, L.

P. 479. ARCA DYDIMA.

Young of *A. antiquata*, L.

P. 485. ARCA GRANULATA.

Limopsis pygmæa, Phil.

P. 489. ARCA UNDATA.

P. 492. ARCA INSUBRICA.

Pectunculus nummarius, L.

P. 497. SOLEN CANDIDUS.

Unfortunately this has disappeared from the collection, and been replaced by specimens of *Solecurtus antiquatus*, Pulteney; although the label marked "*Solen candidus*" has been retained.

P. 515. TELLINA CUSPIDATA.

One valve of *Neæra cuspidata*, Olivi, and another (much larger) valve of *N. crispata*, Scacchi, which was noticed by Brocchi as having been found in the Piacentino.

P. 541. VENUS DYSERA.

Not the Linnean species, but *V. fasciata*, Da Costa.

P. 543. VENUS RADIATA.

V. ovata, Penn.

P. 548. VENUS RUGOSA.

Not Linné's species, but *V. multilamella*, Lamarck.

P. 557. VENUS INCRASSATA.

Astarte sulcata, Da Costa; var.

P. 562. OSTREA EDULIS.

Many varieties with specific names.

P. 574. OSTREA PLICA.

Not Linné's species of that name, but his *Pecten pes-lutræ.*

P. 505. MYTILUS MODIOLUS; var. *superne oblique-truncata.* *M. incurvatus*, Phil.

APPENDICE.

P. 627. Dentalium tetragonum.

Not *D. quinquangulare* of Forbes, or *Siphonodentalium pentagonum* of M. Sars. See Part v. of my papers in the 'Proceedings of the Zoological Society of London,' on the Mollusca of the 'Lightning' and 'Porcupine' Expeditions.

P. 666. Cardium punctatum.

A single valve, and decorticated or deprived of the greater part of the outer layer. It appears to be *C. papillosum*, Poli.

It would be impossible to make a satisfactory analysis of all the species named or described by Brocchi, so as to ascertain which of them are now known to be living, and which of them are supposed to be extinct, because thirty at least of all these species are marked "smarrita" or "citazione" on the tablets in the collection without any specimens. Perhaps a similar analysis could be attempted on a more extensive scale, as regards all the shells from the Pliocene formation in Italy, by a careful examination and comparison of modern collections in the University and private museums by some conchologist who was conversant with the living species of the North Atlantic and Mediterranean seas. Such an undertaking would require much time, but would be exceedingly useful to naturalists as well as palæontologists.

The lines of demarcation between the upper, middle, and lower sections of the Pliocene formation in Italy have not yet been well defined. At Castrocaro in the Bolognese district the "sabbiosa" and "argillosa" divisions of the lower Pliocene are distinguishable, but not the lower from the upper Pliocene, which are intermixed like our Coralline and Red Crag in so many places. As a general rule the upper Pliocene appears to contain by far the greater proportion of living or existing species and no tropical forms. The succession of these fossiliferous strata and of their organisms is still to be investigated. It might throw an immense flood of light on the difficult problem of the devolution or descent of species accompanied by a certain degree of modification or change, which is a very different phenomenon from what is popularly known as "evolution."

My examination of Brocchi's collection, as well as of several other and more extensive collections of Pliocene shells in Northern and Central Italy, has induced me to draw two inferences, viz.—

1. That they represent deposits made in comparatively shallow seas, probably not exceeding fifty fathoms in depth. The only exception seems to be the late discovery of *Sequenzia formosa* (a deep-water shell) in the Valle de Savena. In Calabria and Sicily, however, there are deep-water formations evidenced by the nature of their Molluscan remains. According to Manzoni and other palæontologists the Miocene formation in Central Italy also denotes

shallow-water conditions and is characterized by its abundance of siliceous sponges.

2. That not the slightest difference can be detected by the most critical conchologist between any of the fossil species in the Pliocene formation which are now known to be living and their surviving descendants, although an incalculably long period of time must have elapsed. These species are extremely numerous, and exhibit varietal and abnormal forms of a precisely similar kind in the same fossil and living species.

Discussion.

The President remarked on the value of this revision by Dr. Gwyn Jeffreys of the type collection of Brocchi.

Mr. J. Starkie Gardner said that it would be of great advantage if a conchologist with the extensive knowledge of recent forms possessed by Dr. Gwyn Jeffreys could undertake the examination of the Eocene Mollusca.

The Author thought that the Eocene Mollusca were almost totally different from the recent forms, and he doubted whether there was one species common even to the Eocene and Pliocene.

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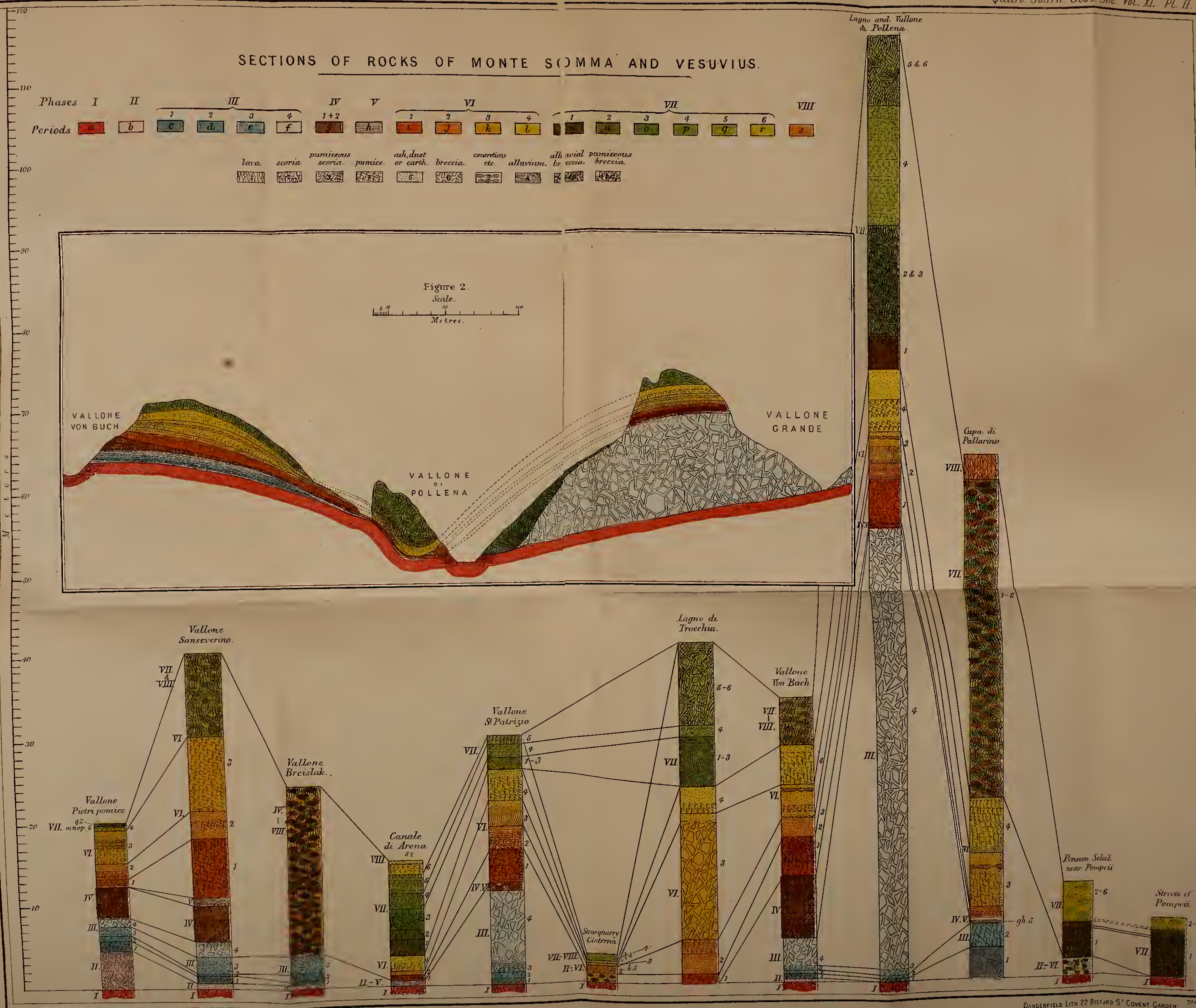

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3. *The* Geology *of* Monte Somma *and* Vesuvius, *being a* Study *in* Vulcanology. By H. J. Johnston-Lavis, Esq., M.D., F.G.S., &c. (Read June 20, 1883.)

[Plate II.]

Contents.

I. *External Form and Features of Monte Somma.*

The general form and outline of Monte Somma, the relation of the cone of Vesuvius piled around the recent eruptive axis, to that of the prehistoric one, have been so often alluded to by various authors, that the subject might appear exhausted.

If Monte Somma is viewed from the north, for example from the bridge at Marigliano *, it presents to the view certain characteristics of many volcanic cones. Its eastern and western flanks rise from the fertile Campanian plain at a gradually increasing angle, until at an average of 1050 metres of altitude, the outline becomes horizontal, presenting an irregular crenated ridge. In fact it exhibits that symmetry of form so characteristic of many truncated volcanic cones.

If the observer has chosen the early morning, the sunlight falling obliquely across the face of the slopes brings out in all the detail of sharply cut light and shade, the ravines or valleys with which the mountain sides are scored.

As the observer winds round the base in a westerly direction, the above-described apparent regularity disappears. From Naples, which lies very nearly west of Somma, the line of truncation is seen to slope from the Punta del Nasone 1137 metres, the highest point on the northern ridge, to the Pedimentina, 650 metres, the summit of the old crater-ridge on the southern side. This curve is concave downwards, and of irregular outline. It marks the edge of the great crater that was excavated by one, or a series of eruptions, which culminated in the first historic one, or that of A.D. 79.

Rising from within and above this curved and inclined ridge, is the Vesuvian cone.

It has been asserted by some writers on the subject, that Vesuvius is exactly concentric with Monte Somma. A little investigation, aided by the large new contour-map, will, I think, convince us to the contrary. It may, however, be noticed that the summit of Vesuvius (*i. e.* its eruptive axis), by measurement, lies about midway between the two extreme north and south limits of the great crater of the Atrio del Cavallo. We may therefore consider the modern

* This town lies about 11½ kilometres north of the present eruptive axis, or crater, of Vesuvius.

cone to be concentric within the old crater, and consequently to have the same eruptive axis. This method is not so easily applicable if used on a line east and west, since there are many irregularities produced by lava and ash of modern date; but as far as possible the evidence is confirmatory.

There is very good reason to deny the concentricity of the great crater of the Atrio with the original cone of Monte Somma. If within a cone we scoop out an inverted conical hollow around an axis eccentric, but parallel, to that of the solid, we shall have the included space bounded by an annular ridge, not horizontal, but sloping down in the direction of the axis of excavation, and inclined proportionally more, the further the axis of excavation is removed from that of the solid.

It is just with such a condition of things that we have to deal in the present instance. If we measure the distance of the modern eruptive axis (*i. e.* the centre of Vesuvius), from, say, the 650 metre contour-line on the northern slope of Somma, and compare it with that of the same line on the south, we shall find that this axis is between 850 and 950 metres to the south of the centre of the contour-lines of the ancient Somma. In a regular cone, such as we suppose this ancient volcano to have been, the centre of the contour-line would be the eruptive axis of the mountain.

From these facts we must conclude that although the eruptions that excavated the great crater of the Atrio, and subsequently piled up the cone of Vesuvius, occurred from the same axis, this was nearly a kilometre to the south of the ancient one, of the primary cone of Somma.

It seems also that the modern axis is slightly displaced to the west of south; but from the obscured features of the ground the exact amount cannot be accurately measured, although it was hardly south-west, as thought by Prof. Phillips.

This change in the position of the eruptive axis appears to be the most rational explanation of the great difference in height of nearly 500 metres, between the southern and northern ridge of Monte Somma.

Breislak * endeavoured to explain this lower truncation to the south, by supposing that the vast mass that would fall back into the crater after the first explosion might be such as to cause the following one to search the weakest point, which would be to the south.

If the igneous forces were able to elevate the great mass of ejected materials in the first instance, they would hardly be directed obliquely by that portion in a fragmentary condition which would fall back again. That any amount of blocking, even by a solid compact mass, would be capable of causing 500 metres of a mountain's side to be carried away, whilst the eruptive force could not again lift that filling up the aperture, hardly seems probable. But such a plug could not be one solid coherent mass, from the fragmentary nature of its components, and it would therefore allow the gas or

* Voyages physiques et lithologiques dans la Campanie,' 1801, p. 132.

vapour to find a passage through it, which in escaping would carry the smaller fragments with it, and, depositing them on the outer slopes of the cone, would very soon clear the vent. The larger masses, if too great, would be subjected to such powerful grinding movements that they would soon be reduced to finer fragments, and would then gradually be ejected. It also presupposes only one paroxysmal eruption as the cause of all this great cavity, whereas a number did the work piecemeal. Phillips * accounts for it by considering the southern side of the mountain weaker, as proved by all recent lateral eruptions, which burst forth from that portion. It seems that there is no reason why one side of the mountain should be weaker than another. This tendency of dykes to reach the surface first on the south side is undoubtedly due to the modern eruptive axis being in much closer vicinity to it.

Von Buch's † opinion of the matter is much the same, except that he is trammelled by his pet hypothesis.

The mention of the southern side of Monte Somma as being either the lowest or weakest point is assuming a condition as necessary which it is intended to explain.

Even in that unique and peculiar volcano the Puy de Chopine ‡, near Clermont, if the eruption had been as violent in character as some of those that excavated the crater within Somma, the obstructing mass of granite would have been carried away.

A change of eruptive axis is a thing not at all uncommon, and dozens of examples may be given; but two remarkable ones of the Italian group Etna and Volcano are sufficient §. From day to day we may see the same process going on, on a smaller scale, in the crater of Vesuvius. Even now the vent opens right away in the E.N.E. corner of the 1872 crater.

Some authors || have supposed that the principal part of the Vesuvian cone was thrown up by the eruption which destroyed Pompeii. Before accepting such a theory, it is worth while considering some general facts bearing thereon.

Let us imagine the condition of affairs towards the termination of the Plinian eruption, which had pared the sides, and cleaned out the bottom of the great crater of the Atrio del Cavallo. The centre of Somma was then occupied by this vast conical hollow which had been cleared out by explosions that were capable of carrying lapilli from 50 to 100 grammes in weight a distance of 22 kilometres, and depositing them on Mt. St. Angelo, nearly 1000 metres higher than the lower edge of the crater.

* Vesuvius, 1869.

† 'Description physique des îles Canaries.' Traduit par C. Boulanger, 1836.

‡ Scrope, 'Volcanos,' 1822, p. 71.

§ Lippi pointed out many years since the remarkable fact that all the principal Italian volcanos, as Roccamonfina, Ischia, Vesuvius, and others, showed great craters truncated lowest to the seaward ('Geologia volcanica della Campania del Dottor Nicola Pilla.' Naples, 1823). The same has been observed in other districts: see Charles Heaphy "Volcanic country of Auckland, New Zealand," Quart. Journ. Geol. Soc. vol. xvi. p. 244.

|| Palmieri, 'Il Vesuvio e la sua Storia,' 1880, p. 9.

We may arrive approximately at a conception of the enormous space and depth this great crater had, by comparing it with the one produced by the eruption of 1822, a space calculated at one kilometre in diameter, and variously at from 300 to 700 metres in depth. It was drilled through lava, scoriæ, ash, &c., identical in composition with those of the ancient Somma.

Comparing these measurements with the diameter of the crater in A.D. 79, at, say, the 650-metre contour-line, the altitude of its lower edge, which was three kilometres, we may estimate the depth. Such a diameter calculated with the median depth of the 1822 crater as 500 metres, would show that of 79 to have been between 800 and 900 metres below sea-level. We therefore see that all the ejectamenta derived from the eruptions since the commencement of the Christian era are not represented by the mass of the Vesuvian cone, but also by another cone, inverted, whose base is now the plain in the Atrio, and whose apex must be more than 1500 metres below its base.

If the Plinian eruption had formed the greater part of the present Vesuvian cone, it must, besides the materials that cover Pompeii and the mountain slopes in that direction, have ejected sufficient also to form a cone twice the size of that of Vesuvius, to fill up the great crater, and upon the base of this, another at least half the size of that now visible.

When we look at the question in this light we can hardly suppose that any thing like a cone of eruption was visible above the edge of the crater after this Plinian eruption.

We shall return to this question more than once as confirmatory evidence is brought out by other facts.

If we speculate for a moment on the results of such a hollow as we have shown this great crater to have been, we may possibly find that some difficult facts are cleared up, and an explanation given of that much disputed question, the eruption of mud and water.

Taking a volcano, such as Vesuvius in its present active state, let us endeavour to examine the conditions which must exist amongst the components of the base of the mountain below sea-level.

From artesian wells sunk in the neighbourhood, and from the surrounding geology, it may be learned that this volcano reposes on a considerable thickness of highly porous strata, through which water can percolate with great ease and rapidity. Only a thickness of six or seven kilometres of such materials separates the fluid magma occupying the chimney, from the open sea. The question therefore arises, what are the consequences of the necessary contact of the molten rock with the water disseminated in the porous walls of the volcanic chimney? This is assuming conditions not differing from those lately put forward by Prof. Prestwich.

The natural tendency of the water in immediate contact with the heated magma would be to flash into steam, which is prevented by the pressure of the superincumbent materials. In such a way we in all probability have a gradual intervention of water at various temperatures between that of the fluid, igneous matter, and the cold ground-water.

This is certainly somewhat at variance with our knowledge of the critical point of water; but all must admit that laboratory experiments may fall far short of the conditions that exist in nature. The presence of water enclosed in the cavities of quartz in granite, seems to demonstrate the possibility of its existing in a liquid state at very high temperatures, provided the pressure is sufficient.

Let us, however, suppose the critical point of the liquid state of water to be passed,—the interstices of the porous materials in immediate contact with the lava would be filled by the steam, and thus prevent the further access of the cooler liquid. In fact, as we shall see later on, a gradual absorption of such water may be going on by the incandescent rock, which water escaping, may form the principal part of the vapour rising from the volcano. If such liquid be derived from the sea, the liberation of those salts may take place that gave rise to the theory of marine infiltration being the actual cause of volcanos. Without continuing for the present a more extensive consideration of the subject than is necessary to our argument, it may be mentioned that what has been said is not supposed to support or contradict any doctrine of vulcanicity. It would in fact be safer to consider these as purely superficial phenomena, quite independent of those far more extensive primary causes of the eruption of igneous matter, whatever they may be.

When, however, the conditions are changed from a tube filled with molten rock reaching far above sea-level to a deep cavity 850 metres below that line, from which is escaping at high pressure a column of vapour and gases, carrying with it fragments of pumice and other rocks, we should look for different results. We should expect that water would enter from all sides of the hollow to be immediately carried upwards in a pulverized state, mixed with the finer pumiceous dust, well suited to set as a fairly hard mass such as forms the latter part of the materials ejected by the Plinian eruption.

The rush of vapour through the chimney would probably accelerate the influx of water in an analogous manner to that by which the liquid rises in the supply-tube of a vaporizer by the blast of air crossing its extremity.

As the eruptive activity diminished, the volcano would assume a submarine character, so far as the eruptive vent was concerned, somewhat like the island of Santorin. It does not seem very improbable that from time to time there were more powerful spurts consisting of a mixture of fine matter with water, so as to form mud.

Such humid material deposited in large quantities, especially on the outer edge of the crater, and rendered more liquid by the torrents of rain derived from the condensed vapour, would form an immense accumulation of the so-called "lava d' acqua," which would sweep down the flanks of the mountain. On its arriving at any obstacle, such as a town like Herculaneum, this would be overwhelmed in a natural cement, that must almost immediately set into the hard mass we now see covering that town and the neighbourhood.

Exactly similar circumstances attended the eruption of Monte Nuovo *, in which the crater bottom is now only a little above sea-level. It is possible that part of the first violence of the outburst of a volcano may be due to the meeting of the incandescent rock and highly aquiferous strata near the surface, as the former gradually rises in the vent. Such conditions are somewhat analogous to the violent explosion that occurs when lava flows into a well of water. In the same manner the latter part of a paroxysmal eruption might vary as the rising incandescent matter battled with the unlimited inpouring water from the walls of the chimney.

There is no doubt that in the latter part of a paroxysmal eruption the volcanic forces can no longer hoist the ejectamenta beyond the crater-rim, and therefore they would fall in again and go towards filling up the hollow. It must be remembered, however, that it is a generally recognized fact that paroxysmal eruptions do not spread their decrescence over a long period of moderate activity suitable to the formation of a cone of eruption, in which category Vesuvius must be placed in its relation to Somma.

In the accounts of all the great known paroxysmal outbursts, the resulting crater has rarely possessed a cone of eruption occupying its bottom. Even admitting such to have been the case in the present instance, the subsequent eruptions, as we shall see, must have done much to destroy any eruptive cone.

Another question that presents itself to one's mind is, What was the original form and height of Monte Somma?

From the remarkable similarity in the lavas and their fragmentary derivatives, and their arrangement in the oldest sections of the mountain, there is every reason to suppose that, like those of Vesuvius, they were ejected under similar conditions and produced quite as regular a cone as Vesuvius, having the same inclination of its flanks. This was interthreaded by radial sheets of lava, which, cooling as dykes, strengthened the great mass, just as was seen in the section of the 1822 crater by Mallet.

An idea of this prehistoric cone may be obtained by the following method.

Construct upon a base which shall be any one contour-line, a cone whose sides are inclined at the same angle of rest as that assumed by the products of Vesuvius. The height of the mountain will be equal to such a cone, plus the height of the contour-line used for the base.

Take a correct outline of the whole mountain and continue curves from the peak of Somma and the Pedimentina parallel to the corresponding slope and irregularities of Vesuvius.

* "In a short time the fire increased to such a degree that it burst open the earth at this place, and threw up so great a quantity of ashes, pumice mixed with water, as covered the whole country; and in Naples a shower of these ashes and water fell great part of the night."—Marco Antonio della Falconi, 'Dell' Incendio di Pozzuoli,' 1538.

By both of these methods we get results very near the calculation of Prof. Phillips, who estimated the height at 7000 feet.

II. *Structure: Stratigraphy, Lithology, and Petrography.*

Era of permanent activity.—A geologist who studies a volcano may depend on various methods for obtaining information. First, examination of the surface; secondly, examination of various sections; thirdly, examination of component materials, as:—

(*a*) Within the crater;
(*b*) Ravines scoring the slopes of the cone;
(*c*) Irregular sections, cut by marine or subaerial denudation;
(*d*) Structure and dip of neighbouring rocks;
(*e*) Ejected blocks;
(*f*) Artesian wells and other artificial sections.

In the study of Monte Somma we shall call in all these, except those under the heading (*c*). We must include also the chemical and microscopical researches, and their comparison with recent materials, the result of observed and known phenomena.

The most convenient order we can follow is to attempt to become acquainted with the rocks upon which the volcano reposes, and to trace its development from its first appearance up to the present time.

The position of Vesuvius has been so often described that it may be passsed over in the following words.

The Campanian plain extends from the foot of the limestone range of the Apennines to the sea-coast, both of which run parallel. The main axis of the Apennines sends off a branch nearly at right angles, which extends across the plain and juts into the sea, forming the Cape of Sorrento and the Island of Capri. Opposite the angle of junction of these two ridges rises this volcano, with its majestic curves from the Campanian plain, forming the most southern member of the chain of vents on the western side of the Italian peninsula. The nearest exposures of limestone to the east are distant about ten kilometres, and to the south about eighteen. At this latter point the limestone dips under the Tertiary plain and does not reappear until after the Campi Phlegræi. This limestone has been encountered in the artesian well at the Royal Palace at Naples, at a depth of 480 metres. We have good reason to suppose that under Vesuvius it is not so far from the surface-level. From our calculations of the great crater of the Atrio del Cavallo, its probable depth was 850 metres; we may therefore easily explain the large amount of altered limestone in the ejectamenta, as probably derived from the last 500 metres of the craterial hollow that was drilled through this sedimentary rock.

Near the Cape of Sorrento (Campanella), the Cretaceous Apennine limestone is overlain by the Eocene Macigno, which consists chiefly of concretionary micaceous sandstones and marls; it is absent in the immediate vicinity of Vesuvius. In the well at the Royal Palace of Naples these deposits were met with at 433 metres, being therefore 47 metres thick. It would not seem that these exist beneath the volcano, judging from the ejected blocks, although perhaps a few peculiar and rare varieties may be the metamorphosed derivatives of this Macigno.

In the artesian well already alluded to, overlying the last, are 215 metres of marine deposits consisting of bituminous and lignitiferous sands and marls, micaceous towards the bottom. The mica is probably derived from the underlying Macigno. These beds are fossiliferous, the shells being all of recent species (I am told).

An examination of the ejected blocks and fragments of foreign rocks, especially from the beds Phase III., *Period* 2, and Phase VI., *Periods* 1 and 4, show many of them to be in all respects similar to the rocks met with in the well-section. The fossil contents of these ejected blocks have been examined by Prof. Guiscardi *, and out of between 60 and 70 species, only one is unknown in the neighbouring seas, showing the very recent date of these deposits underlying Monte Somma.

In the Royal-Palace well † the upper 182 metres consisted of pumice, tufa, fragments of trachyte, and other volcanic ejectamenta, containing marine shells. This is confirmed by two other wells, one at the Piazza Vittoria, where 280 metres of this volcanic débris was pierced, and another lately bored at Chiatamone, which I watched through 180 metres always in similar materials. It is situated at the foot of the escarpment of Pizzofalcone, equal to another 70 metres of tufa.

We have, therefore, underlying the Campanian plain in the immediate vicinity of Vesuvius and resting on Secondary limestone, three distinct formations, viz.:—Eocene sands and marls; Pleistocene, non-volcanic, calcareous sands and marls; and above a series of volcanic deposits, chiefly of marine origin. As the volcano we are studying reposes on these beds, its birth must have taken place in the latest geological time, long after other vents in its neighbourhood.

We often read in works treating of Monte Somma and Vesuvius that "the lower parts" or "base" consist of tufa, and also that this tufa is identical with that forming the plain and other volcanic hills in the neighbourhood. In the first instance, if we understand these two expressions to mean the toe of the mountain, which is of comparatively recent origin, then such a statement is perfectly correct. On the other hand, if the base or early part, or skeleton, of the volcano is implied, as is evident by sections given and also from the context, then we must refuse to accept such statements as true, since we have no evidence whatever to depend upon. Besides, the earliest lavas &c. that can be seen in the section of the Atrio are exactly similar to the latest products of eruption.

* Fauna Fossile Vesuviana.

† I must offer my sincere thanks to Monsieur Chartier, of Naples, for his kindness in placing at my disposal the working reports of these wells, and for permission to examine part of his large and valuable collection of subterranean geological specimens.

It would of course be unfair to deny the possibility of such statements, but it is still more so to assert it without evidence. The error seems to have arisen from supposing the pumice-tufas to be older deposits broken up; whereas they were new materials brought directly from below, as will be shown at a later stage. These light ejectamenta were spread as a mantle over the flanks of the cone, but were afterwards transported to lower levels, rendering the upper part of the mountain bare, whilst the resulting alluvial deposit thickened around its toe.

The true order of succession was fully recognized by Breislak and Von Buch at the beginning of this century, whereas inversion of the order is the work of recent authors *.

Neither is there any evidence to show that the trachytic beds of the Campanian plain have been raised to form the basis of the mountain, as stated by Phillips †.

Another fact of importance that will be brought out is, that the pumiceous deposits of the mountain are not trachytic, as generally supposed.

The tufa of the Campanian plain is for the most part submarine, as proved by the enclosed Mollusca, and, as we have seen, of greater antiquity than Monte Somma. Many of the volcanos which produced these tufaceous deposits were no doubt submarine; whilst others stood out at sea, as so many islands, like the present Lipari group. The currents of the sea that then washed the toe and inlets of the Apennines, swept along the ejectamenta of these eruptive vents, and spread out upon the sea-bottom those tufa-beds we now see above the surface.

When the vent that was eventually to build up Monte Somma and Vesuvius burst through these earlier igneous materials, was it below or above the waters of the Mediterranean?

We have here brought before us a question that presents some difficulties. At Cisterna, leucitic lava of prehistoric age is quarried down to drainage-level, which is very slightly above that of the sea, for which reason the bottom of the flow has never been reached. When we come to consider that, from its nearness to the surface, this must be one of the latest streams that was poured out from Monte Somma, it would seem self-evident that beneath this one there must be many more currents which flowed into at least shallow water. The only other explanation that could be given would be gradual depression, a phenomenon quite contrary to all the geological evidences of the district. Breislak brings forward similar proofs. He mentions that in the villages of St. Elmo, Sirico, and Saviano, it is necessary to dig down to lava before water is found, and he thinks this evidence is in favour of the insular character of the mountain.

We may safely suppose that the first fires of this great volcano were vomited into the sea, that gradually it raised its head above the

* J. L. Lobley, 'Mount Vesuvius, with a notice of the eruption of 1868,' pp. 32 and 33, also section, p. 24.

† Vesuvius, 1869, p. 190.

waves, and perhaps may not have been dissimilar to Stromboli. At the same time gradual elevation was going on, aided partly by the products of some of the neighbouring vents.

The tufas underlying Monte Somma are proved to be of earlier date by the absence of leucitic rock-fragments in them.

Of course these statements must be taken for the present as suggestive, and must necessarily either break down, or be confirmed by further evidence; but they furnish the most rational explanation, so far as facts are forthcoming.

Scheme of the Eruptive Activity of Monte Somma and Vesuvius.

MONTE SOMMA.	ERA A.	Introductory paroxysmal stage.—Problematical.		
	ERA B.	Ancient chronic activity.	PHASE I.	Chronic activity, outflow of lava with scoria, ash, &c.
	ERA C.	Apparent extinction interrupted by paroxysmal and other eruptions.	PHASE II.	Inactivity. Denudation.
			PHASE III.	Violent paroxysm dwindling into
			PHASE IV.	Apparent return of chronic activity.
			PHASE V.	Inactivity. Denudation.
			PHASE VI.	Violent paroxysmal eruptions.
			PHASE VII.	Less violent dwindling into .
VESUVIUS.	ERA D.	Modern chronic activity.	PHASE VIII.	Chronic activity, outflow of lava, scoria, &c.

PHASE I.

Era of Permanent activity.

The nearest approach that a geologist can make to the earliest ejectamenta composing the mountain is by means of the great craterial section of the Atrio del Cavallo. The lowermost beds of this escarpment present to us deposits that must have formed the surface of the cone, when its height could not have exceeded 1800 metres in its completeness. Below this we cannot obtain any direct evidence of the innermost or earliest structure and composition, except by the indirect method of examining the ejected materials, which we shall do at a later period.

The splendid section of the Atrio del Cavallo, 320 metres in greatest depth, and above 5 kilometres in length, has been the great attraction, and studied by many eminent geologists, as Hamilton, Breislak, Von Buch, Monticelli, Scrope, Dufrenoy, Daubeny, Humboldt, not to speak of Phillips, Scacchi, Mallet, and others in more modernd ays.

What we may see for ourselves, and what we learn from the writings of these careful observers, is that we have exposed in this great section a series of lavas and their derivatives, scoria, sand, ash, &c., interlaminated and piled one above the other in the order in which they were ejected. Now, as already remarked, if we compare the crater of Vesuvius in modern times with the prehistoric one of Somma, the exact resemblance of the two is sufficient to prove the similar conditions under which both were formed. From such facts we are led to conclude that the early eruptive phenomena were very nearly, if not exactly, like those going on before our eyes at the present day.

The lavas of the hundreds of streams piled one above another and sectionized in the Atrio exhibit a great variety, within certain limits, as noticed by Von Buch*. Without any apparent order we find mixed together lavas with large leucite crystals a centimetre in diameter, and others in which this mineral is only discernible by the microscope. Some have a uniform grey matrix, which may be broken by crystals of either pyroxene or olivine, or of both together. In others, again, the three principal component minerals are largely developed together. The labours of Zirkel, Rosenbusch, Clifton Ward, Haughton, Hull, Fouqué, and Levy, go to show that there is a great resemblance between these ancient and the modern historic lavas.

There is a popular idea afloat that the ancient lavas are characterized by large crystals of leucite. Let us see the cause of this error.

Most rock specimens that are chosen to represent these lavas are taken from those currents which show the crystalline components well developed; and secondly, from age, this mineral has been partly kaolinized, which results in the change of colour from grey to white, so that the latter contrasts strongly with the dark matrix. On the other hand, although the crystals of leucite are of considerable size in recent lavas, as that of 1858, their colour so nearly resembles that of the rock mass that they are almost invisible. An examination of an extensive and fairly collected series of rock specimens, will show us that on the contrary the majority of the flows are fine-grained, especially with regard to the leucite crystals. The most constant of porphyritically enclosed crystals are those of pyroxene, much as in the lavas of 1631, 1794, and 1872.

* 'Description physique des îles Canaries,' 1836. Traduit par C. Boulanger, p. 339.

One of the most beautiful examples of the parallelism between past and present is to be seen in the Vallone Genzano, and its next fellow to the west. A lava stream has been quarried into, showing a section of the flow, which is covered by a rolled and corded surface exactly like what we see on that of 1858. The old one looks quite as fresh as the modern, although the former is buried by thick beds of pumice and tufa of great antiquity. Such perfect preservation of flow-surfaces of prehistoric lavas of Somma is by no means uncommon, and there is hardly a valley without at least one or two examples.

As in the escarpment of the Atrio, so in the valleys, especially the deeper ones, on the slopes, we have the same superposition of lava streams and their fragmentary equivalents, sometimes in such abundance as to be uncountable. Lyell * remarked the fact that especially in these valleys the sections showed one set of deposits resting unconformably upon the denuded surfaces of those of another. It must be remembered, however, that this is much more common near the base or toe of the mountain than higher up, as would naturally be expected. This erosion seems never to have been very extensive, and is no proof of intermittence of eruptive activity; since often long periods intervene between one violent eruption and another, giving time for considerable erosive action on such incoherent materials with a highly inclined surface.

Of the great lava-flows that have reached lower levels or the plains, most are more or less decomposed at their surface and for some depth beneath it, so that the leucite is kaolinized and the rock reduced to a crumbly mass, which if the stream be thin will involve the whole of its thickness. Good examples may be seen at Cisterna and near the Pension Soleil beyond Pompeii.

The section of the Atrio del Cavallo is described by Scacchi † thus:—" The aggregate is composed of volcanic sand, fragments of the same kind of basalt that forms continuous masses, and often of loose crystals of augite. At some places it appears to have been exposed to high temperature at a later period, so that its elementary parts are fused together, and thus it is difficult to distinguish from the rock intact." We have here an accurate description comprised within a few words. At the lower and central portion of the section the fragmentary materials are so completely and firmly packed together by heat as above described, and also no doubt by pressure, that the rock is quite continuous in structure, so much so in fact, that in breaking out a specimen the fracture passes regularly through the mass. The origin of the materials, however, is exhibited by the difference in colour, vesicularity, and crystallization of the components.

The difficulties that would arise in determining the origin of such a rock, if exposed to altering and metamorphosing influences during long periods of time, may well be imagined. Many of the ancient English volcanic rocks present such enigmatical examples.

* 'Principles of Geology,' 1872, p. 636.
† 'Lezioni di Geologia,' Napoli, 1843, pp. 168 and 169.

The dykes of Monte Somma that thread through the mass of the section of the Atrio in great number, have received special attention from Breislak*, Necker†, Scrope‡, Lyell §, and Mallet ||, to whose statements little can be added until a complete examination of their chemical composition and microscopic structure has been made.

One peculiarity, however, of important bearing on a point about to be discussed is, that nearly every dyke is clothed with a layer or saalband of vitreous structure which graduates into the crystalline interior, but rarely exceeds one or two centimetres in thickness.

Lyell ¶ remarks that the dykes are not seen on the outer slopes of the mountain. This is certainly the case, and for it there are many reasons; but space does not permit of discussing them here. There are, however, exceptions. For instance, a large one that is seen almost perpendicular in the section of the Atrio can be traced over the ridge and is exposed for some distance on the outer slope, where it traverses obliquely one of the great valleys just east of the Punta del Nasone.

With the exception of the saalband these dykes are composed of materials apparently almost identical with those of most lava-streams. But they are generally more compact, except at the upper extremity near the old surface, where in some cases they are highly vesicular, especially in the middle. This condition seems to be explained by the small pressure existing allowing the aqueous matter of the uncooled or central part to separate in the form of distinct bubbles, as in soda-water on removal of the cork. These bubbles were unable to escape entirely from the viscous state of the cooling rock, and remain behind so as to give the rock a cellular structure. This shows that the water was still in combination with the magma at the lower part of the dyke where no bubbles had formed.

So far we must regard this volcano as having burst through various sedimentary strata and volcanic tufas which, except as composing the basement or platform for the mountain, form no integral portion of it. So far as can be ascertained by the legitimate methods of investigation of the geologist, this ancient tufa differs entirely from the old leucitic rocks of Monte Somma**.

The regular superposition of materials, little differing from each other, and the regularity with which they were deposited without any physical evidence of a great break in time, so far as we can obtain

* 'Voyages physiques et lithologiques dans la Campanie,' 1801.

† "Mém. sur le mont Somma." Mém. de la Soc. de Physique et d'Hist. Nat. de Genève, 1828.

‡ 'Volcanos,' 1825 and 1868.

§ 'Principles of Geology.' Different editions.

|| Quart. Journ. Geol. Soc. vol. xxxiii.

¶ 'Principles of Geology,' 1872, p. 136.

** I must express great timidity in employing any special name for these leucitic rocks. They have been so variously classed and named by different authors that although one may have a clear notion of their composition, yet it is difficult to decide what term to use for them. As we shall have continually to refer to them in our description, *Leucilite* will be used, simply for the sake of brevity, and must not be taken to have any other meaning than either a leucitic lava or dyke rock of this volcano.

information from the sections, point to one important fact. This evidence, compared with the results of phenomena of the same volcano daily passing before our observation, must make us conclude that the early phenomena of Monte Somma were identical with those of Vesuvius at the present day, and since A.D. 1631.

At a time, probably many centuries, before the earliest history of Italy commenced, Monte Somma became apparently extinct.

It is possible that before this long but temporary extinction an eruption may have produced a crater of some considerable size; but one is inclined to doubt it for the following reasons. At the lowest levels where sections exist, and where the prehistoric lavas are covered by loose scoriæ, these have always moderately fresh surfaces and seem to belong to permanent activity. There are no breccias such as would be derived from the spreading of the débris of a crater on the flanks of the cone. It is true that the objection may be raised, that such materials may have been swept away by denudation. The loose scoria, where uncovered by lava flows, would certainly have disappeared also, yet it presents no features of being disturbed in any sense. A period of inactivity must have supervened, sufficiently long for the igneous magma to have entirely changed its character, as the subsequent pumice eruptions show.

What was originally ejected as a highly crystalline leucitic basalt, principally in streams of lava, became converted into a vitreous paste, surcharged with water vapour, causing violent explosions and the ejection of the igneous magma in a fragmentary condition.

PHASE II.

That there was a period of quiescence is confirmed by a vegetable soil that was formed and reached some distance up the mountain. The scene then must have been grand—the majestic single cone with its purple brown slopes wreathed by a rich virgin vegetation. Sections showing this old plant-surface may be seen in the Vallone Sanseverino and the lower part of the Vallone Breislak, where we see at the base of the section there exposed, deposits composed of leucilitic scoria capped by a fine yellow dust-bed, having all the characters of an old vegetable soil.

Its components are derived from the subjacent materials. The few lava fragments it contains are much decomposed, showing them to have been exposed to vicissitudes of temperature and humidity, such as their exposure at the surface would render them liable to. In this case the bed is about 40 centimetres thick. Similar conditions I have met with only at the lower part of the mountain where the inclination is slight, thus being favourable to the collection and retention of materials suitable to the growth of plant life.

As already said, these facts combined with other evidence point to a period of complete tranquillity between the last era and the new one that was soon to be ushered in.

Overlying the lava, in the Vallone Pietri Pomice, are to be seen in section 5 metres of water-worn breccia, showing that denudation had been at work. It is possible that this breccia was deposited whilst the volcano was still in a feeble state of activity.

Both of these latter-mentioned facts are but accessory evidence in favour of a long period of apparent extinction which is shown chiefly by the change of character of the ejectamenta.

That this change was not in the primitive magma, but rather produced by the varied influences brought to bear upon it in its journey from its source to the surface, will be demonstrated as we proceed in our study.

Probably the old vent was plugged up by a mass of leucitic lava, a remnant of the last of the permanent prehistoric eruptions, which, from flagging of the primary volcanic forces or their concentration at other foci, had cooled there.

In the extinction of a volcano a series of counteracting influences are at work. As the result of former eruptions, or from other causes, the pressure of the igneous matter at its origin is diminished, and the remnants of the fluid or plastic mass occupying the chimney will gradually cool by solfataric or fumarolic action. In this case the consolidation will proceed from the surface downwards, or irregularly, if the heat be carried away by thermal waters. The magma still deeper will gradually assimilate water, resulting in its tension rising to a certain point at the expense of its temperature. If this be sufficient to overcome the superincumbent obstacles a violent explosion or paroxysmal eruption will occur. On the contrary, if the temperature is low in the first case, or subsequently descends sufficiently for the mass to solidify, an eruption will be prevented, and the solidified mass will be an obstacle to any further attempts at a rupture.

If at a future time igneous matter tries to force its way upwards in the same neighbourhood, it will preferably be by the side of the old axis, which itself would offer the greatest resistance. It is probably in this manner that a variation of the eruptive axis, as in Monte Somma and Vesuvius, is brought about.

Era of Paroxysmal activity.

The leucitic lavas and their derivatives are overlain by a series of pumiceous tufas which form a kind of mantle to the ancient cone of Monte Somma. Breislak * was the first to describe this superposition. He was followed by L. von Buch †, who fell into the error of classing the pumice beds of Somma and those of the district of Naples together. This is easily seen not to be the case for the following reason. The tufa consists of pumice in which various trachytic fragments are common, but amongst which neither the leucitic lava nor large series of ejected blocks like those of Monte Somma, are to be encountered. On the other hand, the trachyte does not occur at Monte Somma; neither do the pumices resemble each other in composition.

* 'Voyages physiques et lithologiques dans la Campanie,' 1801.

† 'Description physique des îles Canaries,' p. 341 (1836). Traduit par C. Boulanger.

Let us follow the description given by Von Buch, who says:—"The remainder of the volcano, formed of black beds singularly contrasting with the white ones of tufa, rises out of this envelope like a ripe fruit which protrudes from its calyx. It is approximately in this manner that one can represent Somma piercing this envelope of tufa." We here see that Von Buch had a perfectly clear idea of stratigraphical sequence, a fact unfortunately lost sight of by some later writers. Prof. Scacchi * also alludes to the superposition of the tufas upon the lava on the surface of Somma. Scrope † describes the lavas as overlain by "whitish or yellowish trachytic tuff composed of pumice and lapilli. This extends up the external flanks of the mountain to nearly two thirds the height."

Lyell ‡ makes various allusions to tufa, but it is often not clear whether reference is made to the leucilitic or pumiceous beds.

Phase III., *Period* 1.

General Characters.—This bed varies in thickness from 0·10 to 1·00 metre, and consists of a white pumice and leucilitic lapilli. The latter, which may form 50 per cent. of the deposit, are chiefly broken fragments of lava, subangular in form and exhibiting evidence of short but violent attrition. There is in addition a small quantity of dust derived from the abrasion of both materials, but which is not nearly sufficient to fill the interspaces between the larger fragments. This fact we shall see to be partly the reason why this bed has been so little disturbed by denuding agencies.

The pumice fragments are angular in form, falling apart when removed from their place *in situ*, so as to appear traversed by cooling fissures. Their original external surface is more compact than the interior, having an irregular knotty aspect, presenting all the appearance of having been cooled from fusion. The pieces float with ease in water, owing to their very spongy structure. The vesicles are seen to be small but moderately regular in size, sometimes pulled out in one direction so as to give the pumice a fibrous appearance. Rarely do the vesicles coalesce to form an irregular cellular cavity.

The dirty white mass is rarely seen to be interrupted by a black spot, which if removed proves to be a scale of black mica, or crystal of pyroxene or amphibole, so far as the unaided eye can judge. Sparsely distributed also throughout the mass are a few small sanidine crystals porphyritically enclosed.

Microscopical Examination.—This light spongy pumice is one of the most difficult rocks to sectionize from its vesicularity, the walls of the cells being so exceedingly thin and delicate. The section must be very thin, otherwise the number of unopened air-cavities, from their refractive peculiarities, will prevent any examination. The greatest difficulty arises, however, from the disproportion in resistance to grinding action of the matrix and the porphyritically

* 'Lezioni di Geologia' (Napoli, 1843), p. 171.
† 'Volcanos,' 1868. ‡ 'Principles.'

enclosed crystals. The latter break out long before the section is nearly thin enough.

By ordinary light and a low power the section is seen to be a meshwork of rock material enclosing a multitude of air-cells, which, if unopened, present their peculiar refractive properties. They assume every imaginable form, the commonest being spherical, ovoid, pear-shaped, fusiform, multilocular, tabular, or irregular.

Scattered about in the matrix are a few small dark green crystals of pyroxene, unfortunately rarely well formed. Sanidine in limpid well-terminated crystals, often twinned on the Carlsbad type, occur, besides a very few with rounded borders. Some examples enclose smaller crystals that extinguish at a different angle. The sanidine is usually surrounded by a coat of dark brown dusty matter, probably magnetite (?), just as we see clear crystals of ice separate out from mud or muddy water. The pyroxene has few cleavage-planes, is very faintly, if at all, polychroic, and has a very large angle of extinction, from which we may safely conclude as to its nature. There are a few crystals, however, that present more the characters of amphibole. One very dark bluish green, rather polychroic crystal gave 18° as the angle of extinction.

The pyroxenic minerals are often surrounded by a wreath of sanidine. Magnetite occurs in well-defined crystals and irregular masses, though none microlithic. Biotite is to be seen in a few cases as large crystals of first consolidation, very polychroic, varying from greenish brown to pinkish black tints.

Under a high power the ground mass is seen to be composed of a very light straw-coloured vitreous base, with remarkably few impurities. The only microliths visible are a few odd ones here and there. They are usually minute rods, too small for exact determination; but by analogy one would judge them to be pyroxene.

The order of crystallization would appear to be :—

I. Amphibole ?, magnetite, and biotite.
II. Pyroxene and sanidine.
III. Vitreous matrix and odd microliths.

There are to be found, amongst the uppermost or last fragments ejected, pumice of a somewhat darker tint. These pieces prove to be very rich in small beautifully well-formed hexagonal plates of biotite * of sepia tint. In the same specimens are a considerable but variable number of crystallites or small microliths, rod-like in form, probably of pyroxene (?). There are also minute crystals, hexagonal in outline, of a blood-red colour, which appear to belong to the cubic system, for they seem to be extinguished without exception between crossed nicols. They might be mistaken at first for small garnets (melanite), a mineral not uncommon in other pumice of similar origin. Their homology in position, arrangement, and other characters, point them out as magnetite partly altered; their

* "Mica is generally of first consolidation; it may, however, have the microlithic stamp." Messrs. F. Fouqué and M. Lévy, 'Mém. pour servir à l'explication détaillée de la carte géologique de la France' (Paris, 1879), p. 340.

form being accounted for by this mineral sometimes occurring in rhombic dodecahedrons *.

Remarks.—Before proceeding further, it is necessary and convenient to speculate for a moment on this somewhat singular change in the character of the products of this volcano.

It will be seen at a later period that there is not so much difference in chemical composition between this pumice and the leucitic lavas as sometimes between different streams of the latter.

Again, nearly all the minerals in the pumice are to be found also in the lavas. The only species of importance existing in the lava and absent from the pumice is leucite.

Even this mineral we shall see to be a component of pumice of later date. The lavas, as a rule, have little if any vitreous base; whereas in the present instance that amorphous material composes by far the largest part of the mass.

We are struck, therefore, by the fact that the difference between these two forms of ejectamenta is rather of structure than of composition.

Pumice-stone is recognized to be the mechanical product of a vitreous rock, and the present instance is no exception to the rule. Up to the present date this rock has generally been classed amongst the acidic volcanic products. In this instance we have a pumice containing from 50 to 55 per cent. of silica, presenting all the characters of a true vesicular obsidian. It is therefore necessary to search amongst the basic rocks for one that is vitreous. This we have in what is called tachylyte, a term probably under which vitreous varieties of many basic rocks have been included, such as some of the lavas of the Pacific islands.

Closely related to the ancient lavas of Monte Somma, and in fact nothing more than a vitreous variety of them, is the thin layer, or saalband, of glassy matter sheathing the dykes.

This proves to us that the leucitic rock, at a comparatively small depth from the surface, had not yet assumed its crystalline structure when suddenly cooled by injection into a fissure. This fact strikes us the more when we remember the words of Messrs. Fouqué and Lévy †, "Toute cristallisation d'une roche ignée a commencé au sein d'un magma fondu. La composition minéralogique et la structure d'une pareille roche ne peuvent donc dépendre que de sa composition chimique en bloc, et des conditions dans lesquelles s'est opéré le refroidissement."

We may, perhaps, extend the latter remark, and add some other influences that may be instrumental in bringing about changes, as shown in the table, pp. 54 & 55.

Admitting the proximate identity in composition of these two products of Monte Somma, now under consideration, let us attempt to discover the conditions necessary to bring about the difference in structure.

The primitive vitreous magma, rising gradually from great depths, may possibly be modified in composition by the chemical reactions taking place between it and the surrounding rocks.

* F. Rutley, 'Study of Rocks,' p. 153.

† 'Synthèse des minéraux et des roches' (Paris, 1882), p. 78.

The aqueous matter contained within the rocks in immediate vicinity of the column of incandescent magma, must be raised to a very high temperature. We are acquainted with the solubility of silica and silicates in water at a high temperature and pressure. The escape of vast volumes of vapour from lava must convince us of the presence of aqueous matter combined chemically with the fused silicates, or, at any rate, intimately diffused or mixed with them.

It is probable that the aqueous matter is assimilated by the igneous matter from the water-bearing strata it traverses at a very high temperature and pressure.

It is evidently the manner of formation and escape of this vapour upon which is dependent the difference of structure in the Somma lavas and pumice.

This mass of aquiferous magma, in proportion as it approaches the surface, passes from a high to a lower pressure, at the same time being reduced in temperature in the same ratio as expansion takes place. A moment arrives when the pressure no longer balances the tension: just as we see the carbonic acid begin to form minute bubbles in seltzer-water when the cork is removed, so does the aqueous vapour develope minute globules which, coalescing, form bubbles distributed throughout the still fluid mass.

If cooling takes place immediately before the escape of the vapour, a spongy or, more properly, vesicular rock or pumice will result.

It is necessary that the magma should come from great depths, that it should have been retained for long periods in contact with aquiferous strata, and that it should be expelled rapidly before the vapour-vesicles can unite together as bubbles and escape. We conclude, therefore, that pumice in a basic rock so far appears to be characteristic of Scrope's 'Paroxysmal Eruptions.'

The question arises, how is it that in a basic rock, which is always very fluid, the vapour-vesicles had not time to escape? If we imagine a fluid mass throughout which the amount of volatile matter is disseminated in large quantity and under high pressure, the removal of this latter will result in the conversion into a gaseous form of the volatile matter, so bringing about a corresponding loss of heat. If this descent reaches sufficiently far to render the mass solid or even viscid, the vapour, unable to escape, will remain behind involved in the magma as so many vesicles or bubbles. The process is analogous, in a mechanical point of view, to bread rising as a plastic mass, which is solidified by baking. The spaces occupied by the vapour nearest the surface of a detached mass will burst and leave a coating of compact matter, as in the crust of bread and the hard envelope of the pumice.

From the rapidity of cooling, the process of crystallization will be arrested, and the structure remain vitreous.

Such, therefore, seems to me the true explanation of this somewhat complex phenomenon.

In the case of Monte Somma a certain amount of the vapour must have escaped and formed the element of explosion or ejection. The endeavour has been to show that rocks apparently of totally different type may have a common origin.

CONDITIONS UPON WHICH DEPEND THE VARIATION OF IGNEOUS ROCKS (see p. 52).

1. *Primary chemical composition.*		result		All the groups of rocks chemically differing, ranging from the highly quartzose types on the one hand, to the ultra-basic on the other.
2. *Rocks through which igneous matter is extruded or into which it is injected.*		result		The metamorphism or alteration of * both, or in other words the chemical reactions and replacements that take place between the fluid igneous matter and the solid walls of the fissure.
3. *Change of temperature.*	(*a*) Rapidity of cooling ...		result	The variation from a vitreous to a highly crystalline rock, such as the crystalline lavas of some dykes clothed with vitreous "saalbands." This is one of the important causes of the variation of ejectamenta of Monte Somma.
	(*b*) Regularity of cooling ...		result	Variations in structure, as columnar in basalt, flaggy in phonolites, and other structural modifications of rocks *en masse*.
4. *Pressure during cooling.*		results		(*a*) Differences between intrusive rocks and lavas. (*b*) The compactness and vesicularity of the latter. (*c*) Indirectly the amount of the formation of scoria-surface.
	(*a*) In the original magma.		results	The variation of certain plutonic rocks (?). Our knowledge in this direction is very limited. Whether the water necessary for the hydrometamorphic origin of granite was of primary or secondary origin it seems difficult to decide.

5. *Presence of aqueous matter.*	(*b*) In rocks traversed	result	To this, it would seem, we must refer the principal origin of that vast amount of vapour that escapes from volcanos and flowing lava. It is probable that this is also a cause of the variation in structure of certain rocks identical in composition.
	(*c*) Into which lavas may be ejected	result	To this cause may be attributed differences between subaerial and subaqueous tufas and lavas.
6. *The conditions of expulsion.*	(*a*) By paroxysmal eruption.	result	The rapid expulsion, and therefore cooling of the mass before crystallization could make any great progress. Rocks that would have flowed as streams are broken up and ejected either as scoria, ash, or other fragmentary materials or derivatives.
	(*b*) Remaining a length of time under low pressure and at a uniform, slowly decreasing, or varying temperature, as in the chimney of a continuously active volcano such as Stromboli, or Vesuvius at the present time	result	Circumstances highly favourable to the regular development of large well-formed crystals, the conversion of the vitreous menstruum into at least a crystalloid if not crystalline condition. The slight variation of temperature will result in the partial refusion of crystals, and their reformation, and also in the deposition of microliths in zones, as in leucite and other minerals.

* This point seems to have been regarded in a somewhat one-sided manner. We continually hear of alterations of rocks by[1] intrusive matter, but rarely of the change produced in the latter by the rocks it traverses. When new materials derived from the igneous intrusion replace others in the surrounding walls, what becomes of those replaced? It would appear more natural, judging from most chemical reactions, that the process is more one of exchange than of gift. This would possibly explain intrusive rocks changing their character as we follow them over a distance, such for instance as the granite passing gradually into basalt as described by Von Buch, a fact inexplicable on other grounds.

[1] Prof. Judd, 'Volcanoes,' 1881, p. 145.

This layer of pumice, of comparatively little importance as to thickness, is yet at the same time one of the most persistent of the group of deposits to which it belongs. It is rarely absent when deposited on scoria, due, no doubt, to the open structure of the latter allowing water to trickle through between the fragments. Where deposited on lava it has commonly been removed, floated away in fact.

Rarely has it left behind it any of its *débris*; nevertheless, in the left lower branch of the Cupa di Pallarino, we see a mass of yellowish dusty earth, containing water-rolled fragments of this pumice, overlain by the products of the eruption immediately following. It appears that this alluvial deposit was derived from the disintegration and decomposition of the pumice-bed, which was collected at the bottom of a ravine which we now see cut through in section.

This alluvial material tells of a quiescent period, probably of no great length, during which subaerial denudation had been going on, and during which preparation was being made for another great outburst of terrestrial forces.

No metamorphosed erratic rocks are found amongst the materials composing this deposit, although the leucilitic lapilli derived from the mechanical disintegration of old lavas are so abundant as to form an important element. The two facts show that a considerable crater must have been excavated, but that it did not extend into the subjacent sedimentary rocks.

Phase III., *Period* 2.

General Description.—It was remarked in speaking of the preceding deposits, that the alluvial materials resulting from them apparently only represented a short interval of tranquillity. This short interval seems to be demonstrated by the passage in other localities of pumice of *Period* 1 into that of the present one, which consists of a heavy, hard, dark scoria, without any intervention of alluvial matter. To the inattentive eye the line of demarcation is very distinct; but on closer examination we may see at the line of junction pieces of rock of different gradations between the upper more crystalline pumice of *Period* 1 and the pumiceous scoria of *Period* 2.

This transition, which may be well seen in the Vallone Sanseverino, is visible not only in the external, but also in the microscopic characters, which exhibit this passage from a more or less vitreous through a half microlithic to a crystalline rock.

This pumiceous scoria, since it still retains somewhat of the pumiceous facies about it, occurs as fragments varying in size up to that of a human head. It is of dark chocolate-brown, black, or dark reddish colour. Usually more compact at the surface, and redder than in the interior, it has an appearance of having cooled from a plastic condition. The density is considerable; it breaks with a slight tap of a hammer into a certain number of fragments along old cooling-fissures, the resulting pieces being rather tough and resistant. The included cavities, of large size, are irregular in shape, and not rounded or cellular. Broken crystals, and fragments of lava and other rocks are exceedingly common as enclosures.

Mixed with the fragments of this primary eruptive matter are a number of very small pieces of altered limestone and its derivatives. By far the most abundant, however, are a number of fragments of marl and clay, very slightly altered and rich in organic remains. The matter is still plastic in the interior ; and often adhering to the surface is a layer of fine lapilli, showing the small amount of heat to which these masses were subjected, and the short time they were exposed to it. These remnants of prevolcanic Tertiaries are most abundant at the bottom of the bed, whilst the dolomitic limestone is found higher up. There are also a good number of leucilitic lapilli.

These substances united form a deposit that rarely exceeds a metre in thickness.

Microscopical Examination.—In the thinnest section this pumiceous scoria makes a very dark, opaque, brown preparation. The essential elements are a few crystals of pyroxene, amphibole (?), biotite, in small irregular plates, moderately polychroic, ranging from dark amber or sherry-colour to light lemon, and crystals of sanidine. Some of the latter are large and broken around their edges, fissured throughout, and their cleavage-planes infiltrated by an earth-brown amorphous substance, which gives them a very peculiar appearance, but has in no way altered their optical properties. Most show Carlsbad twinning very distinctly. They seem to be crystals that have undergone vicissitudes of temperature; others have a clear nucleus and dusty exterior. The included fragments of lava have their sanidine crystals altered and fissured as those belonging to the rock proper. Magnetite is to be found rather plentifully, in large unaltered crystals.

The matrix appears under a low power as a granular brown network of opened vesicles, the walls of which are irregular and roughened by the projection inwards of many microliths. When a higher power is used the granular mass proves to be composed of at least two kinds of microliths, which form the principal portion ; but there seems to be some interstitial glass. The first and commonest are very small transparent rods, which are probably pyroxene ; a few larger ones seem to be sanidine. They are doubly-refractive, clear, and colourless, except where divided along their longer axes by a septum of dark brown matter. This intercalated material is narrow at the centre and widens as it approaches the terminations of the prism, and seems to be identical with that portion of the crystal of sanidine included by the peculiar curved lines described by Mr. F. Rutley*. The opposite halves generally extinguish alternately between crossed nicols. The other microliths, or small crystals, are polygonal in form, showing apparently quadrilateral and six-sided outlines, although, from their small size, it is difficult to see such distinctly. With a very strong light, some of the smaller ones

* Quart. Journ. Geol. Soc. 1876, p. 479, and 'Study of Rocks' (London, 1879), p. 96.

transmit a dark burnt-sienna-coloured light, and are probably magnetite, titaniferous possibly, which has undergone alteration.

Their small size, compared with the large crystals, has rendered them more liable to decomposition, especially on the outer surface, which accounts for the redder-coloured exterior of the rock-fragments. The interstitial glass is small in quantity, and of a brownish tint.

The included impurities are exceedingly abundant, enveloped in the original plastic mass.

The intermediate pumice already mentioned as connecting this deposit with the underlying one, is variable in colour, but usually greenish grey, fading into the tint of the two beds. The larger crystals are well terminated, and there are fewer impurities. Some of the sanidines are filled with a multitude of small pyroxene crystals. The biotite plates are better formed and less broken. The rod-like microliths are usually arranged in stars. The microliths of magnetite are less abundant than in the bed above.

Separating the pumiceous scoria from the bed above, we encounter a stratum of very fine dusty material or ash, as in the Vallone Breislak. In other sections the same material occurs, but apparently partly rearranged by water.

Phase III., *Period* 3.

General Description.—The deposits of this period conformably overlie those of the last, of which they seem to be the continuation. They range from 80 centimetres to 2·30 metres in thickness.

When seen in section they present a curious aspect due to their peculiar characters. The principal portion consists of rounded lapilli, variable in size and order of deposition, mixed with a large quantity of fine powdery matter of the same kind.

Three elements go to make up these lapilli. The first and most abundant consists of pieces of leucilitic lava, bits of old lava, in fact, which have been subjected to very violent attrition, as shown by their subangular and often rounded form. The next are of yellow or rusty-brown colour, of the same material, but altered by solfataric or fumarolic action. The third and rarest element, though most important as regards the story it tells, is the primary eruptive matter, which consists of an opaque black vesicular scoria, usually in very minute morsels. In colour it resembles the scoria below, but, as already remarked, is more open in structure. A few crystals of pyroxene and black mica may be detected by the unaided eye.

The whole arrangement of materials is very variable, but fragments of a given size are usually found on any one horizon; so that a band of coarse lapilli may intervene between two dust-beds, and so on.

Microscopical Examination.—The larger constituent crystals are the same as in *Period* 2, but the development of each species has advanced much further, and the microliths have increased in size and number and are more clearly defined. The greater perfection applies especially to the pyroxene, which is very abundant both as large and small crystals, many of which have as a nucleus magnetite.

Plates of biotite are much finer, and often stand out from the walls of the cells into the cavity, attached only by one edge or angle. There are also some peculiar large lozenge-shaped plates (?) quite transparent, which, rotated between crossed nicols, transmit a faint brownish-grey light. From the absence of any characteristic peculiarities, it is difficult to know to what rock-forming mineral to assign them.

Phase III., *Period* 4.

General Description.—The last-described deposit sometimes passes up into, or may be represented by, a bed of very coarse leucilitic breccia.

In some localities we find this breccia reaching a comparatively great thickness, so that in the Vallone di Pollena and Vallone Grande, above Massa di Somma, the sides of these valleys show a thickness of it varying from 2 to 55 metres. When reaching the latter comparatively enormous development, it is seen to be composed of blocks of lava, with more or less rounded angles, very variable in structure and size, ranging from the finest lapilli up to masses some tons in weight. These are enveloped in a dirty purple or slate-coloured ash-like dust*. This powder proves to be composed of fragments of minerals and a fine granular amorphous matter, probably the result of decomposition of the constituents, especially leucite. The coarser grains only contain those minerals which would be derived from the disintegration of the lava-fragments. All the minerals are in a fragmentary condition. Pyroxene was most abundant, besides which was recognizable olivine (rare), sanidine, plagioclastic felspar (rare), and leucite (abundant), but having lost all its optical properties, being also rounded and eroded on the surface.

The large blocks of lava have only undergone slight decomposition. An odd fragment of much-rolled pumice can occasionally be found by diligent search.

To determine the position of this bed involved some difficulty, and its true horizon is only to be learned high up the valley, where an opening occurs in the superficial vegetable soil, and the other members of Phase III. are seen to underlie the breccia, which is overlain by the deposits of Phase VI.

The ten metres of materials resembling this, which lie between the deposits of Phase III. at the Vallone St. Patrizio, and other similar deposits in that region, must be correlated with this bed.

Its peculiarly excessive development in one particular locality certainly deserves attention. This is still more the case when we remark how high up the slopes of the mountain this deposit retains its great thickness. The area where this occurs is confined chiefly

* This powder was sifted, and levigated so as to separate it into different sizes. The products of each sifting were examined by the microscope before and after a short treatment with hydrochloric acid. In this way the calcareous and limonitic coating of the particles was removed.

to the space between the Vallone Pollena and the two flanks of the Vallone Grande (Massa di Somma), and it rapidly thins out laterally from this district.

Remarks. — Lithologically this deposit is the termination of PHASE III. of Monte Somma, and is characterized by the production of fragmentary rocks only. It is followed immediately, if not continuously, by lavas differing little from what had been produced by the old volcano in its younger days.

This outpour of lavas, really the outcome and result of PHASE III., we shall find it convenient to separate, under the heading of another phase.

PHASE IV., *Period* 1.

General Description.—Overlying the group of beds that we have just been studying in some sections, we meet with one or more lava-streams or beds of scoria.

In the Vallone Sanseverino and in the Vallone Von Buch we encounter beds of lava having characters almost identical both macro- and microscopically. In the former valley the flow varies from half a metre to two or more metres in thickness, and *in situ* presents the following features:—

The lava forms a moderately regular bed on both sides and floor of the valley for a considerable distance. It is traversed pretty abundantly by cooling-jointage-planes, which are usually at right angles to its surfaces. It is covered with a very thin layer of ragged spongy scoria. In addition to the above-mentioned fissures, the rock cleaves easily along planes parallel with its surfaces, to such an extent in some places, where this lava occupies the bed of the ravine, that one might almost mistake it at first sight for a sedimentary rock.

In colour it is grey, with a pinkish or violet tinge. Scattered throughout the mass, especially at its upper part, are a great number of rather small vesicular cavities, generally irregular in form, and having a granular surface covered with minute crystals. The rock breaks with a somewhat dull earthy fracture, due to a certain amount of decomposition that has taken place.

The uniform colour of the matrix is only broken occasionally by a few very small crystals of black mica and dark green pyroxene; there are also seen many minute white spots, especially by using a lens, which turn out to be felspar.

Microscopical Examination.—The porphyritically enclosed minerals are those we have already mentioned as discernible by the naked eye.

The pyroxene crystals are of a light pea-green colour, commonly showing slight alteration along their cleavage-planes, and often containing large octahedra of magnetite. The biotite, or black mica, is of light sepia-brown colour in thin sections, very polychroic, varying from the above tint to complete black when rotated above the polarizer. It often encloses crystals of sanidine! The sanidine itself is very abundantly distributed throughout the rock, and seems to form one of its most important constituents. The crystals are generally well formed, occurring singly or in groups. As a rule the mass is pretty free from impurities, but occasionally trains of dirty glass cavities are met with, or sometimes there is an intimate mixture of this felspar with pyroxene, which seems to be an advanced stage of what one observes in the earlier deposits, and was mentioned when describing the intermediate pumice between *Periods* 1 and 2 of PHASE III. Some crystals of felspar have the triclinic character; they are numerically inferior to the monoclinic.

The microliths of pyroxene range from small crystals downwards. Many of the larger of these form stellate bunches, which sometimes project in a fan-like manner into the vesicles, where their crystalline form may be seen to perfection. Magnetite microliths are large and well developed, being four or five times the size of those in the preceding pumiceous scoria. They are much more altered, and have, as a consequence, lost their crystalline outlines, and appear as irregular rounded masses. They also form a dense black wreath around the sanidine sections.

The decomposed aspect and colour of the lava seem principally due to this alteration of magnetite.

The small microlithic plates of biotite are very perfect, and occasionally project into the cavities, like the pyroxene. The larger elongated microliths are sanidine; although their terminations are brush-like, the Carlsbad twinning is very common and distinctly developed. The smallest rod-like microliths are probably pyroxene, but have no distinctive characters.

There are in the section one or two circular (?) spaces that darken between crossed nicols, although apparently not vesicular cavities, and therefore they may be minute crystals of leucite. They are too small, of course, to show the optical characters of that mineral.

The great resemblance of the lava in the Vallone Von Buch to that just described, their identity of stratigraphical position, and their similar microscopical structure and state of decomposition, incline us to regard them as nearly, if not quite, contemporaneous, although their wide separation from each other shows they were not the same stream.

PHASE IV., *Period* 2.

General Description.—In the Vallone Sanseverino, above the last-described lava-flow, is another, differing considerably in structure and other characters. It is well seen at the cascade, of which it forms the ledge, near the contour-line of 325 metres.

This upper intrapumiceous lava is of a bluish-grey colour, very vesicular and ragged. It is also very tough, and breaks with much difficulty. It differs from the lower stream by the larger and fuller development of the enclosed crystals. The scales of black mica are sometimes two or three millimetres across, and are pretty abundant, giving to this rock quite a peculiar appearance. This lava shows none of that cleavage parallel to the surfaces seen in the earlier one.

Microscopical Examination.—The general structure of this upper lava is the same as that of the lower. The pyroxene and large magnetite are of the usual type. The biotite differs only in its size, and, as in the lower flow, contains crystals of sanidine. The latter mineral occurs as crystals very neatly and sharply terminated. There is also some triclinic felspar. The magnetite microliths are smaller than in the lower lava, but still are of a greater size than in the ejectamenta of PHASE III. The microliths of pyroxene are the same as in the lower lava; the sanidine crystals are larger, with brush or forked ends.

Remarks on PHASES III. AND IV.

In the Vallone Sanseverino and the Vallone Von Buch, if we trace up these streams of lava to their origin, we find them terminating near masses of scoria, which, seen in section, are in some places 20 metres or more in thickness, and occupy exactly the same stratigraphical position as the lavas. This maximum development occurs in the first-named valley near the 375th contour-line, and near the 475th in the Vallone Von Buch, in which part of the scoria may be seen in the section to overlie the lava belonging to *Period* 1, though beneath this there is a thin layer of scoria.

One of the most striking features of these scoria-deposits is the great suddenness with which they make themselves apparent intercalated in the section, the rapidity with which they increase to their maximum thickness, and then as rapidly decrease and disappear. Again, we find them thinning out laterally in the same abrupt manner. Thus, in the Vallone Pietri Pomice, the next valley to the left of Sanseverino, this scoria is from 3 to 5 metres thick opposite the maximum development in its neighbour, and, like it, soon dies out as we ascend and descend the valley. The same remark applies to the Vallone di Pollena, where there are only a few centimetres of scoria to show the rapid thinning out of the curious deposit so largely developed in its neighbour, the Vallone Von Buch.

Such an arrangement could not have been the product of an eruption from the central vent, since this would be much more uniform in its distribution; and it would be impossible thus to explain the usual absence of the scoria in sections where the beds immediately above and below come in contact, the latter showing no signs of erosion.

Again, I have never been able to trace the lavas of this epoch higher up the valley than these scoria heaps. If these streams had flowed from the great crater-lip they surely would have been accompanied by explosive action, distributing a certain amount of fragmentary material generally, which, as has been remarked, only exists, on the contrary, in these very localized spots. The peculiar characters of the scoria, which can be seen to have been deposited directly in its present site while in part plastic, combined with other features already mentioned, all point to one very distinct and almost certain inference.

We have, in fact, to deal with parasitic cones bursting forth on the slopes of the volcano, from which issued scoria, lapilli, ash, and streams of lava.

Remarks.—It will be convenient for the moment to consider the physical history of the ejectamenta we have been studying before returning to the stratigraphical part of the subject.

Two salient facts are recognizable in the study of the series of igneous products that have been included under the headings of PHASES III. and IV., namely, that as we ascend from the lower to the higher members of the series, so do we find a more or less gradual and regular passage from an almost vitreous rock to one entirely crystalline in structure; this being nearly as regularly accompanied by the diminution of contained aqueous vapour, as represented by the diminished and more imperfect vesicular structure of the upper members of these PHASES.

We have seen also that the break in time between one member and another was of comparatively short duration, and that the products of later date are but the more highly developed crystalline condition of the magma from which was formed the white vitreous pumice.

Reasons have already been given for believing that this white pumice shows itself to have been filled with aqueous matter under great pressure, and probably during a long period of time. On the contrary, the materials, following rapidly, would be exposed to hydration for a shorter time, as their stay in contact with the aquiferous strata would be limited. On arrival at or near the surface their ejection would be accompanied by less explosion, less rapid loss of heat, and consequently cooling would be slower, and therefore more favourable to the development of the crystals and microliths constituting these rocks.

Nevertheless, during the latter part of PHASE III. explosive action was still powerful enough to break the fluid magma into fragments, and it was not till all the highly aquiferous material had escaped that the quiet flow of lava could take place.

There were undoubtedly fluctuations in the character and force of eruptive activity before the outflow of lava. The black scoriæ of PHASE III., *Period* 2, show by their denseness, by the large quantity of foreign matter enveloped in the matrix, and by the rounded and broken character of the crystals, both natural and accidentally enclosed, that the fluid must have been for a long time exposed to violent ebullition and churning. In fact, we may well conceive the crater as filled by a fiery lake, which would be confirmed by the yellow altered lapilli in the bed above (*Period* 4); and that the lava fragments were rocks which had been submitted to fumarolic action, such as would exist around the crater-walls filled by a lava lake. Equally probably we may suppose a small cone of eruption to have formed in the crater of *Period* 1.

Likewise we may explain those lateral openings and parasitic cones from which the intrapumiceous lava of PHASE IV. flowed. There is no evidence up to the present, so far as I can make out, of the lavas having flowed over the edge of the crater during this lava phase; but we must certainly require a column of fluid rock extending up much higher than 700 metres (that of the highest lateral crateret) to exert sufficient pressure to rend the flanks of the mountain. This lava must have either been within a cone of eruption, or possibly a lava lake (?).

It would be reasonable to suppose that these dykes were formed gradually, allowing a certain amount of cooling and escape of vapour before appearing at the surface; so permitting the fluid rock to issue more quietly as lava, and only forming a light scoria compared with the preceding products.

The breccias of *Period* 4, Phase III., render these remarks as to the sequence of eruptive forces somewhat more complicated. This is the outcome of the question :—By what method were these breccias deposited, and how is their extraordinary localized thickness to be accounted for? Were they the result of direct ejective force, we should expect their distribution to be much more uniform; besides, we might look for the admixture of some primary eruptive matter with them. Possibly this may be represented by masses of new-looking scoria which occur in moderate quantity intermixed with the breccia, and which might be the ejectamenta of a central cone of eruption (?) of the later part of Phase III. It is true, the gradual passage upwards of *Period* 3 to this may slightly support such an idea.

On the other hand, the thick masses we see in the Vallone di Pollena and the neighbourhood seem to point to some great baranco draining a craterial hollow, whose crumbling walls furnished the materials that were transported along one such gorge and deposited in their present position. Of course a baranco playing such a *rôle* is not incompatible with the presence of a cone of eruption occupying the centre of the craterial plain. What the real condition of things was it is impossible to say, and at the most we can only make a rough conjecture. The presence of a cone of eruption seems more acceptable than a lava lake, but the matter requires further investigation.

Phase V.

General Description.—In the Vallone Sanseverino, overlying the lava, occur 90 centimetres of brownish earthy soil, containing pieces of scoria and broken lava at the bottom. In the Valloni St. Patrizio, di Pollena, and Grande (di Massa), the top of the leucilitic breccia is capped by from half to one metre of yellow-brown soil, of the same composition as the finer matter of the breccia itself. It contains a few fragments of lava much decomposed. The breccia gradually blends with this yellow soil. The matter proves, on examination, to be nothing more than a more advanced state of decomposition of the materials composing the bed below. This same deposit may be seen in the cupa between the Vallone di Pollena and Vallone Von Buch, reposing on the intrapumiceous lava. Both the last locality and the section of the Vallone Sanseverino can give us a correct idea of the exact age of this bed.

Remarks.—This bed has all the characters of an old vegetable soil, and denotes a considerable period of tranquillity separating the outflow of lava and the next grand paroxysmal eruption. This strikes us still more when we remember the time taken to cover a lava-stream with a vegetable soil nearly a metre in thickness. That it was a surface, and therefore in all probability supporting vegetation, is proved by the advanced state of kaolinization and general decomposition of the enclosed lava fragments, brought about by their exposure to frost and heat, combined with moisture resulting from their exposed position. Where the lavas or scoriæ of Phase IV. are absent, these vegetable soils may represent, in time, that phase as well as Phase V.

Phase VI.

Under this heading are grouped a series of eruptions remarkable for their paroxysmal violence, and the pumiceous nature of the ejectamenta, mixed with vast quantities of the leucilitic nucleus of the mountain, together with its sedimentary foundation-rocks. The first eruption of the group is perhaps one of the most violent that ever shook the flanks of this classical volcano, and the last must have far outrivalled the great eruption that destroyed Herculaneum and Pompeii, which succeeded it.

Phase VI., *Period* 1.

General Description.—The ejectamenta of this eruption form a stratum which is one of the thickest and most constant we encounter on the slopes of Monte Somma. Its peculiar lithological and petrological characters render its recognition so easy, that it forms an important datum-line in the determination of the position of more dubious deposits occurring above or below it. It rests often unconformably on strata of earlier date; but where these have not been eroded, it may seem quite conformable with them.

Generally speaking, the materials forming this deposit are derived from three entirely different sources. It will be most convenient to describe these separately, and then compare their importance as to bulk in constituting the whole of the ejectamenta.

The first and most worthy of study is the primary, or essential eruptive matter. It is a hard, moderately compact pumice, the major part of which will sink in water. It is tough, and considerably resists the blow of a hammer. Its colour is usually brownish, ranging from a light buff to almost black. Large cellular cavities are occasionally produced in it by the union of numerous pores, but more frequently by the presence of fragments of limestone, around which they have formed. The pieces of calcareous rock are covered with a white crumbling coat, probably the superficial portion that was converted into caustic lime by the high temperature of the mass surrounding it. The escaping carbonic anhydride would form a vesicle, against the side of which would remain attached the bit of limestone. Possibly these calcareous fragments may have had a catalytic action, just as we see any rough mass, such as bread, plunged into champagne bring about a rapid evolution of gas upon its surface. Or we may roughly compare the action to that of a morsel of yeast in bread, which may often be noticed attached to one side of the cavity, though of course the chemical action in one and the vital action in the other are quite different. So common is this enclosure of calcareous fragments that it may be regarded as one of the less important characters of this rock.

Usually the pieces of pumice have been broken at the time of their deposition, but it is not uncommon to find some entirely covered with their thin but dense crust. The fragments usually vary from the size of a hazel-nut to that of a walnut, and more rarely they are as large as a man's fist.

The usual dirty-brown colour of the matrix is broken occasionally, besides the white calcareous enclosures already described, by white glassy sanidine crystals and black amphibole.

Microscopical Examination.—The most abundant of the large crystals are those of a pyroxene-like mineral. Its sections appear black unless very thin, when they transmit a dirty neutral-green tint. Rotated above the polarizer their polychroic character is most marked, often ranging from a light greenish yellow to a dark dirty bluish-green colour. The cleavage-planes, very abundant, combined with the outlines of the crystals, point to this mineral as being amphibole. This is fully confirmed by the angle of extinction; the maximum I measured was $18\frac{1}{2}°$, but it ranges from that down to $10\frac{1}{2}°$.

The next most abundant mineral is sanidine, which is scattered through the matrix in small and occasionally large crystals, and is sometimes attached to and may form wreaths around the amphibole.

Magnetite is pretty abundant, and occurs in two if not three forms; large crystals, well formed, some loose in the matrix, but more often forming a nucleus to, or at least enveloped in, the amphibole. In some specimens these are decomposed, and convert the surrounding rock into an irregular mass of dirty brown colour, in which, however, its true constituents can be distinguished. In one specimen examined the magnetite occurs as very small but well-formed octahedra, many of which are more or less peroxidized. The third variety will be discussed with the microliths. By employing a large quantity of the rock, and treating it by Fouqué's method with hydrofluoric acid, a number of crystals can be obtained of amphibole, with a few of pyroxene and olivine (?). The two latter, from their rarity and imperfect form, may be assigned as erratic in origin, having been taken up and enveloped with other foreign fragments.

Scattered through the matrix rather sparingly are a number of well-formed rod-like microliths, a few appearing to belong to sanidine (?), amphibole (?), and pyroxene (?). Their characters are very poorly marked. Next we have great quantities of minute microliths, or perhaps more properly trichites, arranged in sheaves, or so as to appear like a long-fibred velvet brush. Each individual component one appears as a dark line, often curved, and does not transmit light between crossed nicols, unless when in a very dense bunch. Then we may observe a feeble greyish patch, which might be compared to the effect produced by a half-dry white-paint brush smeared over a black board. The third microlithic substance, differentiated from the base, presents itself as a multitude of globulites appearing as small opaque spots, which are scattered about between the microliths and trichites, in the same manner that magnetite occurs in some of the more highly crystalline structures already described. If we may judge by analogy, the globulites appear to be nothing more than minute microliths of magnetite. When subjected to very high powers these globulites seem to transmit a reddish-brown light; and in those specimens in which the larger crystals of magnetite are much decomposed these minute specks are absent, which would be expected from their smallness and the ease with which they are consequently destroyed.

It may be taken as a general rule, that the pumice which is richest in well-formed magnetite, and unaltered, or only slightly changed, is the darkest in colour.

The next constituents, and the ones that form the greatest part of the deposit, are the usual rounded and subangular lapilli of ancient leucilitic lava. The only thing worth remarking about them is the evidence of the violent attrition to which they have been subjected, differing very much from what one observes in water-worn pebbles.

The third set of materials contained in these ejectamenta, but of less importance as to volume, are the various erratic fragments of metamorphosed sedimentary rocks. The most abundant of these are pieces of limestone, varying in size, but rarely larger than a moderate-sized orange. One peculiarity about them is that they are least common at the bottom of the deposit. Other varieties, and of more interest, are masses of marl and marly clay, often crammed with fossils, chiefly marine. These pieces of a shallow-water sedimentary rock, are slightly altered on their exterior, and vary from the size of a walnut to that of a large cocoanut. In some places they are very abundant, especially about the middle of the deposit. There are also a few small pieces of those extraordinary series of metamorphic rocks that form the major part of the ejected foreign blocks, shot out at later eruptions.

These three various materials, so different in their origin, together make up a stratum varying usually from ½ metre to 4 or 5 metres in thickness. This stratum generally presents a certain characteristic arrangement of its materials. The lowest quarter or third is very rich in pumice, mixed first with leucilitic lapilli, then with Tertiary marls, and above these with limestone fragments. None of these erratics are absent from any part, but they predominate at certain horizons. The remaining and greater bulk of the stratum consists of a breccia with fine ash, in rather regular alternation, and, near the top, more pumice is again encountered. The breccia is most variable in coarseness, and composed chiefly of leucilitic lava-fragments. The old lava-blocks are much decomposed towards the top, as if they had been much exposed to the vicissitudes of weather before being covered over by the products of the subsequent eruption (?). The upper subdivision, or breccia, is often false-bedded, and it is no easy matter to say whether such an arrangement is due to deposition upon an inclined surface or the effect of aqueous influences.

The most favourable localities where these deposits may be studied are the ridge between the Vallone Grande (Massa di Somma) and the Vallone di Pollena, the cupa to the north of the last-mentioned valley, and the Valloni Von Buch, St. Patrizio, and Sanseverino.

Remarks.—The most interesting fact connected with the primary material of the pumice is the replacement of the usual pyroxene by amphibole. It has been remarked that the latter mineral is most common in those rocks that have crystallized under great pressure; whereas the sister species, pyroxene, is to be found most abundantly in lavas and other igneous rocks that have consolidated at the surface or under slight pressure. Although there are many exceptions in both cases, yet in general the rule holds good.

Such facts would lead us to suspect that the amphibole had begun to crystallize either at great depths, or certainly before the actual eruption took place, that is to say when the tension was very great. Whether such crystallization was brought about by the escape of vapour into thermal water or by conduction, or possibly by the low temperature of the original magma, is not easy to decide. That the magma was not of high temperature or rich in watery matter seems evident from its compact nature in proportion to its crystalline structure. Nevertheless the eruption seems to have been one of the most violent, if we judge by the amount and character of the ejected materials. It must, however, be admitted that all these deductions are of a very speculative character, and therefore must be valued accordingly.

The peculiarly uniform distribution of this bed wherever it is exposed in section, and its great thickness, show us the large mass of material it represents, spread as it is over a considerable area. When we justly appreciate the comparatively small amount of new matter ejected, the components of the cone and subjacent rocks contributing by far the greatest share of the ejectamenta, it becomes quite evident that this eruption must have cleared out and considerably enlarged the preexisting crater.

We may conclude with good reason that the apex of the new crater must have extended downwards through the Tertiary tufas, marls, sands, &c., and also to some extent into the subjacent limestone.

The first rending asunder of the superincumbent obstacles with explosive violence was accompanied by the ejection of part of the magma itself. Very soon the terrific effort exerted by the elastic vapour was partly exhausted, so that a smaller quantity of fluid rock was hurled forth, until at last the escape of the gaseous matters was no longer able to carry up much of it, although there seems to have been a final puff of pumice. The effect may well be compared to the opening of a soda-water or champagne bottle. On removal of the cork the sudden formation of gaseous carbonic acid takes place with such rapidity that in its hasty escape it carries much of the fluid with it. When, however, the pressure has been reduced considerably the gas escapes more quietly.

It is just the latter stage of the above example that is worth considering. The vapour rising from great depths carries up no more primary eruptive material, but in its escape tears away the sides of the vent. As the escape of vapour takes place, the point where it leaves the fluid magma will gradually recede from the surface, in proportion as the latter is ejected, unless there was a compensatory upflow of material from below. It is only when the gaseous materials leave the liquid that the former can exert their eroding power.

These remarks give the interpretation of the prevalence of pumice first, then the Tertiary marls, followed by limestone, and last, ash and lapilli, with lava blocks, which are derived from the crumbling-in of the undermined crater walls and their re-ejection. We see by this that as the apex of the enlarging craterial hollow was lowered new materials made their appearance amongst the ejectamenta. Towards the latter end of the eruption, when the explosions were becoming feeble and irregular, no more planing or excavation of the crater took place; but the loose crumbling components of the walls as they fell down the sides into the vent were subjected to churning and violent attrition, and from time to time were hurled forth on the slopes of the cone.

These are the facts we may learn from the demonstrations left written by the features, arrangement, and structure of the ejectamenta of this great eruption. They are confirmed by the great similarity in the characters of deposits of later eruptions and by what has been witnessed by man in historic outbursts of this and other volcanos. In the Vallone Sanseverino, overlying the deposit just described, is a bed of re-sorted lapilli, rolled pumice, and pieces of scoria, which seem to have been disturbed by the action of water. The best example is to be seen in the Vallone Pietri Pomice, where this deposit is often seen to be eroded, and the subsequent materials rest unconformably on it. We have here again the same evidence as with earlier interruptive periods, namely, a certain amount of denudation going on whilst the volcano was in a state of repose. The epoch of inactivity was probably not of long duration, if we judge by the thinness of these alluvial deposits and the slight amount of erosion, which in many sections is not even visible.

Phase VI., *Period* 2.

This is represented by another bed of pumice and its derivatives with secondary materials, having its own special characters both as a rock-forming matter and in its minute structure, so that it can be distinguished from its fellows with great facility. It ranges from 1 metre in thickness, as at Cisterna, to 4 metres or even more, as in the Vallone Sanseverino and in other localities.

The whole stratum is capable of subdivision into three, a lower yellow loam-like decomposed ash-bed, the middle or pumiceous bed proper, which graduates up, though rather sharply, into another fine yellow ash-bed. The inferior of these subdivisions may probably be in part alluvial (?), preceding this eruptive phase, or more likely the terminal ash-bed of Phase VI., *Period* 1, although it has few diagnostic characters. The middle division appears to be composed of well-rounded pumice, each fragment having a yellow dusty covering. The fragments range from the size of a hazel-nut down to the finest dust. A band on any one given horizon is composed of fragments of uniform magnitude, and may be followed by one composed of much smaller or larger pieces. There are amongst the coarser beds two or three intervening bands of fine ashy matter. These, although only ranging from one to two centimetres in thickness, may be traced over very large areas, showing that the process by which they were brought into their present position was general, and not local as in the case of alluvial deposition.

The internal characters of the pumice are pretty distinctive. The structure is of a light spongy nature, with many large compound cellular cavities. The matrix is of a grey colour, usually with a yellowish or greenish tinge, which is broken rather abundantly by crystals of augite, often large, besides a few of sanidine and biotite.

Mixed with the pumice are exceedingly few small lapilli, the whole bed seeming to be composed of primary matter. Crystals of pyroxene, loose and often broken, sometimes reaching a centimetre in length, are found loose with the pumice. They are similar to the crystals found in the rock itself, and are therefore probably only the same detached.

Microscopical Examination.—The first mineral that attracts one's notice in the rock section by its abundance and perfection of crystallization is pyroxene, which occurs in dark pea-green crystals. This mineral, almost without exception, is twinned along the plane of the orthodiagonal. The average of six measurements gave 37° as the angle of extinction; the elements were very variable, possibly owing to slight superficial alteration. The crystals are exceedingly rich in clear brown glass enclosures, which include vacuoles of gas. One crystal showed three such cavities of amorphous matter all traversed by one large rod-like microlith of pyroxene, the outline of which could also be distinguished where enveloped in the intermediate crystalline mass. That portion, where surrounded by the glass, had deposited on its surface some microliths of biotite (?), which no doubt separated out from the vitreous matter and crystallized on the faces of the prism, though, curiously, none were to be seen on the walls of the cavity.

Magnetite occurs in good-sized unaltered octahedra, sometimes enclosed in pyroxene and at others attached in groups of three or four on one crystal, themselves supporting hexagonal plates of biotite.

This latter mineral, or black mica, is rather abundant in large crystals of the usual characters.

Sanidine is rather rare in well defined-crystals, often surrounding biotite. The most common are irregular, blotchy, or flecked in appearance when seen by polarized light, as if they had been broken up into innumerable fragments and then pressed together, so that unequal strains were exerted on each separate morsel. This really seems to be the case; for all are enclosed in a zoned coating of uniform sanidinic matter, which by its contraction in cooling has compressed the irregular fissured interior mass. This straining may in part be due to glass cavities, which in some cases are very abundant in the mineral. This vitreous material nearly resembles in colour that contained within the pyroxene crystals, and is very rich in gas vacuoles. Sometimes these glass enclosures are arranged in a stratified manner, and, seen edgewise under a low power, might lead to the supposition of triclinic characters in the felspar. One example showed a peculiar concentric arrangement. Within was a well-terminated sanidinic crystal, enveloped in a flecked dirty mass of the same mineral, which had an irregular eroded surface; both the nucleus and its envelope polarized and extinguished alike. These two were again enclosed in a clear crystal of the same mineral polarizing in different colours and extinguishing at a different angle from the contents. Other crystals have been partly dissolved and again covered with numerous irregularly arranged crystalline facets. This mineral sometimes supports on its surface little plates of biotite.

Scattered rather sparsely through the matrix are microliths of pyroxene. They are well formed, but may possess ragged extremities to the prism, and, like the larger examples of the same mineral, they are twinned. Nearly all contain minute elongated cavities. In size they are very variable, ranging from almost invisibility to 0·06 millimetre in length and 0·002 millimetre in breadth.

There is to be seen rarely a bunch of sanidine microliths.

The ground-mass is a slightly dusty brown glass containing a few very minute globulites, and broken up by the vesicles, which are often drawn out into long tubes that sweep round a larger cellular space, so as to assume most varied forms.

Remarks.—Any one who studies this pumice cannot but be struck with the peculiar features of it, which so plainly tell the tale of the prehistoric outburst that gave forth these volcanic products.

The eruption seems to have commenced feebly, so that its earliest ejectamenta could at first not succeed in reaching beyond the enceinte of the crater, into which they must have fallen back. Such action would be favourable to the escape only of ashes at first. The igneous magma would be able to develope its crystalline structure, and the pumice fragments would thus obtain their rounded and worn surfaces. The thin intercalated ash-bands would point to small intermissions or diminutions of expulsive power, which in the middle subdivision must have been sufficiently strong to eject the magma in the form of pumice, but which could not have eroded the crater much, as proved by the absence of leucilitic lapilli. The forces seem to have gradually diminished, resulting in the ejection only of fine ash, which composes the dusty yellow upper subdivision.

It is possible that the deposits above described do not represent all the products of the eruption, since if the north wind were blowing with great force the ejectamenta would be found chiefly on the south side of the mountain, where there are no existing sections to reveal these beds.

PHASE VI., *Period* 3.

General Description.—The products of this eruption that go to make up its representative deposits are very variable in amount, but often reach a very considerable development. At one part of the Vallone Sanseverino they attain a thickness of 13 metres; also in the Cupa di Pallarino, where they seem to have collected at the bottom of the valley, they attain a maximum of 7 metres.

Where the deposit is well developed it forms a striking contrast to the usual yellow and brownish ash-beds between which it is intercalated, consisting as it does of masses of a very light white pumice, often as large as a cocoanut or larger.

Mixed with the primary material are a number of rounded leucilitic lapilli, most abundant near the middle, where they form a band and increase in proportion near the top. In the Vallone Sanseverino many thin ash-bands, varying from 2 to 10 centimetres in thickness, occur at intervals, and are often persistent and uniform for considerable distances. Very few and minute fragments of foreign ejected blocks are with difficulty to be found.

In general characters this pumice, both in external and microscopic structure, is identical with, or at least undistinguishable from, that forming the deposit of PHASE III., *Period* 1. The description of the latter will serve equally well for the former as far as the microscope is concerned. It may perhaps be worth recording that in the more recent deposit crystals of pyroxene may be met with enveloping those of amphibole (?), which latter mineral would appear to be the most abundant.

Remarks.—The general characters of this deposit show it to be the result of a violent paroxysmal eruption; but it would appear that the crater was sufficiently large to allow an easy escape of the igneous products. This fact is demonstrated by the comparatively few leucilitic lapilli. The band of these old lava fragments occupying the middle of the deposit may probably be derived from the slipping-in of part of the crater walls, which would be immediately re-ejected.

The practical absence of all metamorphic rocks from amongst the ejectamenta would rather point to little eroding action exerted on the walls of the vent or apex of the crater.

The amphibole we may suppose to have been formed at great depths, and then enveloped in pyroxene when the magma reached a lower pressure and temperature.

Overlying the white pumice are deposits that vary within certain limits. In the Vallone Pietri Pomice, immediately above the pumice, occurs a concretionary bed 30 centimetres in thickness, of a yellow or buff colour when dry. Stratification-lines are distinctly visible in general coarseness or fineness of structure. The fracture is earthy or irregular. The internal structure shows the mass often to be made up of a blending together of pisolitic concretions; other specimens are more uniform in texture, and are filled with a number of vesicular cavities, which are usually irregularly spherical, ovoid, or even multilocular, and sometimes seem to form the centre of a pisolite.

When sectionized it proves under the microscope to consist of the same minerals as the other primary ejectamenta of this volcano, all, however, broken, abraded, and partly decomposed. Curiously enough a large number of microliths still retain their form and optical properties, and appear to be pyroxenic. These microliths, in proportion to the mass, are much more abundant than in the subjacent pumice. The whole is blended together by a brownish amorphous interstitial cement.

When a fragment is treated with acetic or dilute hydrochloric acid the rock effervesces only at points where it contains calcareous fragments, and does not break down even after prolonged action of these agents, or of concentrated hydrochloric acid in the cold, though, when boiled, the mass gradually falls apart. It would therefore appear that this rock is either a mechanical accretion or a concretion in which the cementing material is some silicate.

In the Vallone Pietri Pomice this concretionary bed is followed by 60 centimetres of fine rounded and false-bedded white pumice and yellow ash, succeeded by another concretionary bed of the same type as the lower one. In the ridge cut through by the path that runs between the Vallone di Pollena and Vallone Grande these rolled pumice and dust deposits may be two, three, or more metres in thickness where there is only one concretionary band.

In the Lagno di Trocchia the deposit is represented in part by a coarse leucilitic breccia mixed with pieces of the underlying white pumice, the upper portion only being a fine yellow dusty soil.

There seem to be a number of questions, not easily solved, arising out of the physical features and constitution of these deposits. The peculiar strata of yellow earth are so persistent and so slightly variable over the whole of the mountain that we might be led to conclude that we had to deal with simple deposition of a volcanic ash falling into its present site. On the other hand the rounded pumice, the false bedding, the eroded surfaces of underlying deposits, and the peculiar sweeping curves of stratification around large stones, show distinctly the interference of water. If these beds were simply re-sorted by water from the higher parts of the mountain we ought to find the constituents of them to be materials derived from all manner of sources; but, on the contrary, the white pumice seems only to have been derived from the bed immediately below.

Then, again, the peculiar structure and composition of the concretionary bands bring in another difficulty. Supposing these to be simple segregations in a fine water-sorted ash, how are we to account for the vesicular cavities and the persistence of these bands occupying nearly always the same relative position over large areas?

Looking at the question from a more general point of view, it would seem that both igneous and aqueous action had played a part in their formation. It has been shown that the lowering of the apex of the crater below drainage-level might result in the simultaneous ejection of both primary and secondary volcanic products with aqueous matter in the form of spray or vapour, derived from the inpouring through the walls of the crater. May it not be that towards the end of the eruption of the white pumice the continual enlargement of the crater had advanced sufficiently far to produce the conditions favourable to the inflow of water? In such a manner we could easily account for the superficial re-sorting of materials, the pisolitic concretions, and the breccias in the bottom of old valleys.

But now arises the difficulty of the vacuoles in the concretionary bands. They may have been formed by the coating of drops of water falling into dusty matter, but more probably by chemical action. The rain derived from the condensation of the vapours of an eruption is rich like them in hydrochloric acid, and is well known to be the great destroyer of plant life for this simple reason. If we figure to ourselves such a weak acid solution falling amongst volcanic ashes containing minute fragments of calcareous rock intermixed, the consequence is evident. The bubbles of carbonic anhydride liberated would remain enveloped in the pasty mud, leaving their traces as the cavities we now see. At the same time the pisolitic concretions separated out, and these, from their abundance, crowded upon each other, and so converted the whole into the compact masses we have now been considering. I have collected materials quite similar on the slopes of Etna; and the same may be seen in other volcanos of the Campi Phlegræi. May it not be that these segregations are analogous to those which occur in certain felspathic glazing-creams used in pottery, which form concretions unless kept constantly in motion?

Whatever may be the cause of this peculiar structure, the example is one of considerable importance in the study of ancient volcanic rocks. Let us imagine these extensive sheets of concretionary rock, having the same inclination as the slopes of the cone, interbedded between other volcanic ejectamenta, still more altered than it is at present, its vesicles filled by zeolites, after having been buried under the pressure of superincumbent rocks. Afterwards suppose these strata cut down to and exposed in section by subsequent denudation, so as to be within reach of a geologist or petrologist. Either of these *scientiates* might be sorely puzzled as to whether the rock was a decomposed lava or an altered ash. The petrologist might point to its minute structure, show that the microliths were enveloped in a "devitrified" (?) matrix, and then confirm his assertion by the amygdaloid condition. The geologist, if it were possible, might point out the concretionary appearance of the bed, its remarkable thinness and uniformity over large areas, and no collection of the material in hollows, such as flowing lava would produce. Altogether I rather fancy that the former individual would get the better of the argument, and geological science would have blundered.

These considerations suggest to our minds many such geological enigmas of quite recent date. As good an example as any perhaps is that of the rocks of the Brent Tor volcano discussed by Mr. F. Rutley *.

* "On the Schistose Volcanic Rocks occurring on the West of Dartmoor, with some Notes on the Structure of the Brent Tor Volcano," Quart. Journ. Geol. Soc. vol. xxxvi. p. 285.

Phase VI., *Period* 4.

General Description.—Probably none of the components of Monte Somma so far discussed has given rise to so much attention and investigation as that we are about to consider. This arises from different reasons, such as the extent and uniformity of the materials and also the richness of the ejected blocks of metamorphosed foreign rocks, which have yielded some of the most interesting and rare of mineral species, besides an abundance of common ones. Last, but not least, this deposit has been brought into the discussion of the physical history of the volcano by many eminent writers. From this it will be evident that this bed of pumice and the associated materials possess so many characters of the utmost interest that a more extensive consideration of them is called for.

Hardly a single valley scoring the slopes of Monte Somma does not show some sections of this interesting deposit. Its usual thickness, where no denuding or other causes of disturbance have been at work, varies usually from one to three metres, but may range from only a few centimetres, as at Cisterna, to seven metres in the Cupa Pallarino.

The whole deposit is capable of separation into three subdivisions. The lowest of these is composed chiefly of a white highly sanidinic pumice and leucilitic lapilli, with few or no fragments of foreign rocks. This, the earliest product of the eruption, in some situations, as in the Vallone di Pollena, is terminated by a band of very fine material, an ash of the same origin as the coarser pumice and lapilli. Where, however, this band does not exist this inferior member passes into the middle division without a perfectly abrupt line of demarcation. This middle portion is composed of a brown or greenish-grey compact pumice, leucilitic lapilli, and a great number and variety of ejected blocks of erratic rocks not belonging to Monte Somma proper. The third and uppermost subdivision is a fine grey ash-bed, always characterized by the number and perfection of the pisolitic concretions it contains.

To the naked eye the primary or essential eruptive matter of the lower division is a pumice of a beautiful white or cream-colour, as a rule, very vesicular and cellular in structure. It is moderately tough and filled with great numbers of large well-developed sanidine crystals, small plates of black mica, crystals of amphibole, pyroxene, and garnet (melanite).

Microscopical Examination.—Sanidine occurs abundantly in large well-formed crystals, variously twinned, usually clear, but sometimes containing slightly dusty glass-cavities with vacuoles &c., or enveloping crystals of amphibole. One peculiarity worth remarking is the large number of amphibole microliths arranged along the planes of growth of some of the sanidine crystals.

The principal of the dark spots that were discernible by the unaided eye prove to be amphibole. It is usually of a dark bottle-green colour, polychroic to brown, the cleavage and crystalline form well developed.

The pyroxene crystals are few and far between, and when they do occur may have a nucleus composed of a fragment of amphibole.

Black mica or biotite is rare. The mineral most common after amphibole is melanite. It is scattered rather commonly throughout the matrix as well-formed crystals about the size of a turnip seed or larger. When in very thin sections it transmits a rich reddish-brown light, and contains various enclosures, chiefly minute transparent microliths. This mineral and sanidine, from the fracture of the one and the cleavage of the other, and especially from the hardness of the former compared with the spongy and fragile matrix, render the sectionizing of this rock a very precarious proceeding. Even with all the precautions conceivable these minerals tear out before the rock is sufficiently thin, so that it is advisable to prepare thick sections for the study of these minerals, and thin ones for the base or glass, microlithic or not, as the case may be.

Magnetite occurs as well-formed octahedra, but is very rare.

Scattered throughout the base are a number of microliths, which seem to consist principally of pyroxene, though they are quite small in quantity in proportion to the amorphous base.

The ground-mass proper is a clear almost colourless glass, filled with vesicular cavities, which assume their usual varied forms, and sweep round crystals or larger cells, or are drawn out into long but slender tubules, showing the great viscosity of the igneous matter.

The pumice of the middle subdivision is compact, sinks in water, and is usually grey in colour with a distinct greenish tinge, due to the abundance of pyroxene microliths; when it is weathered it may become brown from the peroxidation and hydration of the magnetite. When broken open there are to be seen many irregular cavities, usually containing pieces of altered limestone, which have a coating of white crumbling powder, which is probably hydrate of lime. Besides these enclosures there are other impurities, ranging from the finest fragments of crystals to pieces of old lavas, and metamorphic erratic blocks of large size. There are amongst these enclosures minerals that are of uncertain origin, such as large crystals of biotite, pyroxene, melanite, olivine, idocrase, leucite, &c., which may be perfect or broken and eroded. Pyroxene occurs either in the pumice or as loose crystals mixed with the rock fragments, in size sometimes as much as one or two centimetres in diameter, usually broken and of a dark green colour, with poorly developed cleavage, so that the fracture appears vitreous. Melanite may be well formed when small, or irregular and broken when large. The same remark applies to olivine and leucite, both of which are rare and difficult to find, especially the latter. All these have the stamp and appearance of minerals derived from extraneous sources and accidentally enveloped in the plastic magma. They all resemble very strongly both in form and in their minute characters the same species that are met with in the ejected blocks of metamorphic rocks, from which they may be supposed to have been separated by the violence of the explosion, and then enveloped in the pumice paste.

Microscopical Examination.—The sanidine occurs in large well-formed crystals similar in all respects to that of the lower subdivision.

Amphibole differs only by its greater size and perhaps greater abundance, due probably to the smaller relative bulk of the matrix.

Pyroxene is much commoner in this upper subdivision. It shows in section the usual light pea-green colour, and graduates in size from large crystals down to the microliths.

Magnetite is pretty abundant in crystals of various dimensions, which may be enveloped in the amphibole or pyroxene, and also are sometimes slightly decomposed.

Biotite is moderately common in small well-formed crystals, and similar to that from the other pumice.

Melanite is perhaps more common in this subdivision, though part is no doubt erratic.

It is in the ground-mass that the two subdivisions of the pumice differ so much from each other. In the first case we found the amorphous base predominating over the formed material, but in the middle subdivision the conditions are reversed. In the most advanced stage of crystallization we find almost the whole of the base omposed of microliths of pyroxene and biotite.

The first of these minerals transmits a feeble green light, more intense proportionally to the size of the prism. The average of twelve measurements for the angle of extinction gave $41\frac{1}{2}°$, and the extreme variations were confined within narrow limits. The pyroxenes range from the merest trichite, or belonite, through microliths most variable in size, up to large crystals of that mineral. It was impossible to find a single microlith of amphibole.

The biotite, like the pyroxene, is most variable in size, occurring nearly always as well-formed hexagonal plates, either single grouped together, or in pairs, but more often superposed one upon another. They are of the usual sepia-coloured, very polychroic kind.

In addition to these two minerals, there are a few small minerals or microliths of magnetite, which are sometimes altered and at others not so.

As already mentioned, the glassy base may be almost absent; but it seems that a small quantity always remains.

When we examine that part which forms the border-line between the two subdivisions, we find that the crystalline structure is intermediate in development between the very vitreous white and the highly microlithic green pumice. In fact, it is possible to collect all gradations from one to the other. The green colour of the middle subdivision is due to the abundance of formed pyroxenic material.

The pisolitic tufa proves, on *microscopical examination*, to consist of the same minerals as compose the pumice broken up into fine fragments. The pisolitic concretions sometimes attain the size of a walnut, but usually average that of a good-sized pea. When split open or sectionized, they are seen to be composed of coarse grains enveloped in concentric shells of a very fine brown powdery substance.

The nucleus is usually a larger grain, an empty vesicular space with smooth walls, or in some cases there seems to be nothing apparent as the special centre of concretion. The preparation of a section for microscopic purposes is attended with almost insuperable difficulties from the fragility and pulverent structure. The principal mass is seen to be composed of fragments of the different minerals of the pumice and lava, together with a small quantity of some interstitial silicate (?), which would require careful chemical analysis for its determination.

This pisolitic tufa is not easily to be distinguished from other deposits that overlie it, and which may also present the same structure, so that its thickness is not easily determined, though it rarely seems to average more than one metre. The peculiarity of pisolitic concretions seems not to be confined to this bed, since we have already seen it earlier, in the case of PHASE VI., *Period* 3. In fact, whenever we find a fine dusty ash of pumiceous origin, of whatever age, either directly deposited as an ash, or collected as fine alluvium, this structure is apt to develop itself. The reason for considering this pisolitic ash to be derived from the same eruption as the pumice is quite evident when we compare this outburst with the subsequent Plinian one, which produced very similar materials.

The broken-up fragments of ancient leucilitic lava-streams and scoria, which form the principal secondary or accessory components of the lower and middle subdivisions, are of the same type as in earlier ejectamenta. Many are moderate-sized lapilli; but large blocks are abundant enough. Naturally the varieties of structure are very numerous, as they have no doubt been derived from the breaking up of lava-flows of all ages. The most remarkable, however, are those which were originally vesicular in structure, but are now filled with zeolitic and other minerals, the principal amongst which are phillipsite, thompsonite, analcime, calcite, aragonite, and selenite. From what we know of these minerals we should expect that lavas in which they were deposited were derived from some of the most ancient streams situated deep in the bowels of the mountain, where water at a high temperature transported and deposited in their present sites these hydrous silicates, sulphates, and carbonates.

The accidental or tertiary constituents of the ejectamenta consist of altered tufa (few), fossiliferous marls, mudstones, and sandstones already described with earlier ejectamenta, and a peculiar series of altered limestones and metamorphic rocks most variable in structure and composition; in fact, so different are their characters that it seems a most difficult matter to attempt any general classification, even such as is within the scope of this paper.

In my collection I have over four-hundred separate varieties, and each excursion adds new ones. From this we see that the study of these ejected blocks would require years of patient labour, and can yield but insignificant results until the study of the whole geology of the neighbourhood gives us an idea of the kind and quality of the rocks that underlie Monte Somma.

One of the commonest varieties generally included in this group holds a very doubtful place there. It occurs as blocks, very splintery, which attain a considerable size, and consist of a great abundance of sanidine crystals, large and well formed, scattered through a light grey or buff-coloured matrix, the uniformity of which is broken by a number of small garnets and prisms of amphibole. There seems to be no clear distinction between this rock and the pumice amongst which it is found, and of which it seems to be a compact variety. When examined microscopically it proves to be very free from extraneous impurities, and is often slightly vesicular. The minerals that go to form its principal components are exceedingly perfect and uninjured. The most abundant are amphibole, garnet (melanite), and sanidine. The latter, in many of its crystals, presents a great number of amphibole microliths arranged along the planes of growth as in that of the pumice, which seems to confirm the common origin of the two. The analysis of this rock by Vauquelin quoted by Breislak shows it to be identical with pumice. Although some difference apparently exists between the two, it is necessary to repeat the analysis with careful choice of the specimens, and with the modern methods of chemical research. If this rock should really turn out to be of the same origin as the pumice, the amphibole would be the only representative of the bisilicate group to which it belongs, the presence of the pyroxene being simply accidental except that of second consolidation. Such evidence would point to this rock being the same magma that formed the pumice, but cooled slowly under pressure.

We may follow this rock through many most delicate gradations into a syenite, so called. Nepheline, guarinite, titanite, zircon, all make their appearance in the inseparable varieties of it, which, in its highest crystalline states, seems to be composed of a friable aggregate of sanidine, black hornblende (syntagmite), and garnet (melanite), the other minerals being subsidiary. Through such masses, and often forming the greater part of the detached blocks, are to be found veins rich in black, green, or brown mica, which may support beautiful crystals of red garnet or idocrase, and these again sustain dodecahedra of sodalite or hexagonal prisms of nepheline.

By an equally imperceptible gradation this micaceous rock may be mixed with pyroxene, anorthite, humite, and olivine, each of which may preponderate, so that a block may, for example, be composed of nothing but an aggregate of pyroxene crystals. Passing into these there is a most extraordinary series of varieties of altered limestones which have developed within them, to a greater or less extent —pyrrhotite, periclase, lapis lazuli, magnetite, spinel, wollastonite, pyroxene, meionite, anorthite, nepheline, leucite, &c. Next come a series of metamorphosed dolomitic limestones, which may range from the purest white, porcellanous in structure and fracture, through the saccharoidal stage, until each grain may reach the size of a walnut or more. The last degree consists of stratified limestones, in which the lines of deposition may be more or less distinctly exhibited by difference of structure or colour. Between the laminæ I have occasionally found the carbonized remnants of fuci or other vegetable remains. On the one hand we may have this limestone in such a normal condition that it is undistinguishable from the Cretaceous Apennine rock of Castellamare, and on the other entirely converted into a mass of silicates. Thus we may find hand-specimens that show all the details of stratification, folding, and faulting of the laminæ, and at another point its conversion into a saccharoidal snow-white marble with bands of tremolite (?), wollastonite, pyroxene, &c.

Very rarely one may find a specimen of a light grey, compact, true trachyte, probably derived from older volcanic deposits through which the eruptions of Monte Somma burst their way.

Lastly, there is an interesting series of brecciated rocks which have the appearance of old tufas rich in limestone fragments. These are so altered that the interstitial matrix may be converted into a pyroxenic mass, which, however, may contain a most varied series of minerals. The enclosed fragments of limestone are metamorphosed on the surface, and in some cases replaced by cavities filled with crystals of wollastonite, pyroxene, olivine, and other silicates. These altered breccias graduate into compacted tufas of doubtful origin, which exhibit all stages of metamorphosis *.

It has been my endeavour to give here nothing more than a rough enumeration of this interesting series of often ambiguous rocks, not as of use to the mineralogist, but simply for the geological lessons they teach us.

The powerful abrasion to which these ejected blocks were subjected when erupted must have resulted in the detachment of many of their crystals, scattering them loosely through the deposit, or leading to their envelopment in the pumice. In this manner we meet with a large number of biotite and pyroxene crystals which are usually more or less broken.

This deposit was first generally, but correctly, described by Breislak; but the earliest really minute examination of its components was made by Scacchi †, and it is described by him in these words:—"Lapilli of pumice containing large quantities of limestone, various in structure and composition, and containing all the minerals, with finely powdered substance, and also with fossiliferous shells;" and, again, when refuting the statements of Lippi, he redescribes it, together with similar deposits of the Plinian eruption, adding—"The limestone fragments are often enveloped in the pumice, the lava lapilli, and loose crystals of augite, olivine, and leucite (?)" ‡.

Remarks.—The study of this deposit opens up to our comprehension the magnificence and majesty of the eruption to which it was due, and initiates us into some of the secrets of the most important phenomena of volcanic activity.

The same thing is repeated, and the illustration is far more vivid than

* About eighteen months since I met with a block of leucilitic lava containing a mass of metallic iron and a sulphide, possibly troilite. This block is now undergoing investigation, and is likely to be of great interest in the results obtained.

† 'Lezioni di geologia' (Napoli, 1843), pp. 171 and 172, and 'Notizie geologiche dei vulcani della Campania.'

‡ "Osservazioni critiche sulla maniera come fu seppelita l' antica Pompei." Lettera estratta dal Bolletino archeologico Napolitano, No. vi. Marzo, 1843.

in earlier examples, namely, that the eruption commenced by the violent ejection of vitreous matter containing only a few crystals of sanidine, amphibole, and garnet. The second, or perhaps all of these minerals, would lead us to believe in their formation at a time precedent to their ejection, deep below the surface and under great pressure. So rapid was the expulsion and cooling of these earlier materials that they have retained their vitreous and vesicular structure. As this primary matter was hurled into the air, it carried with it the remnants of lava and scoria that during the preceding tranquillity had crumbled in and partly filled the crater.

After the first paroxysm there seems to have been a lull, during which the finer ash-bed was deposited, and during which a more tranquil ebullition was going on, allowing the gradual escape of heat and vapour, so as to favour crystallization.

The bursting through of the superincumbent pressure and consequent explosion, no doubt, must have cleared the vent to enormous depths, and the lull or temporary diminution of violent eruption would be coincident with the more gradual welling-up of new material from below. This, as it rose to the surface, would gradually be reduced in temperature from the regular expansion of the aqueous matter, so that time would be given for its vitreous base to develop into "formed" materials, or in other words, the microliths of biotite and pyroxene. The essential or primary eruptive material of the middle subdivision, characterized by its more crystalline nature and less vesicular structure, shows that the elastic fluid had already, to a great extent, quitted it before its ejection. It is just this escape of aqueous and other vapour that tore off those interesting metamorphic rocks above mentioned, and so greatly increased the size and depth of the crater.

The Apennine limestone, as we have seen, forms the platform on which were deposited the quaternary sandstones, marls, and clays which support probably very early volcanic deposits and certainly the majestic cone of this prehistoric volcano. It was through these rocks that the igneous magma found an outlet, and through them poured, for centuries upon centuries, that lava and its products which, cooling and collecting around the vent, gradually built up a mountain more than 2000 metres in height. During all this time the walls of the chimney had been bathed by a stream of liquid silicates of very high temperature and under considerable pressure, varying with the distance from the surface, &c. Such conditions could hardly be expected to do otherwise than bring about most important chemical changes in the surrounding limestone, so as, in some cases, to replace it by rocks totally different. It is not uncommon to meet with blocks of limestone which have been taken up by a lava-stream as it flowed over the surface, the result of which is that what was a carbonate becomes covered with a shell variable in thickness, but filled with minute crystals of pyroxene and biotite. If such effects can be produced in, at the most, a few weeks, at ordinary atmospheric pressure and lowered temperature, what should we expect to be the condition of the limestone which forms the walls of a volcanic chimney ?

So high, indeed, has been the temperature that sometimes a remnant of limestone in a mass of pyroxenic or other rock had been completely fused, so as to form so many beads covering the walls of the cavity. We know from the experiments of Sir J. Hall on calcic carbonate, that this substance only fuses at very high temperature, and under such pressure as prevents the escape of the carbonic anhydride.

Another example is that of geods of leucite crystals in an altered limestone, rather common among these ejectamenta, which must have, undoubtedly, been deposited by fusion, in addition to which the crystals usually show signs of part refusion. Knowing the very refractory nature of this mineral, we may form some idea at least of the temperature that some of the limestones only slightly altered have undergone.

The earlier eruptions, and especially the first of this Phase, we have shown to have already formed a crater of large dimensions whose apex had reached into the subjacent Tertiary beds, the remnants of which we showed to be commonly mixed with the primary materials. This eruption we have been studying was one of the most violent, if not the most violent, of paroxysms, that had been tearing out the heart of the mountain, and added not a little to extend what had already been accomplished. By re-paring the walls of the crater, it had still more enlarged it, and carried the apex deeper into the sedimentary limestone that formed the base on which reposes the volcano.

Any one who makes himself acquainted with the resulting deposits of this eruption cannot but be astonished at the size and abundance of the blocks of limestone and its derivatives. I measured on one occasion in a section a block of limestone which had a face of 2×3 metres ; and there are many blocks of lava about a metre in diameter, showing with what power they must have been torn off and hurled forth. If we attempt to form a conception of the amount of sedimentary rock that has thus been broken up, we arrive at the conclusion that the crater produced by this paroxysmal eruption must have extended deep into the underlying limestone. It has already been shown that limestone must exist at a considerable depth below the Campanian plain, which is but a few feet above sea-level, and from which this volcano rises. We see, therefore, that this craterial hollow must have extended far below the level of the sea, thus confirming the calculation already derived from the ratio existing between the breadth and depth of a crater.

At the latter part of the eruption, when the expansion of aqueous matter went on more gradually, and the development of the vitreous magma into a crystalline form was complete, the absence of the amorphous base would render the cohesion between the crystals and microliths much feebler, so that, as expansion continued, the whole might be reduced to ash. Even were the cohesion not entirely destroyed, yet we may suppose it to be much reduced, so as to render the mass friable. The explosions, as they became feebler, would no longer hurl the pumice and lapilli beyond the crater-rim, and on falling, they would be reduced to dust by the violent attrition to which they would be subjected. The continual abrasion of each particle would result in dust which, from its lightness, would be all that was carried to any height by the ascending column of vapour, and therefore the only material that could fall on the outer slopes of the cone. It is possible that the pisolitic grains may be due to the falling of the pulverized water derived from the inflow from the sides of the crater below drainage-level and the condensed vapour mixing with this ash either as it fell or afterwards, so as to convert it into a mud or "moya."

From these deposits immediately supporting the products of the Plinian eruption, which is the first true historic outburst of the mountain, we may conclude that this is the last prehistoric one, although there is a kind of legend that may possibly apply to this. Vitruvius * says that, according to history, Vesuvius once burst and covered the environs with its fires, and Diodorus Siculus † reports that Hercules saw Vesuvius, which at that time vomited fire like Etna.

So far as we have gone in the study of the histology of the pumiceous products of Monte Somma, the absence of leucite, either as crystals or microliths, as a component of these vesicular primary or essential materials of paroxysmal eruptive origin, has been very remarkable. Henceforward in all the pumice of similar and analogous deposits leucite plays a very important part as one of the constituents.

PHASE VII., *Period* 1.

The eruption of A.D. 79, *or the Plinian eruption.*

The letters of Pliny the younger to Tacitus, although written half a century after the event, by an unscientific observer, have yet all the appearance of an impartial and correct account of the youthful impressions of an educated Roman. It would be useless to repeat the two letters in their entirety, since they are so well known, and therefore only those passages are quoted that bear directly on our subject. It will be convenient to follow the same order as in discussing earlier eruptions, namely, examination "en gros" and in minute structure, the manner of deposition, and then the comparison of the results with what Pliny records.

Reposing directly on the streets of Pompeii we have about four metres of pumice mixed with many leucilitic lapilli and that same series of ejected metamorphic and other foreign rocks that we see in PHASE VI., *Period* 4. Like that deposit also, the eruptive materials are capable of subdivision into three groups similar to those of the preceding ejectamenta.

The lowest of these is a white light pumice containing a number

* Lib. ii. chap. vi.

† Lib. v. cap. xxi., or 'Histoire naturelle des volcans,' &c., par C. N. Ordinaire, ci-devant chanoine de Riom, Paris, 1802.

of sanidine crystals besides a few of amphibole and garnet. To the unaided eye it is undistinguishable from the equivalent in PHASE VI. *Period* 4.

Microscopical examination.—The sanidine is of the usual kind. The amphibole exists as small crystals and large microliths of the ordinary dark green tint. There are some large well-formed plates of biotite and a good many beautiful hexagonal sepia-coloured microlithic plates of the same mineral, remarkable for their perfection and purity.

Melanite, rather light in colour, occurs in well-formed crystals. In one case there was a melanite crystal traversed by one of amphibole, the prism of which, however, thinned as it approached from either side towards the centre of the garnet, showing that these two minerals were contemporaneous in their growth, although the amphibole had the start. There are a few crystals of pyroxene and also a few microliths.

The most obvious fact that distinguishes this pumice from all we have yet studied is the enormous number of microliths of leucite. These are seen usually as transparent polyhedral sections whose outlines are well marked by the layer of dusty glass that surrounds them. This dusty matter seems from time to time to have increased to such an extent as to impede the regular growth of the crystal, which was compelled as it enlarged to envelope strata of this dusty matter so as to form glass-cavities parallel to the crystalline facets. A few rod-like microliths are often entirely enclosed, or may project from the surface of an individual leucite crystal. The crystals or, more properly, microliths of this mineral are so small that they remain dark between crossed nicols, though a few of the largest examples may, by care, be made to transmit a very feeble grey light, but not strong enough to exhibit the peculiar and characteristic striation of larger crystals of leucite.

The matrix is a clear and colourless glass, very vesicular; the cavities are not uncommonly drawn out into long tubes so as to give a fibrous appearance to the rock.

General Description.—The middle subdivision, or upper of the pumice, is the rather gradual sequent of that we have just described. Towards the upper part, where its special characters are fully developed, the pumice is a very compact brownish or, rarely, greenish grey-coloured rock. It usually encloses many erratic fragments and crystals.

Microscopic Structure.—All the elements that existed in the white pumice, are to be found in this, except that most of the minerals are larger and more extensively developed. The principal difference is in the number of pyroxene crystals and microliths.

The darker colour of the rock is due to the much greater development of the dirty material surrounding the leucite, which seems, under the highest powers, to be composed of minute rods, probably pyroxene, and minute globulites, which may be magnetite partially altered, so giving a brownish tint.

There still remains a considerable quantity of interstitial glass, as all the "formed" materials seem to have collected around the leucites as so many nuclei, which in any but thin sections look like a great number of granular brown balls, crowding one upon another. The vesicularity of the rock is slight, and the cavities, instead of having sweeping outlines, as in the vitreous pumice, are irregular, having to find a place between the leucite and its attendent microliths. In neither of these subdivisions does the leucite attain any considerable size. As already pointed out, these are but artificial subdivisions; just as in other cases, there is not any distinct line of demarcation between them. The upper portion, both to the naked eye and in microscopical structure, is a more highly crystalline condition of the lower.

Superposed in a very abrupt manner upon this thick deposit of pumice is a fine brownish or greyish ash-bed, which forms the third subdivision.

General Description.—It is remarkable for its great richness in pisolites, which are well formed and may reach one or two centimetres in diameter. This pisolitic bed is broken by two thin bands of lapilli, the lower one only separated by a few centimetres from the surface of the pumice, whereas the upper seems to be the last product of the eruption or at least nearly so. The lapilli seem to be of leucilitic lava, mixed with a few fragments of highly microlithic pumice.

This ash-bed, if we may call it so, taken as a whole, is moderately coherent, and must have either been deposited in a moist condition, or have assumed that form very quickly. This is proved by the corpses of some of the fleeing Pompeians which were enveloped in it, which, although they have completely disappeared, have left a perfect hollow mould. Signor Fiorelli has on many occasions been able to reproduce the forms by pouring liquid plaster of Paris into the hollow. The casts prove that the originals were enveloped suddenly; for there are no signs of gaseous distension of the abdomen, which soon results from decomposition.

Remarks.—The subdivisions of the ejectamenta are borne out by the changes that occurred from time to time in the eruptive phenomena. Thus Pliny says, "It [the cloud] appeared sometimes bright, and sometimes dark and spotted, as it was more or less impregnated with earth and cinders." "He was now so nigh the mountain that the cinders, which grew thicker and hotter the nearer he approached, fell into the ships, together with pumice stones and black pieces of burning rock." "They consulted together whether it would be most prudent to trust to the houses, which now shook from side to side with frequent and violent concussions, or to fly to the open fields, where the calcined stones and cinders, though light, indeed, yet fell in large showers and threatened destruction." These quotations from the first epistle show that the earlier part of the eruption consisted of ejection of pumice, stones, &c. (*i. e.* ejected foreign rocks, and leucilitic lapilli); "black pieces of burning rock" also probably refer to these latter materials.

In the second epistle we read this: "Soon afterwards [first or second morning after the departure of the elder Pliny?] the cloud seemed to descend and cover the whole ocean [it probably was the north wind, or tramontana] as it certainly hid the island of Capri and the promontory of Misenum. Soon after they were enveloped in darkness, and a cloud of ashes." "At last this dreadful darkness was dissipated by degrees, like a cloud of smoke; and the real day returned, and soon the sun appeared, though very faintly, as when an eclipse is coming on. Every object that presented itself to our eyes (which were extremely weakened) seemed changed, being covered over with white ashes as with a deep snow." From this we learn that the latter part of the eruption was accompanied by the ejection of ashes.

The size of some of the fragments that fell in Pompeii was occasionally considerable. Sir W. Hamilton mentions* some weighing eight pounds, but remarks that they decrease as we proceed towards Castellamare, a fact we should expect. Large blocks of pumice and lava are commonly to be met with weighing five or six pounds.

It will be remarked that, in general characters, this Plinian deposit resembles very much that described under the heading Phase VI., *Period* 4; so much so in fact as to lead one to correlate them together. We have for instance:—

1st. The pumice capable of two analogous subdivisions quite or at least almost similar.

2nd. The deposit in appearance terminating with a pisolitic ash-bed.

3rd. The similarities in the accessory and accidental components of the ejectamenta, viz. leucilitic lapilli; and the great variety of sedimentary and metamorphic erratics.

4th. The opinions of so many eminent and careful observers as Breislak, Scrope, Daubeny, Scacchi, and a host of others.

Indeed so striking is the resemblance, that up to quite a recent date I fully believed the same myself. When, however, the microscope revealed the enormous abundance of leucite in the Plinian, and its practically total absence in pre-Plinian pumice, with other details of minute structure, and these were superadded to stratigraphical reasons, such preconceived ideas were obliged to give way.

Neither was the conclusion based on only one or two preparations, but sections were prepared from every conceivable variety, and of pumice from many localities.

At the Canale di Arena the deposits of Phase VI., *Period* 4 can be easily recognized, its pisolitic division being well developed. Above this and distinctly superimposed upon it, is a bed of pumice in all respects identical with that covering Pompeii, and with regard to which there seems to be little doubt that they both belong to the same eruption.

In the Lagno di Trocchia, in a section of the valley side at a certain height, may be seen the entombed ruin of a Roman villa reposing on deposits of the pre-Plinian eruption, the pumice of which has been used as a mortar-making material, proving the house to be posterior to that eruption. I have obtained a number of potsherds, bits of

* 'Campi Phlegræi.'

glass and fresco, some tiles, &c. These were submitted to my archæological friend S. Stevens, Esq., of Naples, who pronounces them to belong to a period ranging back at least a century before the Chris-

Fig. 1.—*Section exhibited in the North Bank of the Lagno di Trocchia, Mt. Somma.*

a. Vegetable soil.
b. Alluvial breccia.
c. Black pumiceous scoria. PHASE VII., *Period* 4.
d. Alluvium.
e. Alluvium with potsherds, fragments of glass, tiles, &c.
f. Spongy grey pumice. PHASE VI., *Period* 2.
g. Walls of an old Roman house.

tian era. Naturally such débris can carry no accurate date with them, yet amongst the fragments collected was a piece of a "dolium," or oil-jar, bearing an early inscription which seems to show a farm-house, built about B.C. 150, and probably deserted somewhere near the Christian era or perhaps later. Another bit of evidence of a similar kind, is the foundation of a villa seen in section in the Lagno Genzano, on its western side. The base of these ruined walls and of a cistern (well preserved) is built upon and into the pre-Plinian pumice, but nowhere reach its bottom. The building seems to have been of some importance, if we may judge from the sections of Doric columns scattered about, which are cut out of Nocerine tufa. According to Mr. Stevens's opinion these certainly belong to a period anterior to the Christian era.

We may easily explain the similarity in general features and arrangement of these two distinct deposits, by the conditions under which they were formed and ejected being almost analogous.

We have in the section of the Canale di Arena, overlying the pisolitic bed of Phase VI., *Period* 4, the already mentioned deposits of brown pumice, moderately compact, resembling the upper subdivision of that covering Pompeii even to the minutest details of microscopic structure. It may seem curious that this is the only northern part of Monte Somma where this pumice has yet been met with, and that both the lower subdivision of the pumice and the pisolitic ash-beds are wanting. The two absent subdivisions were the lightest and most capable of transport by the wind, which we know from Pliny's account to have blown somewhere to southwards. We must also remember that the crater had higher walls to the north, so as to prevent to some extent the directing of the ejectamenta on that side. Also the wind reaching the eruptive column at a higher point on the north would impress itself more powerfully on the uprushing materials, there moving at a proportionally diminished speed, so as to direct them towards the south or least resistent side.

That a powerful wind did blow in the direction above indicated is confirmed by the great abundance of pumice, for the most part similar in all details, which is to be found on Monte St. Angelo behind Castellamare. Almost at the summit of this mass of Apennine limestone are extensive deposits of pumice with a few leucilitic lapilli and erratic fragments.

Prof. A. Scacchi * says *à propos* of this :—" But the lapilli ejected in the great eruption of A.D. 79, which entombed Pompeii, and those which, in the direction of Vesuvius and Pompeii, form thick strata on the mountains of Castellamare and Sorrento, are composed in great part of pumice."

That the phenomena of this paroxysmal eruption exhibited extraordinary violence and force, history but too well recounts; yet we are most powerfully impressed with this fact when we encounter large quantities of its products carried a distance of twenty-two kilometres, and there deposited on a mountain which must then have been more than 300 or 400 metres higher than the then existing crater-edge. Nevertheless the ejectamenta of this eruption are comparatively of small volume compared with those of that which preceded it, and it is doubtful whether the already existing crater had more than its bottom cleared out and its walls shaved by the explosions.

Strabo has been often quoted to prove that the summit of the mountain before the Plinian eruption was a plain, which could not possibly have given the peculiar natural protection that Spartacus and his followers sought and found. In fact the words of the great geographer, "Imminet hisce locis Vesuvius mons, agris cinctus optimis, dempto vertice qui magna sui parte planus," may well be understood as a craterial hollow enclosing a large plain and having

* 'Lezioni di geologia,' Napoli, 1843, p. 169, and 'Notizie geologiche dei vulcani della Campania.' (These are the same.)

but one outlet, probably the Fosse Vetrana and Faraone. It is only in this manner that we can reconcile the two descriptions.

According to the opinions of Prof. Palmieri * the Plinian eruption played a most important part in the building up of the modern Vesuvian cone. It is a remarkable fact that very rarely does a paroxysmal eruption terminate in a cone-forming stage, but rather leaves a jagged crater whose sides gradually shelve down to the chimney or vent. Even admitting a cone of considerable size to have been formed, we shall see that subsequent eruptions, and especially that of the fifth century, must have inevitably destroyed it.

This eruption seems to have followed the usual course. It commenced by the sudden explosion and frothing up of the vitreous amphibole-bearing magma. When the tension had been somewhat relieved, the ejection became more regular, and took a longer time to expel a given quantity of material, so that this could undergo a certain amount of crystallization, thus permitting the replacement to a considerable extent of the vitreous base by a microcrystalline one, and increasing the size of the already existing crystals, besides adding pyroxene † to its microliths.

The diminution of force would go on until the pumice and other material would no longer reach the outer slopes of the crater, but would undergo mechanical disintegration by the continual motion to which they would be subjected by the comparatively feeble eruptive action going on in that space. The breaking up of the pumice would be aided by the feebler cohesion among the microliths than between the molecules of the more vitreous examples. The resulting fine ash would be carried by the uprushing column of vapour, to be borne away and deposited as the pisolitic bed. This seems to have fallen as, or soon to have been converted into, a mud by the mingling with the condensed vapour and pulverized water derived from the inflow into the crater and chimney. That this material was a mud when it first reached its present site seems proved by the accurate moulds it took of men and animals before any decomposition had set in. In fact it appears from the Plinian epistle that it was probably this fine material that had such a fatal effect upon the elder Pliny. He was, one would imagine, from the description of him, rather a stout man, whose respiratory and circulatory organs had undergone considerable senile degeneration, so as to be unable to resist what his attendants escaped from.

It has not been considered worth while to go into the long con-

* 'Vesuvio e la sua Storia' and 'Pompei e la regione sotterata dal Vesuvio nell' anno LXXIX.' Napoli, 1879, p. 94.

† This goes to confirm what has been said of the relation between these two allied minerals and the pressure under which they were formed. That they depend upon the different conditions under which they were brought into existence, and the difficulty of the crystallization of amphibole at ordinary pressure, seems well shown by the following experiment: "Nous avons encore produit une andésite augitique en fondant un mélange de 10 parties d'oligoclase et d'une partie d'amphibole; l'amphibole s'est donc transformée en pyroxène." Fouqué et Levy, 'Synthèse des minéraux et des roches,' p. 60.

troversy that arose (and was supported by Pilla, Tondi, Tenore) as to the aqueous deposition of the pumice, &c., which envelops Pompeii; the whole of the arguments in favour of this view being cleverly refuted by Prof. A. Scacchi. An abstract account may be found in Lyell's 'Principles' and in some original papers of Scacchi *.

So far we have said little of Herculaneum. The lower part of the tufa that covers this city seems to have fallen from the air in the same manner as at Pompeii, and only to have been enveloped in the mud at a later period of the eruption. How it was that such an enormous deposit of "lava d'acqua," as it is locally called, collected at this particular spot, is a somewhat difficult question to answer; there may have been above the town the lower extremity of some considerable vallone which may have collected the mud, and directed it upon the doomed city. In the chapter on denudation, it is shown what a sharp shower of rain can do in the way of transporting materials; but when we consider the enormous amount of vapour arising from one of these paroxysmal eruptions mixed with falling and loose pumice, we are aided in the comprehension of this somewhat extraordinary phenomenon.

As this eruption is really the first one distinctly recorded in history, and as its pumice is characterized by the presence of leucite in great abundance, I have thought it convenient to group it with others its direct successors, under the head of Phase VII., all of them being rich in microliths and crystals of leucite as components of the primary or essential material. This leucitic condition of the pumice is a character of no little importance in the study of the formation of volcanic rocks. Messrs. Fouqué and Lévy †, in making a leucotephrite, found that the leucite crystallized at a white heat, but they had to reduce the crucible to a red heat before the felspar separated out.

We must suppose that the magma that gave rise to this eruption had by the gradual escape of heat undergone the crystallization of its leucite, since this mineral does not seem to have increased in size or number from the very beginning to the end of the eruption. We should therefore expect the temperature to have been lower than on former occasions, when the sudden ejection and cooling prevented the development of this mineral.

The experiment of the artificial formation of rocks is thoroughly borne out, when it is stated that the felspar would only crystallize at a red heat, since of all the minerals it seems to be one of the last formed in the pumice, being later than amphibole, magnetite, biotite, and pyroxene in some cases. There is a fact, however, that is hardly reconcilable with the above-mentioned relation of the two minerals under discussion. In a later eruption a rock was ejected in which the leucites may be as large as walnuts, and often partly or entirely envelop large crystals of sanidine and pyroxene.

It seems to me that prolonged "recuite" at ordinary atmospheric

* "Osservazioni critiche sulla maniera come fu seppelita l' antica Pompei," and "Bollettino archeologico Napolitano," no. vi. Marzo, 1843.

† 'Synthèse des minéraux et des roches,' p. 65.

pressure was most favourable to its development, if we may judge from subsequent eruptions.

PHASE VII., *Period* 2.

General Description.—Reposing upon the pumice that we have considered as Plinian, we may see in the section of the Canale di Arena about a metre of yellowish-grey pumiceous lapilli. The primary material consists of, ordinarily, a yellowish or brownish-grey pumice, graduating from a moderately spongy to a very compact texture. A considerable number of crystals of biotite, amphibole, sanidine, and leucite are scattered throughout the mass. The last of these minerals occurs in irregular and impure crystals, ranging from a centimetre in diameter downwards, which, in the more compact fragments, are very abundant. The pumice graduates into a porphyritic rock exactly similar to that described amongst the ejected blocks of the pre-Plinian eruption (PHASE VI., *Period* 4), except that in this case the porphyritically enclosed sanidine is, to a great extent, replaced by crystals of leucite. This rock seems to bear the same relation to the pumice of this *period* as does its earlier analogue to the corresponding pumice.

The primary material is exceedingly rich in enclosed fragments of secondary and tertiary erratics.

Microscopic Examination.—Amphibole, pyroxene, sanidine, garnet, and biotite, all occur in well-formed crystals, having all the characters of the same minerals in earlier ejectamenta. Their relative abundance is in the order in which they are placed above, the amphibole (?) * being the most common.

The leucite occurs as very pellucid crystals, except where traversed by long slender microlithic rods and a few cavities. Occasionally enclosed within the leucite is a well-formed crystal of amphibole. The large leucites are the only ones that exhibit the optical properties of that mineral in polarized light, but they do so to perfection.

Sometimes one meets with patches of an intimate interlacement of amphibole, garnet, and magnetite.

Besides the large and well-developed light-green crystals of pyroxene there are a considerable number of large microliths, or perhaps more properly, small crystals of that mineral. They are light-green rod-like prisms, fairly well terminated. The leucite microliths are somewhat larger than those of the Plinian eruption, and are in such profusion that they are as closely packed together as they can be, only the interspaces being filled by a greenish or brownish mass. This interstitial substance is composed of minute microliths, or belonites and globulites; the former are of doubtful character, but, by analogy, we may refer the globulites to magnetite, though their minuteness prevents one getting a clear sight of any individuals, even under the highest powers.

There would seem to be a small and variable quantity of vitreous base, according to the extent of formed material that in any speci-

* I am not quite sure about the determination of this mineral.

men has been separated out. The large crystals of leucite are excessively rich in minute glass-cavities; a few, however, are large, and may contain as many as six or more vacuoles.

Very long and slender microlithic rods traverse the crystal in every direction, the larger of which seem to be amphibole. The microliths and small amphibole crystals often traverse large cavities of glass of slightly brown colour, which may at the same time contain vacuoles.

Remarks.—The rock under consideration is the more highly crystalline successor of that of the Plinian eruption. The structure is much the same, except that each component has been carried to a much higher state of development, so that the leucite, for instance, has passed from the microlithic state to crystals of considerable dimensions. The facts would lead us to conclude that the igneous matter has been exposed for a time, before its ejection, to exactly the same conditions as its predecessor. If we judge by the limited distribution of this deposit, the eruption that ejected it could not have been a very forcible one.

After the Plinian eruption had terminated, the crater, as is always the case, became partly filled up by the crumbling in of its walls, so as to form a plain over its bottom. This we are led to conclude from what is generally known to follow a paroxysmal eruption, and certainly is confirmed by the account of Galen *, of which Prof. Phillips † remarks, "From this account we may conclude that nothing like the modern cone of Vesuvius existed."

The result of such an eruption as the present, bursting through the crater-plain, and being so feeble that with difficulty it hoisted its products only just sufficiently to deposit a portion on the great crater-rim, would be to build up a cone or crater-ring around its own vent. Such a cone of eruption would be a representative of the present Vesuvius, but was, no doubt, in part, if not wholly, destroyed by the great eruption of A.D. 472.

This eruption, immediately subsequent to that of A.D. 79, so far as stratigraphical evidence is afforded, would correspond with that recorded by Dion Cassius and Galen to have happened in the year 203, and to have continued for eight days.

Phase VII., *Period* 3.

General Description.—Reposing upon the deposit of pumice just described we see, in the section of the Canale di Arena, $2\frac{1}{2}$ metres of coarse breccia, composed of large blocks of lava and lapilli. This is interlaminated at various points by bands of a pumice, to all intents and purposes undistinguishable from the last, except perhaps by a slightly more perfected development of formed materials, besides larger crystallization; but the actual measure of this can hardly be obtained, except as a rough appreciation.

It is interesting to notice that many of the larger blocks of lava contain various zeolites, probably as the result of their exposure in

* Lib. xvi. † 'Vesuvius,' p. 41.

the bottom of the crater to the suitable conditions for the deposition of that group of hydrous silicates, before they were ejected.

Remarks.—From various authorities we learn that there were eruptions during the years A.D. 243, 305, and 321, of a feeble type. These are probably represented by the pumiceous breccia; but from the absence of any unconformability or variation of structure between one part of the deposit and another, it is quite impossible to know whether this may represent one or all of these eruptive phases. At any rate we may suppose that they added their ejectamenta principally to swell the cone of eruption forming at the bottom of the great crater.

PHASE VII., *Period* 4.

General Description.—The next in order in the section of the Canale di Arena is a bed about a metre in thickness. It consists principally of masses of black pumiceous scoria, loose fragments of large leucite crystals, a few leucilitic lapilli, and foreign metamorphic and other rocks, overlain by a metre of coarse breccia.

Around the foot of the mountain are very extensive deposits of this eruption. For example, all the valloni or lagni between the Fossa Faraone and the Lagno di Trocchia usually show in their sections thick accumulations of these scoriaceous materials, mixed with much sand and dust of the same origin. In the Lagno di Pollena we observe that these materials have completely filled the old valley that now lies to the south of the present one, where their thickness is 10 metres or more.

Patches occur in this section where the surface at least has changed colour to a brown, owing to the higher oxidation and hydration of the magnetite. The materials are also very subject to consolidation *en masse* by the infiltration of calcareous matter; their consequent resistance to denudation plays some part in modifying the superficial features of that portion of the mountain where they are found.

The south and west slopes of Monte Somma, although not showing this deposit in sections, which are nearly absent, nevertheless where the mountain is left uncovered by lava-streams, present many loose fragments belonging to it collected together in the garden stone-heaps or employed for wall-building.

This scoria may be detected all over the mountain, but seems not to be abundant west of a line drawn from north-west to south-east.

The scoria, which still retains a slight pumiceous facies about it, is a heavy and fairly compact rock, but very ragged, and containing many irregular cavities, which may be partly occupied by a leucite crystal or fragment of some rock caught up in the plastic mass. The surface presents an irregular corded and denser coat.

The size is very variable, but pieces some pounds in weight are exceedingly common, and still larger ones are not rare. I lately broke up a block that must have weighed 60 or 70 kilogrammes, and which yielded over a hundred fine crystals of leucite more than one centimetre in diameter. One splendid crystal, measuring three centimetres across, was perfect, being free from fracture or interpenetration of other individuals, and is one of the finest specimens yielded by this volcano. The leucite is rarely pure, and often encloses crystals of amphibole or pyroxene: others partly or entirely envelop large crystals of sanidine, showing that here the leucite was formed later than the felspar. One may shell off from some individuals a coat of variable thickness, leaving an exact model on a smaller scale in the nucleus, the line of separation being generally a stratum of glass-cavities or microliths, the whole reminding one of the so-called capped quartz. So abundant are these zones of impurities that the crystals break with great ease along these planes, giving a pseudo-cleavage parallel to the crystalline facets. The most interesting facts to the geologist are the evidence this mineral affords of the great churning and oscillation of temperature that the viscous magma must have undergone. As already mentioned, most of the crystals are broken, others show partial repair, whilst others again have been in part re-fused, so that their angles and edges are all rounded. We may also find crystals fractured and the pieces only slightly displaced from one another; in other cases the crystal is crushed and flattened out as the result of compression in an almost solidified condition of the matrix. The most interesting examples are crystals in which all the crystalline edges and angles have been removed so as to reduce the crystal to a sphere or agglomeration of spheres.

Large crystals of sanidine and pyroxene, and plates of biotite may be easily seen by the naked eye, besides a few grains of olivine.

Microscopical Examination.—The leucite shows to perfection its special optical properties between crossed nicols. Besides the enclosures of other minerals, there are a vast number of glass-cavities, some of which are very remarkable. One of fusiform shape had projecting into it from its extremities two microliths, placed in the same line with each other, but their two extremities separated a certain distance. Near the end of each of these rods was a vacuole in the clear light sepia-coloured glass.

The pyroxene is usually very well formed, though it may be much broken. It is usually of a light-green colour, though there is every shade between white and very dark green, and we may see many crystals enveloped in a darker coat than their interior. The resemblance of the darker specimens of this mineral to amphibole is such that in many cases it is almost impossible to distinguish them. The peculiar variation in colour of the pyroxene is not an uncommon thing, and is well seen in the same mineral from other localities, such, for instance, as the beautiful prisms from Tyrol.

The biotite has the usual colour and character. The plates are often torn asunder, or twisted in various manners. Where a crystal has its plane of cleavage perpendicular to the plane of the section the plates may be seen to have been ruffled and frayed up, and pleated and folded back, showing the kneading action to which the semiviscid or plastic mass must have been subjected. Melanite and magnetite both occur in large and pretty well formed crystals.

The microliths of leucite are difficult to obtain a clear view of; they appear more irregular in form than is generally the case.

This obscuration is due to a dark brownish-green granular material that seems to be composed of broken-up microliths of pyroxene added to a considerable number of irregular ones of magnetite. The blackish colour of this scoria seems to depend on this abundance of magnetite and pyroxene in a dusty form, just as in its analogue of Phase III., *Period* 2.

The microscopic inclusions of foreign matters are even more common than the macroscopic.

Remarks.—The year A.D. 471 or 472 witnessed one of the most terrible of historic eruptions, almost rivalling that of A.D. 79. It is said that ashes fell in various parts of Europe, and even terrified the people of Constantinople, to which city some ashes reached. The eruption is said to have continued for three or four years.

This record seems to correspond exactly with what it would lead us to expect to find in the characters of the ejectamenta, which seem to show signs of long duration.

It appears that the structure and composition of these scoriaceous pumices show that the mass was kept boiling up for some time, so as to allow of the formation of the large leucite and other crystals. At the same time the magma gradually lost its essential volatile components, and was by degrees reduced in temperature; for the evidence of fracture of the crystals, pulverization of the microliths, and envelopment of fragments of other rocks, shows that for a long time the mass was kept in a continual state of movement. Those portions that were already cooled would be ground and pulverized in the crater by the continual explosions, affording those ash-showers that disturbed the peace of Europe. From time to time the solid or still plastic masses were ejected so as to fall on the outer slopes of the cone, on which, during a period of three years, were accumulated those not unimportant deposits already spoken of.

Whether this eruption was, at its commencement, sufficiently violent to have destroyed the cone which had been formed by the small eruptions between A.D. 79 and its date, it is difficult to decide; but there seems little doubt that this one, especially during its feebler spasms, did much to add to the crater-plain and raised up on it a cone of eruption of very considerable dimensions. This was probably the most important contribution to the foundation of the present Vesuvian cone. Of course an exact appreciation of the amount of filling of the crater by the products of this eruption is impossible; nevertheless I am inclined to the opinion that this did much more than any other eruption during the first ten centuries. This opinion is based, first, upon the comparatively feeble but prolonged character of this eruptive period; and secondly, upon the large amount of material ejected compared to that derived from others during that epoch.

The igneous magma seems to have originally been moderately rich in aqueous matter, sufficiently so, at any rate, to prevent any thing like true lava issuing, unless such streams did not reach beyond the

Atrio del Cavallo or great crater, which must then have been an annular valley. Neither does the appearance of the ejectamenta denote them to have been associated with lava.

This bed, of no inconsiderable thickness, is seen to cover over alluvial breccia of earlier but uncertain date, in which is enveloped the Roman house we have described (p. 87) as occurring in the Lagno di Trocchia.

Phase VII., *Period* 5.

General Description.—Superposed on the black pumiceous scoria at the Canale di Arena are about two metres of another scoria in small fragments, ranging from the size of a hazel-nut to that of a walnut. The pieces are exceedingly light and spongy, being filled with large cellular cavities, having smooth glossy black shining walls, giving to the deposit a recent appearance, quite obsidian-like at a short distance, and entirely different from any of its predecessors. Sometimes a slight rusty crust has been formed, giving the bed a dark brown or yellowish tint.

There is totally absent any thing but the primary or essential eruptive material. Interstratified are two thin bands of a fine pinkish coarse sand, which seems to be composed chiefly of isolated and rounded crystals, with fragments of rock-particles abraded in the usual manner. These are mixed and covered with a fine pinkish dust, the result of the powerful and continuous attrition to which they had been subjected. Overlying these materials we have a thin bed of yellow-brown dusty matter, of about 30 centimetres thickness.

These peculiar deposits, from their position and facility of recognition, can be traced at many parts of the mountain. They form a mantle over nearly all the upper part of the northern slope, especially where vegetation has helped to retain them in their present position. They may be well seen in the section of the Valloni Pietri Pomice and St. Patrizio on the north; and I have recognized the same materials from a well sunk in the quarry of, and beneath, the lava of A.D. 1631, near Camaldoli della Torre, on the south.

Microscopical Examination.—The crystalline element that reaches greatest development as regards size is the pyroxene. It is of a very light pea-green colour, enclosed in an outer coat of uniform thickness of the same matter, but of a much darker tint, the separation between the two being usually very distinct and well marked. Wedding remarked the same thing in some Vesuvian lavas; and the same was seen to occur in the products of the preceding eruption. There are usually many and large enclosures of a very granular dusty brown glass.

Next in abundance are beautifully pure and well-formed large crystals of biotite, highly polychroic, ranging from an ochre tint to black.

Forming a most important constituent of the rock, but rarely, if ever, reaching beyond the size of microscopic crystals, is the leucite. This mineral, from its small size, rarely transmits light between crossed nicols, neither is it very rich in inclusions, which, when present, consist more of glass-cavities than microliths. The mineral is easily recognized by the beautiful neatness with which we may see all the crystalline edges by focussing up and down, aided by the purity of the glassy base in which the leucite is imbedded.

A very few well-formed sanidine crystals occur, especially upon and in the neighbourhood of the pyroxene.

There are two distinct varieties of microliths. The first are neat, sharp-cut, but rather small rods, which seem to be principally, if not all, pyroxene. Six carefully checked measurements gave an average angle of extinction of $37\frac{1}{3}°$. It is possible that of the smaller microliths some may be felspar.

Scattered about, but more especially collected into clouds, are minute crystals of a mineral identical with what we have already described as probably magnetite. The more perfect ones show under a high power a six-sided outline, almost without exception; now such could hardly be derived from any other form than a rhombic dodecahedron; for hexagonal plates, as biotite, or prisms, as nepheline or other minerals of the same system, give sections very variable in form, according to the plane of the slice in relation to the crystal. So far as can be judged from their small size, they are uniaxial; the question of choice therefore lies between garnet, titaniferous iron, and magnetite. Their great abundance, their peculiar gregarious arrangement, and their occupying the exact relative distribution that magnetite does in similar rocks, certainly points to that mineral, though the dodecahedron is rare, and the red light transmitted resembles somewhat that of melanite. We have already shown a similar mineral to exist in earlier ejectamenta in which there is little doubt of its constitution. It might be confused with hæmatite, but that mineral usually lines the cavities of a scoria, and is not, as in the present case, enveloped in a glassy base, from which it has crystallized. Besides, this mineral forms more irregular crystals, both in form and size, and the colour is much redder. Sodalite is another mineral not uncommon as a product of sublimation (?), lining cavities in Vesuvian lava, but is rare in the rock mass, and then is of very light colour, if not transparent. This dubious mineral is, as we have already seen, not an uncommon component of pumice &c.

Although the perfect crystalline condition we have described is not uncommon, yet the mineral is usually to be seen in the form of six-rayed stars, or in the shape of those spiked balls used in ancient warfare, and with which the representations of Gog and Magog are armed. This seems to be due to imperfect development, similar to the hollow crystals of halite, bismuth, &c. In this condition each individual is nearly opaque, and we can trace the mineral into granular masses that are quite so.

The whole of these minerals are enveloped in a very pure glass of dark sepia-colour, which is very abundant. The spongy nature of the mass is due to the great abundance of large vesicular cavities: whereas the numerous minute ones characteristic of pumice, or even of pumiceous scoria, are entirely absent, making a distinctive difference between pumice and scoria.

Remarks.—The continual vomiting forth of igneous matters in rapid succession, as occurred in the first four centuries of the Christian era, must have expelled all that which had occupied the chimney or conduits, and replaced it by new material. The short time that this new igneous magma would be exposed to hydrating influences would reduce its heat but slightly, and increase its expansive power but very little. The result would be a more tranquil state of eruption, slower loss of heat, together with an absence of that minute vesicular structure due to the interstitial or intermolecular conversion of aqueous matter into vapour. Such a temperature, with the slight tendency to be broken up by elastic fluids, would render possible, or at least be favourable to, the outflow of lava. As a result of the above conditions, the fragments of scum blown out would have only a coarse cellular structure, and might be very vitreous, from the sudden cooling of a material having a very high temperature.

Such seems to have been the case in the present instance. At times the eruptive action was so feeble that it ground up the loose stones of the crater-walls, and, adding some of its own solidified material, simply from time to time expelled the pink sandy lapilli that we see forming bands in the scoria.

A somewhat similar state of things has been very common at Vesuvius lately, when in a moderately tranquil eruptive condition, as we may there see ejectamenta that approach to a certain extent that which we have been describing.

In the eruption of the year A.D. 512 lava is said to have flowed, but it is not stated whether it was down the slopes of the mountain or within the great crater of the atrio, which it probably was occupied in filling up.

So great was the damage done by the ashes and cinders that Theodoric*, the Gothic king, condoned the taxes in the injured districts.

The information given us by the deposits we have just described agrees in many particulars with the records of the eruption of the sixth century. Procopius, who also chronicled this outburst, describes distinctly a deep crater, nearly reaching to the bottom of the mountain, in which could be seen lava boiling up. Such a condition proves, first, little or no cone of Vesuvius, and, secondly, that the eruption could not be classed as of paroxysmal type. Probably the form of the interior of the mountain was terraced, that is, it had two concentric craters, divided by a low annular cone or plain.

Phase VII., *Period* 6.

The last of the deposits exhibited at the Canale di Arena, except lapilli and ash from very recent eruptions, is a bed of about $1\frac{1}{2}$ metre in thickness. It is composed of highly crystalline pumice, remark-

* 'History of the Gothic Wars,' transl. H. Holcroft, 1653, book ii. chap iv.

able for the perfection of the constituent minerals, especially the leucite, which often attains very large dimensions.

The primary or pumiceous materials consist of fragments very variable in size, and forming about half the deposit, the rest being made up of leucilitic lapilli and foreign rocks. These latter occur in considerable abundance, and sometimes as moderately large blocks. Their origin is, no doubt, the same as that of those of the pre-Plinian eruption, and to the casual observer they appear to be similar. A careful examination of a large quantity of them, and their mineral contents, shows them to be richer in some, and at the same time to abound in certain species, at the expense of others common in similar materials of earlier date. Thus these minerals, common in the pre-Plinian eruption, are replaced to a large extent by those given in the second column.

Pre-Plinian *.	Phase VII., *Period* 6.
Meionite	Mizzonite and sarcolite.
Anorthite	Nepheline. Sodalite. Hauÿne. Lapis lazuli.
Pyroxene	Spinel (black).
Sanidine	Leucite.
Amphibole	Pyroxene.

This list shows a certain relation between the two sets of minerals, but it is difficult to draw any definite conclusion therefrom, until our knowledge of the chemical relations of these minerals to the variety of igneous ejectamenta is much more extended. Nevertheless the great abundance of hauÿne, lapis lazuli, and nepheline in foreign blocks, associated with a primary material rich in well-crystallized leucite, is worth thinking over when we remember the close relationship of these mineral species. Their comparative rarity in the other deposit, where leucite is almost, if not entirely, absent, adds still more force to the fact. Although such an interesting relationship may light up in our thoughts a slight glimmer of some important speculations, it is safer to be patient until we have a more solid foundation to build upon, and our materials are more clearly worked out and arranged. Before leaving the subject, perhaps one other fact may be simply mentioned with regard to the replacement of pyroxene and spinel. Messrs. Fouqué and Lévy †, in making a nephelinite, fused 3 parts of nepheline and 1·3 of augite together, and obtained the same minerals. When they diminished the dose of augite, they got fine crystals of nepheline, little crystals of spinel, and brown dodecahedra of garnet (melanite).

* These are the general observations of the author, who has broken up many hundreds of ejected blocks from both eruptions. It must be remarked, however, that there is only a prevalence; for all these species may be obtained from either deposit with more or less difficulty. No accurate statement can be made; the above, therefore, is only the expression of an opinion derived by experience, and confirms the mineral-hunters' dicta as to certain species being found in certain localities.

† 'Synthèse des minéraux et des roches,' p. 60.

Let us now direct our attention to the primary material and its

Microscopical Structure.—The most remarkable are the leucite crystals, which are moderately pure, though they do contain amphibole and pyroxene, besides glass-cavities.

Next are a large number of crystals that might at first be taken for amphibole from their dark colour and considerable polychroism; but the measurements of the angles of prism-sections show them to be pyroxene. There are others that are undoubtedly amphibole; but there are many that, from want of sufficient evidence, remain undetermined. The colour is very variable, ranging from white to dark green, or the crystals may have a nucleus different from the exterior. The amount of cleavage is also most variable. Besides these doubtful ones are other large crystals of lighter colour, covered with a darker coat, about which there can exist no suspicion. The size of all these is most variable, ranging from large macroscropic crystals down to minute microliths. The inclusions are chiefly magnetite and glass-cavities. One peculiarity about the larger crystals is the extremely flecky appearance that they possess, the cause of which is not very evident. This irregularity may be confined to the central portion of the crystal, whilst the external part is clear, and shows fine striations or lines of accretion parallel to the crystalline faces. The light transmitted by the prisms of pyroxene at right angles to the principal axis is a pure green; whereas, seen in transverse section, the light being parallel to the principal axis, it has a brown tint.

Biotite occurs in well-formed and characteristic crystals of large size.

Sanidine is abundant in large, well-formed, or broken crystals. They are remarkable for their dirty state, and showing a minute parallel striation. Other examples present an irregularly flecked interior, enclosed in a laminated and clearer coat or shell, similar to those in the pumice of Phase VI., *Period* 2. The dirty appearance is chiefly due to a number of glass-inclusions. The mineral may also envelop pyroxene or amphibole.

There are large, perfect crystals, hexagonal in outline, either of magnetite or titaniferous iron.

There are a few crystals that seem like idocrase, but, from their want of certain characters, and the fact that this mineral is usually of metamorphic origin, it is wise to examine more specimens before coming to any decision.

The microliths are of leucite, pyroxene, biotite, sanidine, and magnetite. The last is seen in minute microcrystals of hexagonal and quadrangular outlines of a blood-red colour, showing the true nature of the mineral that has already been discussed as somewhat problematical.

There remains usually a small quantity of dusty glassy base. The rock is, as a whole, very slightly porous, and in some cases remarkably compact.

Remarks.—This pumice is unique among all those we have studied for the remarkable development and perfection of its crystalline structure. In size, each component mineral species is gigantic compared with what it usually is in other cases.

The histology of the component minerals and the mass itself seems to point to a somewhat feeble paroxysmal eruption, that is to say, one in which the ejection was sufficiently slow to allow of the great development of the formed matter. Yet at the same time we must remember that it was violent enough to tear out a large cavity deep enough to reach the underlying limestone of the volcanic floor. There is little doubt that a considerable part of the cone that had been built up by former eruptions must have been gutted, leaving a craterial hollow in the great crater-plain, so as to form a terraced depression.

To what date does this eruption belong?

In the year 1036 occurred one of the historic eruptions of this famous volcano, but as large streams of lava are said to have flowed down the sides of the mountain, this would not suit the character of the ejectamenta. These may therefore be, in all probability, referred to one of the two eruptions said to have occurred in the years A.D. 685 and 993, but of which we have no details.

This is the last deposit that has, so far, been discovered of which there is any possibility of determining the date, except the modern lava-flows, or of any ejectamenta that have the pumiceous type of structure.

All these beds we have been describing are at various points overlain by dense scoria, lapilli, and lavas undistinguishable from the products that are at present constantly ejected from Vesuvius.

All the eruptions, 1036–1038, 1049, 1138–1139, 1306, 1500, 1568, from what we know of them, seem to have been semi- or non-paroxysmal in type. It appears that, with the exception of one or two, no lava is mentioned as being derived from them. This hardly excludes the overflow of lava; and we must rather regard it as finding its way into the atrio, and filling up the space around the base of the cone of eruption within the great crater-wall. At the same time the cone of eruption increased, and was raised by the direct deposition of new ejectamenta upon its outer surface, or was from time to time gutted, having its interior broken up to form a crater, the materials being spread over its slopes.

From the description of Sorrentino, it appears that, before the eruption of 1631, in descending into the great crater one arrived at a plain; then, after traversing woods, another craterial hollow was seen, the bottom of which was occupied by some warm lakes.

The great eruption of 1631 may be looked upon as the first of that wavering but continuous action that has continued uninterruptedly to the present time, and which seems to be identical in character with that permanent activity which gave birth to the earliest lavas we know as issuing from this volcano.

Overlying the deposits of Phase VI., *Period* 4, often inseparable from, or appearing to be continuous with, the pisolitic bed, comes a series of materials that may even reach 80 metres in thickness. They are seen in greatest abundance around the foot of the mountain, and rarely extend in any thickness above and beyond the junctions of a lagno and vallone.

This deposit is of the most varied type, ranging from the coarsest breccia to the finest ash, or from a collection of pumice to a bed of rounded leucilitic lapilli. The arrangement may show great false-bedding or long parallel strata, which are often most misleading. In the Valloni Grande and di Pollena one may recognize the Plinian pumice forming the lower part of these deposits, but having the appearance of having been transported and rounded by water, so as to resemble very much some of the tufa over Herculaneum.

This more or less variable agglomerate of different materials is usually broken near its middle by the thick bed of black pumiceous scoria of PHASE VII. It is occasionally possible to recognize remnants of products from other eruptions of the same PHASE.

Any one who follows the road that winds round the foot of the mountain from St. Giovanni di Teducio to St. Anastasia will be strongly impressed by the wayside sections. These are rarely more than two metres in thickness, the upper third being disturbed vegetable soil, whilst the lower limit is not visible. Beneath the top soil are fine undulating laminæ, which may be traced for very long distances. As we enter the town of St. Anastasia, there may be seen a series of alternations of fine dusty tufa with beds of coarser materials, some remarkably crumpled or undulating in arrangement.

No one seeing these beds would regard them otherwise than as the result of gradual aqueous deposition. I have examined them over and over again, with the hope of finding some organic remains, but without a shadow of success; nevertheless their remarkable stratigraphical characters certainly seem to make one require other means than simple alluvial deposition.

In a few cases it has been possible to show that these deposits immediately follow the end of PHASE VI. It is therefore possible that some very important changes of level took place between the last prehistoric outburst and the Plinian eruption. Of this no historic evidence is known to us, and therefore we are left without any sound facts from which we could safely arrive at a conclusion either way. It is, however, to be hoped that something will crop up to decide so interesting a question, such as the finding of organic remains or antiquities.

If we should really find these tufas to be of marine origin, they will prove that, at no distant epoch, Vesuvius was an island, and that almost, if not really, in historic times the sea surrounded the greater part of its base.

Let us now return to those deposits of the same age that are found at a higher level, and of whose origin there is no doubt. They are, as already pointed out, most variable in composition, necessarily depending on the rocks from which they were derived. So much is this the case that, where the origin has not been mixed, the re-sorted lapilli or pumice may easily mislead an observer into error and trouble by showing an apparent reversal of order; and there are examples that require the most careful examination. When these materials are very fine, they may enclose organic remains, chiefly vegetable structures.

At the Fontana Olivello and the Lagno di Trocchia, where these tufas can be seen to great advantage, trunks of trees, leaves, and fruits are preserved. If we follow the galleries cut into this rock for the collection of water at the first-mentioned locality, we may observe a great number of hollow tubes branching out from the passages in all directions. A careful examination of the surface of these shows markings derived from the mould taken by the mud enveloping the bark on the trunks of trees that once filled these hollows. The only remnants of woody structure now left consist of a little brownish powdery lignite, which, squeezed in the hand, leaves a dirty brown slimy mud. By breaking up the friable tufa we may obtain impressions of leaves and, rarely, land-snails.

Between Cercola and St. Sebastiano, in the midst of the 1872 lava, a quarry has been opened in similar deposits, which are used as pozzolana for mortar-making. Lately I saw a house which had apparently been enveloped in this material, for the roof was still intact. A remarkable fact was the almost complete carbonization of the wood used in the construction, as if it had been burnt, and not lignitized. The same state of carbonization is observable at Herculaneum and Pompeii and elsewhere, where the wood had been seasoned and dried, as it would be, in the walls or ceilings of a house. It would therefore seem probable that dry and wet (*i. e.* green) wood would conduct themselves quite differently when exposed to almost similar conditions, as at the Olivello and Cercola, where both were enveloped in mud.

The fragments of carbonized trees and their branches, which are commonly met with amongst the pumice, probably owe their state to partial burning when enveloped by the hot lapilli, since we sometimes find intermediate stages.

From the fact that in the lower subdivision of these tufas we may recognize part of the Plinian pumice, and from the frequent occurrence of a band similar in character to the band of compact pumice and lapilli in the pisolitic tufa above Pompeii, it seems, therefore, quite reasonable to suppose that a large part of the deposit below the black pumiceous scoria is referable to the mud formed from and during the Plinian eruption, as at Herculaneum.

III. *Denudation.*

Agencies.—One of the most striking features of the outer surface of Monte Somma is the number of valleys scoring its slopes, presenting to the observer from a distance, and also in the immediate vicinity, a type of scenery quite unique. This is dependent upon the valleys differing, both in form and size, from their equivalents found on other volcanoes of Italy and elsewhere, which we shall see to be due to the variation of the rocks that enter into their composition.

From the point of physical geography we may divide these deposits into two great groups dependent on their characters as rock-forming materials, and on their resistance to denuding influences. The first of these, both in point of age, density, and durability, are the lavas and scoriæ of the ancient active volcano. As a rule, the most spongy of lapilli and scoriæ have a specific gravity above 2, and are often so closely blended together, either by pressure, decomposition, or the infiltration of calcareous matter, as to be rendered capable of resisting the disintegrating subaerial influences. Even were this not the case, the great openness of structure *en masse* would allow the water to sink by the interspaces between each fragment and its fellow, and to gradually issue at a lower level in the form of springs, instead of rushing impetuously over the surface, and carrying materials away with it in its course to lower levels.

The lavas, again, are threaded through and through with contraction-jointage, but are so irregular, that one piece is as it were dovetailed into its fellow, so that we are often struck with the amount of molecular erosion that has gone on at the surface without being able to break up a comparatively thin flow.

When, however, we come to consider the other group of materials which overlie the first, that is to say, the pumiceous tufas and ash-beds, the products ejected during the paroxysmal phases, characters are detected quite opposite to those of the first series of deposits. Loosely thrown together, with little or no binding material, fine dust often prevailing over larger fragments, we have large quantities of pumiceous rocks that, taken in mass, are much lighter than water. Again, owing to the much closer texture of the ash-beds, they offer greater resistance to water-sinkage, although readily becoming saturated and again giving up their water and drying. It is just these characters that account for the incredibly rapid denudation going on, so that we can actually measure differences from month to month.

The average rain-fall at the Vesuvian Observatory is 780 millimetres. This, although not a very extraordinary quantity, produces very evident effects by the manner in which it falls. For instance, not a drop may make its appearance for two or three months, followed sooner or later by a downpour, lasting from twelve to thirty-six or more hours, and having quite a tropical character. This large mass of water falling on the mountain slopes must necessarily be rapidly got rid of.

The first thing, of course, will be to saturate the tufas; this accomplished, they may be considered as practically impermeable, at any rate to such a large bulk of water as is suddenly poured upon them. This is aided also by the vegetation, which is much richer on these pumiceous deposits. The water must therefore run over the surface, which, being highly inclined, gives to that liquid great rapidity of motion. The pumice, from its lightness, is rapidly swept along, leaving the denser lava-fragments without support, and these therefore are obliged to follow. When the current is deep enough, especially in the bottom of the gorges, a curious spectacle often presents itself, namely, a moving river of stones; that is to say, the pumice floating along on the top of the torrent. If we think over the effect of such a stream, we may well comprehend its transporting power; for although the pumice is lighter than water, the impulse with which it strikes and presses upon obstructing objects, is far greater than that of the fluid which supports it, which divides and finds its way around the obstruction. The effects are analogous to the destructive action of floating bodies, such as ice, on the piers of bridges. The wearing action of this floating pumice is such that where a fine-grained lava-stream forms the floor of a valley, its substance is eroded into peculiarly-shaped cavities with rounded sides, so polished as to appear like the result of glacial action, or even the handiwork of a lapidary.

Little undergrowth or grass exists on the middle and upper parts of the mountain, so that aqueous action can have full play. To this must be added other denuding influences, and amongst them we will first discuss that of ice.

In the months of December, January, February, and March, frost is rarely absent during the night, which arises from the northern aspect of most of the great valleys. Besides this, the great amount of evaporation brought about as the result of the porosity of the rocks, the currents of air sweeping along the valley, and the little sunshine that enters them, combine to produce a very low temperature.

The ice, by its expansion as it forms, splits the lavas and scoriæ, and separates large crusts from the damp tufa escarpments, exposing fresh surfaces, to be, in their turn, submitted to the same action. Not only does it destroy lava-currents, by separating them in blocks, but those especially containing large leucite crystals are molecularly broken up, the water finding its way along the fractures of this mineral, causing it to expand and, as it were, explode the rock. If we break up a coarse, decomposed, rather vesicular leucitic lava, we may often see a crystal that has burst its way into one of the cavities. This, of course, is aided by the kaolinization of the mineral; but that decomposition of leucite seems to be greatly facilitated by expanding ice and water caused by the continual thawing and refreezing.

During the great heats of summer another agency similar to ice-action is at work. The porous rocks, loaded with moisture by capillary attraction from below, suddenly receive a hot summer sun, which, in a short time converts the superficial water in the saturated tufa into vapour, and by its expansion a constant crumbling is produced in the less coherent beds.

Last, but not least, we must take into the calculation the effects of wind. Any one who has had the misfortune to be caught in one of the ravines during a storm, especially where there are high escarpments of loose materials, besides having his face and hands cut by rock particles carried by the violent gusts that sweep the valley, will have his courage fully tried by large masses that are detached and rolled down, often making a veritable avalanche of stones, from which he can only dodge but not retreat.

Perhaps in addition may be mentioned earthquakes, which, although producing much displacement at the moment, from their transitory character are fractional in their value as a denuding agent compared with those other natural influences which, although quieter and less obvious in action, illustrate fully the fable of the hare and the tortoise.

There is still remaining one cause that has produced very marked effects in shaping and directing the course of the valleys, and that is man; for although he acts unconsciously, we shall see, when speaking of the forms of the ravines, that he has played and is playing a very important part.

Form of the Valleys and their Course.

As we approach the foot of the mountain from the plain, we first commence by ascending a gentle slope, covered with gardens, and rarely traversed by rivulets or beds of torrents, except where these have been artificially constructed, the great porosity of the soil sopping up all the mass of water brought down by the valleys. This has been aided by shallow wells and other irrigation-works intended to arrest the precious fluid. This slope continues in an unbroken manner till about the 200-metre contour-line, when the lower terminations of the ravines are met with.

A valley, as a whole, may be considered, for convenience of description, as consisting of three parts. First, its ultimate ramifications; secondly, the ravine proper, or "Vallone"; and, thirdly, its expanded termination or "Lagno," as these portions are locally called.

Towards the upper part of the mountain little of the slightly coherent tufas have been left; almost as soon as spread over this the most inclined portion by the eruption which ejected these materials, they were swept down by the heavy rains, either during or soon after the eruptive period. Nevertheless, we do find on the very summit of the ridges, where only exposed to the amount of rain that fell directly upon their surface, and not to that collected from other areas, that tufas have been able to hold their ground. It is in such a way that the very interesting and instructive section of the Canale di Arena and others have been preserved. Such cases, however, are the exception, and generally the ancient lava and scoria beds are only covered by a thin layer of volcanic sand, held together by the roots of chestnut trees and broom bushes, both of which add much to the preservation of the mountain.

In this region only small narrow gorges are excavated, their floor being formed of broken blocks of lava, and often interrupted by cascades of small depth, produced by the cutting back, as Lyell has called it, of old lava-flows. A variable number of these unite together, and roughly, where the first diminution of inclination takes place, form the "vallone" or great valley.

The valloni, as we may conveniently call them, present certain general characters. As already mentioned, they commence at the decrease of inclination, not suddenly, of course, but by gradual thickening of the soft tufas forming their sides or walls. They, naturally having a less inclined base, have been able longer to resist the destructive action of flowing water, and therefore the sum of their components often reaches very nearly a maximum of 100 metres, no insignificant thickness. The impulse of the torrent collected from the rivulets above, and rushing down a slope, first roughly at an angle of 35°, and here often 25° to 30°, can be well understood to cut its way through these soft beds. As the bottom is excavated, the soft sides crumble in, giving the valley a V-shaped section; and when this reaches deep enough to encounter the underlying lavas, a new type of erosion results.

Let us suppose we have to deal with lava-beds regularly interlaminated with scoriæ and other fragmentary materials, and dipping in the direction of the flowing water. The torrent will find some weak place in the uppermost lava-flow, and having broken up the sheet of rock at this point, will produce a miniature cascade. The impulse of the water bounding over this rocky step will remove the subjacent incoherent scoria, leaving the lower edge of the opening in the lava unsupported, so that the torrent can act upon it below and behind, conditions very favourable to its being broken up. At the same time the lip of the cascade recedes by loss of material; but as its inclination is upwards and backwards, it correspondingly increases the height of the waterfall, so that profound precipices may result, which are often very abundant, forming, as it were, so many steps along the valley. In many cases the opening in the uppermost lava-stream is very long in the direction of the valley, but very narrow, whereas at its bottom it is dilated, forming, as it were, half of a pointed dome.

These cascades often cut through many lava-streams. Lyell describes the one near the Fontana Olivello, which shows in section as many as six. In another I have counted thirteen of those streams.

The number of cascades that may occur, with their depth, may be judged from the measurements taken in the Vallone Cancherone. Beginning near where the 450-metre contour-line crosses the valley, we have in less than a kilometre no fewer than six of them, giving a perpendicular fall inclusively of 89½ metres, divided as follows from below upwards, 10½, 29, 2, 19, 9, 20 metres. Again, in the Vallone Sacramento, in the main trunk, before its bifurcation, both arms of which are rich in profound precipices and cascades, we have at the

560-metre	contour-line	a cascade of		7	metres.
603	„	„	„	3	„
615	„	„	„	4	„
640	„	„	„	14	„
655	„	„	„	13	„

Thus out of a total descent for the water of 95 metres, nearly a half, or 41 metres, occurs by perpendicular falls.

From the peculiar narrowness of the gap in the shedding lava-stream, this, not widening as it is cut back, gives to the valley, or that portion cut through the lava, a very narrow form with perpendicular or overhanging sides, of which we have fine examples in the Valloni Sacramento, Cancherone, and Sanseverino.

We therefore see that the upper portion of the sides of a vallone are broad and inclined, whereas the lower are narrow and perpendicular, often reaching such depths as 120 metres or more, as towards the upper part of the Vallone Breislak. This particular type of gorge or valley has been compared to a boat; but perhaps it would be better represented by the letter Y.

It is usually this middle division of the valley that yields the finest sections of the later ejections of the volcano.

The third portion, or lagno, as it is locally called, is generally the result of the union of two or more valloni. The character of this inferior or ultimate division of the ravines also is dependent for its special characteristic upon the further diminution in the inclination of the mountain-slope, which rarely reaches 15° and is usually nearer 10°. These lagni may be described as broad flat-bottomed valleys bounded by nearly, if not quite, perpendicular walls, which are high at the junction of the lagno and vallone, and gradually decrease until they are reduced to mere low banks a metre or so in height. As a consequence of this it will be seen that the bed of the lagno is much nearer the horizontal than the mountain's side through which the water has cut its way. It is rather uncommon to find an old lava-flow forming the bed of the lagno, and still rarer to find any such cut through.

The torrent that has been formed by the union of the water falling in the basin of the first division of the valley, descends into the second part carrying but a small load of materials. Here, however, it cuts away the incoherent tufa where this is within its reach, or is added to by the water and disintegrated substances from the sides of the vallone. Thus laden it dashes over the precipices, breaking up the lava-beds, detaching and carrying forward the subjacent scoria and other substances. The cascades act as so many weirs absorbing a considerable amount of the downward impulse of the stream, so that when the lagno is reached, where further retardation takes place from diminished fall, the larger of the transported materials begin to be deposited, and this continues until the water reaches beyond its self-cut banks. Then, if left alone, it breaks up into a number of little rivulets which gradually lose themselves by sinkage, and all the finer alluvial materials are left on the surface. It is just this peculiarity that renders the lower slopes of the mountain one of the richest gardens in Europe. This form of aqueous denudation, aided by the other agencies already mentioned, produces certain definite results. First there is the removal of nearly all the softer materials of the upper portion of the mountain, which takes place from above downwards. Next we have the formation, widening, and deepening of the middle division of the valley or the vallone proper, and lastly a deposition of the transported material around the toe of the mountain. As a consequence of these operations a kind of delta is formed that gradually ascends the lagno until it produces too great an obstruction to the torrent, which is either diverted from its course or cuts a new passage through its earlier deposits. We see, therefore, that the upper third of the mountain is rendered more steep, since its crest is little affected; but as we reach the middle third erosive action is rapidly gaining power and at this part reaches its maximum until a sudden check is put upon it at the commencement of the third part, or lagno, where, instead of a loss of material occurring, an actual gain takes place. Thus there is a tendency to produce a depression in the middle of the slope of the mountain, and at the same time to prolong the bottom part or toe. The whole group of phenomena may be said to render the upper parts of the mountain more steep and the lower parts less so, in such a manner that the general profile becomes more concave. This remarkable concavity I am inclined to attribute much more to the above cause, namely denudation, than to the sinking of the mountain by its own weight*.

This leads us on to the inquiry as to when the valleys began to assume their present form; and whether they have materially altered their shape and position during their formation. These two important questions open up a most interesting field of inquiry.

There is little doubt that denuding influences had commenced work while the volcano was still in its period of tranquil activity, and also in the period of temporary extinction, prior to the change in its eruptive character, producing irregular shallow valleys that had already begun to score its sides. The exceedingly small space of lava exposed in each section, the fact of all these valleys being nearly parallel, and a few sections being at right angles to them, render it difficult to determine how much had already been done when the first ejection of the white pumice came. That there were valleys there is no doubt; for in a circumferential section I have lately constructed, cutting tangentially and continuously through more than a quarter of all the valloni of Monte Somma, this fact is brought out most distinctly, though, from the partly problematical character that such a work must have, and from the impossibility of knowing the internal structure of the intervening ridges, only an imperfect idea can be gained of the form and depth of these ancient ravines.

We see in many sections how the products of each eruption were partly washed away before the deposition of the next ejectamenta. This is well illustrated in Plate II. fig. 2 of the Vallone di Pollena, happily showing the rare occurrence of a natural transverse section. Here it is observed that the present valley at this point has shifted its axis to the right, or south-west, since the Plinian eruption that choked the gorge, which before that time appears always to have remained stationary. Lower down in the lagno a valley existed to the right (in ascending) of the present, now choked by the large quantity of black pumiceous scoria of PHASE VII., *Period* 4, which seems to have caused the lagno to take its present direction. Thus we see that this ravine has changed its position on

* J. W. Judd, F.R.S., 'Volcanoes,' 1881, p. 166.

no less than three occasions within recent historic times; and any one seeing the great size of it cannot but be astonished at the vast amount of material displaced.

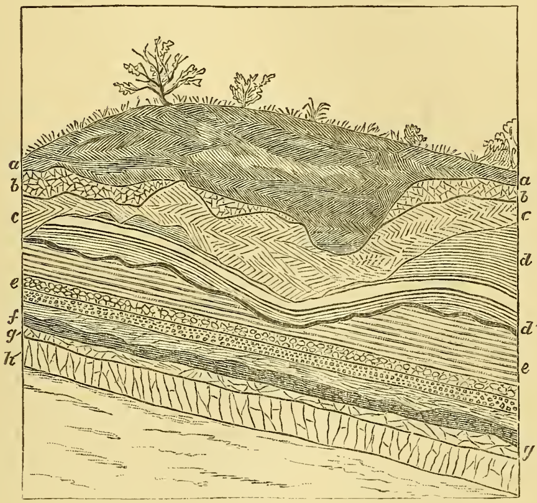
The section we have just been studying affords evidence of another important fact. At each new paroxysmal eruption the falling fragments were deposited in various manners: those that pitched upon the ridges between the valleys formed a general mantle, thickest towards the centre or least-inclined surfaces, thinning away as the slope increased, until a point would be reached where all would roll down into the valley beneath. Thus the ravine would receive what directly fell into it *plus* that which rolled down its sides and which might more or less fill it. The rain would subsequently clear them out, and so, choking the lower part or lagno where the inclination is small, would have to cut a new course, or, doing so from the beginning, change the axial position of the valley at a higher point.

In some cases, when denudation extends to such a depth in the valley as to meet with some insurmountable obstacle, the eroding action will be deflected to the side opposite and wear away the banks at that point. Such a case is beautifully illustrated in the Lagno Cancherone, where at the 250-metre contour-line a boss of old lava has diverted the stream, giving its valley a serpentine form below that point, so that the new sections thus produced show the original straightness before erosion had extended down to the disturbing rock-mass.

The manner in which each new mantle of pumice or lapilli covers the irregularities of the mountain renders the study of the stratigraphical portion of the subject very complicated. The radial sections, that is those in the valleys, show each stratum to extend in pretty uniform thickness for a considerable distance, and there is apparently little unconformity between one bed and another. When, on the contrary, the section is tangential or transverse to the ridges and valleys, the variation in thickness is very great in short distances, and the unconformability well marked. This is well illustrated by the Vallone St. Patrizio, where all the deposits seem conformable except where a sharp double bend occurs, and the valley cuts across its own axis (*vide* Figure 2). Often where the inclination of the sides of a vallone are slight the latest tufa lines or coats each slope, which not uncommonly causes an anomaly; for if such be denuded away towards the upper edge, an older bed may appear to rest upon a younger, two good instances being the Vallone Grande, above St. Anastasia, and the Vallone Pallarino. A similar error might arise from the floor of a valley cut through lava showing a more recent pumice deposit which might seem to underlie the lava. It is very common to see deposits of the last prehistoric or pre-Plinian eruption occupying such a position; but in most cases this has been due to the tufa becoming consolidated and converted into a compact breccia by the infiltration of calciferous waters, and thus resisting the scouring-action of erosion. This may be well seen in the west branch of the Vallone Cancherone.

A peculiar and important feature of the ridges intervening between the valloni is the more or less deep incision or "cupa"(as locally called) which furrows them along their spine. These cupe are often of considerable depth, occasionally as much as 20 metres, and have almost perpendicular walls. Their origin in all cases seems to be the result of human agency. As they play an important part in odi fying the superficial form of the mountain, a few remarks *à propos* of the manner in which they are produced will be necessary.

Fig. 2.—*Section in the Vallone St. Patrizio, about the* 550-*metre contour-line on the right side in ascending.*



a. Alluvial breccia, sand, &c. = Phases VII. and VIII.
b. Pumice of Phase VI., *Period* 4.
c. Yellow earthy ash, with fragments of pumice=Phase VI., *Periods* 2 and 3.
d. Compact grey pumice and lapilli = Phase VI., *Period* 1.
d′. Vegetable soil = Phases V., IV., and III., *Period* 4.
e. Regularly stratified rounded lapilli and sand of different sizes, with a few fragments of black spongy pumiceous scoria, Phase III., *Period* 3.
f. Black compact pumiceous scoria = Phase III., *Period* 2.
g. Light and white pumice = Phase III., *Period* 1.
h. Ancient lava = Phase I.

This section is intended to show the erosion of one bed before the deposition of another.

Above the 300- or 400-metre contour-line the two chief vegetable products of Monte Somma are chestnut trees and bushes and an undergrowth of two or three species of broom or *Genista*. The first of these supply sapling poles, brushwood, and charcoal; the second brushwood only. The mountaineers occupied in the collection of these products make both the ascent and descent of the mountain along the ridges instead of the valley-bottoms. As the latter are rough and jagged from the lava-beds, and intercepted from time to time by precipices or cascades, although usually dry, they are forsaken by these men for the soft and ashy paths only to be obtained on the higher ground. The reason for this is the more obvious when it is remembered that boots are never worn, and all the methods of transport are human. The sapling poles are tied into a bundle, varying in number according to their weight, by their lower and thick ends, which part is supported on the back and shoulders in a stooping position, the knotty and branched and pointed ends dragging along the ground behind. These bundles act as so many harrows ploughing up the ground and sweeping it down the steep incline, aided at the same time by the feet of the porter, producing very evident effects. The same with the faggots of brushwood composed of chestnut and broom bushes, which, in bunches of six tied together, hauled along behind the transporter, play the part of so many brooms.

It might appear that the above agencies were of the most feeble effect. The great luxuriance of the vegetation of the mountain, which is completely stripped during the summer months when these soft incoherent rocks are easily reduced to fine light dust or small fragments, must, however, be remembered. It is really astonishing to see the progress made in the course of such a period as three years, during which I have had many of the paths under observation. When we see the disturbance produced by a single passage of one of these loads, we have no difficulty in imagining the effect of many hundreds during the year.

Of course these human denuding agencies are aided by rainfall and other natural ones. Water, however, can do little, as these cupe occupy the centre of the ridge, where the surface slopes away, instead of towards the depression, and therefore the rain does not fall into these gorges, which are in reality principally the cutting downwards of paths made by man. From receiving no extraneous water laterally, their sides remain nearly perpendicular. Two irregular examples may be seen in section, in Pl. II. fig. 2, on the high ground between the Vallone di Pollena and the two large collateral valloni. When, as happens occasionally, the valleys have at a certain depth a loose incoherent breccia entering into the composition of their sides, this by simple gravity crumbles away, leaving the upper more resistent deposits above unsupported, which fall in blocks, are reduced to dust, and carried down by the various methods we have mentioned. The result is, the walls of the path become inclined, and catch more rain, which soon gives to the cupa the characters of a small valley. Various examples of these may be seen on the high ground flanking the Valloni Cancherone, Grande, di Castello, and many others. Sometimes aqueous denudation has gained such a hold that the hard lavas are reached and eroded, but usually the cupe join a great valley at the upper surface of the lava-beds or at the branching of the Y, so that their drainage falls over the side as a cascade.

There are many valleys that in all probability owe their primary origin to a simple footpath, such as the Vallone St. Patrizio and many others of its type.

The erosive action of water may be easily comprehended by any one who pays a visit to the mountain after a heavy rain. In September 1881, after a downpour of a day and a night, I saw the result of a few hours' erosion just above Resina, where the slope of the ground is less than 10°, and covered with cultivation-works such as terraces, banks, &c., which tend to break the impetus of the water. Many walls were completely overthrown, and in one place the water, after bursting through two high well-built ones, with drainage-holes through them, then traversed a vine-garden, where it excavated out of smooth nearly level ground a ravine $4\frac{1}{2}$ metres deep and $3\frac{1}{2}$ broad at the top. The débris of this excavation, consisting in part of large blocks of lava, &c., was spread over the surface of the ground, tearing up and breaking off the vines, and removing the bark of the trees in the torrent's course.

The roads around the base of the mountain are often covered with a deposit of sand, which in some cases, after much rain, renders them impassable. In 1881, men were employed many days in carting away this alluvium near Torre del Greco and at Resina, the site of Herculaneum; this year, 1882, I am told that the Castellamare railway traffic was suspended for some days from the same cause. It is this mass of material continually being deposited after each storm that accounts for those large beds of alluvial breccias and tufas that have been formed since the end of Phase VI.

The valleys we have been discussing extended higher up the original cone. This conclusion is forced upon us by the peculiar serrated outline of the ridge of Monte Somma. Each depression usually corresponds to the basin of one or more valleys, and is often cut through so many thick and tough lava-streams that we can only explain the eroding away of such rock by water derived from greater heights, which at this line must have already formed a torrent of enormous excavating power. The serrations may be regarded, therefore, as so many natural sections of the valleys which have been sheared from above downwards, and from within outwards, by the enlargement from time to time of craters of paroxysmal eruptions.

EXPLANATION OF PLATE II.

Figure 1.

Twelve sections taken at different points around Monte Somma to show the correlation of one deposit with its equivalent in a neighbouring section (see next page).

Figure 2.

A tangential, or more correctly circumferential section taken at the end of a radius of 3160 metres from the centre of the 1872 crater. This exhibits the change in position of the valley at different epochs and the variability in thickness of each bed.

Note. In both figures the colours show the age of the deposit, whilst the shading represents its lithological characters. Where the figure shows the bed only as a thin line its characters are indicated by index letters for colours, and numbers for shading.

SECTION 1. *Vallone Pietri Pomice.* A compound section taken between the 500- and 675-metre contour-lines, chiefly on the N.W. side of the valley.

		metres.
PHASE I.	Ancient lava.	
PHASE II.	Subangular or angular leucilitic breccia	5·00
PHASE III.,	*Period* 1. White light pumice and	1·00
	Period 2. Black compact pumiceous scoria	0·50
	Period 3. Fine rounded leucilitic lapilli, some yellow or brownish, with a few black vesicular pumiceous scoriæ..	1·00
	Period 4. Angular and subangular breccia	1·00
PHASE IV.,	*Periods* 1 & 2. Red and black scoriæ	4·00
PHASE VI.,	*Period* 1. Hard, brownish grey, compact pumice, leucilitic lapilli, &c.	1·00
	Period 2? Yellow ashy soil	0·60
	Period 2. Rounded spongy, and light grey or yellowish pumice, with thin ash bands	0·60
	Yellow dusty soil	0·60
	Period 3. White, light pumice, with thin interlaminated ash-bands	2·40
	Coarse yellowish concretionary bed	0·30
	Waterworn lapilli and pumice	0·40
	Another concretionary bed	0·25
	Decomposed yellow ashy soil	0·60
	Period 4. Greenish grey, compact, or light pumice, with many altered sedimentary rock fragments	0·50
PHASES VII. & VIII.	Mixed, waterworn and re-sorted tufa, enclosing at one point	
	Period 5. Fine black, light vitreous scoriæ, and a pink ash-band	very variable

N.B. The sections in the Vallone della Trofa very much resemble that of the Pietri Pomice.

SECTION 2. *Vallone Sanseverino.* A compound section derived from both sides of the valley between the 250- and 350-metre contour-lines.

		metres.
PHASE I.	Coarse leucilitic lava.	
PHASE II.	Fine brown soil	0·60
PHASE III.,	*Period* 1. White, light pumice, &c.	1·00
	Period 2. Black compact pumiceous scoria, with a few ejected fragments of limestone, fossiliferous marls, &c.	1·00
	Fine ash-bed	0·25
	Period 3. Subangular and rounded leucilitic lapilli, some yellow or brown with black, vesicular, pumiceous scoriæ	2·00
	Period 4. False-bedded fine dust, or coarse breccia, waterworn, reddened at the contact with the overlying lava .	2·00
PHASE IV.,	*Period* 1. Spongy pinkish or violet-grey lava, much laminated horizontally	2·00
	Period 2. Reddish spongy scoria	0·80
	Tough, bluish grey vesicular lava	1·50
PHASE V.,	*Period* 2. Greyish brown earth, with scoria and subangular lava blocks at bottom	0·90
PHASE VI.,	*Period* 1. Hard, brownish grey compact pumice, with many lapilli of leucilitic lava	0·75
	Rolled and bedded pumice, scoria, and lapilli, chiefly of the bed below	0·50
	Period 2. Yellow soil with fragments of white pumice ...	2·50
	Light grey, spongy, yellow, or grey pumice, rounded and with thin ash-bands	0·75
	Fine yellow ashy soil, with bits of pumice	1·00

metres.

PHASE VI., *Period* 3. White, light pumice, with fine ash-beds .... 9·00
PHASES VII. & VIII. Vegetable soil obscuring overlying beds .... 10·00

SECTION 3. *Vallone Breislak.* The main eastern branch of the Lagno del Purgatorio. The section is taken on the west side of the valley where the 290-metre contour-line crosses it.

metres.

PHASE I. Scoria .... 0·80
PHASE II. Fine dusty earth, greyish brown in colour, its components decomposed ....
PHASE III., *Period* 1. White, light pumice .... 0·30
Period 2. Compact, black pumiceous scoria .... 0·40
Period 3. Fine, interbedded with coarse, greyish ashy matter.. 0·20
Black vesicular pumiceous scoria, with fragments of limestone, &c. .... 0·40
Leucilitic lapilli, many brownish yellow, subangular, or rounded .... 0·50
The same, but finer even to dust .... 0·80
Period 4? Loose rounded lapilli, somewhat similar ...... 0·80
PHASES IV., V., VI., VII., & VIII. Coarse angular mixed breccia about 20·00

SECTION 4. *Canale di Arena.* This section is a portion of the upper edge of the great escarpment of the Atrio del Cavallo, near the upper ramifications of the Vallone Breislak.

metres.

PHASE I. Lavas, scoria, lapilli, and other allied materials ......about 300·00
PHASES II., III., IV., & V. Yellow soil much decomposed, with fragments of pumice, &c. .... 0·50
PHASE VI., *Period* 1. Hard, brownish grey, compact pumice, much decomposed.
Periods 2 & 3. Yellow dusty soil, containing bits of pumice 0·70
Period 4. White, light pumice, with large sanidine crystals in matrix, and few ejected blocks .... 0·50
More compact, greenish grey, and with more foreign matter.. 0·20
Grey ashy pisolitic bed .... 1·00
PHASE VII., *Period* 1. Fine grey pumice, moderately light .... 2·00
Period 2. Subangular lava-lapilli, many yellow or brown 1·00
Period 3. Coarse large breccia with fragments of leucitic pumice.. 2·50
Period 4. Black pumiceous scoria, with large broken leucite crystals, free, and enclosed in matrix.. 1·00
Coarse breccia .... 1·00
Period 5. Light black scoria, with two pink bands ...... 2·00
Yellow ashy soil .... 0·30
Period 6. Blackish and brownish grey pumiceous scoria, rich in large well-formed leucite crystals, leucitic lava-lapilli, many various ejected foreign blocks, and loose fragments of large leucite crystals .... 1·50
PHASE VIII. Loose lapilli of late eruptions.................................... ·25

SECTION 5. *Vallone St. Patrizio.* Section on the western side of the valley immediately above the junction of the path from the Cupa di Olivello, or near the 460-metre contour-line.

PHASE I. Lava. metres.
PHASE III., *Period* 1. White, light pumice .... 0·80
Period 2. Black pumiceous scoria.................................. 0·60
Period 3. Lighter black spongy pumiceous scoria (rare), alternating with sand, and passing up to .... 3·00
Period 4. Coarse breccia with blocks of lava .... 7·00
PHASE V. Fine decomposed brownish soil .... 1·00

		metre.
PHASE VI., *Period* 1.	Hard brownish grey compact pumice,	0·50
	graduating into partly rounded lapilli with more pumice at the top	3·50
Period 2?	Yellowish dusty soil, with blocks of much decomposed lava (rare), and bits of white pumice	1·00
	Rounded or subangular, grey, light pumice, yellow coated, with very thin ash beds, passing up into	0·80
	Yellow dusty, or loamy soil, with fragments of the underlying pumice	1·00
Period 3.	White, light pumice	0·75
	Yellow ashy soil	1·00
Period 4.	White, rather light pumice, rich in sanidine, together with a few foreign ejected blocks ...	0·40
	More compact, greenish grey pumice, mixed with more foreign blocks	2·60
	Fine grey pisolitic tufa, passing up into	0·75
PHASE VII., *Periods* 1 to 3.	The same, non-pisolitic	1·25
Period 4.	Black, pumiceous scoria, enclosing broken leucite crystals, with subangular lapilli, and dust	0·80
	Fine ash, false-bedded	0·80
Period 5.	Light, black, vitreous scoria, with an interlaminated band of pink lapilli	1·00

NOTE. A few yards beyond where this section was taken, the valley curves to the west, and in the section there presented nearly every member can be seen to rest unconformably on the denuded surface of the bed below.—*Vide* Fig. 2, p. 111.

SECTION 6. *Stone-quarry at Cisterna.* This section is taken in the quarry belonging to Signor Francesco Monte. It is the first one encountered after leaving Cisterna on the road to Marigliano. There are others along the same road, showing similar deposits, and demonstrating the presence of a coarse leucilitic lava of unknown thickness, and at least more than half a kilometre broad.

		metres.
PHASE I.	Lava, rather porous, and decomposed at the top, highly crystalline, the leucite, pyroxene, and olivine being large and well developed. Quarried down to drainage-level	20·00
PHASES II., III., IV., V., & VI., *Period* 1.	Yellow, decomposed soil, with rotten, white (?) pumice	1·00
Period 2.	Light grey, spongy pumice, yellow dust, &c....	1·00
Period 2 or 3.	Fine ash	0·10
Period 4.	White sanidinic, and greenish-grey compact pumice, with fragments of ejected blocks	0·12
PHASES VII. & VIII.	Modern vegetable soil	0·90

SECTION 7. *Lagno di Trocchia.* Section taken on the north side of the valley below the space included by the contour-lines of 250 and 260 metres.

		metres.
PHASE VI., *Period* 1.	Fine grey lapilli, earthy at top	0·30
	Hard, brownish grey, compact pumice	0·80
Period 2.	Yellow pumiceous soil	2·50
	Rounded, grey or yellowish spongy pumice, with yellow soil (false-bedded)	1·50
Period 3.	Coarse breccia	6·00
	False-bedded breccia, coarse in patches, with a little white pumice	8·00
	Fine yellow earth	1·00

metres.

PHASE VI., *Period* 4. White and greenish grey, compact pumice, with fragments of foreign ejected blocks .... 1·50
Fine grey ashy bed with pisolitic concretions . 2·00
PHASE VII., *Periods* 1 to 3. Very irregular false-bedded breccia and tufa .... 6·00 to 25·00
Period 4. Black pumiceous scoria, with broken leucite crystals, &c. .... 1·50
Periods 5 & 6 and
PHASE VIII. Coarse breccia .... 10·00

NOTE. The section is for the most part inaccessible, the loose large blocks preventing it being scaled and minutely examined, as in other cases. Figure 1, p. 87, is taken a little lower down the lagno, on the same side.

SECTION 8. *Vallone Von Buch.* The Lagno di Pollena divides near the 250-metre contour-line into two large branches; the left hand one, being nameless, I have called after the celebrated vulcanologist. It is in the more southern branch of this, near the 450-metre contour-line, and at the foot of a cascade, that the following section was taken.

PHASE I. Lava and scoria — metres.
PHASE II. Fine dusty soil, probably ancient vegetation-surface......... 0·30
PHASE III., *Period* 1. White light pumice, &c. .... 0·40
Period 2. Compact, black, pumiceous scoria .... 0·40
Period 4. Subangular breccia, with black spongy scoria at bottom .... 4·00
PHASE IV., *Period* 1. Pinkish, or violet-grey lava .... 0·50
Period 1 or 2. Black, or reddish spongy scoria .... 6·50
PHASE VI., *Period* 1. Compact, brownish-grey pumice, &c. .... 1·50
Stratified, coarse and fine breccia .... 3·00
Period 2. Yellow ashy soil.. 2·50
Period 3. White, light pumice, &c. .... 0·20
Fine, white, ashy pumice .... 0·50
White, light pumice, &c. .... 0·50
Fine rolled pumice... 2·00
Concretionary bed .... 0·10
Yellow, ashy soil .... 0·50
Period 4. Compact, greenish-grey pumice, with a whiter sanidiniferous variety at bottom. Many ejected foreign blocks.................................. 3·50
Fine, grey pisolitic ash .... 1·00
PHASES VII. & VIII. False-bedded sand and breccia .... 5·50

SECTION 9. *Vallone, and Lagno di Pollena.* General section on S.W. side of the valley.

PHASE I. Lava and scoria alternating — metres.
PHASE III., *Period* 1. White, light pumice .... 0·40
Period 2. Black, pumiceous scoria .... 0·30
Period 3. Fine ashy matter, rounded leucilitic lapilli, passing up into.. 0·80
Period 4. Very coarse, violet-brown breccia, with large lava blocks, scoria, &c... 55·00
PHASES IV. & V. Brownish yellow material resembling the above but more decomposed .... 0·40
PHASE VI., *Period* 1. Hard, brownish-grey, compact pumice with leucilitic lapilli, containing consolidated bands ... 2·00
Fine ashy-grey sand, with many blocks of lava much decomposed .... 3·00
Period 2. Fine yellow dusty soil, with occasional bands of rounded waterworn pumice, often very false-bedded .... 2·00

		metres.
Phase VI., *Period* 3.	White, light pumice, &c.	0·20
	The same rolled, rounded, and false-bedded ... passing up into—	1·80
	Yellow, much decomposed, dusty soil, often pisolitic, and containing near its middle a concretionary bed (0·20)	2·00
Period 4.	Fine-grained, light, white, sanidinic pumice, mixed chiefly with leucilitic lapilli, very ashy at top	0·50
	Compact, greenish-grey pumice, with leucilitic lapilli, and abundance of foreign ejected blocks	3·50
	Light grey, pisolitic tufa, passing up into	4·00
Phase VII., *Periods* 1 to 3.	Pumiceous breccia very variable as to its components and coarseness. (It shows sometimes thick beds of Plinian pumice ?)	14·50
Period 4.	Black, pumiceous scoria (leucitic), occasionally compacted together, and altered to a brown colour ...	15·00
Periods 5 & 6.	Breccia, very variable as to its components and coarseness	9·50

SECTION 10. *Cupa di Pallarino.* General compound section of this valley and its large northern branch. These two are often known as Riva and Cupa di Quaglia; but in this paper I follow the great contour-map so as to avoid ambiguity.

		metres.
Phase VI., *Period* 1.	Yellowish-brown earth with much rolled, light, white pumice	4·00
Period 2.	Black pumiceous scoria in rather large masses with leucilitic lapilli	3·00
	? Fine ash bed	0·25
	(Break in continuity of section).	
Period 3.	Light, white pumice, with leucilitic lapilli forming a band, especially near the middle...	4·50
	White, light pumice, but smaller and richer in leucilitic lapilli as the top is approached ...	2·00
	Greyish ash-bed with pumice, very pisolitic ...	2·00
Period 4.	White, light sanidinic pumice, water-rolled, with many bits of scoria	0·60
	The same unrolled, passing up into coarse, compact, greenish-grey pumice, rich in ejected foreign blocks and leucilitic lava	6·50
	Grey ash-bed, pisolitic, passing imperceptibly to	0·50
Phase VII., *Periods* 1 to 6.	Coarse and fine breccia, false-bedded, sand, &c.	2 to 70·00
Phase VIII.	Lava of 1872	3·00

SECTION 11. *Quarry near Pension Soleil, S.S.E. of Pompeii.*

		metres.
Phase I.	Coarse leucilitic lava, much kaolinized near the top	3·00
Phases II., III., IV., V., & VI.	Yellow-brown dusty soil, with a few fragments of highly decomposed pumice (old gardens of the Pompeians)	2·00
Phase VII., *Period* 1.	Plinian pumice, whiter and more vitreous at the bottom, but coarser and microcrystalline at the top	3·50
	Pisolitic ash	0·10
	Leucilitic lapilli, and compact greenish pumice	0·10
	Pisolitic ash	0·50
	Leucilitic lapilli, and compact greenish pumice	0·10

PHASE VII., *Periods* 2, 3, 4, 5, 6, and
PHASE VIII. Ashy soil, pisolitic at bottom and cultivated on the surface .... 5·20

SECTION 12. *Streets of Pompeii.* Section taken just beyond the Vico dei Duodici Dei, in the Strada di Abondanza.

PHASE I. Lava?

	Streets of Pompeii with their pavements.	metres.
PHASE VII., *Period* 1.	Plinian pumice, the lower third more vitreous and whiter; the upper two thirds more compact and microcrystalline, with greater abundance of ejected foreign blocks..........	5·50
	Pisolitic ash	0·10
	Leucilitic lapilli, and compact greenish pumice	0·10
	Pisolitic ash	0·60
	Leucilitic lapilli, and compact greenish pumice	0·10
Periods 2, 3, 4, 5, 6 and		
PHASE VIII.	Pisolitic ash passing up into vegetable soil	2·00

4. British Cretaceous Nuculidæ. By J. Starkie Gardner, Esq., F.G.S. (Read November 7, 1883.)

[Plates III.–V.]

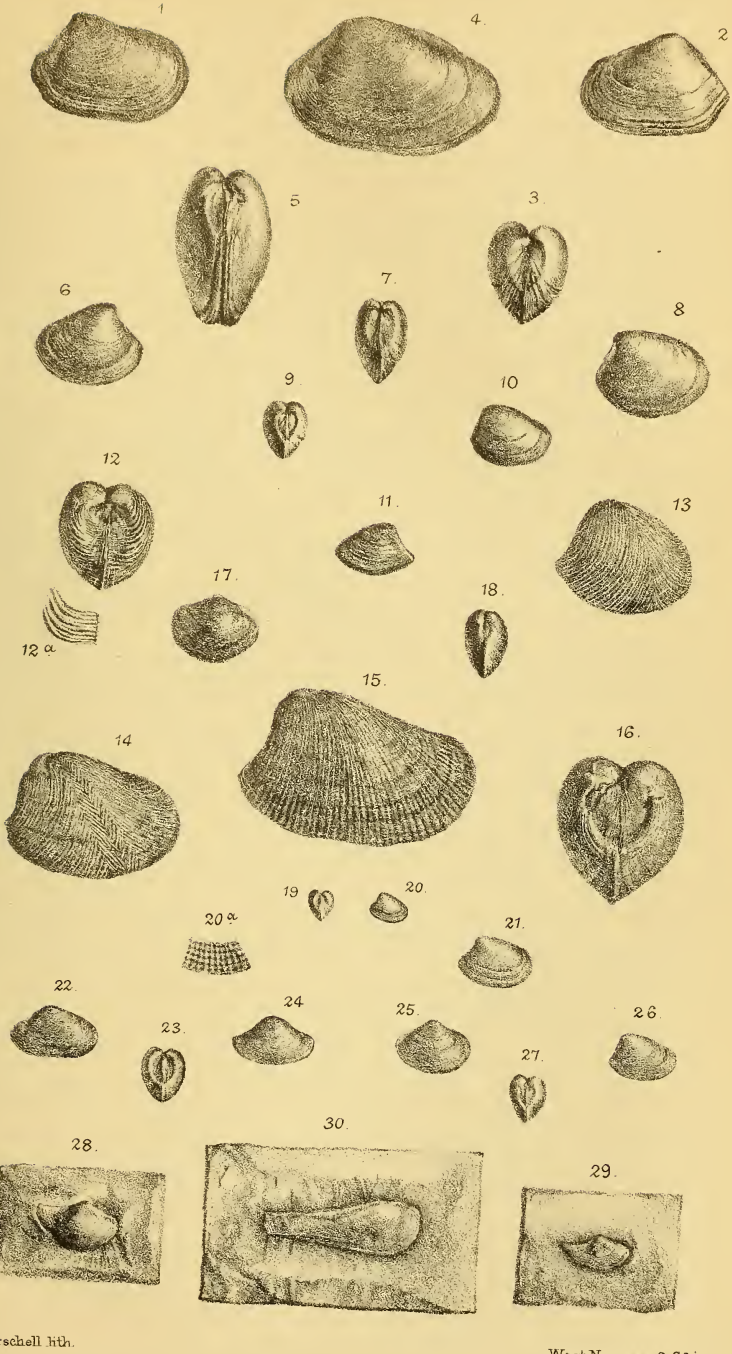
The *Nuculæ* and *Ledæ*, with their allies, are now generally separated from the Arcidæ, and in a palæontological point of view this separation is amply justified; for their distinctive characters have persisted throughout many geological periods, and may be recognized to some extent now in the Silurian fauna. The family of the Nuculidæ includes a number of genera and subgenera which it would be inconvenient to adopt here; for while probably every geologist would distinguish a *Nucula* from an *Arca* or from a *Leda*, even if imperfectly preserved, none but a specialist would be able to separate a *Yoldia* from a *Leda*, and only then in the event, not common among Cretaceous fossils, of the internal characters of the shell being revealed. Were all adopted, the Nuculidæ from the Gault of Folkestone alone would require seven subgeneric names; but their distinctive characters are relatively too trivial to be of palæontological value.

The details of the hinge and the position of the muscular attachments do not appear to be of very great importance in this group and are not always visible in the fossils; they are therefore omitted from the abridged descriptions of the species.

Both *Ledæ* and *Nuculæ* occasionally abound in the marine formations of the Cretaceous system, except in the White and the Red Chalk, whence they may have been dissolved out. The species do not differ greatly from those of the Jurassics, nor from those of the present day.

Besides the definition of new or imperfectly described species, a revision of the family is necessary, as confusion still exists in works on Cretaceous geology between the genera *Nucula* and *Leda*, owing to Sowerby, D'Orbigny, and other authors having described all the Cretaceous species as *Nucula*; and although a few *Ledæ* are now sometimes distinguished, these are still assigned indifferently to one genus or the other in lists of fossils. Yet the two genera are perfectly definable, and both have been established for more than half a century. Again, several of the species are credited with a much wider range than they actually possess. Some species have clearly been founded on misapprehension, and a few others have crept into our lists which have not hitherto been met with in Great Britain, while the published illustrations of most of them are indifferently executed, and must be sought in expensive and often voluminous publications long since out of print, and the few descriptions of them in our language are meagre and imperfect.

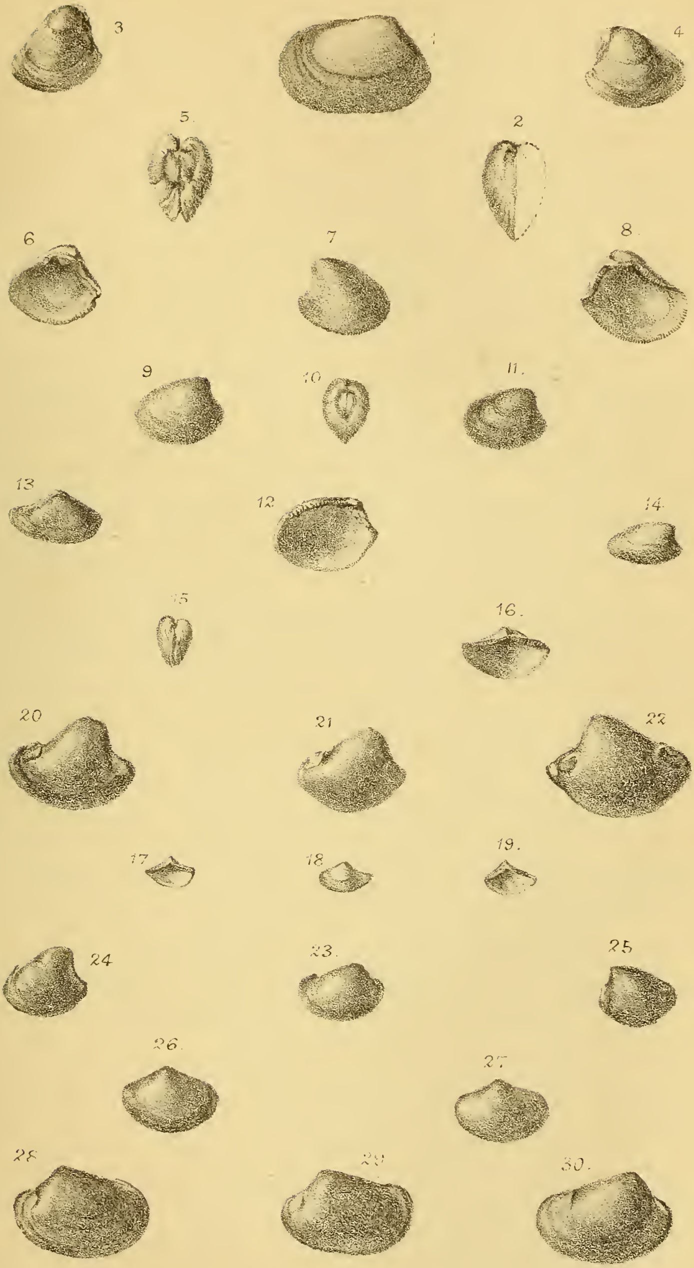
If we examine the Nuculidæ of a single Cretaceous horizon, as the Gault, and exclude all others, we see an assemblage of species which differ for the most part as widely as possible from each other. These seem to be forms whose ancestors were differentiated at least prior to the Jurassic period. But when the Nuculidæ from the



G. M. Herschell lith.

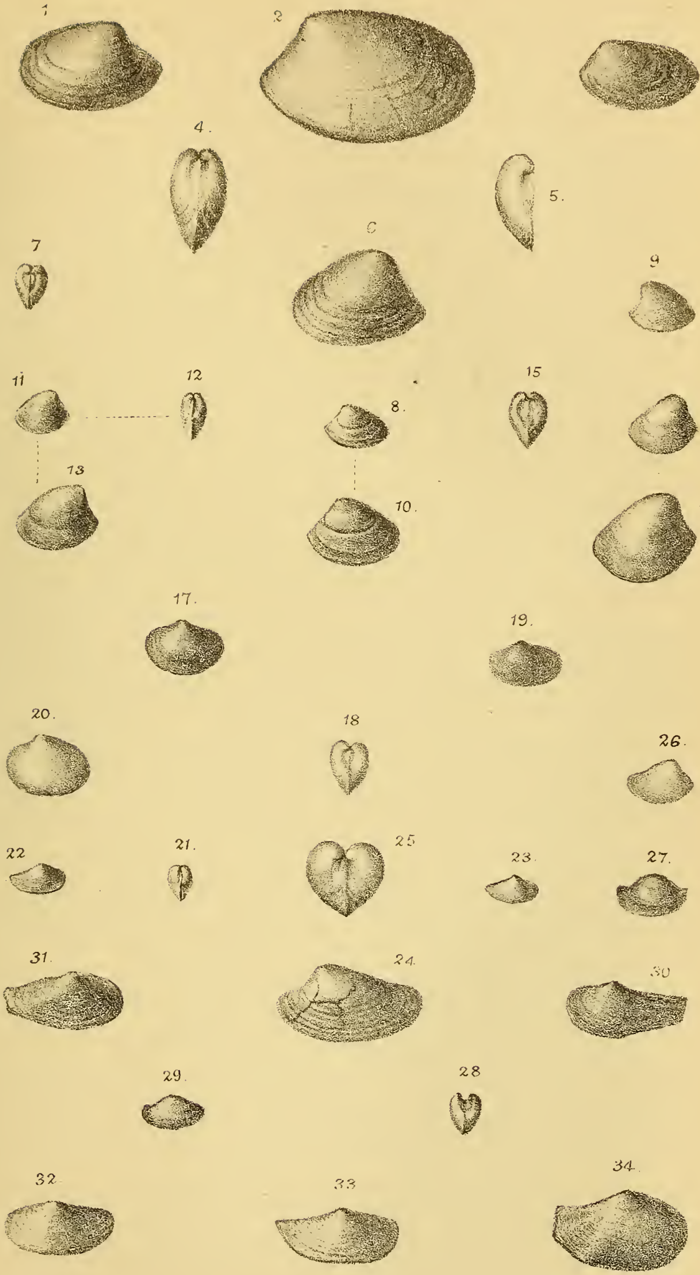
West Newman & C^o. imp.

GAULT NUCULIDÆ FROM FOLKESTONE.



G. M. Herschell lith.   West, Newman & Co. imp.

NUCULIDÆ FROM BLACKDOWN AND CAMBRIDGE.



G. M. Herschell lith.

West Newman & C° imp.

NEOCOMIAN NUCULIDÆ.

whole of the Cretaceous series are embraced, we find types reproduced at each stage which so closely resemble each other that it is almost impossible in some cases to formulate any distinguishing specific characters, and it is clear that they are in a direct line of descent. Yet the slight differences between the same type of *Nucula* or *Leda* from the Neocomian and from the Gault, or the Blackdown Beds, are constant and permanent modifications in some given direction, brought about by lapse of time or changed conditions, and once produced never revert, and with our present system must therefore rank as species*. It is preferable rather to emphasize the successive modifications than to conceal them under a common name.

These several parallel lines of descent traverse the whole Cretaceous system, and each of its stages or subdivisions contains a link representing a modification through lapse of time or changed physical conditions, in some definite direction, either towards a last representative species, or towards a still existing type. The group of "Ovatæ," after having persisted from remote periods, appears to have become extinct with the close of the Cretaceous, though it is by no means certain that we yet possess any knowledge of their latest representatives. Some of the most typical "Pectinatæ" of the Cretaceous no longer survive; but the externally smooth type with crenulated interior margin, which appears for the first time in the Blackdown Beds, is the prevalent type throughout the Tertiaries and at the present day.

If it were permissible to base a generalization on a single group, this evidence would lead us to regard the Blackdown Beds as a younger member of the Cretaceous system than the Gault, or than any other English representative of the Upper Greensand. This is in accord with all the other evidence, and bears out the view I have long held, that, taking the south-eastern counties of England and the N.E. of France, and thence S.E. towards Switzerland, as the Cretaceous centre, we shall find that as we travel away from it the

* It is certainly deplorable that all these forms must, under the present system, have specific names conferred upon them which do not in the remotest degree convey the closeness or the remoteness of the relationship between them. Forms utterly unlike each other, and which must have been separated from their common ancestors by scores of intervening species, and whose differentiation doubtless took place in Palæozoic times, are not distinguished from each other in any higher degree by their nomenclature than are forms so closely related that not a single specific generation has intervened. It is thoroughly impossible with a simple binomial nomenclature to indicate the degree of relationship subsisting between fossil species, and it will most assuredly some day be necessary to introduce additional terms adequate to express their interrelationship. If we come into possession of even an approach to a perfect record of the descent of a group, as we may certainly hope to do, link after link being discovered, the present system must absolutely break down. The possible, and even probable, variations brought about by lapse of time, changing physical conditions, and migrations during the geological period, in any family of Mollusca that has been long persistent, must be so endless that, as these are brought to light, it must certainly become impossible to classify them as species, or even subspecies; and is it not even now obvious that species among Brachiopods and other groups that have been specially studied are not the equivalents of what are ordinarily recognized as species among less perfectly known groups of Mollusca?

beds hitherto regarded as equivalent in age become actually and relatively newer. The Cretaceous series of Devonshire, Ireland, Limburg, and Denmark, though almost identical in their sequence and lithological characters with those of Kent and Sussex, nevertheless contain assemblages of fossils of much younger aspect. The approach to Tertiary types is least marked in the Blackdown Beds at Blackdown, but they contain types, and even genera, not met with elsewhere in the Cretaceous series except at Aix-la-Chapelle, where at least 50 per cent. of the Mollusca incline to Tertiary forms. In the Cretaceous rocks of Denmark, which are still more remote from our centre, the approach to Tertiary forms, though naturally less obvious in the White Chalk with flints, is very intimate in the overlying coral band and limestone, the only Cretaceous form among a large number of *Cypræœ*, Tritons, Volutes, *Mytili*, *Rostellariœ*, *Turbinellœ*, &c.—all of Eocene aspect—being a *Pleurotomaria*. In the Irish Chalk, again, we have *Turritellœ* and *Scalariœ*, as well as casts of *Mitra*-like shells, which approach Tertiary types. In an area of prolonged and gradual subsidence, as Europe undoubtedly was throughout the Upper Cretaceous period, the deep sea, or ancient gulf of the Atlantic, as represented by the Chalk, would gradually encroach further and further in every direction as the levels were lowered. At a certain depth the physical conditions rendered the deposit of Upper Greensand alone possible, and the deposition of this quality of sea-bed seems to have been accomplished in deeper water than that in which the Gault mud was formed, but less deep than that required for the Grey Chalk. It precedes the Chalk in what I designate its central area, and was continued in ever widening contours as long as the depression was maintained, or, in other words, for as long as the Cretaceous period lasted. Its ultimate margins must be beyond and younger than all but the newest true Chalk, if, as appears certain, the deposition of Greensand or Chloritic Marl was a necessary phase leading up to Chalk. During the Cretaceous subsidence, wherever the Atlantic Ocean penetrated, a Greensand bottom was nearly invariably followed by one of Chloritic Marl, and this by Chalk without flints, and this again by Chalk with flints. What we take for horizons or zones of age are no more than travelling zones of depth, which radiated from a centre throughout a long period of depression, commencing in our area at the base of the Middle Cretaceous series and enduring elsewhere without interruption to a period immeasurably more recent than the newest of our English Cretaceous rocks, which have since suffered vast denudation. It is thus misleading to speak of the Upper Greensand, as a formation, being older than the Chalk, though in any given area it is older than the Chalk of the same area, because its deposition preceded that of Chalk on that spot. Purely local causes seem to have led to the chert formations of Blackdown and Aix, the Firestone, Marne rock, the Red and Grey Chalks, &c.; but these causes may have recurred at any interval and anywhere along the margin of the Chalk ocean, and similarity of lithological character does not in this case imply contemporaneous deposition. The old classification of the Chalk into zones of age has been greatly favoured by the fact that each zone of depth seems to contain a fauna somewhat special to it, and that these faunas in the deeper sea-zones were so slightly modified with lapse of time that hardly any specific distinction is visible, and the faunas of the newest beds or outliers of the Chalk with flints can be almost correlated palæontologically with the oldest; though even in these a careful study will reveal progressive change*. A modified Cretaceous fauna survived in the newest members of that series in America, into what were, perhaps, almost the older Eocene times in Europe. Much of the true Chalk fauna still exists in the moderate depths of the Atlantic; and it is doubtful, save for the extinction of some of the most characteristic groups, whether an upheaval would not reveal beds which not many years since might, too, have been classified as Cretaceous. In the more littoral outlying Greensand Beds, where Gastropods are preserved, we have, however, a successive and rapid modification towards an Eocene fauna; and upon the present hypothesis not only is this fact explained, but the far more anomalous one, that beds hitherto supposed to be of the same age were preceded and accompanied in England by a purely Jurassic flora, while in Rhenish Prussia and America they were preceded by a flora with a preponderance of dicotyledons of a singularly Tertiary aspect. These are problems not perhaps immediately connected with the subject in hand, and an apology is needed for so long a digression; yet, as a scratched pebble may lead to the discovery of an ancient glaciation, so the apparently most uninteresting group of fossils may furnish a clue to the mode of deposition of a great formation.

Nucula, Lamarck, 1799.

This genus, exclusive of *Leda*, comprises small inequilateral shells, nacreous internally, with a hinge composed of numerous interlocking teeth and a cartilage-pit. They are more or less truncated in front, with a flattened region termed the lunule; possess prominent umbones, and are tumid or seldom compressed. The genus is restricted by some writers to those species which possess a denticulated margin†.

The Cretaceous species, exclusive of *Leda*, are separable into two great divisions, the ovate and the subangular forms, and these may again be subdivided into smooth-shelled and sculptured-shelled groups. The two principal divisions are of great antiquity, their separation dating back in all probability to Palæozoic times. In the ovate division, which I refer to as the Ovatæ, the apices of the umbos are

* *Mosasaurus* takes the place of the older Cretaceous Reptilia; *Baculites* and *Aturia* appear among Cephalopods; the *Belemnitella* of our Upper Chalk characterizes alike the Chalk of Ireland, Aix, and Denmark. *Scaphites* and *Ammonites* remain; but in what direction the newest forms had developed before they became extinct is still unknown. These with *Inoceramus* and *Pleurotomaria*, and some Brachiopods, form the latest Cretaceous groups.

† Such a classification would, in this case, be extremely inconvenient; for the entire division of "Ovatæ" would have to be removed.

situated about one fourth the length of the shell from its anterior margin, and the lunule is usually ill defined, and the test and lips smooth. In the subangular, or trigonal division the umbos are situated further forward, generally at one fifth of the whole length from the anterior margin, the lunule is a distinctly defined region, and the species are generally sculptural and the lip toothed. For this division I propose to adopt D'Orbigny's term Pectinatæ, a name recalling the prevailing sculpture and the most typical form. The characters implied by the proposed terms will most readily be recollected if they are associated with the two most classic and best-known fossil *Nuculæ*, *N. ovata*, Mant., and *N. pectinata*, Sby., of the Folkestone Gault. The short side to which the umbones are turned is termed, and perhaps correctly, the posterior side by some authors; but in the present description the short side on which the lunule occurs is referred to as the anterior, the long side as the posterior, and the side opposite the umbo as the inferior margin. Length is the extreme measurement from anterior to posterior margin; height the distance from the inferior margin in a straight line to the top of the shell above the umbo; and breadth or depth the distance from the chief projection of one valve through to the chief projection of the other valve.

For the sake of brevity I have stated the chief characteristics of each subdivision but once, and they are not recapitulated in the descriptions of species. I have also tabulated together the dimensions of the species and the position of the umbo for convenience of reference and comparison, instead of stating them separately.

The Cretaceous forms are capable of subdivision into groups of species which resemble each other so closely as to seem, at first sight, little more than varieties, though each presents, when carefully examined, some definite modification, and characterizes a particular horizon in the English Cretaceous series. This peculiarity has led me to select as types for description, and as standards of comparison, the group from the Folkestone Gault, which not only contains the best-known and most perfectly preserved shells, but also occurs at about the middle of our Cretaceous series. They are, moreover, singularly abundant, being represented in my own collection alone by so great a number of specimens that the approximate limits of their variation are easily ascertainable.

OVATÆ.

OVATÆ LÆVIGATÆ.

In this group the shells are smooth or marked concentrically only, with scarcely any trace of ribs or pectinate structure. The umbones are situated at about one fourth the entire length of the shell from the anterior margin. The lunule is small and usually ill defined. The lip is smooth, without notches. The shell is thick, and very nacreous internally.

There are two distinct types in the group, one represented by

N. ovata and the other by *N. impressa*, each type having ranged throughout the greater part of the Cretaceous period. Of these, the following have been met with in our area:—

TYPE OF N. OVATA.

N. planata, Desh. Neocomian.
N. ovata, Mant. Gault.
N. capsæformis, Mich. Gault.
N. obtusa, Sby. Blackdown and Grey Chalk.

TYPE OF N. IMPRESSA.

N. Cornueliana, d'Orb. Neocomian.
N. simplex, Desh. Neocomian.
N. albensis, d'Orb. Gault.
N. impressa, Sby. Blackdown and Grey Chalk.
N. Meyeri, Gardn. Neocomian.

OVATÆ RETICULATÆ.

The few species belonging to this group possess a reticulated structure and toothed margin. Only one is British.

Subdivision OVATÆ LÆVIGATÆ.

TYPE OF N. OVATA.

Gault Species.

NUCULA OVATA, Mantell. Plate III. figs. 1–3, Plate IV. figs. 28–30.

Nucula ovata, Mantell, Geology of Sussex, pl. xix. figs. 26, 27 (1822) (non *ovata*, d'Orb., Pal. Franç. vol. iii. p. 173, pl. 302, figs. 1–3). It has been included, on imperfect data, in the genus *Cucullella*, M'Coy.

This shell averages, length 19 mm., breadth 10 mm., height 16 mm.; but these dimensions are occasionally exceeded, attaining as much as 25 mm. in length, 12 mm. breadth, and 16 mm. height *. The form varies considerably, the anterior outline being subovate to subangulate, and even slightly produced into a blunt beak. The opposite end is more regularly ovate. The inferior margin is straight for some distance, slightly constricted opposite to the umbo and slightly sinuous towards its anterior termination near the lunule. The test is solid, and has a white and glossy appearance; it is strongly marked by lines of growth, which in very many specimens become deep furrows, especially numerous towards the inferior margin. There are no transverse ribs externally, though a radiating structure can always be seen in certain lights. Internally, the test is nacreous, the cast smooth, the adductor muscles not prominent, the denticles of the hinges very numerous and defined.

* In the department of the Aube, in France, it is found in several places equalling *N. capsæformis* in size, and at St. Florentin it passes into that species.

It appears to occur throughout the Gault, in the Cambridge phosphate-beds, and at Upware (*fide* Keeping); but it should be removed from the Speeton-Clay and Blackdown lists of fossils. Its range in France is comparatively restricted, and at St. Florentin it passes into the allied species *N. capsæformis*, Mich. Very perfect specimens with tightly closed valves may be picked up by the score at Folkestone, when the tide is out. Mr. Jesson's collection includes 70 specimens from Cambridge, so that it appears to be abundant there also. Examples of these are figured, Plate IV. figs. 28–30.

Pictet, like D'Orbigny, confounds this species with *N. capsæformis*, and apparently describes casts of true *N. ovata* as *N. gurgitis*.

Blackdown Species.

NUCULA OBTUSA, Sby., in Fitton, Geol. Trans. 2nd ser. vol. iv. pl. xvii. fig. 11, p. 342 (1836). Plate IV. figs. 1–2.

This shell is of about the same size as *N. ovata*. and similarly smooth, marked with lines of growth and deep furrows towards the inferior margin, but differs very strikingly in its truly ovate form and regularly curved inferior margin, and in the absence of any tendency to constriction. The umbo also is much more forward, and the lunule is less defined. It is evidently a rare shell, for it is absent from the private collections that I have seen, and of the three specimens at Bristol, one is a mere fragment, and none has the hinge perfect. One shows the pearly nacre under the outer layer, which is of the crystalline structure usual in Blackdown fossils. I have a single cast from the Grey Chalk of Folkestone which seems to be identical in every respect with *N. obtusa*, presenting precisely the same differences from *N. ovata*. It shows the muscular impression, and appears to have been only an interior mould when imbedded.

The *N. obtusa* described by D'Orbigny, Terr. Crét. vol. iii. p. 163, and figured pl. 300, figs. 1–5, as *N. planata*, Desh., is certainly not the same species; but D'Orbigny himself subsequently rectified his error in the 'Prodrome.'

The specimens originally figured by Sowerby are still preserved in the Bristol Museum, and I am indebted to the courtesy of the Keeper for the opportunity of comparing them at leisure in London.

The figured specimen is from the Jermyn-Street Museum, and others are preserved at Cambridge and in the British Museum. There are specimens from the Upper Greensand of Devizes, in both the British and Jermyn-Street Museums, which seem to connect this with the true *N. ovata*.

Neocomian Species.

NUCULA PLANATA, Desh., in Leym., Mém. de la Soc. Géol. t. v. p. 7, pl. 9, f. 3 (1842). Plate V. figs. 1–4.

The only difference that I observe between this and *N. ovata* is a more compressed shape, and perhaps slighter tendency to constriction, and more curved inferior margin. D'Orbigny remarks that it is related in form to *N. ovata*, but that it is distinguishable by its better-marked and smaller lunule and by a different form of cast.

One of Mr. Meÿer's specimens, and others in the Woodwardian Museum, show that the difference in the lunule is correctly noted; but there are no British casts to compare in other respects. It is by no means an uncommon fossil in the Speeton Clay.

Of two specimens figured (Pl. V. figs. 2, 3) from the Leckenby collection in the Woodwardian Museum from this deposit, one greatly exceeds the ordinary dimensions, measuring 27 mm. in length by 19 mm. in depth; this is the *N. ovata* of Phillips, from the Speeton Clay, figured in the 'Geology of Yorkshire.'

Mr. Meÿer has two specimens from the '*Perna*-Bed' of Redcliff, Isle of Wight, and one from the same horizon, from East Shalford. Those in the British Müseum and at Cambridge are from the 'Cracker rocks' of Atherfield, and the Speeton Clay. D'Orbigny describes it under Sowerby's name *N. obtusa*, Terr. Crét. vol. iii. p. 163, and figures it as *N. planata*, pl. 300, figs. 1–5. All references to *N. impressa* and *N. obtusa* from the Neocomian or Lower Greensand should probably be read as *N. planata*, the two former species being apparently confined in England to the Blackdown Beds.

Gault Species.

NUCULA CAPSÆFORMIS, Michelin. Plate III. figs. 4–5.

Nucula capsæformis, Michelin, Mém. de la Soc. Géol. vol. iii. pl. 12, fig. 8 (1836). (*N. ovata*, d'Orb. *l. c.* ante, *N. de Rancei*, Price, Quart. Journ. Geol. Soc. vol. xxx. p. 358.)

The outline is very similar to that of *N. ovata*, but the shell is more compressed, and of larger dimensions. I have not come across any British specimens quite equalling the length, 35 mm., mentioned by D'Orbigny. The test is very thick, but has not the white and glossy appearance of *N. ovata*, owing its appearance to the relatively thin covering of the nacreous layer. The striæ of growth seem more regular, and there appears to be a far less tendency to form those deep furrows parallel with the ventral margin which are so characteristic in *N. ovata*; but in all other respects their descriptions would be identical. It has never been met with in England, so far as I can learn, except at Folkestone, where it seems to be confined to the Lower Gault *. It is relatively rare, and I have only been able to secure about 15 specimens. Its range in France is much greater, and among specimens from St. Florentin, a locality repeatedly referred to by D'Orbigny, there is a complete passage into the allied species *N. ovata*. This may account for the confusion in regard to them that exists in D'Orbigny's and in Pictet's works, and it is not a little instructive to find species perfectly definable in our area, incapable of separation in another area so little removed. It

* It is recorded by Price, *l. c.*, only from the lowest and from the 11th 'bed' at Folkestone.

is a result, however, which we may expect to find of very frequent occurrence when species are critically compared. The specimens showing this passage are in D'Orbigny's collection in the Jardin des Plantes.

Type of N. impressa.

Gault Species.

Nucula albensis, d'Orb., Pal. Franç., Terr. Crét. vol. iii. p. 172, pl. 301, figs. 15–17 (1843). Plate III. figs. 6–8, Plate IV. figs. 24, 25.

The average dimensions of this species are tabulated; but I possess a unique specimen reaching a length of 21 mm., a height of 16 mm., and a breadth of 10 mm. It is very variable in form, more angular and more compressed than *N. ovata*, with a very inconspicuous lunule, a glossy and striated surface, and if furrowed, by no means deeply so. The test is moderately thick, and the nacreous layer very thin. The posterior region seems more developed relatively than the anterior, giving the shell an unsymmetrical appearance. A variety is more trigonal and tumid, but preserves the ill-defined lunule (Plate III. fig. 7); an exceptional specimen modifying the relative measurements in a remarkable degree, 14 mm. in length, 12 mm. in height, and 8 mm. in breadth, with a less glossy shell. The species appears to be very abundant at Cambridge, for 70 specimens were sent to me for examination by Mr. Jesson. These casts, Plate IV. figs. 24–25, average rather smaller dimensions, agreeing better with those given by D'Orbigny, and are easily distinguishable from casts of *N. bivirgata* (Plate IV. figs. 20–22), by the much slighter prominence of the adductor muscles, and the more compressed form of the valves. It is one of the most abundant fossils at Folkestone, though possessing, according to Mr. Price, only a limited range towards the upper part of the Lower Gault, and is met with in the same condition as *N. ovata*. Of three specimens from the Grey Chalk, one appears identical with the present species, while the others approach more closely perhaps to *N. impressa* from Blackdown. A specimen from Speeton, in the British Museum, labelled *N. subangula*, MS., resembles this form, but may be an imperfect specimen of *N. planata*.

Blackdown Species.

Nucula impressa. Sby., Min. Conch. vol. v. p. 118, pl. 475, fig. 3 (1823). Plate IV. figs. 9–12.

This is a very variable shell, greatly resembling *N. albensis*, but is smaller, broader, more beaked anteriorly, and possesses a much more sunken and strongly defined lunule. The lines of growth are more pronounced, and the valve is divided into two regions by a deep concentric furrow situated nearly midway between the umbo and the inferior margin, the upper region being smooth, and the lower traversed by other more or less pronounced furrows in the direction of the first and repeating the contour of the shell.

D'Orbigny * describes a much larger species from the Neocomian under this name, but figures it as *N. Cornueliana* (plate 300, figs. 6–10). It is erroneous to include it in lists of Gault fossils, as is frequently done, its horizon being the Upper Greensand of Blackdown, where it seems to be common. I believe, however, that the casts from the Grey Chalk of Dover are of the same species. It has often been quoted as a Lower-Greensand fossil, doubtless in mistake for *N. planata* or *N. Cornueliana.*

Neocomian Species.

NUCULA CORNUELIANA, d'Orb., Pal. Franç., Terr. Crét. vol. iii. pl. 300, figs. 6–10. Plate V. figs. 5–10.

N. impressa, d'Orb. *l. c.* p. 165 (1843).

This is a larger and broader species than *N. albensis*, angular, elongate, and more symmetrical. The lunule is slightly larger, more defined, sunk, but seeming to project a little towards the centre. The anterior region is more or less produced in different specimens. The shell appears on the whole to be nearer to *N. impressa* than to any other species, and it is in fact difficult to formulate any characters by which it can be readily distinguished, except that when well preserved, it is seen to be longer in proportion to its height and more produced anteriorly. Mr. Meÿer has specimens from Shanklin, from the Atherfield Beds of Sevenoaks, and from the base of the Folkestone Beds of Nutfield; and I have three specimens in most perfect preservation from the "Cracker rocks" of Atherfield. The latter are young shells, but being the most perfect, have been enlarged for illustration. There are also examples from the Tealby Series of Bennyworth Haven, in the Woodwardian Museum, which differ somewhat from the rest in their greater depth and less open angle. The species, though described by D'Orbigny as *N. impressa,* is correctly figured as *N. Cornueliana.* It is not always easy to distinguish it from *N. planata*, but it is less ovate and more angular anteriorly, and slightly less compressed.

Neocomian Species.

NUCULA SIMPLEX, Desh., in Leym. Mém. de la Soc. Géol. vol. v. p. 7, pl. 9, f. 5 (1842). Plate V. figs. 11–13.

This species differs from *N. albensis* and the other *Nuculæ* of the group in the smaller development of the anterior region, which is somewhat abruptly truncated, and rounded, instead of rostrated, inferiorly, so that the beaks almost overhang the anterior margin. The shell is nearly triangular, the inferior margin much curved, and the lunule small and ill defined. Mr. Meÿer possesses it from Redcliff (Shanklin, Isle of Wight), East Shalford, and Sevenoaks, and I have several specimens from Atherfield. The latter, though small, are exceedingly perfect, and one is enlarged in figure 13, Plate V.

* Terr. Crét. vol. iii. p. 165.

Neocomian species.

Nucula Meyeri, sp. nov. Plate V. figs. 14–16.

This appears to be a small species, nearly triangular, very high in proportion to its length, and deep relatively to the other Neocomian species. The umbo is small, the anterior margin slightly produced, and the inferior margin greatly curved and almost crescentic in outline. It is striated with lines of growth, but has no pectinate structure, and the margin is consequently entire. The lunule is large and moderately well defined, and there are no very deep furrows on the test. I possess two specimens from Atherfield, which were found with *N. simplex* and *N. Cornueliana*; and Mr. Meÿer possesses one from Shanklin. The species are named in compliment to Mr. Meÿer, F.G.S., whose work in the field has so greatly enriched our British Cretaceous fauna. It is most nearly allied to *N. impressa* of Blackdown.

Subdivision Ovatæ reticulatæ.

Gault Species.

There are very few sculptured forms belonging to the group "*Ovatæ*," and these are confined to the Gault. They are reticulated, and the lip is apparently notched or toothed internally.

Nucula arduennensis, var. pumila, d'Orb. sp., Pal. Franç., Terr. Crét. vol. iii. p. 174, pl. 302, figs. 4–8 (1843). Plate III. figs. 19, 20, 20*a*, 21.

Our variety is very much smaller than that described by D'Orbigny, barely reaching a third of the dimensions given by that author. It has the characteristic form of the *Ovatæ*, with an inconspicuous lunule, but is finely ribbed and striated by transverse lines of growth, their intersection forming a regular and delicately reticulated ornamentation. It has, like *N. ovata*, occasional deep furrows parallel with the inferior margin. The test is thick and nacreous internally, and the umbos generally abraded. The longitudinal striæ seen rather more conspicuous, and the form less angular than D'Orbigny's description would lead one to suppose; but having examined his original specimen I can see no reason to separate the Folkestone form, except on account of its minute size. D'Orbigny's specimens were found in the Gault of the Ardennes; and in England it appears to have a restricted range in the Lower Gault of Folkestone.

Casts of a large and undetermined species, agreeing with D'Orbigny's description, are by no means rare at Cambridge, and may possibly belong to D'Orbigny's species. A large specimen is figured, Plate IV. fig. 23.

List of Species.

OVATÆ LÆVIGATÆ.

	Length. mm.	Height. mm.	Depth. mm.	Position of umbo.	Angle.
N. planata	18	12	8	60–70/100	115°
N. ovata	19	13	10	66/100	128°
N. capsæformis ...	33	21	13	68/100	128°
N. obtusa	19	15	10	75/100	115°
N. Cornueliana	17	12	7¼–10	70–80/100	107°
N. simplex	13	9	6½	85/100	95°
N. albensis	16	13	7	80/100	105°
N. impressa........	12	9	6	82/100	85°
N. Meyeri	8½	8	5½	70/100	70°

OVATÆ RETICULATÆ.

N. arduennensis	16	12	9	76/100	97°
N. arduennensis, var. *pumila*	6	4	3	70/100	128°

These dimensions are the average and not the extreme sizes in millimetres. The position of the umbo is stated by the percentage of the distance from the posterior extremity, relative to the entire length of the shell, at which the beak is situate. The angles are those formed by the hinges or superior margins, and are chiefly after D'Orbigny. All the species being liable to considerable variation, the above dimensions and figures should be regarded only as approximate, particularly those referring to the imperfectly known Neocomian forms.

ANGULATÆ.

The *Angulatæ* are less numerous than the *Ovatæ*, and the species are far more isolated or distinct from each other. They appear to differ structurally from the *Ovatæ*; for though the radiating structure so apparent in the rib-like sculpturing of certain species is invisible, at least externally, in others, where the shell has been abraded, it is very distinct internally, and is also betrayed in the crenulated lips. The shells are angular, the umbones very prominent and far forward, and the lunule distinctly defined and large.

Subdivision ANGULATÆ PECTINATÆ.

Gault Species.

NUCULA PECTINATA, Sby. Plate III. figs. 15–16.

Nucula pectinata, Sby., Mineral Conchology, vol. ii. p. 207. pl. 192, fig. 6–7 (1828). One of the types of the subgenus *Portlandia* of Mörch.

The dimensions tabulated are the extremes reached, and agree with those stated by D'Orbigny in the 'Paléontologie Française.' The form does not vary to any great extent. The test is thick and strongly ribbed all over, except the lunule, and there are generally about 50 ribs on each side; the interior is nacreous and smooth, except the ventral margin, which is deeply denticulate. The spaces between the ribs, and sometimes the ribs themselves, are finely decussated by striæ of growth, and there are always in adult specimens one or several furrows, or grooves parallel to the ventral margin. The teeth of the hinge are very strong and long, there being apparently as many as 24 on the longer one. It ranges with *N. ovata*, except at Cambridge, where all the casts hitherto assigned to it belong to *N. bivirgata*. The adductor muscles in the latter are situate much nearer to the umbo, and consequently further from the ventral margin, and are more salient; and the form of the cast is less produced posteriorly, more truncate and smaller. The species is widely distributed in France, over the Paris and Mediterranean areas.

It does not occur either at Blackdown or at Speeton, as stated by various authors.

NUCULA PECTINATA, var. CRETÆ, var. nov.

A pectinate form occurs in the Grey Chalk of Devon, which, while measuring only half the length of the Gault form, is considerably higher in proportion. The riblets are also perhaps rather finer, though it is difficult to judge of this in the condition in which the Grey Chalk fossils are preserved. It is obviously a distinct variety.

Gault Species.

NUCULA BIVIRGATA, Sby. Plate III. figs. 12–14; Plate IV. figs. 20–22.

Nucula bivirgata, Sby. in Fitton's "Strata below the Chalk," Geol. Trans. 2nd ser. vol. iv. p. 335, pl. xi. fig. 8 (1836). Including *N. ornatissima*, D'Orb. Pal. Franç. vol. iii. p. 175, pl. 302, figs. 9–12, 1843. Type of the subgenus *Acila*, H. & A. Adams.

The dimensions tabulated are considerably exceeded in a few rare specimens, the largest I have measuring 25 mm. in length. The form is very variable, as shown by the fact that although D'Orbigny admits that the type, with zig-zag marking, may be a variety, the relative dimensions of his two supposed species differ very considerably. The test is thick, strongly ribbed all over, including the lunule; the umbones frequently abraded; interior smooth, nacreous; margin denticulated. The width and prominence of the ribs is about the same as in *N. pectinata,* but their arrangement differs essentially. The anterior and posterior regions are ribbed at different angles, so that the two sets of ribs meet and form a series of chevrons or inverted V's. In all the specimens I have seen the umbos are abraded, and it is therefore impossible to see how the ornament originates. In some cases the ribs diverge or converge twice, so as to constitute a region in which they form a series of inverted W's, but the double divergence is seldom extended to near the umbo. Pl. III. fig. 14 presents a very distinct example of this highly ornamented variety, named *N. ornatisima* by D'Orbigny. Sometimes the ribs meet for short distances all over the shell, and in one case there are five series of diverging ribs side by side. The divergence takes place centrally or nearer the posterior extremity; but I have an example in which a secondary divergence takes place close to the umbones. The sculpture differs in plan, however, even on the two valves of the same shell. As the ribs cross the ridge of the lunule they bifurcate (Pl. III. fig. 12 *a*), so that the lunule is twice as finely ribbed as the rest of the shell, and the same thing occurs towards the posterior margin as far as the hinge extends, and occasionally elsewhere. There is this important difference, that while in *N. pectinata* the ribs are parallel with the margins on both sides as far as the hinge extends, and are only at right angles to the inferior margin, in *N. bivirgata* the ribs abut at right angles to the whole periphery of the shell.

The variability of the ornament completely precludes its use for the subdivision of the species, and there is hardly an adult shell which does not tend to assume the "*ornatissima*" character, at least along its inferior margins. D'Orbigny considered "*N. ornatissima*" to be a smaller shell than *N. bivirgata*; but my largest specimens are all of the more richly sculptured type, to which about ten per cent. of the whole may belong.

A finely ribbed surface all over the shell seems to have been required in the economy of the animal; for the chevron-like breaks prevent the ribs from becoming coarser as the periphery enlarges. The interspaces are very finely transversely striated. The cast is much smaller, more compressed, and with far less space between the inferior margins of the valves than in *N. pectinata*; and these characters, in addition to those mentioned *, seem to distinguish it. It appears to be very common at Cambridge † (Pl. IV. figs. 20–22), Mr. Thos. Jesson, F.G.S., having sent me no fewer than 260 specimens, four of which have portions of the test adhering; and though there is considerable difference in the form of the cast, I do not think they represent more than one species. It ranges, according to Mr. Jukes-Browne, through the Upper and Lower Gault at Cam-

* See *N. pectinata.*

† It was identified with *N. simplex* of the Neocomian by Prof. Seeley; but the error was pointed out by Mr. Jukes-Browne, Quart. Journ. Geol. Soc. vol. xxxi. p. 299, who figured several specimens (pl. xv. figs. 4–8).

bridge. It is limited by Mr. Price to the 7th "bed" of the Lower Gault, and the "Junction bed" at Folkestone; I have, however, also found it there in the basement bed and, I believe, in the Upper Gault.

H. and A. Adams proposed a subgenus, *Acila,* to receive the present and other species with diverging ribs.

Blackdown Species.

NUCULA ANTIQUATA, Sby., Min. Conch. vol. v. p. 118, pl. 475, fig. 4 (1823). Plate IV. figs. 3–8.

This is another extremely variable species, its height sometimes equalling its length. The umbones are very far forward, even occasionally overhanging the lunule, which is heart-shaped, as wide as high, flattened and sharply defined. The surface of the shell is slightly ribbed and strongly reticulated by lines of growth with occasional grooves or furrows; but when the outer surface is removed, a deeply pectinate sculpturing is exposed without any transverse lines. The lips are denticulated, and the hinge is frequently well exposed. It is only known from Blackdown, where it seems to be a not uncommon shell. *N. apiculata*, Sby., Geol. Trans. 2nd ser. vol. iv. p. 342, pl. xvii. fig. 10., is supposed by Mr. Downes to be a synonym for this species; but I have not come across the original, and no specimen of it exists in any museum to which I have had access. The pectinate structure sometimes exposed (Pl. IV. fig. 6) through decay of the surface doubtless led Dr. Fitton to include *N. pectinata* in his list of Blackdown fossils.

Subdivision ANGULATÆ LÆVIGATÆ.

Gault Species.

NUCULA GAULTINA, sp. nov. Plate III. figs. 9–11, 26, 27.

N. impressa, auctorum, of the Gault, non *N. impressa*, Sby., from Blackdown.

This is a small triangular somewhat tumid species, with very distinctly separated, heart-shaped lunule; smooth and polished, finely striated test, crossed by almost invisible pectinate markings, and one or more deep furrows; nacreous internally with finely denticulate inferior margin As in *N. antiquata*, a pectinate structure is completely masked by a thick outer shelly covering. The cast is smooth, with the scars of the adductor muscles very indistinct, and the denticulated margin only visible with a lens. It is a much smaller species than Sowerby's Blackdown *N. impressa*, with which it has so frequently been confounded, only one specimen out of a large number reaching 10 mm. in length by 8 mm. in height and 6 mm. in depth. It is also more triangular, more truncated anteriorly, with a less curved and denticulated inferior margin and larger and more defined lunule. It is an exceedingly abundant fossil at Folkestone, though limited apparently to the Lower Gault. A more elongated form with less-defined lunule is very rare, and is considered a distinct species by Dr. Gwyn Jeffreys. (Plate III. figs. 26, 27.)

ANGULATÆ PECTINATÆ.

	Length. mm.	Height. mm.	Depth. mm.	Position of umbo.	Angle.
N. bivirgata	18	11	9	70/100	104°
N. bivirgata, var. *ornatissima*	17	14	12	68/100	96°
N. pectinata	30	18	15	17/100	100–105°
N. pectinata, var. *cretæ*	15	13	—	67/100	85°

ANGULATÆ LÆVIGATÆ.

	Length. mm.	Height. mm.	Depth. mm.	Position of umbo.	Angle.
N. antiquata	11	9	7–8	90/100	70°
N. gaultina (largest specimens)	10	8	6	80/100	75°

LEDA, Schumacher, 1817.

This genus comprises a number of small, oblong, transverse shells, rounded anteriorly, beaked, and sometimes slightly gaping posteriorly. The hinge is similar to that of *Nucula*, but the shells are not necessarily nacreous, and the margin is always smooth. For the purposes of the present notes, the nearly allied genera *Yoldia*, &c., are united with it. They comprise the Cretaceous group of Nuculidæ described as "*Rostratæ*" by D'Orbigny.

Neocomian Species.

LEDA SUBRECURVA, Phillips, sp., Geol. Yorkshire, pl. 2, fig. 11 (1829). Plate V. figs. 24–25.

No description of the species is given by Phillips, and the figure is almost too imperfect to enable it to be identified. There can, however, be little doubt as to the well-known recurved species of the Speeton Clay being intended, though the name has since been extended to a distinct Gault species. The shell is very inflated, produced anteriorly, with moderately defined lunule, deeply furrowed or corrugated except at the extremities, and finely striated. The umbones are much further forward than in *L. phaseolina*, from which its greater size, far greater depth, and coarser corrugations also suffice to distinguish it.

There are casts from Speeton both in the British Museum and at Cambridge, which are probably of this species, though there is no conclusive evidence of this.

Gault Species.

LEDA PHASEOLINA, Michelin, sp., Mém. Soc. Géol. vol. iii. pl. 12, fig. 6 (1836). Plate III. figs. 22–24; Pl. V. figs. 26–29?

This is a small and rather inflated species, somewhat produced, or beak-shaped anteriorly, with subcentral umbones, a moderately defined lunular region, and the inferior margin very slightly constricted. Its surface is deeply striated, except towards the extremities, which are smooth. There is no nacreous layer, and it occasionally presents remains of colouring in the form of alternating pale brown and cream-coloured bands.

D'Orbigny combines the species with *Leda subrecurva*, Phillips, from Speeton; but they are certainly distinct. Michelin's specimens were from the Gault, and the dimensions are stated at 16 mm. in length, while the longest I have met with in England do not exceed 11 mm.; it is further characterized as compressed, with central umbones and indistinct lunule.

Since, however, I have only come across, in French collections, specimens bearing this name which are in every respect identical with those of our own Gault, I think the description may be inaccurate. Pictet describes, as *L. Neckeriana*, a very similar but even larger shell, 18 mm. long, from the Gault of the Perte-du-Rhône, distinguishing it from Michelin's described type chiefly by the more open umbones and greater depth of the valves, characters which agree more with the actual French and English specimens which I have seen. It is possible that these may be distinct local varieties; but I think it preferable at present to admit but one Gault species of the "*L. subrecurva*" type.

It appears in lists of Cambridge fossils; but I have only seen two imperfect specimens belonging to Mr. Jesson, which might possibly be referred to it. Mr. Meÿer has shown me imperfect specimens from East Shalford, which render it certain that it, or a similar species, is present in the *Perna*-bed there; and some casts from Speeton in different collections approximate very closely to it *. It ranges through the Lower Gault of Folkestone, and is rarer than the other species.

Blackdown species.

LEDA LINEATA, Sby., sp., in Fitton, Trans. Geol. Soc. 2nd ser. vol. iv. p. 342, pl. xvii. fig. 9 (1836). Plate IV. figs. 13–16.

This species strongly resembles *L. subrecurva*, but is more elongate at both extremities and thus skiff-shaped. The umbones are less central and the lines of growth continued over the entire shell. The lip is strongly crenated internally, a character I have not hitherto detected in *L. subrecurva*. Sowerby's description of the shell makes it "elliptical, posterior extremity slightly truncated, with a short point at its upper angle; surface transversely striated, with lines straighter than the lines of growth, which they consequently cross twice." Even with Sowerby's original specimens before me, I am not able to detect the latter character, which would indeed form a very unusual ornamentation. In his most perfect specimen however the growth has been arrested at about midway, the inner region being marked off from the marginal region by a deep constriction

* They are undistinguishable from it, and bear in the British Museum the MS. names *N. semiaperta* and *N. cordiformis*. Pl. V. figs. 26–29.

while the striæ are interrupted and subsequently continued on a new plan, this interruption having probably led to the description above cited. The series from the Bristol Museum, five in all, appears a remarkable one; for another shell is highly distorted and has the beak almost overhanging the anterior margin (Pl. IV. fig. 14). *L. lineata* has been confounded with *L. subrecurva* in almost all Cretaceous lists, and Sowerby's name regarded as a synonym, though the differences between the two species or varieties are quite apparent. Some casts from the Grey Chalk at Dover indicate the presence of this species there.

Gault species.

Leda Vibrayeana, d'Orb., sp., Pal. Franç., Terr. Crét. vol. iii. p. 172, pl. 301, fig. 12–14, 1843. Pl. III. figs. 17–18, 25; Pl. IV. figs. 26–27.

This is a small ovate rounded shell, not nacreous, of a glossy brown colour with irregular lighter bands, and is the most symmetrical of all the Cretaceous *Ledæ*, the umbones being nearly central and the lunule inconspicuous. It is exceedingly abundant at Folkestone, especially towards the upper part of the Lower Gault, and may be picked up in quantity on the shore, its bands of colour giving it a singularly recent aspect. The average length is but 10 mm., though exceptional specimens reach 13 mm. in length, 7 mm. in width, and 11 mm. in height. The average dimensions of 70 Cambridge specimens sent me by Mr. Jesson are larger than those of the Folkestone specimens, yet without surpassing the largest of the latter*. The muscular impressions and the form of the teeth are very ill defined on the cast, which I find, upon an examination of the specimens at Cambridge, has been described by Prof. Seeley as *N. subelliptica* and *N. rhomboidea*†. It seems to be equally common in the Gault of the Paris Basin, D'Orbigny's description making it rather more compressed than is found to be the case in measuring our own very perfect specimens.

A very thin, smooth, and flattened shell is not uncommon in the Upper Gault at Folkestone, where only single valves occur. It may be but a slightly modified form of this species, under different conditions of preservation.

Neocomian Species.

Leda Seeleyi, sp. nov. Pl. V. figs. 17–20.

There is nothing to distinguish this species from *L. Vibrayeana* unless it be a slightly more flattened form with more rounded and obtusely oval extremities. Seeley's name, originally given to *L. Vibrayeana* of the Cambridge Gault, had fallen into disuse as a synonym, but is still attached to the tablet of Speeton-clay specimens in the Woodwardian Museum. It would be inconvenient to retain it, even restricting it to the Neocomian form; and a new

* A length of 14 mm. is quoted by Pictet as the average of the Swiss form.

† Ann. Mag. Nat. Hist. ser. 3, vol. vii. p. 120.

specific name is necessary, unless the Speeton and the Gault forms are to be united. There is a similar shell in the British Museum from Atherfield.

Gault Species.

Leda Mariæ, d'Orb., sp., Pal. Franç., Terr. Crét. vol. iii. p. 169, pl. 301, fig. 4–6 (1843). Plate III. figs. 28–29.

The dimensions of this shell are usually much under those I have tabulated. It is skiff-shaped, with the anterior hinge-margin concave and terminating anteriorly in a more or less produced or rounded and obtuse rostrum, while the posterior margin is blunt and irregularly rounded and the inferior margin strongly and slightly sinuously curved. It is a smaller and much more compressed shell than those hitherto described, and, unlike them, the valves are more frequently detached than otherwise. It is striated, except towards the extremities, which are smooth, as in *L. subrecurva.* D'Orbigny's description points to a larger and less compressed shell with a less central umbo; but his specimens show the species to be the same. Pictet mentions a length of 14 millims.

The species is very common in the Lower Gault of Folkestone, and appears to pass unchanged into the Folkestone Beds of the Lower Greensand and into the Upper Gault. The variability of the shell precludes me from fixing any specific character by which to distinguish it from *L. angulata*, Sby., from Blackdown; but it is a more elongate and delicate shell, and I hardly like to reunite them on the present material.

Blackdown Species.

Leda angulata, Sby., sp., Min. Conch. p. 120, pl. 476, fig. 5 (1823). Plate IV. figs. 17–19

There are no definable characters by which this can be distinguished from *L. Mariæ*, but the latter appears to be more delicate and more elongated or rostrated. It is, however, so variable a shell in the Gault that some specimens come well within the form of the Blackdown types, though the latter seem less compressed and have a slightly denticulated margin. To determine whether sufficient modification had taken place during the lapse of time between the deposition of the Gault and the Blackdown beds to have furnished new specific characters, would require a very large series from the latter and an acquaintance with the marginal and hinge-characters of the former. In the mean time it appears useless to exchange D'Orbigny's well-known name in favour of the nearly obsolete name of Sowerby, and by retaining the two names we at least mark the difference in horizon and perhaps of species.

Neocomian Species.

Leda scapha, d'Orb., sp., Pal. Franç., Terr. Crét. vol. iii. p. 167, pl. 301, figs. 1–3. Plate V. figs. 21–23.

This shell resembles the Gault species, *L. Mariæ*, in the closest possible manner. It is more regular in outline, however, and the inferior margin is less sinuous. Prof. Forbes called attention to the omission by D'Orbigny of any reference to the striæ, which occupy precisely the same position as in the Gault species, leaving the two extremities smooth. My own specimens from Atherfield are small, but singularly well preserved. Mr. Meÿer has also some larger though imperfect specimens; there is a shell from Speeton in the British Museum; and I have it from near Hunstanton. A well-preserved series might possibly reveal further slight differences, though it is quite obvious that *L. Mariæ*, *L. angulata*, and *L. scapha* are merely slight modifications of a single true species, and present an instance in which the necessity for a trinomial terminology becomes especially apparent.

Its presence at Atherfield has been recorded by Profs. Forbes, Fitton, and Morris.

Neocomian Species.

Leda spathulata, Forbes, Quart. Journ. Geol. Soc. vol. i. p. 245, pl. 3 fig. 4 (1845). Plate V. figs. 30–34.

This species seems to be intermediate between *L. scapha* and *L. solea* of the Gault. It is somewhat large, elongated, with the posterior extremity obtusely rounded, and slightly produced or rostrated anteriorly. The shell is thin and finely striated and compressed. D'Orbigny identified it with an Aptian species, *L. lingulata*, but this appears to have been wider posteriorly and to have tapered towards the beak, more as in *L. solea*. Pictet mentions specimens far exceeding ours in size, and reaching a length of 25 millim.

It seems by no means a rare shell, and is mentioned by both Forbes and Fitton as occurring at Atherfield. Mr. Meÿer has some singularly well-preserved specimens from the Atherfield beds of Sevenoaks, and others from the Perna Bed of East Shalford and from Shanklin. The Leckenby collection in the Woodwardian Museum contains it from Speeton; and it was met with in abundance in a quarry near Hunstanton by members of the Geologists' Association. Specimens from the Folkestone Beds near Nutfield, belonging to Mr. Meÿer, almost indicate the presence there of another species, *L. lingulata* of D'Orbigny. A specimen from Speeton in the British Museum bears the MS. name *L. pandata*.

Gault Species.

Leda solea, d'Orb., sp., Pal. Franç., Terr. Crét. vol. iii. p. 170, pl. 304, figs. 4-6 (1843). Plate III. fig. 30.

This is by far the most elongated type of Cretaceous *Ledæ*, and possesses a very thin glossy shell of a brownish colour. It is skiff-shaped, the inferior margin is slightly sinuous, the posterior region short, with an irregularly rounded margin, the anterior prolonged into a rostrum, with sharply truncated extremity, and a slight ridge running diagonally from the umbo to the lower corner of the truncated end. The whole surface is marked with exceedingly fine striæ. It is a little larger, and more compressed, and has more central umbones than D'Orbigny's description admits, and he does not notice the fine striæ; but actual comparison shows that those from English and French localities belong to the same species. From its likeness to the recent *L. lanceolata*, Lamarck, it seems probable that it gaped at the extremities, and in that case it would fall into H. and A. Adams's subgenus *Adrana*. There does not appear to be any representative of this type at Blackdown.

Dimensions tabulated.*

	Length. mm.	Height. mm.	Depth. mm.	Position of umbo.	Angle.
L. Vibrayeana	10	8	5	50/100	119°
L. phaseolina	11	7	6	55/100	100°
L. subrecurva	18	10	10	80/100	—
L. Seeleyi	10	7	6	50/100	—
L. lineata	11	7	5	55/100	—
L. Mariæ	7	4½	3	40/100	145°
,, *largest*....	11	6	3½		
L. angulata............	6½	4½	3	40/100	—
L. scapha..............	8	4	3	40/100	135°
L. solea	21	7	3	25/100	135°
L. spathulata	18	7	0	40/100	135°

To sum up, it does not appear that the Nuculidæ will ever be of great importance as aids to the field geologist or in stratigraphy. Their species seem to have been so slowly modified that the lapse of time between one Cretaceous stage and another was insufficient in most cases to effect any change that can readily be grasped without very close comparison; and it requires considerable study to convince us that the seemingly identical Neocomian, Gault, and Blackdown species possess characters by which they can with certainty be distinguished. The pectinate forms, however, *N. pectinata* and *N. bivirgata*, by their very easily recognizable characters and their

* The dimensions are given in millimetres. Average specimens are selected as far as possible. The position of the umbo is expressed in the percentage of the entire length of the shell at which it is situate from the anterior margin. The angles are taken from D'Orbigny, as I possess no instrument capable of including any so wide. The measurements in the last two columns are not quite reliable.

sudden appearance and disappearance, afford data by which, in England at least, horizons might be unerringly recognized; while the rest of the *Nuculæ* and *Ledæ*, from their great abundance, are also not without a certain value in this respect when carefully studied. The accompanying lists will at all events show clearly what species may be looked for in each of our British Cretaceous series, and will render the, at present, exceedingly difficult task of determining them a comparatively light one.

That portion of this paper which deals with the Neocomian, is, I regret to say, the least satisfactory. Only stray specimens seem to have been collected, and when all are united, we possess nothing approaching the grand series that can be brought together for examination from Folkestone, Cambridge, or Blackdown. Add to this the very different states in which they are found, that many are imbedded in hard rock, and are imperfect, or casts, or compressed, and it will be seen how relatively unfavourable are the conditions for determining their limits of variation. By using great care, however, and comparing them again and again, I believe results are now arrived at which will be upheld by any future investigation.

Of the group of "Ovatæ" we have apparently four distinct Neocomian types. Of these *N. planata* seems almost ubiquitous, ranging from Speeton to Atherfield, whilst the range of the remainder seems considerable, though scarcely yet ascertained. They may be roughly distinguished from each other as follows:—*N. planata* is the most ovate and compressed; *N. Cornueliana* is thicker and more subangular; *N. simplex* has the beak almost overhanging the front margin, and is not at all produced anteriorly; and *N. Meyeri* is easily identified by its tall triangular form and well-defined, heart-shaped lunule. A *Nucula subtrigona* occurs in several British lists; but I have not been able to ascertain that it is distinct from the preceding. This appears to include all the well-defined species of the continent. The group "Angulatæ," it is strange to find, is so far totally unrepresented in the Cretaceous series of England or France, earlier than the Gault. The *Ledæ*, four in number, require, with the exception of *L. spathulata*, very careful comparison to distinguish them from those of the overlying series, but are easily separable from their companion species in the same rocks; the only possibility of confusion which might arise being perhaps between the young of *L. spathulata* and *L. scapha*. It is not improbable that further collecting may bring new species to light in so varied and extensive a series of strata as our Neocomian and Aptian, but the complete list of those known to me at present is:—

N. planata, *Desh.*	L. Seeleyi, *Gardn.*
N. Cornueliana, *d'Orb.*	L. subrecurva, *Phillips.*
N. simplex, *Desh.*	L. scapha, *d'Orb.*
N. Meyeri, *Gardn.*	L. spathulata, *Forbes.*

The Gault forms are in such perfect preservation and so thoroughly well defined from each other that confusion is impossible, except in the rare case of a variety being met with departing abnormally from the specific type. The species are: —

N. ovata, *Mant.*	N. bivirgata, *Sby.*
N. capsæformis, *Mich.*	N. gaultina, *Gardn.*
N. albensis, *d'Orb.*	L. Vibrayeana, *d'Orb.*
N. arduennensis, var. pumila, *Gardn.*	L. phaseolina, *Mich.*
N. pectinata, *Sby.*	L. Mariæ, *d'Orb.*
	L. solea, *d'Orb.*

A comparison with lists that have been published, both of the Cambridge and Folkestone Gault species, will show that the number is here rather reduced than added to. Two new species are added, both being exquisitely preserved and abundant little shells, whose distinctness, though most obvious, had hitherto remained unrecognized.

Many, the majority in fact, of the Gault forms reappear, slightly modified, in the Blackdown Beds, with the notable exception of the two forms, *N. pectinata* and *N. bivirgata*, which, we have seen, are equally unknown in the Neocomian. The forms *N. obtusa* and *N. impressa* of the "Ovatæ" are perfectly distinct from each other; and *N. antiquata* can be immediately distinguished by the toothing along its margins; nor is there any fear that the two species of *Leda* can be confused; for the one is of the "*subrecurva*" form and the other a smaller and sharply beaked skiff-shaped shell.

The Blackdown species are:—

N. impressa, *Sby.*	L. lineata, *Sby.*
N. obtusa, *Sby.*	L. angulata, *Sby.*
N. antiquata, *Sby.*	

And for the Grey Chalk:—

N. pectinata, var. cretæ, *Gardn.*	N. impressa, *Sby.*
N. obtusa, *Sby.*	L. lineata, *Sby.*

In the Grey Chalk we have apparently Blackdown species, with the noteworthy addition of a small form of *N. pectinata*. Their condition, however, does not permit of the minute comparison necessary to determine them with the same exactitude as other Cretaceous species. The White Chalk has proved hitherto singularly barren of Nuculidæ, and I have not even met with specimens from the Antrim chalk, which is otherwise rich in bivalves and gastropods, so that we are wholly without information in the British area as to the further development of the genus until the Eocene period. The considerable lists of species, however, from the Cretaceous of Limburg and Aix-la-Chapelle, show that they are by no means absent from the newer Cretaceous faunas; and there is no doubt that further collecting in the chalk of Ireland and Scotland would enrich our fauna with a few additional species.

All the Gault species have been examined by Dr. Gwyn Jeffreys, with the result that he is only able to connect *N. impressa* among the "Ovatæ" with an existing species, *N. nitida* of Sowerby, so that the remaining types must be regarded as extinct. He remarks that *N. capsæformis* rather leans towards *Leda*. Of the "Angulatæ," *N. pectinata* seems to have no living representative; but *N. bivirgata*, with its beautiful sculpture, is allied to *N. insignis* of Gould, and *N. gaultina* to *N. sulcata* of Bronn. Among the *Ledæ* he considers *L. phaseolina* to be allied to *L. abyssicola* of M. Sars, *L. Mariæ* to *L. fragilis* of Chemnitz, and *L. solea* to *L. cuspidata* of Philippi. The result of his examination of these and other groups of Gault fossils has led him to believe that the depth of the sea in which the Lower Gault of Folkestone was deposited was somewhere between 50 and 100 fathoms, though some of the smaller bivalves, especially belonging to other genera, are now inhabitants of much greater depths.

The accompanying list is arranged in the manner which, I take it, is the most useful to those desirous of naming specimens; and as it is as complete as the material will allow to the present date, it would be convenient were no other names attached to specimens unless they present clearly marked characters different from those described. If read vertically, the lists are separately complete for each of the three stages of the Cretaceous system in Britain; and if horizontally, the representative species, or the lines of descent of each, can be traced through the three stages.

NUCULA.	*Neocomian.*	*Gault.*	*Upper Greensand and Grey Chalk.*
Group 1. OVATÆ.			
Ovatæ lævigatæ.			
Type "*ovata.*"	N. planata.	N. ovata. N. capsæformis. }	N. obtusa.
Type "*impressa.*"	N. Cornueliana. N. simplex. } N. Meyeri.	N. albensis.	N. impressa.
Ovatæ reticulatæ.	....	N. arduennensis. ——, var. pumila.	
Group 2. ANGULATÆ.			
Angulatæ pectinatæ.	....	N. pectinata. N. bivirgata.	N. pectinata, var. [cretæ.
Angulatæ lævigatæ.	....	N. gaultina.	N. antiquata.
LEDA.	L. Seeleyi. L. subrecurva. L. scapha. L. spathulata.	L. Vibrayeana. L. phaseolina. L. Mariæ. L. solea.	L. lineata. L. angulata.

Synonyms or species belonging to other families, to be definitely excluded are:—*N. pulchra*, Sby., and *N. undulata*, Sby. (*Neæra*), *N. apiculata*, Sby., *N. subelliptica*, Seeley, and *N. rhomboidea*, Seeley (synonyms).

EXPLANATION OF PLATES III.–V.

PLATE III.*

Figs. 1–3. *N. ovata*, Mant.
4, 5. *N. capsæformis*, Mich.
6–8. *N. albensis*, d'Orb.
9–11. *N. gaultina*, Gardn.
12–14. *N. bivirgata*, Sby. Fig. 14. var. *ornatissima*. D'Orb.

* All the specimens on this Plate are in the author's collection.

Figs. 15, 16. *N. pectinata*, Sby.
17–18. *Leda Vibrayeana*, d'Orb.
19–20. *N. arduennensis*, var. *pumila*, d'Orb., sp.
21. Id. enlarged.
22–24. *Leda phaseolina*, Mich.
25. *L. Vibrayeana*, d'Orb.
26–27. *Nucula gaultina*, Gardn.
28, 29. *Leda Mariæ*, d'Orb.
30. *L. solea*, d'Orb.

Plate IV.

Blackdown Fossils.

Figs. 1, 2. *Nucula obtusa*, Sby. Jermyn-St. Museum.
3–8. *N. antiquata*, Sby. Fig. 6. from the collection of the Revd. W. Downes, B.A., F.G.S.; the rest from the Bristol Museum.
9–12. *N. impressa*, Sby. Figs. 9 and 12, from the Bristol Museum, figs. 10 and 11, from Mr. Downes's collection.
13–16. *Leda lineata*, Sby. Bristol Museum.
17–19. *L. angulata*, Sby. Bristol Museum.

Cambridge Fossils.*

Figs. 20–22. *N. bivirgata*, Sby.
23. *N. arduennensis?*, d'Orb.
24, 25. *N. albensis*, d'Orb.
26, 27. *Leda Vibrayeana*, d'Orb.
28–30. *Nucula ovata*, Mant.

Plate V.

Fig. 1. *Nucula planata*, Desh., Atherfield. Woodwardian Museum.
2, 3. —— ——, Speeton Clay. Woodwardian Museum.
4. —— ——, Redcliff, Isle of Wight. Mr. Meyer.
5, 6. *N. Cornueliana*, d'Orb., Tealby. Woodwardian Museum.
7, 8. —— ——, Atherfield. Author's collection.
9. —— ——, Redcliff. Mr. Meyer.
10. —— ——, Atherfield (enlarged). Author's collection.
11, 12. *N. simplex*, Desh., Atherfield. Author's collection.
13. —— ——, Atherfield (enlarged). Author's collection.
14, 15. *N. Meyeri*, Gardn., Atherfield. Author's collection.
16. —— ——, Atherfield (enlarged). Author's collection.
17, 18. *Leda Seeleyi*, Gardn., Speeton. Woodwardian Museum.
19. —— ——, Speeton. British Museum.
20. —— ——, Atherfield. British Museum.
21, 22. *L. scapha*, d'Orb., Atherfield. Author's collection.
23. —— ——, Speeton. Woodwardian Museum.
24, 25. *L. subrecurva*, Phillips, Speeton. Woodwardian Museum.
26. *Nucula cordiformis*, MS. (?*L. phaseolina*), Speeton. British Museum.
27, 28, 29. *Leda phaseolina*, ? Mich., Speeton. British Museum.
30. *L. spathulata*, Forbes (*L. pandata*, MS.). British Museum.
31, 32. —— ——. Woodwardian Museum.
33. —— ——, Sevenoaks. Mr. Meyer.
34. —— ——. Author's collection.

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* All these are from Mr. Jesson's collection.

Discussion.

Dr. Gwyn Jeffreys doubted the necessity of forming a separate family of Nuculidæ. He included them in the Arcidæ. He had examined the Gault collection of Mr. Gardner, which appeared to contain ten times as many species as had already been described from that formation. He considered that the Gault Nuculidæ lived at a depth of from 50 to 100 fathoms, and this view was confirmed by the nature of the materials forming the Gault clay.

Prof. T. Rupert Jones said that in many parts the Gault swarms with Microzoa, and these seemed to confirm Dr. Gwyn Jeffreys's view that the Gault was formed at a depth of about 100 fathoms.

The Author thought that the limited area covered by the true Gault clays and the presence of coniferous wood and fruit pointed to the conclusion that the Gault was an estuarine deposit. He believed the evidence indicated that the Gault was deposited in a gradually deepening sea.

5. *On the* Skull *and* Dentition *of a* Triassic Mammal (*Tritylodon* * *longævus*, Owen) *from* South Africa. By Sir Richard Owen, K.C.B., F.R.S., F.G.S., &c. (Read November 21, 1883.)

[Plate VI.]

A collection of fossils from the Trias of Thaba-chou, Basuto-land, submitted to me by Dr. Exton of Bloemfontein, Cape of Good Hope, included the subject of the present paper. It was associated with remains of some of the Reptilian genera (*Kisticephalus*, *Batrachosaurus*, e. g.) described in my 'Catalogue of the Fossil Reptilia of South Africa in the British Museum' †.

It is a skull with mammalian characters, lacking the hinder cranial end and the mandible, but retaining with the upper jaw its dentition, though many of the teeth are more or less mutilated. This dentition consists of incisors and molars, with a diastema of the relative extent shown in many Rodents and some Marsupials. The subjoined figures (Pl. VI. figs. 1–4), being of the natural size, dispense with notes of admeasurements.

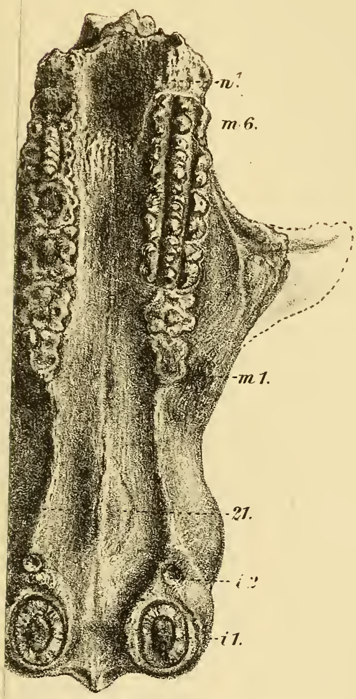
The matrix adhering to this fossil is identical in colour, density, and composition, with that attached to the Labyrinthodont and other Reptilian remains therewith associated: the degree of petrifaction and the specific gravity of the mammalian fossil are the same. No Tertiary deposits or any recent petrifying formation, inducing such mineral change in bone and contiguous bed, exist in the locality whence this skull and the associated organic remains were obtained.

In the preserved portion of the cranium (Pl. VI. figs. 1, 2, 3) sutural tracts are recognizable: these determine the pair of parietal bones by the portions of them, 7, 7, which contribute to the calvarium; they meet above the upper mid line, and there develope a crest which has undergone abrasion. This part indicates an anchylosis of the parietals into a single bone. A short anterior divarication bounds a small vacuity exposing matrix which has filled the cerebral cavity; which vacuity is completed anteriorly by a similar divarication of the mid and hind angles of the frontal bones, the mid suture of which is unobliterated. The above vacuity, *v*, if natural, represents a fontanelle, or it may be interpreted as a 'pineal' or parietal foramen; it may, however, be due to posthumous injury.

Each frontal (fig. 1, 11, 11) expands and forms the upper border of the orbit, *o*, of its side, which border is obtuse. The upper surface of the frontal, at a short distance mesiad of the orbit, is traversed by a rather shallow longitudinal groove. To the anterolateral angle of each frontal is articulated a lacrymal bone (fig. 1, 73) of moderate size, encroaching a short way upon the face, perforated

* τρεῖς, three, τύλος, knob, ὀδοὺς, tooth.
† 4to, 1876, pp. 88, pls. i–lxx.

2.



A. S. Foord del. Mintern Bro's imp.

A. S. Foord del. et lith.

TRITYLODON LONGÆVUS.

Mintern Bros imp.

on its orbital surface by a lacrymal foramen, and articulating below with the anterior end of the malar bone, 26. This defines the lower, and almost the anterior half of the border or boundary of the orbit, which was not completed behind by bone. The frontals contract as they extend forward, articulating with the nasal, 15, and maxillary 21, bones, between which are their pointed terminations.

The nasal bones, 15, at first narrow and convex, gradually expand and contribute the upper half of the border of the external nostril. This is terminal (fig. 4), opening directly forward with a slight inclination to the lower border, which is contributed by the premaxillaries, 22. In their forward course the nasals articulate laterally with the maxillary bones. The anterior termination of the nasals, which slightly overhang the aperture, has suffered abrasion.

The facial part of the maxillary extends from the lacrymal, expanding as it advances to unite above with the frontal and nasal bones, and swells outwardly where it joins the premaxillary: it is separated from the nostril by the union of that bone, 22, with the nasal. The alveolar part of the maxillary (fig. 2, 21) extends from the maxillo-malar suture backward, supplying a partial floor to the orbit and a sufficient case for the series of large and complex grinders (fig. 2, 1–6).

The premaxillary (fig. 3, 22) curves upward and backward, ending on the upper surface of the skull in a point, where it is interposed between the nasal and maxillary (fig. 1); it expands as it descends, advancing, to form the thick smooth convex side wall of the nostril, bulging outward to complete the socket of the large anterior incisor; mesiad it contracts to join its fellow, the pair forming at their junction beneath the nostril a short pointed process (fig. 4).

The premaxillary part of the bony palate (fig. 2) is short, convex lengthwise, concave across. The terminal expansion of each premaxillary is occasioned by the formation of the socket of the large incisor, *i* 1. Behind each socket is a much smaller one, *i* 2. Behind these sockets may be discerned a trace of the transverse suture between the palatal portions of the premaxillary and maxillary bones. The mid-palatal suture of the maxillaries is slightly produced for a short extent, and this region of the bony palate is bounded laterally by ridges dividing the palatal from the facial parts of the maxillary. These lateral ridges slightly converge as they pass backward to terminate each at the fore wall of the socket of the anterior molar tooth. The extent of this 'diastema,' or toothless interval between incisors and molars, is shown in fig. 2. The intermolar part of the bony palate is moderately concave lengthwise, rather more deeply across: it terminates between the fifth and sixth molars: at least careful removal of matrix failed to expose further osseous extension: and the cavity so exposed (Pl. VI. fig. 2) I take to indicate the hinder or palatal nostril, n', which opens obliquely backward.

The tracts of bone continued backward from the orbits (fig. 3) expand vertically, and converge, leaving a contracted cranial or cerebral cavity, represented by the matrix exposed by the breaking away of the occipital part of the skull.

The thin plates of bone bounding the postorbital part of the cranium may include parts of the parietals, 7', and alisphenoids. There is no trace of an ectopterygoid. The loss of the occiput is to be regretted; but the mammalian characters in the preserved parts of the skull dispense with the confirmatory conclusion of double condyles, which, however, are common to Batrachians as well as Mammals.

I next pass to the dentition of *Tritylodon*. Its condition in the fossil indicates the following formula:—$i\,\frac{2\text{·}2}{2\text{·}2}$, $m\,\frac{6-6}{6-6}=32$. The grinding-surfaces of the upper teeth bespeak the number of the lower ones; but, in the case of the incisors, a single modified pair might have been opposed, after a leporine fashion, to the two pairs above. As in the Leporidæ also, the six upper may have been opposed by five lower grinders; but in *Tritylodon* the upper grinders are implanted by long fangs, two of which are external: the molars of Leporidæ are rootless.

As before remarked, the crowns of the front and chief incisors are broken off near their sockets. Sufficient remains to show a thin coat of enamel upon their front and sides: the exposed dentine behind is scored by vertical striæ; any cement which may have covered the striæ has perished. The dentine has the usual mammalian compactness. The size, sectional shape, and relative position of these incisors are given in Pl. VI. figs. 2, 3, & *i* 1. The exposed part of the pulp-cavity, fig. 2, *p*, is of a size suggestive of these incisors having enjoyed uninterrupted growth; removal of part of the outer wall of the socket of the left incisor showed the body of the tooth to be continued without diminution through the premaxillary into the maxillary, as in a scalpriform incisor of continuous growth. Behind each of the incisors, with an interval of 2 millims., is the socket of a smaller premaxillary tooth, fig. 2, *i* 2, of which the remains of a thin wall only of the base of the tooth can be traced, enclosing a pulp-cavity relatively larger than in the front incisor, but, as in it, filled with the reddish matrix. This difference of size of pulp is due to the fracture of the implanted root, and is also suggestive of continuous growth of the tooth. After the ridged diastema without trace of socket, we come upon a similar mutilated condition of the tooth (fig. 2, *m* 1) which is the foremost of a series of six contiguous grinders. The crown of this tooth is subtriangular, as as seen on this fractured surface, the base turned backward and in contact with the next molar, *m* 2. This tooth is the foremost of five similar molars, to which it is very little inferior in size. It presents the same subquadrate figure, and shows the external notch partially bisecting the outer side of the tooth (fig. 5); its crown being broken away at the level of the alveolus, the character of the part lost is given by the succeeding teeth. In these the crown is impressed by a pair of antero-posterior grooves, dividing the grinding-surface into three similarly disposed ridges, and each ridge is subdivided by cross notches into tubercles (fig. 7). Of these, there are, in the second to the fourth molar inclusive, four tubercles on the mid ridge, *b*, three on the inner ridge, *c*, and two on the outer ridge, *a*. Of the tubercles on the mid ridge, *b*, the hindmost is smaller than the others; and, in the fourth molar, a minute one projects between the bases of the first and second tubercle. There is a similarly minute tubercle behind the base of the second normal one of the outer coronal ridge. But the number of the tubercles which first catches the eye on the middle and internal ridges of the crowns of the best-preserved molars is "three": and this has suggested the generic name, which must not be interpreted to mean that there are but three tubercles on each tooth, but to indicate that the tri-tuberculate pattern prevails, more or less, on each of the three ridges of the singularly complex and unique grinding-surface of the molars of the present oldest known genus of Mammals. The sixth and last molar—last so far as the mutilated condition of the post-maxillary part of the skull permits a judgment—is rather smaller than the rest, and the subquadrate transverse shape of crown here inclines to a trihedral shape, with the apex outward. The threefold division of the crown is, nevertheless, as strongly marked; but one knob of normal size only is developed on the outer ridge, flanked by a minute tubercle on each side of its base. The normal tubercles of the mid and inner ridges are two in number; the larger one on the inner ridge repeats or completes the transverse array of three.

In an outer side view (Plate VI. figs. 3 & 5) these molars, from the second to the fifth inclusive, present a bilobed character; the anterior tubercle is reduced to the basal cusp in the sixth molar. The inner or mesial side of the 2–5 molars gives a trilobate outline, fig. 6. I subjoin views of the best-preserved, third, right-side molar, enlarged three diameters, showing its outer, 5, inner 6, and masticating, 7, surfaces, the characters of which, in my odontological experience, are unique.

If reference be made to the 6th Volume, 2nd series, of the 'Transactions' of our Society, p. 203, pl. xxi., the enlarged view, fig. 4, of the upper molars, grinding-surface, of *Hyracotherium leporinum* may suggest a resemblance to those of *Tritylodon*. But the middle multicuspid ridge is represented by only two small tubercles, and both the outer and inner risings of the crown are also limited to two tubercles. Moreover it will be noticed that such degree of approach to the grinding-pattern in *Tritylodon* is restricted to the three true molars characteristic of the placental Ungulates. The repetition of the multicuspidate character in five consecutive grinders recalls the lower marsupial numerical type of dentition (*Thylacotherium*, e.g.). Nevertheless *m* 1 & *m* 2 may be "premolars."

In the further course of comparisons, I have found the nearest approach to the masticating character of *Tritylodon* in teeth of Mammals of equal, or nearly equal antiquity. These evidences are afforded by two extinct genera. The first, from the Keuper of Diederloch, consist of teeth or a tooth-crown, on which the discoverer, Plieninger, in 1847, founded his genus *Microlestes* *. Teeth of like character

* 'Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg,' 8vo, Bd. ii. p. 164, Taf. i. figs. 3 & 4.

discovered by our late Fellow-member, Mr. Charles Moore, in a bone-bed at Holwell, Somersetshire, are referred to, and are now accepted, as of a like geological age, the "Rhætic."

I reproduce three of the figures, somewhat enlarged (Plate VI. 8, 9, 10), of these teeth. They are molars, and the two fore-and-aft ridges of their grinding-surface are divided into a number of small tubercles *; these, like the ridges, run in the same antero-posterior direction as in the tuberculate ridges of the upper molars of *Tritylodon*.

Not any teeth of Tertiary or existing Mammals, known to me, show the multituberculate character of fore-and-aft ridges or raised portions of the grinding-surface; the nearest approach is presented by members of the lower lissencephalous and lyencephalous groups (*Chiroptera, Insectivora, Rodentia, Marsupialia*): but the tubercles are fewer in number, relatively larger, and the lengthwise arrangement of both knobs and ridges is wanting.

Another extinct mammalian genus, with molars of the same masticatory proportions as in *Tritylodon*, has been discovered in the Oolitic slate of Oxfordshire; it was described under the generic name *Stereognathus* by Mr. Charlesworth †. The teeth were included in a portion of jaw, referred to a mandibular ramus, and two of them showed the characters of the grinding-surface. This unique fossil was kindly submitted to me, and the best-preserved molar I described as "of a quadrate form, of very little height, and supporting six subequal cusps in three pairs, each pair being more closely connected in the antero-posterior direction of the tooth than transversely" ‡. The dental generic distinction is shown in the minor subdivision of the summits of the ridges: but their number and course are the same: "the crown of these molars might be described as supporting three parallel antero-posterior ridges; but each ridge in *Stereognathus* developes but two tubercles" §.

Now, this is the character more definitely expressed by the antero-posterior series of cusps in the quadrate upper molars of *Tritylodon*: its lower molars may show a nearer resemblance to those of *Stereognathus*.

The dental characters of *Tritylodon* are thus repeated in extinct genera of Secondary periods, but are repeated, apart, in distinct genera.

Microlestes shows the antero-posterior ridges of its multituberculate molars (Plate VI. figs. 8–10); but such ridges are limited to two in number.

* "The inner side of the tooth is indicated by the more prominent part of the wall, which is divided into three tubercles; the outer side by the lower wall with indications of subdivision into smaller and more numerous tubercles." Owen, 'Researches on the Fossil Remains of Australian Mammals, with a Prefatory Notice of British Mesozoic Marsupials.' 4to, vol. i. p. 6, plate i. figs. 1, 6, 7, 9, 19.

† Quart. Journ. Geol. Soc. vol. xiii. (1857), p. 1, pl. i.

‡ *Op. cit.* vol. i. p. 19.

§ *Op. cit.* plate 2, figs. 27–30.

Stereognathus repeats the three parallel antero-posterior ridges; but the tubercles on each ridge are limited to two in number.

In *Tritylodon*, these characters are combined.

Such testimony was, I confess, a relief to me; for my experience of the air-breathing Vertebrates of the old Secondary formations of South Africa had been, throughout its great extent, so uniform in respect of their limitation to the cold-blooded series, that I hesitated, at first view of the subject of the present paper, to acknowledge it as, in the scale of life, so far above the series of fossils with which it was associated. The more obvious characters of cranial structure and of dentition, even in the comparatively undeveloped state of the fossil skull, could only be interpreted, however, as in the foregoing details.

The mammalian characters of *Tritylodon* may be briefly summed as:—Dentition of scalpriform incisors divided by a long interval from a series of broad-crowned tuberculate molars, implanted by distinct roots (fig. 3, *m* 5), showing end of growth (the Leporidæ and some other mammalian genera have rootless grinders); no trace of provision for succession of teeth; osteology of skull, as above described, showing mammalian conformity with the characters of the dentition.

Having obtained the sanction of Dr. Exton, I took our experienced mason, Mr. Barlow, into council, instructed him as to the portions of the fossil which might be safely subjected to his skill, and the result is the specimen which I have now the honour to submit, with an interpretation of its characters, to the Geological Society.

DESCRIPTION OF PLATE VI.

Fig. 1. Upper view of the skull of *Tritylodon*: nat. size.
2. Under view of the same: ditto.
3. Side view of the same: ditto.
4. Front view of nasal end of the same: ditto.
5. Outer side view of right fourth upper molar of *Tritylodon*: three times the nat. size.
6. Inner side view of the same: ditto.
7. Grinding-surface of the same: ditto.
8. Outer side view of an upper molar of *Microlestes Moorei*: ditto.
9. Grinding-surface of the same molar: ditto.
10. Grinding-surface of an upper molar of *Microlestes rhæticus*: ditto.
11. Grinding-surface of a molar of *Stereognathus ooliticus*: ditto.

(Figs. 9–11 have been drawn at right angles to fig. 7.)

DISCUSSION.

The PRESIDENT remarked upon the singularity of the form of the skull and of its dentition, and on the great interest of the communication.

Mr. LYDEKKER said that the interest of this specimen rested in the remarkably differentiated character of the dentition. The only groups it would seem to be connected with are the Marsupials and the Rodents. The high specialization is most remarkable, and it does not seem to throw any light on the common origin of the existing groups of Mammalia.

Dr. Exton said that, as Curator of the Museum at Bloemfontein, many very interesting forms came under his notice. The specimen was found with Batrachian fossils of Triassic genera, and the matrix was quite similar in each case. In association with the species was a *Ceratodus*, a form found in the Triassic rocks of India. The fossils were found within a radius of 50 or 60 miles.

Prof. T. Rupert Jones said that Messrs. Wylie, Dunn, and Green had separated the Upper beds of the Triassic Series in South Africa from the Karoo beds under the name of the Stormberg beds. The Karoo beds contain Dicynodont remains. In the Stormberg beds reptilian remains occur, but without Dicynodonts. The fossil appeared to have come from the Stormberg beds, and was therefore within the great Triassic formation of South Africa. Palæoniscoid fishes had been found in the Karoo beds, and an allied form in the Stormberg beds, and these may possibly indicate a Permian age for the beds; but the balance of the evidence was in favour of the Triassic age of the fossil.

Mr. Blanford said that in Africa, Australia, and India a great series of beds, without marine fossils, had been found, the age of which was chiefly based on the uncertain evidence of plants and land or freshwater vertebrates. He thought it unwise to call the fossil in question Triassic. The beds in India which contain *Ceratodus* are now considered post-Triassic, and the genus is still living. He deprecated too hasty conclusions as to the age of the beds from the evidence of plants and terrestrial fossils.

The Author said all agreed with him that the skull is Mammalian. As to the question whether it is Marsupial or not, the size of the brain, so far as it could be determined, pointed to Marsupial analogies. The characters of the lacrymal foramen pointed in the opposite direction. The double incisors were paralleled in certain Rodents (*Leporidæ*) and among the Marsupials in *Phascolomys*; in *Macropodidæ* they are $\frac{3-3}{1-1}$; but in most of that order they are more numerous than in Placentals. The molars, by the number of the "true" ones, reminded one rather of the marsupial than of the placental forms. The nearest analogies to these molars in pattern of grinding-surface were found in the extinct genera *Microlestes* and *Stereognathus*.

6. *On the* Cranial *and* Vertebral Characters *of the* Crocodilian *Genus* Plesiosuchus, *Owen*. By Sir Richard Owen, K.C.B., F.R.S., F.G.S., &c. (Read November 21, 1883.)

In the 'Preliminary Remarks' to the palæontology of the Crocodilian Reptiles, Cuvier urges the need of a precise determination of the generic characters, with regard to which he writes, "observations, however novel, lose all their merit, unless they rest on this basis" *.

He proceeds to exemplify the apophthegm by descriptions which have never been surpassed of new and interesting species of extinct Reptiles, especially Crocodilian, which he shows to have been erroneously referred to other previously defined genera.

Cuvier refrained from attaching generic names, distinct from those of his "subgenera" of existing Crocodiles, to the extinct forms of which his keen and careful observations had detected characters since generally admitted to merit such distinction, and of which a contemporary availed himself.

The characters which Cuvier defines as forming for the Crocodiles a "very natural genus" † are now recognized as defining an ordinal group of the class Reptilia ‡. But of this group he admits and names "Subgenera," and to their distinctive characters he devotes special "Sections," as, for example, "I°, Espèces de Caymans" (p. 30); "II°, Espèces de Crocodiles" (p. 42); "III°, Espèces de Gavials" (p. 59). Our Catalogues accordingly admit these groups of Crocodilia, under the generic names *Alligator*, *Crocodilus*, *Gavialis*.

In the Section III, "Sur les Ossemens Fossiles de Crocodiles," the vertebral, dental, and narial characters of the extinct species are defined, and those of the "Secondary" or "Mesozoic" formations are of higher value than he assigns to his recent "Subgenera;" but he forbears to invent special terms for the extinct groups so differentiated. He even expresses a doubt whether the fossils from the Whitby Lias described by Stukely (1718) and by Chapman (1758) should be admitted among his wide group "les Crocodiles;" and the doubt would be reasonable if the species so associated formed a series of only generic value. However, the Liassic fossils are admitted in the Crocodilian chapter of the "Ossemens Fossiles,' and their distinctive characters in relation to existing groups are pointed out with the author's usual clearness.

The Crocodilian remains from the later calcareous schists of Monheim, from the Oolitic stones of Caen, Havre and Honfleur, are described as kinds of "Gavial" §; those from the Weald of Sussex,

* "Les vues les plus nouvelles perdent presque tout leur mérite quand elles sont dépourvues de cet appui." 'Ossemens Fossiles,' tom. v. pt. ii. p. 14: 4to, 1824.

† "Un genre très naturel." Id. ib. p. 20.

‡ 'Crocodilia' auctt.; Loricata, Merrem; Emydosauria, Blainville.

§ Of the vertebræ of his "Gavial de Caen," he expressly states, "Il a ses deux faces très-légèrement concaves, et son milieu rétréci."

"C'est là, comme en voit, un caractère fort différent de celui des Crocodiles vivans, où toutes les faces postérieures sont très-convexes, et les antérieures très-concaves." Tom. cit. p. 137.

the Chalk of Meudon, the Lignites of Provence, and the Tertiaries of Sheppey, Argenton, and Brentford, are described as kinds of "Crocodile."

We owe thanks to Cuvier's contemporary, though he added nothing to the palæontological characters, for the generic terms which later accessions to the Crocodilian cohort have found so useful.

In the "Divers Mémoires sur de Grands Sauriens" * Geoffroy St.-Hilaire observes:—"I end this first Lecture by premising that of the objects represented in plate vii. of the 'Ossemens Fossiles' there are only applicable to *Teleosaurus* the subjects of figures 1, 2, 3, 4, 5, 10, 11, 12, 14, and 17. The other objects (figs. 6, 7, 8, 9, and 13, 15, 16) came from a more distant locality, 'Quilly;' they belong to another species, referable to another genus which I have already determined and named:—I shall treat of them, subsequently, under the denomination of *Steneosaurus*."

Geoffroy recognized that the Oolitic Crocodilian from Quilly made a nearer approach to the Gavial than did the Liassic Teleosaur. The beak was relatively shorter and the external nostril less terminal. "It has not," he rightly remarks, "a skull so long and slender as in *Teleosaurus*, but longer and more slender than in *Gavialis*."

Of the relative "narrowness of the temporal region, the extremely large crotaphite foramina, the lofty sagittal crest, and the lateral orbits" no mention is made as distinguishing *Steneosaurus* from *Teleosaurus*: it needs only a reference to the plate vii., above cited, and to the subjects of the figures 1, 2, and 3 in that plate, to see that they are Teleosaurian characters, but characters which that genus has in common with *Steneosaurus*.

These quotations and remarks are premised in support of a rejection of a Kimmeridgian fossil Crocodilian from Geoffroy's genus, to which it has been referred, as *Steneosaurus Manselii*, Hulke †.

But I am, mainly, induced to submit this correction in order to show the characters by which the more recent Mesozoic Crocodilian has acquired certain agreements with, and approximations to, the cranial proportions and construction characteristic of the majority of Tertiary and existing species.

A resemblance to the modern genera *Crocodilus* and *Alligator* is manifested in the proportions of length and breadth of the antorbital part of the skull; whilst the difference from the Mesozoic genera *Teleosaurus* and *Steneosaurus* with gavialic proportions of the skull,

* 'Mémoire lu à l'Académie Royale des Sciences, le 4 Octobre, 1830:' see also "Recherches sur l'organisation des Gavials" in 'Mémoires du Muséum d'Histoire Naturelle,' tom. xii. pp. 148, 149 (1825).

† Hulke, Quart. Journ. Geol. Soc. vol. xxvi. 1870, p. 167. "A closer examination lately made by Mr. Davies, Sen., of the fossils presented to the British Museum last year by J. C. Mansel, Esq., has led to the identification of a large crocodilian head"—"covered with matrix, this head had been previously put aside as Pliosaurian," *loc. cit.* p. 167. That this collection included Pliosaurian remains is true; but that the crocodilian skull was referred by any authority of mine to the Sauropterygia is incorrect.

is more definitely exemplified by the extension of the nasal bones (see plate ix. vol. xxvi. Quart. Journal, 1870, p. 172) to the outer or anterior nostril; and the difference from *Steneosaurus* is increased by the smaller number of teeth—15 on each side of the upper jaw —than has been noted in any existing species of Alligator or Crocodile proper.

Cuvier assigns to the latter genus 19 teeth on each side of the upper jaw; and to the Alligators 19 or 20 teeth in the upper jaw. In both genera the teeth are signalized as of unequal size. But this proportional character is absent in the fossil skull now in the exhibited series of the British Museum of Natural History, when tested by the size of the series of sockets and by the absence of the premaxillo-maxillary constrictions shown in the species (*Crocodilus vulgaris* and *Croc. acutus*) which the fossil most resembles in the shape of the skull. A more important character of difference, in the comparison with Tertiary and existing Crocodilia, is shown by portions of vertebræ attached by matrix to the skull and of size corresponding thereto; it is presented by the articular surfaces of the centrum, which deviate little from flatness, and that in the direction of concavity. One of these vertebræ includes, with a great part of the centrum, the neural arch and spine; the latter shows its obtuse free termination. The total height of the vertebra is 9 inches; that of the neural arch, spine inclusive, is $6\frac{1}{2}$ inches, the neural spine being 4 inches in length. The frontal bones converge forwards to a point ten inches distant from the premaxillary apex of the skull; the nasal bones gradually narrow to a point penetrating the hind border of the nostril, as shown in figure 2 of the plate ix. (Quart. Journal, 1870) above cited.

Cuvier had shown in all the evidences of fossil Crocodilia from the quarries of Oolitic stone in the vicinity of Caen, in which the conformation of the outer or anterior nostril was demonstrable, that it was bounded exclusively by the premaxillary bones, the nasals ending in a point between the maxillaries (fig. 1, *n*, p. 156), and at some distance from the premaxillaries and from the nostril which those bones exclusively bounded *. In this he pointed out their resemblance to the modern Gharrials, as well as in the length and slenderness of the upper jaw. A difference of aspect in the outer nostril was also indicated by these fossils, from which was inferred their specific difference †.

Geoffroy, in his Memoirs on these Crocodilian Fossils ‡, connoted such distinctions by generic names; but their chief value in relation to the present paper consists in the characters which he gives and illustrates of the fossils which he separated from those to which he gave the name of *Teleosaurus*, to represent, or form types of the genus to which he applied the name of *Steneosaurus*. Cuvier had associated reduced, but accurate and instructive, views of the original fossils of both

* 'Ossemens Fossiles,' 4to, 1822, tom. v. pt. 2.
† Id. ib. p. 134.
‡ "Divers Mémoires sur des Grands Sauriens, &c." Lu à l'Académie Royale des Sciences, le 4 Octobre, 1830.

genera in one plate, distinguishing them in the descriptive letter-press by their respective localities. Upon this, Geoffroy offered the remarks already quoted (p. 154).

Fig. 2.—*Palatal surface of Skull of* Steneosaurus, *from Cuvier's fig.* 8.

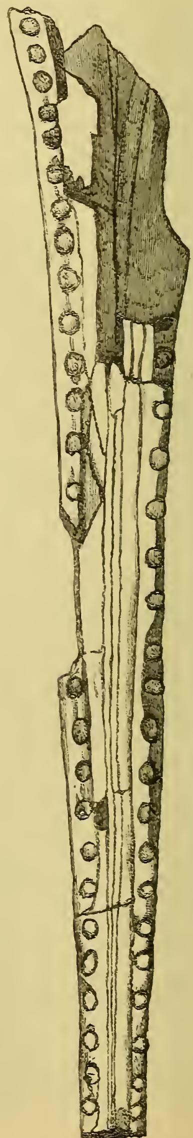


Fig. 1.—*Upper surface of Head of* Steneosaurus, *from Cuvier's fig.* 13.

n. Point of nasal bones.

Of the figures which he selects as illustrative of his genus *Steneosaurus*, I append copies of figures 8 and 13. The latter (fig. 1) represents the upper surface of the best preserved fossil skull, one twelfth of the natural size; Cuvier's fig. 8 (fig. 2) represents the palatal surface, one fourth the natural size. Geoffroy recognizes in the narial character, *n*, and proportions of the skull, that his Oolitic *Steneosaurus* made a nearer approach to the Gavial than did the Liassic *Teleosaurus*. "*Steneosaurus*," he remarks, "has not a skull so long and slender as in *Teleosaurus*, but longer and more slender than in *Gavialis*"; and this character is exemplified in the Cuvierian figures, copied from the plate above cited. They may be compared with the upper and under views of the Crocodilian skull from Kimmeridge Bay, Dorset, given in figures 2 and 1, in plate ix. of the volume of our 'Quarterly Journal' above cited. The mere rectification of a generic name would not have been deemed sufficient ground for this trespass on the attention of the Geological Society; nevertheless, in pursuance of my official duty of labelling accurately the specimens arranged for public inspection in the present 'Museum of Natural History,' the substitution of *Plesiosuchus Manselii*, Ow., for *Steneosaurus Manselii*, Hulke, requires an exposition of the grounds; and a stronger motive for submitting them to the Geological Society is the interesting relation of the nearer approach to Tertiary Crocodilian cranial characters which is made by the proportions of the skull with the conformation of the anterior nostril, of the fossil from a Mesozoic formation nearer our own time than that which yielded Cuvier and Geoffroy their evidences of the Teleosaurian and Steneosaurian extinct species.

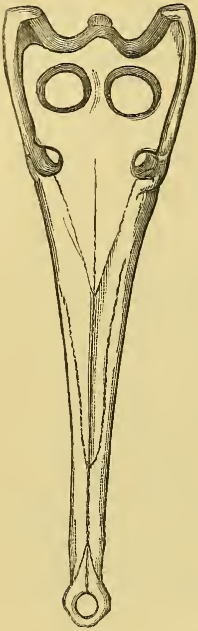
The frontal bones of *Plesiosuchus* converge to a point ten inches distant from the premaxillary apex of the skull. The nasal bones gradually narrow to a point penetrating the hind border of the nostril *. This opening is ovoid, three inches and a half in length, three inches in greatest breadth. The premaxillaries meet and join an inch and a half anterior to the horizontal nostril.

The transition to Tertiary and existing Crocodiles is manifested by the proportions of the skull and of the teeth; but these, in the degree of general equality of size, are Gavial-like, while in relative size and paucity of number, in *Plesiosuchus*, they show the Crocodilian character in excess. There is no trace of an alveolar pit in the upper jaw for the reception of a lower canine as in the Alligators, nor of any lateral notch for such a tooth as in the Crocodiles. The general equality of size in the tooth-crowns seems a remnant of the earlier Mesozoic dental character; but the number of teeth is even less than in any known Crocodile or Alligator. I add a brief definition of the generic formulæ, applicable, respectively, to *Steneosaurus* and *Plesiosuchus*:—

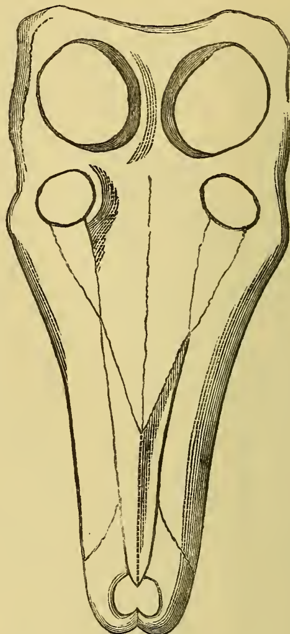
Genus *Steneosaurus*, Geoff. Vertebræ platycœlian; nasals not

* "Les intermaxillaires, *a*, *a* (fig. 1, 2, 3), entourent les narines externes, excepté un endroit fort étroit où la pointe des os nasaux, *k*, *k*, se place entre eux." "Détermination des os de la tête dans les Crocodiles proprement dits." 'Ossemens Fossiles,' v. pt. ii. pp. 69, 71.

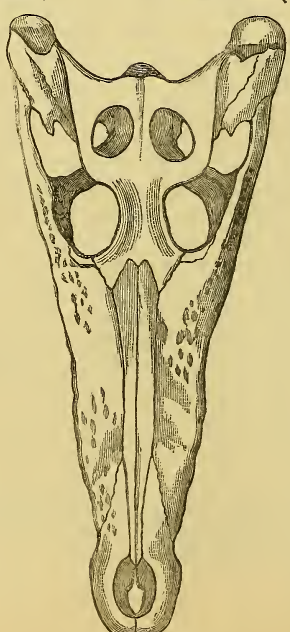
Fig. 3.—*Diagrammatic figures of the upper surface of the Skull in* Steneosaurus, Plesiosuchus, *and* Crocodilus.



1. *Steneosaurus* (Oolitic).



2. *Plesiosuchus* (Kimmeridgian)



3. *Crocodilus* (Eocene).

extending to the outer nostril; jaws long, slender, with numerous small, sharp-pointed teeth (fig. 3, 1).

Genus *Plesiosuchus*, Owen. Vertebræ platycœlian; nasals extending to the outer nostril; jaws short, stout, with few large teeth (fig. 3, 2). (The terms "numerous" and "small," "few" and "large" relate to the Crocodilian series.)

In connexion with the annectant or transitional characters of *Plesiosuchus*, already referred to, I may finally remark, that the gist of Geoffroy's 'Mémoires' of both 1825 and 1830 was to interpret the Cuvierian facts according to the Lamarckian 'Evolutional Hypothesis of Species' with modification of its dynamics. This hypothesis Geoffroy adopts in the following terms:—"La formation successive et leur évolution dans le cours des âges." He then proceeds:—"Je montrerai des formes remplacées insensiblement par d'autres, qui n'auraient pu s'accommoder de l'ancien ordre des choses;" in other words the "battle of life" was against them.

Reflecting on the palæontologist who guided his course in science "*par de faits positifs*," Geoffroy affirms "qu'il renonce à ce qu'il y a de plus vif, de plus enivrant, et de plus philosophique dans la vie des sciences."—"Les modifications insensibles d'un siècle à un autre finissent par s'ajouter et se réunissent en une somme quelconque. Si ces modifications amènent des effets nuisibles, les animaux qui les éprouvent cessent d'exister, pour être remplacés par d'autres, avec des formes un peu changées, et changées à la convenance des circonstances"*. Geoffroy's fourth Mémoire is entitled "Le degré d'influence du monde ambiant pour modifier les formes animales."

Under this conviction Geoffroy rejoiced to see the transitional step, though short, which the extinct Oolitic Crocodile of Quilly, his *Steneosaurus*, made towards the modern Gharrial. Still more exultant would have been his reception of the form here described of an advance, in a Secondary formation nearer our times, beyond the long and slender-beaked primitive Mesozoic forms to the shorter and broader cranial organization of the widely distributed Crocodilia represented by the existing genera of that order of Reptiles.

Discussion.

The President said that both he and E. Deslongschamps had arrived at the same conclusions as those announced by Sir Richard Owen as to the Crocodilian affinities of the Kimmeridgian fossils. The greatest confusion had arisen with regard to the genus *Steneosaurus*. He found that the Kimmeridge fossil agreed in certain respects with the definition of the genus by Geoffroy, and he thought it preferable to employ the old name rather than to invent a new one.

The Author said that in the Oolitic Crocodiles the vertebræ are amphicœlian, in the Tertiary ones they are united by ball and sockets; in an intervening formation proportions of the modern crocodilian skull are combined with amphicœlian vertebræ. The discovery of a form intermediate in age and transitional in form between *Steneosaurus* and *Crocodilus* had an interesting bearing on Geoffroy's often expressed views on evolution.

* Loc. cit. 4ème Mémoire, p. 79.

7. *On some* Postglacial Ravines *in the* Chalk Wolds *of* Lincolnshire. By A. J. Jukes-Browne, Esq., B.A., F.G.S. (Read December 5, 1883.)

[Communicated by permission of the Director-General of the Geological Survey.]

In a paper recently read before this Society I pointed out that the disposition of the Boulder-clays (Purple and Hessle series) along the eastern border of the Chalk Wolds enables us to determine the relative age of the valleys which intersect the hills, and proves that some of them are older and some newer than the formation of those Clays.

Most of the larger and wider valleys are occupied by deposits of glacial clay and gravel, which are continuous with the main mass or sheet of these beds lying to the eastward, and are, in fact, mere arms or prolongations of that sheet; it is clear therefore that all such valleys are of anterior date and must have existed prior to the formation of the East-Lincolnshire Boulder-clays. It would not be safe, however, to call them *Preglacial*, because these particular Boulder-clays are believed to be the latest glacial beds in England, and therefore the valleys may be really of Interglacial age. On the other hand such valleys or portions of valleys as can be proved to have come into existence after the formation of these Clays may safely be termed *Postglacial* in the most rigid acceptation of that term, and may consequently be regarded as some of the most recently formed valleys in the British Isles.

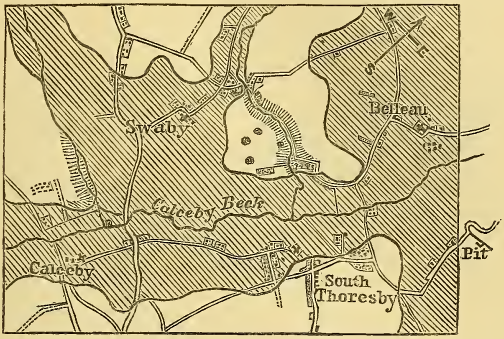
There are several short valleys, from one to three miles in length, which open eastward on to the Boulder-clay plain, which are probably of *Postglacial* date; for the boundary line of the Boulder-clay passes straight across their mouths; no tongues of clay are thrust westward into these valleys, which are completely free from any trace of glacial deposits. Some of these valleys are narrow and ravine-like, but others are wider, and in the latter case there is nothing about them which would distinguish them from the older valleys occupied by glacial deposits.

Much more interesting cases occur in the course of some of the older valleys where the original watercourse has been so blocked up with drift-deposits that, in the process of reexcavation, the stream has found it easier to cut a new channel for itself through the solid chalk than to remove the obstacle in front of it. It is some of these cases which I propose to describe in the following notes.

1. *Swaby Vale, near Alford.*—The first instance I observed was in the course of a tributary to the Calceby Beck (see map and description in Q. J. G. S. xxxix. p. 600). The valley of the Calceby Beck is filled from end to end with glacial deposits, through which the modern stream finds its way without anywhere cutting down to its ancient bed in the Chalk. Near the village of Swaby, on the N.W. side of this valley, there are large mounds of glacial clay and gravel which completely block up the course of a tributary coming in from

the north. This little stream, instead of continuing its southerly course, turns abruptly to the east and enters a narrow ravine excavated out of the Chalk, which extends for a distance of about half a mile and then opens into the main valley opposite the village of South Thoresby (see fig. 1).

Fig. 1.—*Plan of the country near Swaby.* (Scale 1 inch to a mile. The ground occupied by Drift is indicated by diagonal shading.)



The sudden change in the form of the valley below Swaby is very striking. Above the village, the valley-bottom is some 150 yards wide, and the valley-sides have the usual gently sloping outline of chalk hills. Below the village the valley is contracted to a trench-like ravine, the bottom of which is perhaps 40 yards wide, and its sides rise in steep slopes, the angle being in many places that of chalk débris (viz. 35°–38°).

The wider and older valley is actually continued southward through the village for some distance, the barrier of drift being about 400 yards beyond the point where the stream turns aside to enter the ravine. This modern continuation of the watercourse is clearly therefore a new cut made through the solid mass of chalk, which originally formed one flank of the ancient valley.

It would seem that on the cessation of glacial conditions the stream was able to occupy its former valley as far as Swaby, but being there ponded back it made its way over a col in the chalk hills which was lower than the surface of the drift barrier, and having once taken this course it would naturally maintain and deepen the new channel, forming the ravine above described.

The glacial clays and gravels also occupy for some distance the valley of another tributary which joins the Calceby Beck south of Swaby. This stream also has cut into the chalk and runs in a small ravine for a distance of about three furlongs; but it is only just outside the limits of the drift area and is not so striking as the valley first described.

There can be little doubt that the ancient courses of the two brooks are concealed beneath the glacial deposits; they probably united somewhere near Swaby church, and thence the combined waters flowed south-eastward to join the main stream in the Calceby valley.

2. *Valleys near Louth.*—Two other similar cases occur in the neighbourhood of Louth. The Wolds here (see plan, fig. 2) are intersected by two ancient valley-systems, both of which are largely occupied by drift; and in neither case does the modern watercourse coincide entirely with the line of the ancient valley.

Fig. 2.—*Plan of the Valleys near Louth.* (Scale 1 inch to a mile. Drift indicated as in fig. 1.)

The main stream of the river Ludd takes its rise from springs near the village of Welton, about 3½ miles west of Louth. For about a mile this stream runs in the ancient valley over a bottom of Boulder-clay; but although the old valley still continues eastward as a well-marked hollow, the modern stream turns suddenly southward and enters a narrow winding ravine, the sides of which are far too steep for the plough, and have in consequence been laid out as plantations. This ravine has a length of about three quarters of a mile, and then opens into a broader valley running eastward and joining the old main valley at a point about one mile and a quarter west of Louth church. A tongue of Boulder-clay runs up this broad valley for about half a mile, proving it to have been a tributary of the ancient main valley; the stream therefore has here made a new cut, three quarters of a mile long, from the main valley into one of its tributaries, and thence its course coincides with the continuation of the ancient valley in which the town of Louth now stands.

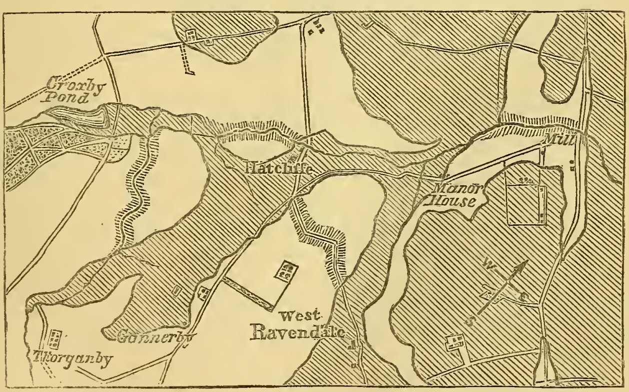
The narrow wooded ravine above mentioned is known as Welton Vale, and is one of the sights of the neighbourhood of Louth. Its depth at the southern entrance is about 60 feet, and the sudden change from the ordinary scenery of open chalk valleys to a steep-sided ravine which has more the aspect of a Derbyshire or Yorkshire vale, is very remarkable. The clear beck rippling over its stony bed, and the winding valley with its wooded sides sloping steeply up from the water, are features which one is not accustomed to associate with hills and valleys in Chalk districts.

Another remarkable ravine near Louth has been formed in the same way. The valleys of the small becks which descend from Tathwell and Withcall respectively are filled with Boulder-clay *; they unite near Hallington, and thence the drift-filled valley continues eastward and leads out of the Wolds a short distance south of Louth (see fig. 2). The modern stream, however, deserts this ancient valley at a point about three quarters of a mile E.N.E. of Hallington ; curving to the north and passing through a deep gorge similar to those already described, it joins the Ludd near Thorpe Hall, about half a mile west of Louth.

The ground thus cut through by the stream is some of the highest near Louth, and is known as Hubbards Hill, while the depth of the ravine in the centre cannot be far short of 100 feet. To an observer standing on the Boulder-clay in the continuation of the old valley, which is only some 20 feet above the bed of the stream, and looking northward into the mouth of the gorge which the stream has cut for itself through the chalk hills, the course of the stream seems most remarkable; and the origin of the ravine is utterly inexplicable except on the hypothesis that the pre-existent valley was once filled with Boulder-clay up to the level of the hill-tops, and that during the process of re-excavation the beck found it easier to make a passage northward over the Chalk than eastward through the mounds of Boulder-clay.

3. *Valleys near Caistor.*—The third locality where similar ravines of Postglacial origin have been observed is the neighbourhood of Hatcliffe, a small village in the Wolds about 6 miles E. of Caistor. Here there are no less than four new cuts through the Chalk in different parts of one valley-system (see plan, fig. 3).

Fig. 3.—*Plan of the valley near Hatcliffe.* (Scale and shading as before.)

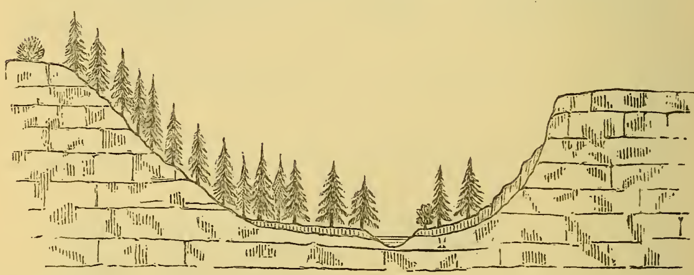


* See map in Quart. Journ. Geol. Soc. xxxix. p. 600.

The pre-existing valleys seem to have been filled with drift forced into them from the north or north-east; that to the south of Hatcliffe is blocked with immense mounds of gravel, sand, loam, and Boulder-clay, so mingled that it is impossible to separate them completely on the Survey map. These glacial deposits form a broad tract filling the ancient valley and extending to within half a mile of Thorganby, where they end in a sort of natural ampitheatre formed by the closing in of the chalk hills.

Through a narrow gap in these hills the modern stream makes its way, and thence flows northward for about half a mile over a Boulder-clay flat, till it suddenly bends N.W. and enters a magnificent ravine excavated through the hill which forms the left flank of the ancient valley. The slopes of this ravine are, as usual, planted with fir trees, and the whole scene, when viewed from one of the curves in the valley, presents quite an Alpine appearance. The depth of the gorge about its central part cannot be less than 100 feet, and in one place on the outside of the last curve, where the stream would act with the greatest force, a vertical cliff appears to have existed, the upper part of this still remaining as a bare face of chalk, while its foot is buried in a long talus-slope of fallen débris. Fig. 4 is a section across this part of the ravine, and though drawn from an estimate by eye only, and not from actual measurement, it may be taken as being a fairly accurate view as regards width and angle of slope.

Fig. 4.—*Section across ravine S.W. of Hatcliffe.*



Emerging from this ravine, the stream enters a much broader valley just below a great mound of Boulder-clay which has blocked up the drainage and caused the formation of a small lake called Croxby Pond. The occurrence of this Boulder-clay proves the valley in which the lake lies to have been coexistent with the main drift-filled valley to the eastward, and a little lower down a hollow filled with Boulder-clay actually leads from one valley to the other; there can be little doubt therefore that the Croxby valley was tributary to the ancient valley south of Hatcliffe, and that the modern stream has made a cut through the hill which originally separated the main valley from its tributary.

Still impeded by the mounds of drift in the old valleys, the modern beck has made a second cut through the low Chalk hills which jut out beyond the point where the two older valleys united. This second cut is not nearly so deep or so striking as the first, but has the same trench-like character, and is about half a mile long, emerging at last into the old pre-existent valley at the village of Hatcliffe. Hence its course coincides with that of the ancient valley for the distance of about a mile, the stream flowing to the N.E. through a flat alluvial level, which is underlain and flanked by Boulder-clay. At the end of this reach the hollow of the ancient valley turns abruptly to the N.N.W.; but the modern stream continues its north-easterly course directly through the opposing Chalk ridge, forming a third ravine precisely like the others, only less winding, and with a length of nearly half a mile. Emerging from this at Hatcliffe Mill, the stream pursues a tame and unimpeded course through the undulating plain of Boulder-clay which intervenes between the Chalk Wolds and the marsh land of the seaboard.

We have now described three out of the four Postglacial valleys near Hatcliffe. The fourth is in connexion with another ancient valley tributary to that above mentioned, and coming down from Wold Newton and Ravendale to join the former near the old Manor House five furlongs below Hatcliffe. This also is filled with Boulder-clay from end to end: but in its case the Postglacial beck has been able to re-excavate a channel through the Boulder-clay which occupies its ancient valley. There is proof, however, that it was not able to effect this completely in the first instance; for at a point about three furlongs N.W. of the ruins of West Ravendale church the Chalk hills forming the west side of the valley are breached by just such another ravine as those above described. Its course is a double serpentine curve, its total length just half a mile, and it emerges into the Hatcliffe valley a little south of the village, the road from Ravendale to Hatcliffe being conducted along its bottom.

It seems clear therefore that at one epoch during the Postglacial erosion the Ravendale brook ran through this ravine, but was subsequently enabled to revert to the course of the pre-existent valley. In this it was doubtless assisted by the action of the rain draining off the steep slopes on either side of the old valley north of West Ravendale; the eastern side of this part of the valley seems to have been the steeper, and the junction of Chalk and Boulder-clay, where the latter was banked up against the former, would become a line of least resistance along which the rivulet resulting from the rain-drainage would naturally take its course; the channel thus commenced would be deepened until in some time of flood the Ravendale Beck was directed into it. This course once taken would be maintained, and the brook now runs at the foot of the steep Chalk bank with a Boulder-clay slope on the western side.

Conclusion.—A few words in conclusion are needful to explain the conditions under which the brooks seem to have acted; and in order to picture these, it is not necessary to subscribe to any theory of the origin of Boulder-clays. We have only to accept their existence, and the mapping of the country proves that, whether formed by land-ice or shore-ice, the Red and Purple Clays were banked up in mass against the eastern edge of the Wolds and spread over their eastern border for a breadth of about three miles, covering hill and dale alike in one continuous sheet. No traces of these clays have been found along the western ridges of the Wolds, though near the eastern border they run up to a height of 480 feet, a height which is only exceeded by the highest hills near Caistor.

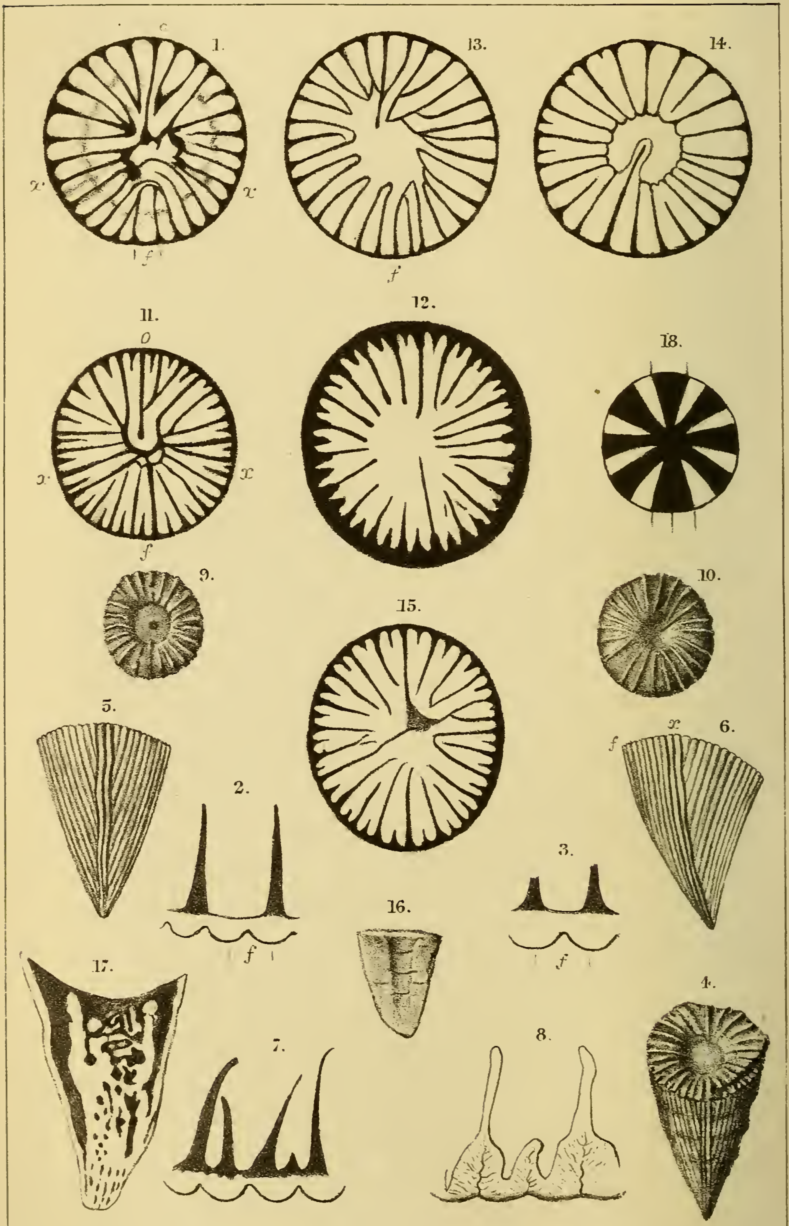
Whatever was the original extension of these deposits, it may safely be assumed that after the glacial conditions had passed away, and when more normal climatal conditions had returned, the eastern border of the Wolds was completely invested with a mantle of Boulder-clay, covering the highest hills as well as filling the deepest valleys. From the fact that the streams have in so many instances reoccupied the pre-existent valleys, I infer that the surface of this mantle of Boulder-clay was by no means level, but that though naturally thicker in the hollows than on the hill-tops, it to a great extent draped the features of the former surface, and that the rain-streams were therefore naturally directed into the hollows of the pre-existent valleys.

It was only, then, at points in these valleys where the drift happened to be heaped up in especially massive mounds that the stream was forced to take a different course, and to excavate an entirely new channel for itself outside the limits of the old valley. In every case the waters were probably ponded back, and a lake was formed (as at Croxby), the level of which rose till it overflowed the lip of the enclosing basin where that lip was lowest.

It is probable that in our climate the mechanical wear of rain removes the material of clay more rapidly than its chemical action removes the material of limestone. In Lincolnshire it certainly seems as if the Boulder-clays had wasted more rapidly under pluvial influences than the Chalk; consequently the tops of the barriers which have caused the diversion of the streams are now in most cases lower than the Chalk hills through which the ravines have been cut.

In the olden days of geology, when cataclysmic ideas prevailed, "some convulsion of nature" would have been the simple and easy method of accounting for such valleys; and perhaps even at the present day more than one observer might regard them as in some manner due to the pre-existence of faults and fissures. It may be well therefore to state that, though the Chalk is everywhere broken by small faults or slips of a few feet throw, such as might be caused by the upheaval of a mass resting upon a foundation of sand, yet no strong faults were detected anywhere in the neighbourhood of these valleys; certainly none exist which bring soft and hard rocks into contact, for the Chalk is all hard. Further, such lines of fracture are seldom or never so serpentine as is the course of these ravines.

It is the simplicity of the general geology of the district which makes the alteration in the course of the streams so very striking, and enables the geologist to trace the connexion between cause and effect with greater ease than in other cases; so that the ravines above described may be regarded as among the most remarkable and interesting instances of river-erosion to be met with in England.



P. Martin Duncan dir. A. Gawan lith.

Mintern Bro's. imp.

STREPTELASMA RŒMERI.

8. *On* Streptelasma Rœmeri, *a* new Coral *from the* Wenlock Shale. By Prof. P. Martin Duncan, M.B. (Lond.), F.R.S., V.-P. Geol. Soc. (Read January 24, 1883.)

[Plate VII.]

Very numerous specimens of simple Corals belonging to the Rugosa were found in the washed Wenlock Shale prepared by G. Maw, Esq., F.G.S. Amongst them are forms which have not hitherto been described, but which are allied to a species from Girvan. They belong to the genus *Streptelasma*, Hall, and are specifically distinct from any others. As the variability of some parts of these Corals is great, and there are some interesting points about their morphology, I have brought them before the Society in this communication.

Streptelasma Rœmeri, sp. nov. Plate VII. figs. 1–18.

The corallum is simple, free, reversely conical in shape, slightly bent and horn-like, sharp at the base, longer than broad, and with a circular or elliptical calicular margin.

The calice is widely open, shallow, and has a central depression leading to a more or less distinct fossula. About fifty costæ cover the corallum, and they are subequal in breadth, slightly rounded, and separated by linear depressions. Their length differs according to their position and direction, and there are four sets of them: three on the convex side of the bent corallum and partly on the flanks, and one on the concave side and partly on the flanks (figs. 4, 5, 6).

Of the three sets on the convex side, one is composed of two costæ placed side by side, and reaching from the base to the calice in a vertical line. They are usually slightly larger than the other costæ, and are very distinct and parallel (fig. 5). There is another set on either side of these. Each of these sets consists of ten costæ, which pass obliquely from the outer edge of the vertical pair upwards and outwards, and reach in succession the calicular margin (fig. 4). The longest costæ leave the vertical pair close to the base, and the shortest close to the calice, and the others at intermediate distances. The result is a pinnate arrangement.

The shortest costæ, and three, four, or five that follow, are decidedly oblique in their direction; but the longest, which are of course found at about a quadrant of the calicular circle from the vertical pair, are barely oblique; their direction is nearly vertical, and they reach the base.

The fourth set of costæ is on the concave side of the bend of the corallum and on the flanks (fig. 6); it is more numerous than the others combined, and the direction is not identical. The longest costæ of this set are opposite the vertical pair on the other side of the corallum, and reach from calice to base, but they are not very if at all distinct from the others of this set, except in their vertical direction. No costæ pass from these vertical ones, but they commence at the calicular margin and pass downwards and outwards, impinging, one after the other, on the edges of the longest and nearly vertical and outermost costæ of the sets which are pinnate on the vertical pair on either side (fig. 6). The most oblique costæ of the fourth set soon reach those against which they impinge and are short; and with increasing length the rest of the costæ diminish in the obliquity of their course, and become at last nearly parallel with those which are along the median line on the concave side. Hence the costæ of the fourth set are semipinnate on the limiting pinnate costa of the second and third sets on either side of the corallum at the quadrants of the margin. This double pinnation produces a very remarkable ornamentation, which, although a few more costæ may be introduced, is invariable.

The costæ may have a plain outer surface, or they may be covered here and there, with a close cross-ridging resembling a very delicate epitheca, but it is inseparable from the costal structures (fig. 6). In a few instances the costæ are rather more prominent than in the type.

Finally, as regards the outside of the corallum, it is marked more or less by feeble growth-swellings and transverse contractions (fig. 4).

Seen in the calice the septa are distinct, stout, curved at their free upper margin, often bilobed, and variable in their length and direction around the fossa and fossula. Those which reach far inwards and bound or enter the central or axial fossa are about twenty-five in number; and there is one (and sometimes there are two) longer than the others. A variable number of small septa exist, and they are placed between all or only a few of the larger. The fossula may or may not correspond with the vertical pair of costæ; and when it is fairly developed the long septum is usually opposite (fig. 1); or there may be no fossula, and in its stead two long opposite septa. When the fossula is well developed it may be bounded by well-developed septa, and may contain one, or even two, smaller septa (fig. 7), a long one being sometimes between them. The direction of the septa on the calice is not universally radial, for in one half—and that which is remote from the vertical pair of costæ—a pinnate arrangement in relation to a large septum is very constant. No union of the ends of the septa is visible at the calice; they do not transgress upon the surface of the fossa; and they may be flat, concave, and marked with a slight projection.

Two conditions of growth of the septa and costæ are noticed: in one the septa are continuous with the centre of the respective costæ; and in the other the intercostal space fits into the median line of the septum (fig. 8). When transverse sections are made with the view of studying the septa, very different appearances are presented from those observed in the calices; and the sections made just below the calice and midway down, differ remarkably in their illustration of the septal arrangement.

The principal differences are, that in the sections made below the calice the septa unite in groups at their inner ends, and bound the axial fossa with a more or less dense structure (figs. 1, 12); that this structure is continued here and there across the fossa (fig. 15); and that the smaller septa may be very generally absent or universally present. The usual arrangement is for the long septum to remain unattached to others, and the rest join their neighbours at the free end (figs. 13, 14). Often the septa are in groups of three, a central one being free and overlapped by those on either side. The septa are rarely straight, and curve slightly here and there.

Longitudinal sections indicate that the septa are made up of solid laminæ, which increase in thickness at the inner end where junction occurs with other septa, and that those junction-processes, grouped around the fossa, transgress here and there on its area, and form a kind of false columella (figs. 1, 11, 15).

The amount of dissepimental structure is very small and variable. A few small curved and short dissepiments occur between a few septa near the wall, and they are best seen in weathered specimens, stretching from septum to septum. No tabulæ stretch across and close in the corallum below entirely; and small central tabulæ are not observed in some specimens, whilst a very few exist in others (fig. 16). A large septum may reach a tabula and have a groove around it there, whilst the inner ends of all the larger septa may join the tabula. This is exceptional, however (fig. 14).

The coral is usually free, and when the contrary condition is noticed the adhesion was by the side of the sharp base, and a cicatrix remains. Growth occurs in a very remarkable manner, and, starting when about a millimetre in length with fine, light, pretty regularly spaced septa (fig. 18), the coral grows in height and breadth. Growth in this last direction necessitates a gradual enlargement of the diameter of the calice and a corresponding increase in the costal and septal number.

The increase takes place in four regions of the periphery. The vertical pair of costæ, and those on the other side of the corallum, simply grow in height; but there is a steady increase of successive costæ on either side of where the vertical pair join the calice, and also where the most oblique of the costæ of the concave side join the longest of the costæ pinnate to the vertical pair (fig. 1, at *f* & *x*, also fig. 11).

At the very base are about ten costæ; but the vertical pair, which are very distinct, have only one septum between them; there is one opposite to it on the other side, and three others on both sides. These eight septa, which are rather stout, converge and unite in a central mass.

The theca can hardly be said to exist, and the solid structure beyond the broad bases of the septa merges into costal structure, the whole being composed of a sclerenchyma which is fibrous-looking. The structures which resemble epitheca are clearly mural in office, and are not to be distinguished from those of the theca. Calicular gemmation occurs in some instances.

The height of the specimens is from $\frac{3}{8}$ to $\frac{3}{4}$ inch, and the breadth of the calice is from $\frac{3}{16}$ to $\frac{1}{2}$ inch.

Locality. Wenlock Shale; common.

Remarks. The variability of the septal arrangement in different specimens in which that of the costæ is constant is very striking; moreover, the vertical pair of costæ, and those at the lateral quadrants of the calicular marginal circle, vary in a most irregular manner in their relation to the fossula, to large and small septa, and to the septal pinnation.

In some individuals the vertical pair of costæ at the calicular margin are at the fossula, and then the long septum is opposite, and the pinnate half of the calices commences at the quadrants (x). This is the normal condition; but it is by no means constant. For a long septum may replace the fossula, or the whole septal arrangement may be out of its normal condition, and there is no relation between the vertical pair of costæ and special septa (fig. 14).

Again, the thickness of the wall varies: in some it resembles an epitheca, and in others it is a stout union of septal and costal bases with intermediate tissue.

The relation of the intercostal space to the median line of the septum, seen in several instances, is very interesting (fig. 8). It is rare in corals usually, but it is seen very constantly in Australian Cainozoic Aporosa. The development of the septum occurs from the sides of a median plane of connective tissue in these instances, and this tissue must have been continuous with the epitheca outside the corallum.

Ordinarily the relation of costa and septum is that the latter is continuous with the former, and then there is no connexion between the mesenteries and the extramural soft parts (figs. 2, 7).

The costulation and the septal arrangement of the species connect it with the genus *Streptelasma* of Hall; but it is slightly aberrant on account of the defective obtortness of the septal ends and the presence usually of a well-marked fossula in the calice. But the method of septal junction, the presence of the rod-like tissue of the false columella, and the rarity of dissepimental structures, all seen in the species, are very characteristic of this genus.

Compared with *Streptelasma europæum* of Römer*, the new form is noticed to differ on account of its septal fossula and extremely defective tabulæ and dissepiments. The number of the septa and their arrangement, and the presence of the very distinct double pinnation of the costæ and of the vertical pair are very distinctive.

The genus was briefly and hardly sufficiently diagnosed by Hall in his magnificent 'Palæontology of New York' (1847, vol. i. p. 17), and he relied too much upon the value of the obtort septal ends in classification. MM. Milne-Edwards and Jules Haime introduced the genus into their 'Histoire Naturelle des Coralliaires' (vol. iii. p. 392). They did not consider the twisted septa of generic importance, as it is a well-known character of some species of *Cyatho-*

* Silurische Fauna von Sadewitz, p. 16, pl. iv. fig. 1, *a. b* (1861).

phyllum; but they insisted upon the generic value of the absence of epitheca, and relied upon the feeble development of the dissepiments and tabulæ.

We owe the first notice of the occurrence of the genus in Great Britain to Messrs. Nicholson and Etheridge, who describe species and carefully consider the generic characters of *Streptelasma* in their valuable work on 'The Silurian Fossils of the Girvan District' (p. 67). They amend the generic diagnosis, and show that the differentiation must rely upon the union of the inner ends of the septa to form a false columella, and upon the feeble amount of endothecal tissue *. I agree with these authors in every important particular, and admire their careful and elaborate work very much. Any difference of opinion which may occur between us relates rather to terminology than to matters of fact.

The structure of the theca or wall of the Rugosa, and its homologies with the theca or epitheca of the Aporosa and Perforata, have been fertile subjects for discussion. Messrs. Nicholson and Etheridge write, "Epitheca well developed. Proper wall doubtfully present, but a thick false wall, formed by the fusion of the broad outer ends of the septa with intermediate calcareous deposit" (*op. cit.* p. 67). There is no doubt that the wall in many Rugosa and in *Streptelasma* resembles an epitheca in its external appearance, and it is not separable from a subjacent structure like a theca. The delicate transverse lines of ornamentation are exactly like those of many species of Aporosa, where there is a structure separable from the true wall or theca, and which is called epitheca. They resemble, however, those ornamental lines seen on species of *Zaphrentis*, where a thickish mural structure is covered here and there with what resembles an epitheca closely.

In the Aporosa the wall is certainly formed by an extension of septal structures, and it appears after the septa in the embryonic state; and the epitheca, a most variable structure, is developed after the wall, for it often covers costæ and their spines. It often appears to be produced by a basal tissue which reaches up to near the calice. But in some Aporosa (in some species of *Flabellum*, for instance) the epitheca is pellicular, and forms an intrinsic part of the wall. Again, in *Phymastræa* the epithecal processes, distinct enough in some parts, blend with the true thecal structures elsewhere.

For purposes of classification the epitheca is comparatively of only specific or subgeneric value; and it would lead to confusion, unless there were better reasons for so doing than now present themselves, to employ the term epitheca for theca.

Again, the ridges and furrows on the outside of *Streptelasma* are plainly the analogues of the costæ and intercostal spaces of the true Corals, and should be thus termed.

In the instances where the costal interspace or groove corresponds

* In the drawing of *Streptelasma europæum*, by F. Römer, the tabular structures are extraordinarily develo ed, and the septa curve right over the axis. Probably there is an error; for it is not easy to see how the succession could occur.

with the median line of a septum, the mural character of the outside structures is quite evident.

Messrs. Nicholson and Etheridge remove the genus *Streptelasma* from the Cyathophyllidæ into the Zaphrentidæ. I quite agree with their able arguments; and it is clear that the costulation of the forms mentioned in this communication strengthens their views; for a single pinnation is to be observed in some species of *Zaphrentis*, and the straight costæ are then seen in relation with the septal fossula.

The new species should be placed at the end of the *Streptelasmata*; and it approaches the simple Rugosa with uninterrupted interseptal loculi. Probably the Upper Silurian is the highest horizon on which the *Streptelasmata* will be found, and the genus flourished in the Lower Silurian in America.

NOTE, *January* 1884.—Lindström, in his 'Index to the Generic Names applied to the Corals of the Palæozoic Formation,' Stockholm, 1883, gives *Ptychophyllum*, Ed. & H., 1850, as synonymous with *Streptelasma*. Now the diagnosis of *Ptychophyllum* is as follows:—"Corallum simple, pedicellate, mainly constituted by a series of superimposed subinfundibuliform tabulæ (planchers), and whose surface presents numerous septal rays tolerably equally developed; these rays are strongly twisted near the centre of the tabulæ, so as to form a false columella" (Hist. Nat. des Corall. vol. iii. p. 399, 1860). Certainly there is a very considerable distinction between the two genera; and I retain the original genus as diagnosed by Hall, with a slight modification. The close similarity of costal structure in *Hadrophyllum conicum* and *Zaphrentis Candezi* of C. Barrois (species from the Devonian of the Asturias and Galicia, Spain), and in *Streptelasma Rœmeri*, is evident.

EXPLANATION OF PLATE VII.

Fig. 1. A transverse section of *Streptelasma Rœmeri*, Duncan, made close below the calice; *f* denotes the position of the vertical pair of costæ; *o* of the costæ of the opposite side; *x* the position where the costæ change their direction (magnified).

2. The small septa which sometimes bound the fossula in transverse section, showing their relation to the costæ. There are three costæ and two septa, and the costæ to the right are the vertical pair, one being without a septum and corresponding to the fossula (magnified).

3. Two smaller septa bounding the fossula and corresponding to the vertical pair of costæ (magnified).

4. Corallum slightly magnified, showing the calice, septa, and the costæ; note the vertical pair and the others on either side and their direction.

5. The costæ (magnified); the vertical pair are seen, and the others joining them at different angles.

6. Side view of a corallum (magnified); *f* is at the position of the vertical pair, *x* is where the costæ change their direction.

7. The two central septa relate to the vertical pair of costæ and are in a fossula which is bounded by the two larger septa; a rudimentary septum has appeared (magnified).

Fig. 8. Intercostal spaces continuous with the median lines of septa (magnified). Rarely observed.

9.\} Calices (slightly magnified).
10.\}

11. Transverse section low down in a coral (magnified).
12. Transverse section high up in the same coral (magnified).
13. Transverse section in another coral, low down, showing junction of septal ends (magnified).
14. Section showing large septum ending in the midst of a tabula (magnified).
15. Section showing septa crossing the axial space (magnified).
16. A longitudinal section showing faint tabulæ (slightly magnified).
17. Septa ending in the columella; longitudinal section (magnified).
18. Section of the base: the lines denote the position of the vertical pair of costæ.

Discussion.

The Chairman (Dr. J. Gwyn Jeffreys) referred to the difference of generic names used by palæontologists and zoologists.

Prof. Seeley agreed with the President in thinking that all palæontological work should be based on zoology.

Dr. Hinde remarked on the curious fact that the same coral, as interpreted by Dr. Duncan, showed different septal arrangements, such as might belong to different genera, at different heights in the calice. He asked on what grounds the form was placed in the genus *Streptelasma*.

The Author, in reply to the Chairman, said that the true Palæozoic corals are really of very different types from the Mesozoic and recent ones. He stated that *Streptelasma* occurs in the Lower Silurian in America, but in the Upper Silurian in England. He stated also that some species of *Streptelasma* present the characters assigned to the genus by Hall, namely, the convolution of the septa around the axis of the calice.

9. *On* Cyathophyllum Fletcheri, *Ed. & H.*, sp., *from the* Wenlock Shale, *with* Remarks *on the* Group *to which it belongs.* By Prof. P. Martin Duncan, M.B. (Lond.), F.R.S., V.-P. Geol. Soc. (Read January 24, 1883.)

This coral occurs in the Wenlock shale, and the specimens are small and not numerous; those which are now under consideration come from Mr. G. Maw's shale-workings.

The forms are young, and have a deep calice with septa barely projecting; there is a very perfect epitheca, and there are traces of costæ beneath it and of crossbar-like structures between them. There are no synapticulæ between the septa, and a tabula closes in the calice below.

The species is one of those which were associated by MM. Milne-Edwards and Jules Haime with the Fungidæ, under the genus *Palæocyclus*, in 1851. They remained thus included until 1867.

In the 'Philosophical Transactions' of the Royal Society*, 1867, p. 651, pl. xxxii. figs. 6*a*–6*e*, a criticism of the genus *Palæocyclus* was published by me, and it was demonstrated from specimens and sections that the species included in it by MM. Milne-Edwards and Jules Haime could not be associated with the Fungidæ.

The necessity for examining into the minute structure of the *Palæocycli* came from the discovery of a Tertiary coral in Australia, which, from its shape, its possessing synapticulæ, and the absence of endothecal dissepiments was clearly a Fungid and a *Palæocyclus* †. To believe in the descent without modification of a coral from the Silurian to the Australian Cainozoic was improbable, and sections were therefore made of a series of *Palæocycli*. It was stated in the essay (p. 651), that "the absence of synapticulæ was proved, as was also the presence of an inclined dissepimental endotheca at the sides, and of tabulæ in the centre of the corallites."

Then the cause of the error of the distinguished French zoologists, to whom the observer owed all his knowledge, was explained, and the essay concluded as follows:—

"The removal of the genus *Palæocyclus* from the family of the Fungidæ is necessary, and it is very evident that the species classified

* P. M. Duncan "On the genera *Heterophyllia*, *Battersbyia*, *Palæocyclus*, and *Asterosmilia*," Phil. Trans. 1867.

† Ann. & Mag. Nat. Hist. Sept. 1864, pl. vi. fig. 2. Milaschewitsch, in his 'Die Korallen der Nattheimer Schichten,' ii. Abtheil. p. 210, writes, in relation to certain Fungidæ, "Die zweite aber gehört zu den Rugosen, wie das bereits durch Duncan und Kunth nachgewiesen wurde." Herr Kunth's relegation of *Palæocyclus* to the Rugosa occurred some years after the publication of my essay and drawings, and he added nothing new to what was well known. Kunth wrote in 1869.

under it belong to two divisions of the family Cyathophyllidæ. The Cyathophyllidæ with large tabulæ and short septa have been separated from the genus *Cyathophyllum*, whose species have the septa passing to the axis of the corallum, and have been arranged under the genus *Campophyllum*, Ed. & H.; but it is too specific a distinction to be of generic value. It is therefore proposed to place all the species of *Palæocyclus* in the genus *Cyathophyllum*."

The genus *Palæocyclus* may therefore be abolished altogether, and its species be named as follows:—

1. Cyathophyllum porpita, *Linné*, sp.
2. —— præacutum, *Lonsdale*, sp.
3. Cyathophyllum Fletcheri, *Ed. & H.*, sp.
4. —— Edwardsi (P. rugosus, *Ed. & H.*).

The third report (1871) on the British Fossil Corals alludes to the absorption of *Palæocyclus* by *Cyathophyllum*.

The finding of the species *C. Fletcheri* in the Wenlock-shale workings occurred during an investigation, the results of which have been published by another Society, into the nature of the synapticulæ of *Fungia*, a genus of Fungidæ, and I was tempted to go over my work again, and to reconsider my opinion that the corals placed by MM. Milne-Edwards and Jules Haime in the Fungidæ, and called by the generic name of *Palæocyclus*, were rugose corals.

The calice of such a type as the species named *C. porpita* is very open and shallow, and the septa are very visible. Now they are separate and do not ever unite by their sides, after the fashion of simple Fungidæ, but they have decided swellings on their sides which dip down and line the flanks of each septum down to the base.

A section made longitudinally through the corallum shows these swellings to be a number of more or less vertical and slightly curved continuous lines on either side of each septum. They extend from the free upper margin of the septum to near the base.

Omitting all reference to other structures, it is evident to those who have studied the synapticulæ of a recent *Fungia*, that the distinguished French zoophytologists were not without some reason in their classification. But it is clear to me now, as it was in 1867, that these curved ridges did not meet in the interseptal loculi, and all the sections prove that there was no fusing or connexion in any way after the manner of synapticulæ. With regard to the other structures, sections show that the axial space is bounded below by a dense wall-like structure, which is imperforate; I have not seen any tabulæ beneath the floor of the calice in the species *Porpita*; and I disagree with those palæontologists who persist in retaining the name *Palæocyclus* to express a Silurian Fungid.

There are dissepiments between the septa close to the axial space.

In the other species of the group, taking that species named *C. rugosum* (my *Edwardsi*) as the type, the ornamentation closely resembles that of the species just mentioned, except that the septa are less beaded. Sections prove that they have tabulæ, and of considerable relative size, besides a vesicular endotheca near the wall between the septa.

Under these circumstances there is no reason for altering the classificatory position in which I placed these corals in 1867.

NOTE, *January* 1884.—Immediately after this communication was read I received Lindström's interesting paper on the Operculum-bearing Corals read before the Swedish Academy, Sept. 13, 1882. It required very careful consideration. Later on I received Lindström's Index to the generic names applied to the Corals of the Palæozoic Formation, and as it contained a statement in relation to *Palæocyclus* which required investigation, it necessitated further delay.

In the first-mentioned essay there is a list of synonyms of one of the *Palæocycli*, my *Cyathophyllum Fletcheri*, Ed. & H., sp., which shows that no less than thirteen genera &c. may be associated with it, and that it may have twenty-two specific titles ! ! Since I wrote on the necessity of placing *Palæocyclus* in *Cyathophyllum*, the genus has been called *Campophyllum*, *Haliophyllum*, *Pholidophyllum*, *Acanthocœnium*, *Tæniocyathus*, *Acanthocyclus*, and even *Acanthodes*. Seven authors have worked at the form, one of whom has given it five specific and two generic names, and another six specific names, still keeping it in the genus *Cyathophyllum*. At least this is according to Lindström's synonymy*. I find that I am said to have named this form *Cyathophyllum Loveni* and *Petraia bina* in the same year in which the Essay on the Palæocycli was published in the Philosophical Transactions ! !

What Lindström must mean, so far as I am concerned, is that I placed *Patraia bina* amongst the Corals described in 'Siluria,' and also *Cyathophyllum Loveni*. He considers those forms to be the same as *Palæocyclus Fletcheri*, Ed. & H., = *Cyathophyllum Fletcheri*, Ed. & H., sp.

I demur very decidedly against the identity of *Cyathophyllum Loveni* and *C. Fletcheri*; and as I never attempted to predicate what a cast might turn out to be, I object to the synonymy of *Petraia bina* and the last-named species.

On comparing the morphology of *Cyathophyllum* (=*Palæocyclus*) *Fletcheri* and *rugosum*, as described in the Philosophical Transactions, I do not see any definite difference between it and that given by Lindström, so far as the internal structures are concerned. What I have termed variolar endotheca, Lindström terms "like-formed," "uniform" stereoplasma. I have always considered the comparatively new term "stereoplasma" to be something in addition to ordinary endotheca, a filling-up stuff or a substance environing epitheca. But I hold to the old term in this particular.

The outside of the coral, however, has yielded to Lindström very remarkable structures, *not a trace of which have I ever seen in English specimens*. Lindström states in his description that the costæ are

* "Om de palæozoiska formationernas Operkelbärande Koraller." K.-Svensk. Vet. Akad. Handl. Band vii. no. 41, p. 64.

beset with rows of rhomboidal scales, a row of scales existing for each half of a costa. Thus on Tab. i. fig. 2, the costæ are marked with a herring-bone ornament, the axis of each series being along the middle of the costæ. There is nothing like this in the British specimens. The magnified view of the scales, Tab. v. figs. 18–22, shows something entirely new.

The presence of these scales in specimens of corals seen by Lindström caused him to evolve a new genus, *Pholidophyllum*, in 1870, and from the synonymy it was first associated with *Cyathophyllum Loveni*, and not with the form under consideration.

PHOLIDOPHYLLUM, Lindström, 1870.

Synonymous genera:—

Triplasma, Lonsdale.
Scarithodes, Dybowski.
Acanthocyclus, idem.

"Corallum composite, budding on the quadrisection of the mother calice. Longitudinal plications (costæ) of the surface of single individuals arranged in pairs, beset with rows of rhombic scales, a row of scales for each half of the longitudinal plication. In individuals crowded into colonies these scales are wanting. Septa of equal size. Loculi filled with 'like-formed' stereoplasma, numerous in the midst of the coral, most frequently in regular equidistant tabulæ"*.

This generic description, doubtless admirably correct for the forms described by Lindström from the special area of his researches, will not include the British *Palæocycli* = *Cyathophyllum*, upon the evidence which I have had.

In the Index to the Genera of Palæozoic Corals, by Lindström †, we find "*Palæocyclus*, Edw. & H., 1849, Comptes Rendus, xxix. 71. From this genus are to be excluded *Pal. Fletcheri* and *P. porcatus*. *P. porpita* is the only species as yet known." In the communication to the Royal Society published in the Philosophical Transactions, 1867, p. 643, the absence of synapticulæ in *Palæocyclus porpita* was proved, and the microscopic appearances figured. The nature of the septal nodules was explained, and it was shown that they did not stretch across the loculi as synapticulæ. I got dissepiments here and there. This statement requires refutation by Lindström before it can be simply ignored.

Under the circumstances I retain the species of *Palæocyclus* in the genus *Cyathophyllum*, and consider that *Pholidophyllum* is a genus whose diagnosis does not cover the English forms.

* I have to thank Mr. Percy Sladen, F.G.S., for this translation.
† Communicated to the Royal Swedish Academy of Sciences, May 8, 1883.

10. *On some* TRACKS *of* TERRESTRIAL *and* FRESHWATER ANIMALS.

By T. M'KENNY HUGHES, M.A., F.G.S., Woodwardian Professor of Geology, Cambridge. (Read November 21, 1883.)

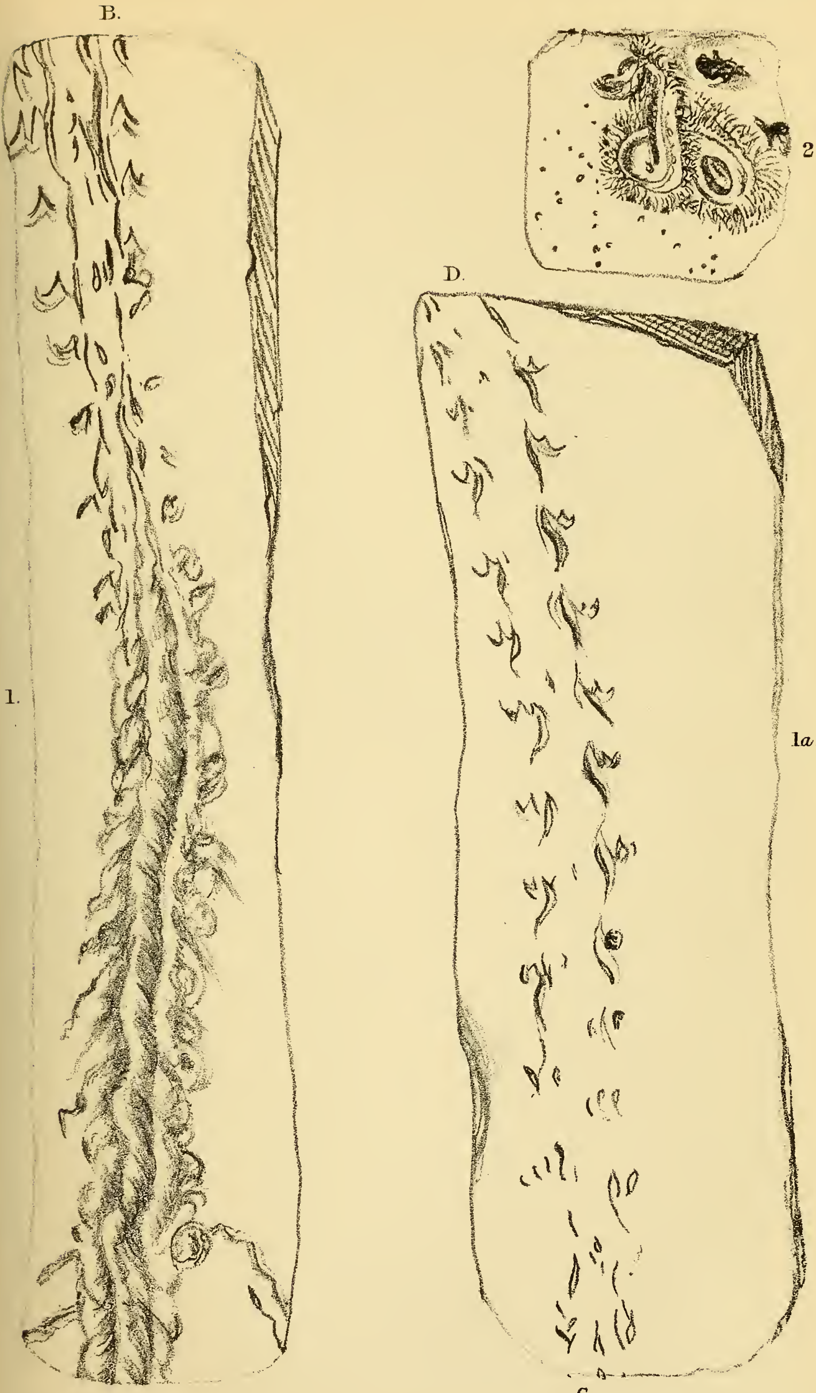
[PLATES VIII.–XI.]

THE ancient rock-markings known as "Bilobites," and afterwards described by D'Orbigny under the name of *Cruziana*, have long been known, and have proved a fertile source of controversy, some regarding them as plant-remains, and others looking upon them as traces of animals. A host of smaller, but similar markings, such as *Rysophycus*, or simpler forms, as *Palæochorda*, or the various very constant and symmetrical varieties known as *Nereites* and *Myrianites*, or those with a more plant-like outline, as *Chondrites*, all belong to the same line of inquiry. Few writers on the Cambrian and Silurian rocks have not had to refer to what they called fucoidal markings, or worm-tracks, which often have their importance increased by being the only traces of life in the bed. Throughout the geological series to the present day, similar things are found.

But though observations on the tracks made by recent animals had long ago been made by Emmons (American Geology, Pt. vi. 1857), and though Dawson had watched and recorded the various markings produced between tides on the long shores of the Bay of Fundy (Acadian Geology, p. 25), it has remained for Nathorst, in his splendid monograph on "Tracks of Invertebrate Animals" (K. Svenska Vet. Academiens Handlingar, Band xviii. No. 7), to place the whole question on a new footing by his experiments with living marine animals, and his extended observations on recent and fossil forms.

The very full bibliography given by him renders it unnecessary to refer more particularly to the various authors alluded to above; but in the following notes, which may be considered as supplementary to his, I give the results of further and different observations upon the manner in which the tracks of animals anastomose, terminate in foliated or branching heads, or stand out in relief with a solid section, —how the same animal may produce a dotted, unilobate, bilobate, or quadrilobate track, or a track in one place smooth throughout, in another place having striæ oblique or almost parallel to the direction of motion, and in another striæ at right angles to it.

In the neighbourhood of Cambridge there is, at the base of the Chalk, a bed from 10 to 20 inches in thickness, which we call the Cambridge Greensand, as there is not quite sufficient palæontological or stratigraphical evidence to justify our correlating it exactly with the Upper Greensand of other districts. This bed consists of a clayey shale full of glauconitic grains, phosphatic nodules, and phosphatized fossils; all of which increase in quantity towards the base until sometimes the bed is quite green from the glauconitic grains, or black from the phosphates. As, however,



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Mintern Bro's. imp.

TRACKS IN MUD.

M. Strickland del. et lith.

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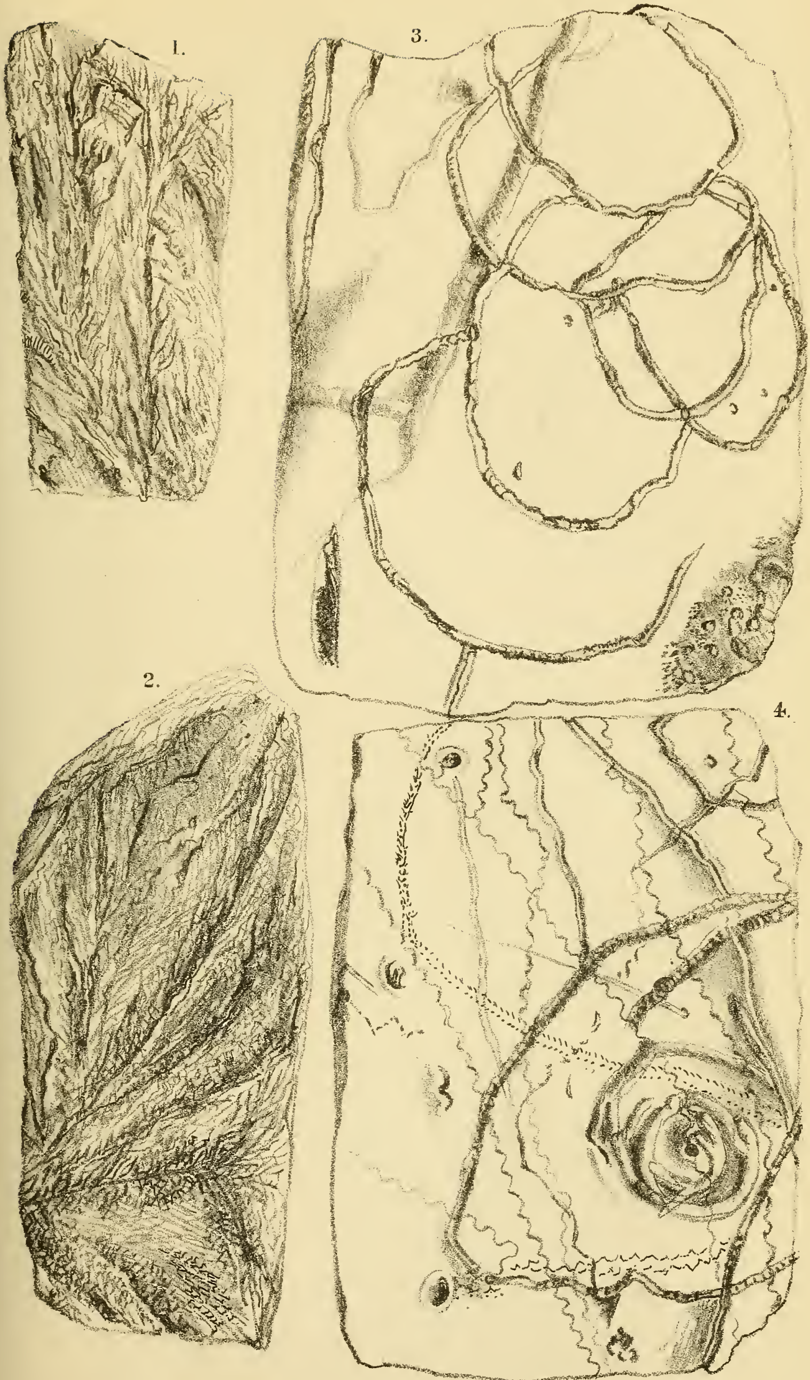
TRACKS IN MUD.



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TRACKS AND MARKINGS IN MUD.

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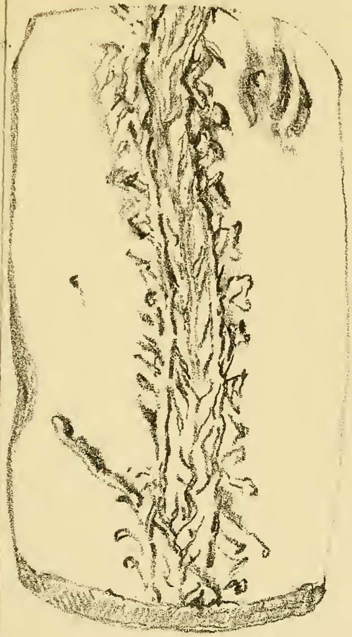

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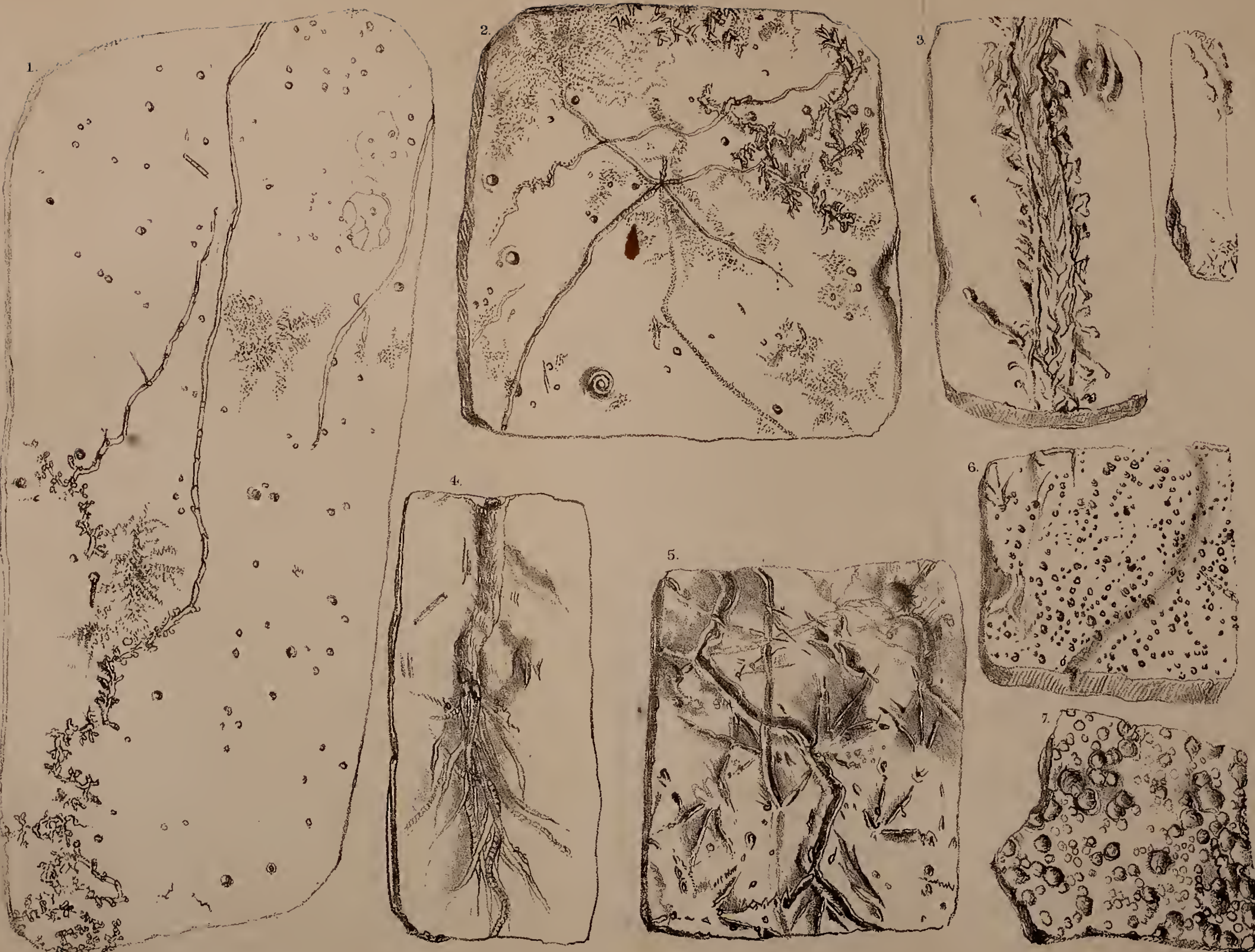


M. Strickland del. et lith.

Mintern Bro's. imp.

TRACKS AND MARKINGS IN MUD.

these run well up into the chalky upper portion, and the bed is clayey throughout, it is necessary that the material dug out should be washed in a mill to separate out the phosphate, which is required for commercial purposes. This mill consists of a circular pit into which the rough material is thrown with a constant supply of water. An instrument like a harrow is drawn round and round by a horse working at the end of a beam, as we commonly see in farmyards and brickyards. The muddy water is let off from time to time along a wooden gutter generally supported on upright poles, and is conveyed to a convenient place where it is received into large tanks; the water is allowed to evaporate, and the fine mud, which is locally known as "slurry," is covered with mould and the land restored to cultivation. The sandy portion generally settles along the trough, which has to be regularly cleared out to get rid of it. The result is, that what settles in the tanks is the finest calcareous mud, most insinuating when thin, most tenacious when thick, as the inexperienced who have got in on foot or on horseback, when the mould has been newly spread over an unconsolidated bed of it, know to their cost; as, also, do many other land-animals which drop from the trees or unwittingly hop on to it; as do also even the water-beetles which plop down on to it, taking it for a pond; as do the earth-worms which try to get through it, or the various tribes of pond-life which find the water disappearing and no outlet for them.

As the thicker central portion sinks most, and the margins dry first, we can see the kind of track made by each creature when he is in the softest slime, and trace it on till he gets to the dried portion where he leaves little or no mark; and we find that many very different tracks must be referred to the same animal.

Other phenomena producing peculiar marks or modifying the tracks can be well studied on the "slurries," where accidental circumstances, depending upon the season, temperature, and so on, can be watched, and many of these offer suggestions for further experiment.

In the first place we must notice that although the mud poured into the tanks is exceedingly fine, there are degrees of fineness, and the less fine settles first, so that the deposit, when seen in section, is often finely laminated, the thickness of the laminæ depending upon the proportion of the area of the tank to the body of water let off each time from the washing-mill. By splitting the clay along these laminæ we can see successive series of tracks belonging to old surfaces.

If there has been any drifting of sand and dust over the dried surface, or if the inequalities have been filled in any other way with a different material, we can study the modifications of an infilled track. The first point of importance to notice is, that the mud contracts enormously in drying; and it often happens that the top lamina shrinks before the next below it can adjust itself to the smaller surface, so that cracks are formed in the upper lamina only, which slides over that below by a kind of small horizontal fault. It then sometimes curls up by the more rapid drying and contraction of the upper surface, as toast bends, showing its

N 2

concave surface to the fire. So sometimes a thin film of mud which has run down a face of rock, or settled from rain-water on a smooth surface, curls up like the curled wafers eaten with ices. Along the lines thus exposed through the top lamina the next layer dries most readily, and so the cracks are continued through layer after layer, which are seen projecting in steps along the sides of the little abyss now formed.

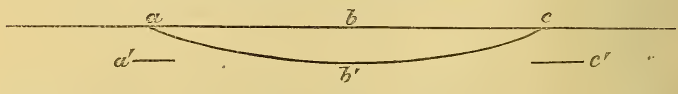
This mode of cracking only occurs in certain cases when the drying goes on rapidly and the laminæ are well-marked off and easily parted.

More commonly the crack cuts through all the layers evenly to a depth of from 1 to 2 feet; it gapes some 8 or 10 inches across the top, and closes altogether before it reaches the bottom of the tank.

Such being the character of the deposit and the circumstances of its drying, it is clear that if anything begins a groove in the top layer, any subsequent cracking would be likely to follow that line; indeed, the trail of some creatures would be as deep as the thickness of one lamina. So we see when we are examining the pattern of the tracks which traverse the "slurry," that they sometimes follow curious curves, which I have often traced to the tracks of large worms, the slight fluting along either edge of the track due to the split worm-track enabling one to follow the original groove far along an opening which has afterwards attained a depth of a foot or more.

More rarely we can see how a groove filled with coarser dust or sand is well marked off from the layer below, and somewhat, but less distinctly, separated from the newer layer which has rushed over it. In such cases, when the mass has settled by its weight, and shrunk on the evaporation of the water in it, we see that the form of the less yielding material which has filled the groove has been modified. For, since the portions *a a'* and *c c'* (see figure) shrink more than the portion *b b'*, therefore the ends *a* and *c* must get squeezed down and the infilled groove present a somewhat lenticular section; and if the groove be quite filled up, the central portion *b* will bulge up a little into the overlying bed.

Diagram Section of Groove.



It will be observed that this answers the objection to the view that *Cruziana*, for instance, might be a track because it sometimes shows a lenticular section, as if it had been a solid body; and also shows how in some cases the imprint may appear on the underside of an overlying stratum.

I have frequently seen on a ripple-marked shore that every depresssion was filled with black grains of peat or broken blackened vegetation, caught in the embayed water in each trough, and I have thought how easily it might happen that if a track were so filled, covered, and pressed down, the relief imprint might have a thin film of carbonaceous matter over it.

Again we observe from the different rate of progress of animals with legs or swimming-apparatus, as they get into the thicker or thinner parts of the mud, that no inference can be drawn as to the form of the animal, or distance between its legs from the strokes it leaves at right angles to, or oblique to the direction of its motion. The oars of a boat that has run aground return to the same place at each stroke. When the boat begins to move, the distance between the lines where the oars are lifted out of the water increases, until at last the boat may glide on and the distance between the dip of the oars may be longer than the stroke of the oar through the water. So, if a cockchafer has fallen on a somewhat thick part of the slush, many strokes of his legs advance him but a little way, and the ridges of mud pushed up by each stroke are very close together. They may be nearly at right angles to the direction of motion, or the animal may draw them very close to his body and never get a good sweep. This commonly happens when the slime is thick, and in such a case the striæ are only slightly inclined to the direction of motion.

I have seen such a track made under very favourable circumstances. The insect had fallen, from an overhanging tree, into water from which it struggled towards shore. When I saw it, it had just reached mud of sufficient consistency to allow it to make some progress. The result was the formation of a fringed Bilobite.

The ovipositor, dragged through the mud, formed the median line, the stroke of the legs produced the ridges on the lobes. There were two less distinct marginal furrows formed, as it appeared to me, either by the ends of the wing-cases (elytra), or by the bristly edge of the animal's body; I could not observe this point clearly; these, somewhat interrupting the ridges due to the legs, gave the appearance of a fringed edge. Unfortunately, I was unable to preserve this track, and attempts to reproduce exactly the conditions were unsuccessful. Of all the tracks of land and freshwater animals which I have seen, this was the one which most closely resembled *Cruziana semiplicata*.

Water-beetles (*Dytiscus* &c.), however, are frequently caught in the "slurry" and produce tracks somewhat similar, one of which is figured (Pl. VIII. fig. 1, 1 *a*), in which C D is the continuation of A B, and (Pl. XI. fig. 3) in which a median line can be more clearly traced *.

These differ from the tracks made by land-beetles in several important points; for the water-beetles have long rowing-legs, which sweep far beyond the short walking-legs, which therefore with the trail of the body produce a median lobe, the long rowing-legs producing two similar marginal lobes. When the animal gets on

* The figures have been drawn for me by Mrs. Hugh Strickland, a skilful artist, who helped her father to illustrate the Ichnology of Annandale.

to more solid ground these strong sweeps, the rowing-legs, lift the body along; so we see at the ends B and C of the specimen figured (Pl. VII. fig. 1, 1 *a*), that the mark produced by the body and walking-legs occurs only at intervals between distinct and well-defined impressions left by the ends of the long and strong swimming-legs as they are pressed into the mud at each stroke.

Small animals which walk on their feet, such as *Lithobius*, *Oniscus*, *Asellus*, &c., produce tracks such as those shown in Pl. IX. fig. 1.

When, however, they are moving through softer mud, the marks produced by their feet become more and more obliterated, as seen in Pl. X. fig. 4, till we see only the ridges due to the sweep of their legs as they try to propel their body through the thick slime, Pl. VIII. fig. 2, and Pl. IX. fig. 4. They frequently turn round and round, producing a knot-like twist. At length they give it up and are smothered or wriggle away, leaving a smooth trail, like that of an earthworm. One such animal, which perished in the slush, I was able to preserve, still sticking at the end of the track it had made; and this has been determined for me by Professor Westwood, of Oxford, to be a young specimen of *Lithobius forcipatus*, Pl. IX. fig. 4.

Any insect, even a large fly, sticking on the surface of the mud, in its efforts to get on, catches at the ground before it with its front feet, turning now rather to this side, now rather to that, in its attempts to get a grip, and makes the curious markings seen on Pl. IX. fig. 2, which somewhat resemble the appearance produced by a kind of alga on smooth rock-surfaces between high- and low-water mark. This kind of mark is also produced by the dipping point of a bending blade of grass moved by the wind; but in this last case the marks are somewhat less regular.

I have noticed incidentally above, that earthworms and similar animals generally produce a smooth trail. The cross-barred tracks, such as those seen in Pl. X. fig. 4, are made by the larvæ of beetles &c., which move like caterpillars by shifting each body-ring in turn, whereas, when a worm has pushed the long anterior portion of its body forward far enough to get hold, as it were, it drags all the tail part after it by one continuous movement, so that the track is a smooth furrow; where, however, there are no inequalities in the ground, and it is too slimy for the worm to get a hold with its bristly rings, it is apt to follow a winding course, apparently in order to get a grip after the manner of a corkscrew. Some smaller creatures allied to earth-worms always do so, the fine wriggling track, Pl. X. fig. 4, is, I believe, made by *Tubifex rivulorum* or some such form; but I have not been able to observe this accurately.

Some of the most interesting tracks are those made by burrowing animals; and in connexion with them, I will notice several other phenomena related to them only by a deceptive similarity of form.

There are three kinds of small pits or circular depressions common over all mud flats:—

First, there are the impressions made by rain or hail, which always have a small rim *all round* the hole, when there has been a straight downpour; *on one side*, away from the direction in which the rain or hail was coming, when that has fallen obliquely—see Pl. XI. fig. 7.

Secondly, besides this there is the round hole left by bursting bubbles—see Pl. XI. fig. 6. These are due to the caving in of the mud when the bubble has burst and left a cavity; and they therefore have not the rim due to the violently displaced contents of the depression, as in the case of the rain-spots.

Thirdly, there is the hole made by worms, burrowing into or coming out from the mud. These are often in pairs, as they showed only a short time above ground or remained only a short time below. In this case, as might naturally be expected, the margin of the hole down which the worm went shows the indrag of the animal's body in the rounding off of the edge, and the hole from which it emerged shows the out-push in a kind of rim. The holes soon get filled with mud. In these we often have *Arenicolites didymus* exactly reproduced. Sometimes a worm or larva, or other burrowing animal, bores just under the surface of the mud so close to the surface that it raises a round archway in considerable relief above the level of the surrounding mud, which is seen in section as the roof of the tube or tunnel along which the animal has passed (Pl. X. fig. 3). Sometimes a worm pushes the fore part of the body out along the surface, making trials in several directions and producing a long cylindrical tube with a flattened branched extremity (see Pl. XI. fig. 4). As the posterior part of the animal is not dragged after the anterior in this case, the barred track is not obliterated. The cross markings are, however, shown a little too strongly in the figure. This is quite unlike the forms described and figured by Nathorst (*op. cit.* pl. iii. fig. 5, pl. v. fig. 3, &c.). Some of his are curiously like *Oldhamia radiata*. The organic origin of this fossil is more obvious in the other species, *O. antiqua*.

Some smaller animal (? a beetle) pushes its head out at very regular intervals, forming a long hollow tube with symmetrically arranged cell-like openings, just such as might be referred to a zoophyte with cœnosarc and hydrothecæ (Pl. XI. figs. 1 & 2).

Should the mud in such a case harden sufficiently to allow of the infilling of the tube, we should have a track in relief on the upper surface of a slab, and showing a solid section and branched extremity (see Pl. XI. fig. 4), or a branching base and long trailing extremity (Pl. XI. figs. 1 & 2).

The tracks which somewhat resemble *Nereites* and *Myrianites* are produced by a great variety of animals. I have seen *Limnæa peregra* make a mark on very fine wet mud in a ditch, exceedingly like *Nereites*; but this was quite exceptional, as the animal generally glides along smoothly, and it seemed that the interrupted motion in the case observed, was due to the necessity of pushing the head far forward and lifting the shell with a jerk. Very small frogs crawling out of the slush, where hopping is impossible, produce by their alternate step a lobed mark analogous to *Nereites*; while some varieties of the beetle-tracks, especially those of land-beetles, strongly approach *Nereites* and *Myrianites*.

I have noticed above the occurrence of marks produced by worms and grubs in relief on the surface of the mud; another curious example I may also give. In some cases in the footprint of a frog the line of the toes is marked in relief (Pl. XI. fig. 5), not depressed, as one would naturally expect, on the upper surface of the mud. This appears to happen where the mud has just that consistency, which causes it to stick to that part of the foot which is well pressed into it, and which, on being withdrawn, lifts it up, as a spoon or finger draws up after it a column of treacle or honey.

When a night's frost catches the wet surface of the mud, the most beautiful sprays of ice-crystals grow from the margin and from each projecting stick or stone. The water crystallizes out free from impurities, and needles of ice shoot through the mud in all directions. If a morning succeeds which is favourable to rapid evaporation, the ice evaporates directly, or the drying of the mud goes on fast enough to preserve the casts of the groups of ice-crystals. These are extremely difficult to procure, as the surface so scored readily cracks up and is not easily removed. The curious plume-like markings shown on Pl. X. figs. 1 & 2 represent the frost-pattern on the mud, but give only a poor idea of what they are when fresh.

Nathorst, in the valuable work referred to above, does not, of course, put forward as the result of his observations, that there were on the shores of the early Cambrian Sea the very same species of Crustacea as those he selected for his experiments, nor would I suggest that the *Cruziania* was the track of *Melolontha vulgaris*; but I quite agree with him that from the analogy of these recent forms it is most probable that *Cruziana*, *Nereites*, *Crossopodia*, *Palæochorda*, and all that class of fossils are mere tracks, and do not represent either marine vegetation, as has been suggested in explanation of *Cruziana*, or the impression of the actual body of ciliated worms, as supposed by some in the case of *Nereites*.

EXPLANATION OF PLATES VIII.–XI.

Plate VIII.

Figs. 1 & 1 *a*. Track of Water-beetle (*Dytiscus* &c.), showing variation in track as the animal passed from the more slimy part at A to the firmer mud at D.

Fig. 2. Track probably of a Myriopod: compare with Pl. IX. fig. 4.

Plate IX.

Fig. 1. Track of *Lithobius* or similar form, crossing tube formed by burrowing animal.

2. Track made by large fly?

3. Track of burrowing animal.

4. Track of *Lithobius forcipatus*, showing the marks made by the feet at one end of the track, a smooth trail in the softer slime, and the animal itself at the other end.

Plate X.

Figs. 1 & 2. Plumes left by ice-crystals.

Fig. 3. Track of burrowing animal, showing how it sometimes crosses and sometimes again enters the old track.

4. Wriggling track of small worms. Track of animal with feet, showing how it draws its legs closer to the body in one part than in another, thus producing a tapering mark. Track of larva, in which the cross-bars due to the impress of the body-rings are clearly shown. Spiral track, with the hole in the centre by which the animal came up to the surface.

Plate XI.

Fig. 1. Track of small burrowing animal (beetle?), showing the manner in which it at first looks out from its tunnel at regular intervals, occasionally leaving it for a short distance, and then goes away uninterruptedly under the surface.

2. The same, showing in places the track of the same animal when not burrowing. The footmarks are sometimes fairly distinct, but sometimes only a confused brushing of the surface.
3. Track of Water-beetle, showing an approach to the quadrilobate form.
4. Track of worm, feeling its way out in various directions from the end of a tunnel which it has formed just under the surface of the mud. In this the bars formed by the bristly rings of the worm are not obliterated by the posterior portion of the animal's body being subsequently dragged over them.
5. Footmark of frog, in relief on the upper surface of slab.
6. Bubble-rings.
7. Rain-spots.

Discussion.

Prof. Dawson remarked that in the Silurian, Devonian, and Carboniferous rocks of Canada were forms described as fucoids which he himself thought were more probably traces of animals, though it was hard to say of what animals. The deposition of sediment from coarse to fine, described by the author, might be seen in the Bay of Fundy. Shrinkage-cracks had often been described as fucoids, one of them being a cracked surface, modified by the in-running of little rills of water. So, too, had the marks made by rills on the mud. It was well to remember that dissimilar animals might make similar tracks, and similar animals, under different circumstances, would make dissimilar tracks. *Limulus*, for instance, made three kinds of tracks. The explanation of the bilobate worm-marks given by the author appeared to him to be correct; also that of the tracks in relief on the upper surface. The pulling-up of the mud might often be seen in modern tracks. Nearly all these phenomena could be paralleled by the action of sea-worms, Crustacea, &c., on the sea-bottom. We must, however, remember that in some cases structure remained, showing that in these we had vegetable tissues.

Prof. T. Rupert Jones said that there were some drawings of markings by marine animals by the late Hugh Strickland in the possession of the Society. He also described various markings of characters other than those described by the author. He thought that the Crustacea made as many marks as the Worms.

Mr. Etheridge commented on the difficulty of interpreting these markings in the field, and said he quite agreed that the Annelida and Crustacea made many of them. He referred to a description by Mr. Gray of the tracks of Gasteropoda. The mud-fans on the Norfolk coast offered excellent opportunities for a study of phenomena of this kind. He called attention to the burrows seen in the Assynt quartzites and the so-called fucoids.

Rev. E. Hill referred to the cracks in these muds, and agreed with the author that the worm-tracks help to produce them.

Dr. Hicks referred to the markings of *Cruziana*, and to some researches he made near Nant Ffrancon last summer. He had traced one for over 10 feet in length ; some appeared to be even longer. He thought that they were relief burrows of worms produced in the manner described by Prof. Hughes. He agreed with Dr. Dawson that it was not safe to class any of these markings as plants unless they showed organic structure or retained carbon.

Prof. Hughes said that his object had been simply to describe some peculiar markings on mud, the manner of formation of which he had been able to observe, and to point out in what respects they explained away difficulties which had arisen in the interpretation of certain fossil tracks. He thought he had been able to show that some of the characters most relied upon to prove the vegetable origin of the fossil forms, such as branching, solid section, &c., could be produced by animals. He had seen the curious symmetrically branching grooves, due to streamlets on the sea-shore, mentioned by Dr. Dawson, and some tracks of Crustacea, such as those mentioned by Prof. Rupert Jones ; but he had been unable to preserve any of these owing to their being generally on sand, and also because they were obliterated by the succeeding tide instead of being left to dry.

11. *On the* Cambrian Conglomerates *resting upon and in the vicinity of some* Pre-Cambrian Rocks (*the so-called* Intrusive Masses) *in* Anglesey *and* Caernarvonshire. By Henry Hicks, M.D., F.G.S. (Read December 5, 1883.)

In papers which I communicated to the Geological Society in 1877 and 1879, I brought forward evidence to show that some rocks in Caernarvonshire and Anglesey which were indicated on the maps of the Geological Survey as great eruptive masses intruded into strata of Cambrian and Silurian age, were really rocks of Pre-Cambrian age. I pointed out that there was the clearest evidence to show that the lowest Cambrian conglomerates known in those areas, instead of having been altered by these so-called eruptive masses, as would be inferred from the maps of the Geological Survey, repose unconformably upon the rocks composing these masses, and were mainly built up of materials derived from them by denudation. In the paper of 1877 I stated that the pebbles in the conglomerates were "usually distinctly rounded and generally imbedded in either an unaltered or semicrystalline matrix, from which they can be easily removed," and that "they were evidently in their present state, as regards consolidation, before they were cemented together to form the conglomerates, and must have been derived from rocks highly metamorphosed at that time, such rocks, indeed, as now occur immediately under them, and which, we venture to believe, belong to a Pre-Cambrian series." In the same paper I mentioned that the false appearance of being intrusive masses exhibited by these rocks and "the passage by gradual alteration mentioned by various observers, are mainly due to the fact that the matrix in the conglomerates has been derived from rocks immediately below or from similar ones, and from a slight subsequent change in the matrix, due, probably, to proximity to the intrusive dykes, aided by a readiness perhaps in the material to assume this change. This is clearly observed by watching the weathering of these conglomerates even when in direct contact with the porphyritic series; for any apparent melting-away of the hard pebble is shown not to be a fact, since on very slight weathering the pebble becomes easily separable from the matrix, and its outline is as perfect as on the day it became cemented in the mass."

Professor Bonney's very important paper (Quart. Journ. Geol. Soc. vol. xxxv. p. 309) added the necessary evidence to make these facts certain, and in it he showed also the rhyolitic character of some of the Pre-Cambrian rocks. Professor Hughes, Professor Bonney, Dr. Callaway, and Dr. Roberts have also from time to time, in different papers read before this Society and elsewhere, called attention to the same facts as are referred to above; and I should hardly have thought it necessary to bring forward this further evidence, highly conclusive as it may be, were it not that the last edition of the Geological Survey memoir relating to these areas, published in

1881, and revised, as stated therein, after the appearance of our papers, contains not only the same statements in regard to these so-called igneous masses and the strata surrounding them, but a charge is there made that we arrived at our conclusions "on purely theoretical grounds," and additional details are therefore given in support of the statements made in the previous edition. Moreover the present Director General of the Geological Survey, in his paper on the St. David's area in Quart. Journ. Geol. Soc. for August last, especially casts doubt on the value of the evidence adduced from conglomerates, and even quotes some of those in Anglesey in support of his view. He further reproduces his predecessor's (Sir A. Ramsay's) statement that there are no rocks of Pre-Cambrian age "in any part of the Principality."

Certainly the present Director General, in the paper referred to above, at p. 262, says—"It should be clearly understood that the conclusions to which I have come refer solely to that [the St. David's] district, and that, in the meantime, I offer no opinion regarding other so-called Pre-Cambrian areas in the Principality;" but most persons I think will agree that it is undoubtedly clear, from the paragraphs in his conclusions at pages 292 and 293, that his remarks throughout are intended to have a far more general application. At p. 292 he says—"But the same treatment which Dr. Hicks meted out to them in the St. David's area, he has consistently continued in his subsequent excursions over Wales. Having apparently convinced himself—on what grounds I have endeavoured to show—that the rocks coloured on the Survey Maps as felstone or quartz porphyry must belong to his 'Arvonian' group (that is to say, are not intrusive in the Cambrian or Lower Silurian strata, but prominences of Pre-Cambrian age), he has proceeded to apply this conviction to the Geological Survey maps all over Wales. With the most complete disregard of the evidence by which the officers of the Survey were led to regard certain rocks as intrusive, he simply turns the felstones, syenites, &c., into metamorphic and volcanic Pre-Cambrian masses." In a footnote to this paragraph he also says—"It will be a work of some labour to follow Dr. Hicks in his rapid traverses of Wales, with the view of testing his corrections of the work of his predecessors. Mr. Peach and I had time to visit a few of the areas he has renamed, and always with the same result." To show that it is absolutely necessary, in my own self-defence, that I should lay all possible evidence before the Society in regard to all the areas, to prove that I did not arrive at conclusions at variance with the views of the Geological Survey in the hasty and careless manner attributed to me in the above quotations, I need only quote one further paragraph, which concludes the first part of his paper:—"This was not the style in which the Survey Maps were constructed; nor is it the style in which they should be corrected. The intrusive character and comparatively late origin of the eruptive rocks were deliberately asserted by my colleagues after prolonged examination. Had this view been erroneous, it ought to have been disproved by a detailed review of the evidence on which it was based. I have gone fully into the assertions made by Dr. Hicks himself in regard to the area of St. David's, and have proved them to be untenable. If this is the result of the critical examination of his typical Pre-Cambrian district, over which he has spent most time, I can hardly anticipate that his more rapid traverses elsewhere will, when properly tested, be found to have been more successful."

After listening to the above statements which have been made by the present Director General, I hardly need ask the Members of this Society, in whose Journal they have appeared, to consider this paper only as a first instalment of that thorough criticism of the work of the Geological Survey which is demanded in the above paragraph, and as necessary in reply to the indictment, from the only district which I have been able to reexamine since Prof. Geikie's paper appeared in the Journal.

Though the title of my paper shows that I purpose mainly to deal with evidence derived from the Cambrian Conglomerates, it is clear that it will be advantageous to refer incidentally also to any new facts obtained relating to the Pre-Cambrian rocks themselves. The rocks which we claim to be of Pre-Cambrian age have, however, been so fully described in papers by Prof. Hughes, Prof. Bonney, Dr. Callaway, and myself that it will not be necessary to do more than call attention very briefly to their characteristics. Prof. Geikie has also, in his descriptions of these rocks, included all peculiarities which have been pointed out by us as specially applicable to any of these North-Wales areas.

In the Geological Map issued with the Survey Memoir referred to, published in 1881, there is a great elongated mass coloured as "intrusive felspathic porphyry," reaching from Llanllyfni in the south of Caernarvonshire, to Bethesda in the north, a distance of about fifteen miles. It has an average width for the most part of from a mile and a half to two miles, but becomes narrower towards the north. At its south-western extremity and for a short distance along its south-eastern edge, altered Cambrian rocks are shown to be in contact with it, but at all other points ordinary Cambrian rocks. This so-called intrusive mass is stated in the index to be "chiefly of Lower Silurian age." Another mass of the so-called "intrusive felspathic porphyry" is shown to extend from Caernarvon to Bangor, a distance of about ten miles, with a width at its broadest part of rather over a mile, and narrowing towards each end. At Bangor altered Cambrian rocks are shown along its north-eastern edge; further south along the same side the ordinary Cambrian colour is given; and beyond this, to Caernarvon, Lower Silurian rocks are indicated as being in contact with the mass. Along the western edge Carboniferous rocks are shown. This mass, like the one above referred to, is marked as "chiefly of Lower Silurian age."

In Anglesey, extending from the coast south of Llanfaelog to the north-east of Llanerchymedd, there is, on the same map, a great patch coloured as granite. At its broadest part it is three miles across, and its length is about eleven miles. It is stated in the index to be "probably of Lower Silurian age." What I have maintained in previous papers to this Society is this, that neither of these so-called intrusive masses could possibly be of Lower Silurian age, that they could not possibly have eaten into and metamorphosed the Cambrian and Silurian rocks in their immediate vicinity, as maintained by the Surveyors, since they are truly Pre-Cambrian rocks, which were in their present condition before either the Silurian or Cambrian rocks were deposited. Where views are so diametrically opposed to one another as are those of the Surveyors to those which we have put forward, it is clear that we are bound to furnish very conclusive proofs in support of our views; and I venture to believe that from the evidence I have to bring before you in this paper, it will be allowed that the proofs are of the most conclusive character, even when tried by the most rigid tests. I have given the rough superficial areas of these rocks, as it might be supposed from some of the remarks which have been made that, as geological features, their importance is scarcely deserving of consideration. These, however, are but a few of similar areas which we claim, and when it is considered that they are now the exposed fragments only of part of that old Archæan land which extends everywhere under the newer formations, and that it is in these fragments we obtain evidence of the geological structure, the physical history, and geographical features of that primæval land, I believe the true man of science will grant that in this case the value of the inquiry cannot well be measured by the superficial area exposed now to examination.

The visit of the Geologists' Association to Bangor in the last week of July offered favourable opportunities for reexamining many of the areas previously described, and the evidence in that neighbourhood was freely exposed to the criticism of over fifty Members who were present. It was in the week subsequent to that visit, however, that, accompanied by Mr. Marr, Mr. Myers, Mr. Murray, Mr. Love, all Fellows of the Society, and by Mr. McPherson and Mr. Bartlett, and afterwards, I was able to collect the facts given in this paper, and I wish to express my obligations to those gentlemen for the very valuable assistance which they rendered me.

Hitherto, though pebbles and fragments of almost every variety of the rocks claimed by us as of Pre-Cambrian age had been occasionally observed in the Cambrian Conglomerates, no actual necessity had arisen for making a special collection, to prove their identity with the rocks immediately underlying them or in their immediate neighbourhood. The importance of making such a collection, however, became imperative after the statements of the Director General that the Conglomerate in South Wales (and according to the same reasoning in North Wales) could not possibly contain a pebble of the characteristic granite (Dimetian granitoid rock), or of the quartz-felsites or porphyries, because, as he led us to infer, they were all newer than the Cambrian rocks. Moreover if we can prove conclusively that typical Dimetian fragments, and undoubted quartz-felsites and porphyries, identical with the rocks below, do occur in the Cambrian Conglomerates, then, so far as North Wales is concerned, the Director General, by his own statements, will be compelled to grant that our views are correct, and that he and his predecessor have been completely in the wrong in their interpretation of the geology of those areas, so far at least as the oldest rocks are concerned. The following statement occurs at p. 305 of the paper already referred to:—"There can be no doubt that conglomerates frequently mark the natural base of a series of sedimentary deposits. They do so more especially where they are formed of materials that have had an obviously local origin, and where they rest unconformably on the rocks below, from the waste of which they may have been mainly derived. In such cases they must be regarded as littoral deposits; and in this respect they possess importance from the light they throw on former geographical conditions. Of other conglomerates which possess local value as stratigraphical horizons only, he says—" Unlike the basal conglomerates just referred to, they are composed of well waterworn pebbles, for the most part comparatively small in size, derived from some distant, and in many cases, unknown source, and consisting usually of quartz, quartzite, or other exceptionally durable rocks." I accept to the fullest extent the tests suggested by the Director General in the above quotations, and I now submit the facts to the Society, feeling confident that the verdict must be in our favour. As the Director General has acknowledged that we are correct in placing the Pebidian rocks below the basal conglomerates, as a great volcanic series, though Sir A. Ramsay maintains that the oldest volcanic rocks known in Britain (as may be seen by referring to his Address as President of the British Association in 1880), of which he had any personal knowledge, are of Lower Silurian age, I will only refer to those rocks so far as it may be necessary to point out evidence of their Pre-Cambrian age, by showing the Cambrian Conglomerates resting unconformably upon them, and being here and there made up very largely from their denudation. It is more important that in this paper I should confine myself to the above-mentioned rocks, which are claimed by the Surveyors as irruptive masses of a date long posterior to the deposition of the Cambrian Conglomerates, which now surround them.

Llanfaelog, Anglesey.

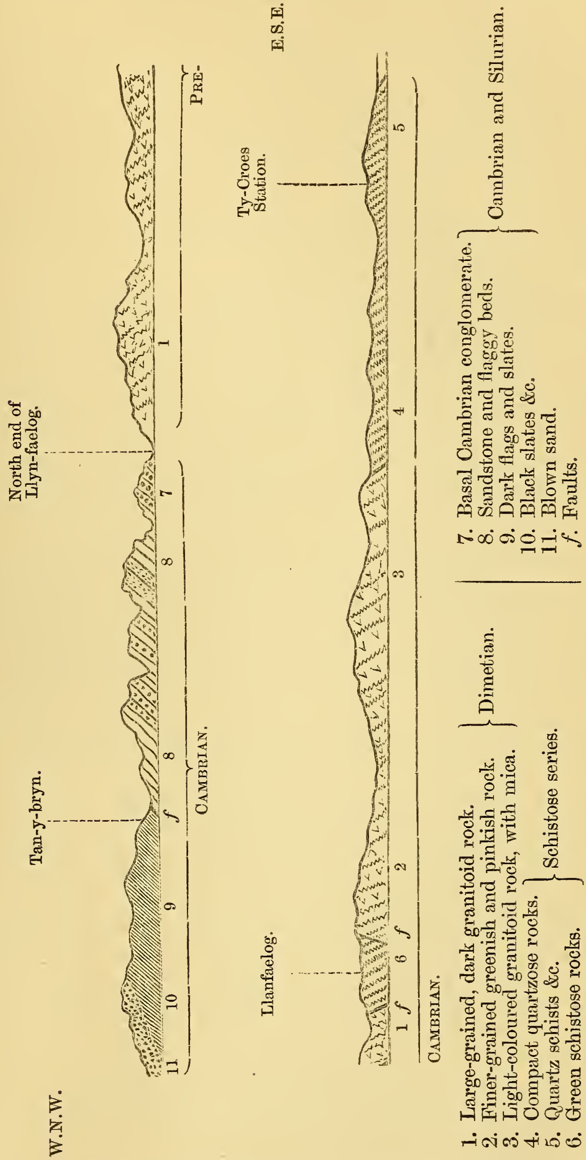
In my paper of 1879 I pointed out that the so-called intrusive granite as exhibited near Llanfaelog, in Anglesey, was almost identical in character with the Dimetian granitoid rocks at Twt Hill, Caernarvon, the so-called Rhos Hirwain syenite, and the Dimetian at St. Davids; and my views were fully confirmed by Professor Bonney's examination of the rocks in the field and under the microscope. I maintained that this so-called granite patch, instead of being, as stated by the Surveyors, composed of granite intruded into the Cambrian and Silurian rocks in Lower-Silurian time, and of metamorphosed and entangled portions of those rocks, actually consisted of the oldest rocks in Anglesey, and formed an old axis not only to the Cambrian and Silurian rocks, but even to the newer of the Pre-

Cambrian rocks. The evidences on which we based these conclusions were chiefly such as could be obtained by comparing the rocks with those found in other areas which we had examined, and by noticing carefully whether any alteration had been produced in the neighbouring rocks. We recognized that along one side the rocks were entirely unaltered, and that the material out of which the latter had been built up may have been, in part at least, derived from the denudation of the granitoid rocks; but at that time we found no fragments which could be stated definitely to have been derived from the rocks in the so-called granite patch. Moreover the actual horizon of these conglomerates and grits along the western edge had not at that time been made out; and we owe it entirely to Professor Hughes that their position as basal Cambrian Conglomerates has been clearly defined. In his excellent paper on "The Geology of Anglesey" published in 1881, he has worked out the succession of these rocks near Llanerchymedd, by fossil and stratigraphical evidence, and has proved conclusively not only that they are the basal Cambrian conglomerates and grits, but also that the Tremadoc and Arenig rocks follow them in succession. I had an opportunity of examining the sections near Llanerchymedd under Prof. Hughes's guidance, and there cannot be the shadow of a doubt that his conclusions are correct. If further evidence is necessary, it is furnished in the sections we examined to the west of Llanfaelog. In descending order are the following rocks. (See section, fig. 1.) Under the blown sand to the east of Traeth Crigyll black irony slates of true Arenig type are found, with a high dip to the north-west. At Ty-croes farm* and Tan-y-bryn, black slates and more flaggy beds are seen, still dipping to the N.W. In the depression which separates these farms from Ty-hen, the beds are not exposed, and the appearance here would rather indicate a line of fault with the loss of some of the strata. The next beds which are met with going eastward are flaggy sandstones, and these are underlain at Ty-hen by rather rough conglomerates. Between this point and the Dimetian rocks on the east shore of Llyn-faelog, a distance of about half a mile, the rocks are mainly flaggy sandstones alternating here and there with bands of conglomerate. The beds all dip towards the north-west, at an angle of from 30° to 35°. If there are no repetitions by faults, we have here a very considerable thickness of the Lower Cambrian rocks exposed. The lowest beds of the conglomerates are within 30 yards of some exposures of the granitoid rock, in the field on the east side of the lake, and I have no doubt an actual contact may be seen by the removal of some of the soil in the depression at the head of the lake. The lowest conglomerate at this point is in some respects the most interesting and important of the basal conglomerates that I have yet examined; for it shows clearly that when it was deposited the granitoid rocks immediately to the east must have been exposed, and that they formed the old shore-line on which the conglomerates were deposited. Not only is the matrix chiefly made up of an arkose material, as is some of the conglomerate at Twt Hill, Caernarvon,

* Two miles west of Ty-Croes Railway Station.

but here large fragments of undoubted Dimetian rocks occur as well-rolled pebbles, and every variety found in the underlying

Fig. 1.—*Section from Tan-y-bryn, by Llanfaelog, to Ty-Croes Railway Station, Anglesey.* (Horizontal scale 6 inches to 1 mile.)



rocks may be recognized in the pebbles or fragments in the conglomerate. I have had several of these pebbles cut, and also some of the granitoid rocks from below. These have been submitted to Prof. Bonney for examination with the microscope, see his Notes 1–6, pp. 201–203, and his conclusions agree entirely with mine, that the pebbles are identical with the rocks below, that the peculiarities exhibited by the granitoid rocks of the ridge are shown equally clearly in the pebbles, and that it is evident the granitoid rocks were much in the condition in which they are now found before the fragments now lying in the conglomerate were broken off from the original mass *. Even superficially these pebbles show evidences of this fact. The crushed appearance exhibited by the parent rock is equally clear in the pebble; and that infiltration of a green material along the joints, so commonly found in the Dimetian, had taken place in Pre-Cambrian time, is made certain from finding that it is equally abundant in the fragments.

Subsequent crushing is occasionally indicated by fracture-lines across the pebbles, usually filled by quartz; but these lines are quite independent of the indications of the original crushing, which seems to have affected the whole structure of the rocks even to a point only revealed under the microscope. It has been frequently stated that the quartz in the Dimetian has a dirty appearance, and that this is due to an immense number of inclusions, chiefly of vesicles arranged in well-marked lines. These vesicles are supposed to indicate that the quartz was formed in the presence of abundant vapours. This view of their origin is now so universally accepted that I fear it will be considered rank heresy even to suggest an additional cause. Still, after a prolonged study of a large series of slides made from the Dimetian rocks and also from the older gneisses of Scotland, in which the vesicles occur in equal profusion, I must confess that the above view does not appear to me to be sufficiently satisfactory to account for their unusual abundance, or for the condition generally of the quartz in the old rocks. We know that these rocks have been crushed to a microscopical degree, and that this has allowed infiltration to take place to such an extent that the majority of the minerals have undergone a process of decomposition. One result of these decompositions would be that liquids with powerful solvent properties would be produced, which by a kind of capillary action would pass along the minutest fissures and so attack the quartz and cause decay. The quartz shows abundant evidence of having been broken up, and the fragments are frequently separated by the deposition of secondary minerals. The lines of fracture are also traceable from one fragment to another by thin strings of these secondary minerals; and it is an important fact also that occasionally these strings are seen to connect lines of vesicles in different fragments. The

* As it is a matter of great importance that no possible doubt should exist as to the identity of the pebbles in the conglomerate with the rocks below, Prof. Bonney took the precaution to examine all the slides submitted to him, distinguished by numbers only, before looking at the rock-specimens, and it is undoubtedly a highly satisfactory proof of the great value of the microscope in these inquiries that the results required no modification in any of the main facts when it was found from what areas the specimens had been obtained. In several of the slides also there was no evidence to guide him as to whether they had been cut actually from the parent rock or from a pebble.

majority of the lines extend to the edges of the quartz fragments, but others appear sealed up. The latter may have originally been lines of fracture which have been closed up by a secondary deposition of quartz. The vesicles of vapours and liquids would naturally be arranged in rows if along fissures, but not necessarily so if they were original inclusions. These lines of vesicles therefore may be the result of infiltration. A rock of so old a date as the Dimetian has suffered many great changes since it was first formed, and it may have even been several times under the influence of heated waters and vapours. The false schistosity exhibited by the more massive portions of the Dimetian may be chiefly due to this crushed character, and to the abundance of the green mineral along the joints, sometimes present in such proportions as to give the rock a *pseudo*-brecciated appearance. The secret why this old granitoid rock is useless for building- and other purposes, may be found in its crushed character; but I am inclined to think that it is also partially due to its being, as I have lately maintained, a metamorphic rock, and not, as I formerly supposed, an igneous rock of Pre-Cambrian age. It varies so much in character at different horizons here, as at St. David's, Rhos Hirwain, and Twt Hill, that it seems more natural to regard it as originally a deposited rock, like the older gneisses of Scotland and Canada, than as an igneous rock. It is, however, now so completely crystalline that its origin even, as in the case of the massive gneisses, can only be a matter of conjecture. It seems that for the present, therefore, we cannot do better than be satisfied with the critical opinion of the late Mr. Tawney, who devoted much time to the examination of the Dimetian rocks, when he says, in a paper published last February in the Geological Magazine (p. 67), "The constitution of the rock, however, is against its being igneous, and its great variability within short distances also."

About the centre of the Dimetian axis there are some green schistose rocks, which I believe are much newer than the Dimetian, and either folded or faulted in at this point. In the railway-cutting it appears as if, with the exception of the rocks above mentioned, we had an ascending section towards Ty-Croes Station, as explained in my former paper. The Dimetian at the east end of the cutting is lighter in colour than that towards the west, and it contains a certain proportion of a silvery mica. Beyond this are the compact quartzose rocks which we classed as belonging to the hälleflinta series, and these are followed by the quartz-schists and the chloritic schistose rocks so common in Anglesey. Dr. Callaway, in his paper, placed the granitoid rocks above the schists and compact quartzose rocks; but in this I feel confident he is in error, and that my original view as to the order of succession here is in the main correct. Fragments of almost every variety of the rocks in this section, besides those of the Dimetian already referred to (see Prof. Bonney's note 8, p. 203), occur in the conglomerates; therefore the evidence that all the metamorphic schists in Anglesey are of Pre-Cambrian age is abundantly clear. Fragments of the various schists have been frequently mentioned by other authors as occurring in conglomerates in Anglesey; and Prof. Hughes states in his paper, at p. 22, that the Llanerchymedd conglomerates vary "according to the character of the underlying rocks," and contain "bands composed chiefly of white quartz with occasional fragments of jasper, quartzite, schists, &c., and some beds of large felsite pebbles." Sir A. Ramsay also, at p. 247 of vol. iii. of the Memoirs of the Geological Survey, gives a list of fragments found in the conglomerates in the north-west of Anglesey; but immediately afterwards says that they could not have been derived from the Anglesey rocks themselves, as it would be evident on reflection that such could not be the case, "the metamorphism of the Anglesey rocks having taken place after the deposition of the Lower Silurian strata." Our contention, on the other hand, is that the fragments of granitoid and compact quartzose rocks, and the chloritic and mica-schists &c., are identical with rocks in Anglesey which now underlie the conglomerates in which they are included; and hence that these rocks, instead of being metamorphosed "after the deposition of the Lower Silurian strata," were in their present condition even before the Cambrian rocks were deposited, and are therefore clearly to be classed as of Pre-Cambrian age. The average test, as applied to the conglomerates of St. David's by Prof. Geikie, could be used here greatly to our advantage; for instead of quartz pebbles and quartzites forming, as he claimed they did there, over 90 per cent., we may safely say that rocks of undoubted local origin form here more than 90 per cent. of the fragments. It must be understood, however, that as we consider the basal conglomerates to have been deposited along old shores, the percentage of any special rocks must vary much even within very limited distances. This must always be the case with basal beds where the rocks which are being denuded vary in their character, and when currents and other influences affect the drift of the shingle. Nothing can be more fallacious, therefore, than to select pieces of conglomerates from one or two points, and make the average of the pebbles in these applicable to a whole district.

Bangor and Caernarvon.

The conglomerates in contact with and lying directly along the east side of the ridge, composed of granitoid rocks and quartz felsites, which extends from Caernarvon to Bangor, have been so frequently referred to in papers by Prof. Hughes and Prof. Bonney that very little need be added concerning them. The evidence as to their having been derived by denudation from those rocks has been accumulating every year since the first papers on these rocks by Prof. Hughes and myself were read. An unusually good exposure, however, of the quartz-felsite conglomerate at the east entrance of the west tunnel, is now being made in consequence of excavations for widening the siding room. The pebbles here are of very large size, and particularly well rounded, and all the varieties exhibited by the underlying quartz-felsites may be found*. Fragments of the

* These quartz-felsites have been shown by Prof. Bonney to be true rhyolites, and were so indicated by him in his appendix to Prof. Hughes's paper read Dec. 1877.

Pebidian (Bangor) beds are also plentiful, and it is interesting to note that here, as in South Wales, the porcellanites of that series are found in exactly the same condition in which they now occur in the beds in the neighbourhood. This, to my mind, proves conclusively that the change in the Pebidian rocks had taken place to the extent now observed before the basal Cambrian conglomerates were deposited upon the Pebidian rocks, as these porcellanites are undoubtedly rocks of detrital, and not of volcanic origin. Specimens Nos. 13 and 14, described by Prof. Bonney (p. 205), are from the conglomerates on the shore of the Menai Straits, south of Garth Ferry, and they are interesting in showing that the spherulitic quartz-porphyries here, as at St. David's, formed a part of the Pre-Cambrian ridge *. I did not happen to meet with any typical fragments of the Dimetian at Bangor, but in the conglomerates at Dinas Dinorwig, east of Llanddeiniolen (see Section, fig. 2), which is about halfway between Bangor and Caernarvon, I was fortunate enough to meet with many pebbles of most typical Dimetian. These conglomerates are mentioned by Sir A. Ramsay as among the lowest Cambrian beds of the district, therefore the evidence of their position is not disputed. Two of these pebbles, Nos. 10 and 11, are described by Prof. Bonney (p. 204) †. The other fragments in this conglomerate are mainly quartz-felsites as at Llanddeiniolen, where they rest directly on the quartz-felsites (Dinorwig beds of Prof. Hughes). In the Cambrian conglomerates, about a mile further south, on the road to Pont Rothell, I also found fragments of the typical Twt Hill (Dimetian) rock (no. 9, p. 203), and the associated fragments were again like those of Dinas Dinorwig and Llanddeiniolen. The Cambrian conglomerates on both sides of the quartz-felsites of Llyn Padarn were described in my former paper, and specimens deposited in the Society's Museum. Further examination of these conglomerates has proved conclusively, as I had previously stated, that they are mainly derived from the quartz-felsite ridge. I examined the conglomerates at Bettws-Garmon, about four miles south of Llyn Padarn, on the east side of the ridge, and here also the pebbles were mainly quartz-felsites and fragments of Pebidian rocks. I also reexamined the great conglomerate at Moel Tryfaen, and in this I found bits of Dimetian as well as the usual fragments which have been described as characteristic of this basal conglomerate. The masses of Pebidian rocks in this conglomerate are very large, some of the porcellanites being from 8 to 10 inches across. The felsite pebbles are also of large size. This conglomerate is undoubtedly the

* In the discussion on Prof. Geikie's paper Mr. T. Davies mentioned that large pebbles of the well-known spherulitic quartz-felsite exposed in the Church-school quarry at St David's occurred in the specimen of the Cambrian conglomerate which I had some years previously presented to the British Museum. These quartz-felsites at St. David's are stated by Prof. Geikie in his paper to be peripheral quartz-porphyries to what he calls the mass of intrusive granite (Dimetian), and are therefore claimed to be very much newer than the Cambrian conglomerates, which actually contain the rolled fragments of the rocks themselves!

† Prof. Bonney has described in a previous paper a fragment of Dimetian from the Llyn Padarn Conglomerate. See Quart. Journ. Geol. Soc. vol. xxxv. p. 316.

basal conglomerate, from its position under the lowest purple slates, as worked in the Alexandra quarry, in the district. The conglomerate is marked as altered Cambrian in the Survey maps. I examined the conglomerate also on the west side of the ridge about Glyn-Llifon, and there also recognized clearly that the conglomerates were mainly the result of the denudation of the Pebidian and quartz-felsite rocks of the area, with occasional fragments of Dimetian.

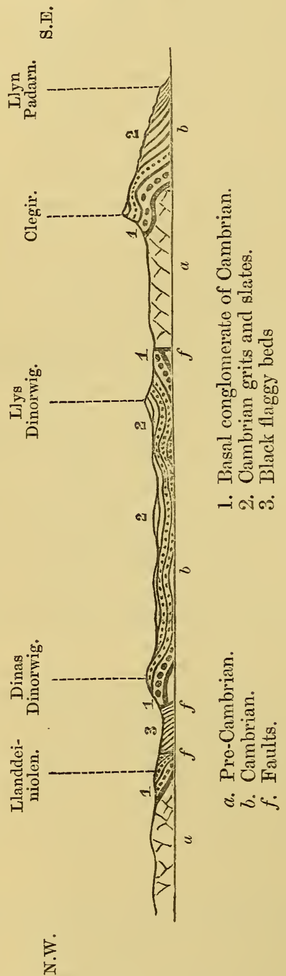


Fig. 2.—*Section from N.W. of Llanddeiniolen to Llyn Padarn.* (Scale 1 inch to 1 mile.)

That there may be no possibility of doubt as to the meaning of the interpretation given by the Surveyors in their latest remarks on the so-called intrusive masses marked on their maps which we claim to be of Pre-Cambrian age in Caernarvonshire, I quote the following explicit passage from the last edition of the Survey Memoir, vol. iii. p. 200 (1881):—" On Twt Hill the rock consists of a mixture of felspar and quartz, forming a distinct binary compound such as was once called granitella, and is now often called aplite or granulite. But for the absence of mica it would be a true granite.

" Near Brithdir, a mile and a half south of Menai Bridge, the continuation of the crystalline mass is a purple quartz-porphyry, and nearer the bridge a quartz-porphyry much resembling that of Llyn Padarn in the pass of Llanberis. Between these points and Caernarvon, though much of it is a quartz-porphyry, it is not always easy to give it a definite name; for though still composed of felspar and quartz, it sometimes passes into a rudely foliated rock rising here and there in bosses through the glacial débris that fills the hollow. And yet though it never perhaps deserves the name of gneiss, to me it sometimes conveys the impression of stratified rocks in a very advanced stage of metamorphism, which for the most part may have originally consisted of the Cambrian strata that lie between Bangor and Dol-deilo, and perhaps of some of the Silurian strata that border it from Dol-deilo to Caernarvon. This may possibly be explained on the hypothesis of the metamorphic alteration of the stratified rocks in part, as at Twt Hill, beyond the point of fusion, and while the whole lay deeply buried under overlying strata during part of the Lower Silurian epoch. When compared with the porphyry of Llyn Padarn, it often exhibits more free silica, and in lithological character, as a whole, it may be said sometimes to come between the quartz-porphyry of Llyn Padarn and the imperfect granitic rocks of Anglesea."

Conclusions.

As fragments of the Twt Hill and Anglesey (Dimetian) rocks, and of the typical quartz-porphyries and quartz-felsites mentioned in the foregoing quotation, have been discovered in abundance in the basal conglomerates of the Cambrian, in the immediate vicinity of those rocks, there cannot remain, at least to my mind, the shadow of a doubt that those rocks in the condition in which they are now found in those areas were there in Pre-Cambrian times; and therefore that the views of the Surveyors of their being metamorphosed Cambrian and Silurian strata, or intrusions posterior to the deposition of those strata, are most erroneous.

Finally I must state that I am truly sorry that I have been compelled to draw further attention to so many points which I cannot characterize otherwise than as serious blots on the maps of the Geological Survey. It must, however, be borne in mind that much of the *older* work of the Survey was done before the great importance of the microscope as an aid in the study of rocks was recognized.

I have been driven to do this because in the Memoir referred to we are charged with claiming these rocks as Pre-Cambrian on "purely theoretical grounds" (p. 199); and also because in the attack made by the present Director General of the Survey on my St. David's work he has obliquely attacked also my work in North Wales. I shall shortly have very much to say on the main questions, where they refer specially to St. David's. But as I have not had an opportunity of revisiting that district since the publication of the paper in the Journal, I thought it advisable to lose no time in bringing these facts before the Society from the only areas I have since been able to reexamine. In self-defence I have had to show that work to which others as well as myself have devoted years of study in the field, and with aids which recent scientific knowledge has suggested, has a good and solid foundation, and that it has not been built up like a house of cards to be demolished by the first storm of opposition. Moreover, if the work has cost us so much labour, we can hardly be expected to allow these rocks and the names we have suggested for their definition, which have, to our minds, meanings of some importance, to be so easily "dropped out of geological literature" —as it has been suggested they should be by the present Director General of the Geological Survey.

For the Discussion on this paper, see p. 207.

12. *On some* Rock-specimens *collected by* Dr. Hicks *in* Anglesey *and* N.W. Caernarvonshire. By T. G. Bonney, D.Sc., F.R.S., Sec.G.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read December 5, 1883.)

This series of specimens, which has been entrusted to me by Dr. Hicks for description, appears to me of the very first importance as throwing light upon the relations of the earlier rocks of North Wales. By his fortunate discovery he has welded, if the phrase be permitted, the last link in the chain of evidence which demonstrates the existence of Archæan rocks in that region. I propose, then, in addition to giving a description of the microscopic structure of the slides which he has had prepared, to offer a few remarks as to the significance of these structures and their bearing on the general question. But as some of the slides closely resemble specimens which have already been described at length by Mr. T. Davies and myself*, I shall not feel it necessary in every case to enter into very minute details, unless they appear to me of some special importance.

(1) *Railway-cutting east of Llanfaelog.*—The rock-specimen is a very characteristic representative of the pale-coloured granitoidite † from this neighbourhood. Its peculiar subcompact aspect distinguishes it readily from a normal granite, the quartz and the felspar appearing to the eye as if imperfectly separated one from the other. Parts of the specimen have a greenish hue, as if tinted by a mineral which varies from a yellowish to a pale dull green. Small scales of silvery mica and crystals of pyrite are visible. Under the microscope the slide is seen to consist mainly of quartz and felspar, the former predominating. There is no marked foliation in the strict sense of the word; but in the irregular, ill-defined outline of the felspar, the aggregation of the quartzes, and what I may call the confused mottled look of the slide when the polarizing apparatus is used, the rock presents more resemblance to a gneiss than to a normal granite. But as it evidently has been much crushed and subsequently recemented by secondary quartz and a minute scaly colourless mineral (probably a hydrous mica), it is difficult to decide what value may be attached to its present aspect. All that it is safe to say, with our present knowledge, is that the *onus probandi* lies on those who affirm it to be a granite. In general aspect it corresponds with the more granitoid specimens of such ancient

* In the pages of this Journal and the Geol. Mag. at various times since 1878.

† For definition of this term see Quart. Journ. Geol. Soc. vol. xxxv. p. 322. I admit its inelegance, but, as no one proposes a better, must continue to use it.

gneisses as I have examined. The quartzes are rather full of minute cavities, often irregular in form; some of these appear to be empty, and look as if coated by a dusky pigment; others, however, contain small moving bubbles. The felspars are rather decomposed, and contain minute "flecks" of a pale filmy mineral; but probably orthoclase and a plagioclase with rather small extinction-angles are present. In these and in all other respects the rock agrees with specimens already described.

(2) *Railway-cutting near Llanfaelog, to show Change of Colour from Decomposition.*—The less altered parts of the specimen show this to be another variety of granitoidite, having a little more of a dark micaceous constituent and being a shade more definitely crystalline. The rock has evidently been greatly crushed *in situ*, the felspar being in places absolutely pulverized, and the quartz grains broken through again and again. Along these fissures, and in certain cases laterally also, water has evidently percolated, converting the crushed felspar into kaolin, and depositing stains of iron peroxide.

(3) *Railway-cutting near Llanfaelog.*—This rock is identical with one which I have already described (Quart. Journ. Geol. Soc. vol. xxxv. p. 305, &c.). Were no controversy involved, it would, I think, be accepted without hesitation as a gneiss, so closely does it resemble specimens from the oldest Archæan gneisses in various parts of the world. The quartzes contain, as in the preceding slides, the same minute enclosures, among which are small fluid cavities with tiny moving bubbles. There is, as usual, a closely twinned plagioclastic felspar, and, I think, a little microcline. Mica is more abundant than in the other two specimens. Most of it has been a black mica, but it is now much altered, having been replaced by a viridite or a minute chloritic mineral, by flecks of a colourless mica like paragonite, and by others that are rendered opaque by a black staining. This rock gives indications of crushing, but not to the extent of the others.

(4) and (5). *Sections cut from the Pebbles in a specimen of Conglomerate from the north end of Llyn-faelog.*—The one pebble is $1\frac{1}{4}$ inch, the other about $2\frac{1}{4}$ inch in longest diameter, both being well rolled. (4) is a fragment of rock macroscopically and microscopically in all important respects identical with (3), while (5) is more nearly allied to (1) and (2). Even the quartzes, with their numerous minute inclusions and fluid-cavities, correspond; and there are the indications of local crushing already described. The slide cut from (4) also includes a portion of the matrix. This is composed of angular and subangular fragments, mingled with, and sometimes imbedded in, a black dust, which probably to a large extent consists of an iron oxide. These fragments are mostly quartz and felspar; the former exactly resemble the quartzes in the three preceding specimens; the latter are probably derived from similar rocks. A micaceous mineral, exactly like that described in (3), is also present. With these occur some fragments of a different nature; one is a slightly felspathic quartz-grit, with a little of a minute chloritic

mineral; others appear to be a kind of argillite; one or two may be little fragments of a mica-schist, and another possibly a decomposed rhyolite; but of these, without a larger number of slides, I cannot speak quite confidently.

(6) Another specimen from the same conglomerate, with same matrix as above, and part of a pebble about $\frac{1}{2}$ inch diameter. The latter is a granitoidite, and, except that it has rather more quartz, very closely resembles one of the paler varieties of that rock collected by myself near Llanfaelog (*loc. cit.* p. 307, no. vii.).

(7) *Bryn Golmon, east of Llanerchymedd.*—A pale purplish quartzose compact rock, to which one might well apply the name "hälleflinta." On close examination it has a rather brecciated aspect. Under the microscope it is seen to be a fine-grained quartz-schist, foliation being indicated by the elongated form of the quartzes and by the general direction of minute films of a pale green mineral, probably a mica. The quartz contains numerous very minute cavities, generally, I believe, empty, though in one or two I think I detect bubbles. There is also more or less of an almost colourless granular dust, probably the residuum of a felspathic mineral. The rock has considerable resemblance to one which I have described for Dr. Callaway, from Bodafon mountain (Quart. Journ. Geol. Soc. vol. xxxvii. p. 233, no. 29. Compare also no. 25). There are indubitable indications of a fragmental structure, the fragments being more or less outlined by a black dust, some showing a displacement by the direction of their foliation-planes. Without a larger number of specimens I cannot positively say whether this is a remanié quartz-schist or one broken *in situ* by crushing; but so far as I can judge, I strongly incline to the latter view.

(8) *Fragment of Conglomerate, Llyn-faelog.*—The slide includes a portion of a subangular pebble, about $\frac{1}{2}$ inch diameter. This consists of grains of quartz of rather irregular outline, with the usual inclusions, and one crystal of white mica; no felspar is included in that portion seen on the slide. The pebble is probably from one of the more quartzose parts of the granitoidite. In the matrix are two or three fragments of a similar but less coarse rock, which contain kaolinized felspar. Others, yet finer, resemble the more quartzose portions of a mica-schist. There is much material in the matrix which resembles the detritus of a mica-schist, with one fragment of this rock, consisting of quartz with a white and an altered brown mica, the latter being more or less replaced by chloritic minerals. I cannot precisely match this schist with any one that I have yet examined from Anglesey. It is not one of the dull lead- or green-coloured schists of the Holyhead district, but more resembles a mica-schist which occurs near the Menai Bridge. Lithologically, however, it might very fairly be grouped with the schists either to the north or the south *. A fragment of argillite is pre-

* The aspect of the matrix in the block from which the slide is cut (about $5\frac{1}{2} \times 4 \times 1\frac{1}{4}$ inches) would, however, lead me to believe that the dull greenish or lead-coloured schists near Ty-croes had contributed to the materials.

sent, which has been broken across twice and, as it were, "faulted" by subsequent pressure.

(9) *Cambrian Conglomerate from Pen-y-Gaer, Pont Rothell, Caernarvonshire.*—Pebbles well rounded, about as big as peas, many of them evidently the usual quartz-felsite (old rhyolite), a few paler and rather granitoid in aspect, matrix dull green. One of the latter pebbles is included in the slide. It is a crystalline mixture of quartz and felspar; the former occurs in larger irregularly outlined grains, with a rather corroded look at the edge; the smaller are rounder in outline, and interrupt the felspar crystals. This mineral is rather decomposed, but orthoclase and microcline are recognizable. The structure is a perplexing one; certainly it is not that of a normal granite, but it is not unlike that of some vein-granites, so that at present we must remain uncertain as to the true nature of the rock. In structure it is more nearly allied to the specimens from Twt Hill than from Llanfaelog, the former rock, in one or two respects, approaching a little nearer to the characteristics of a true granite. Besides this the slide shows well-rolled fragments (*a*) of a rhyolite, exactly resembling that so often described in my papers on the N.W. of Wales, (*b*) of a rock of the same class, but with a less clearly marked fluidal structure, and rather numerous blackish belonites; both contain the usual crystals of quartz and felspar. The smaller fragments, so far as they can be identified, consist of numerous bits of rhyolites (some black and slaggy-looking, some containing abundant elongated crystallites of felspar), together with broken quartz and felspar. Among these, often as a kind of setting, and sometimes penetrating into cracks in the fragments, is a green chloritic mineral, feebly dichroic, and with but little depolarizing power, probably the altered detritus of a pyroxenic mineral. One of the fragments contains a patch of two of it.

(10) *A pebble about $1\frac{1}{4}$ inch long, from Cambrian Conglomerate, Dinas Dinorwig.*—The slide shows this to be a granitoid rock, consisting of quartz, felspar, and a green mineral. The usual inclusions are noted in the quartz; the felspar is rather decomposed, but orthoclase, microcline, and albite (?) are present. Part of the green mineral is hornblende, the rest is a chloritic mineral, probably replacing it. The remarks made about the granitoid rock in (9) apply to this specimen, which only differs in the larger proportion of the green mineral.

(11) *Cambrian Conglomerate from Dinas Dinorwig*, containing a well-rolled pebble about 1 inch diameter, similar to the last. The microscope shows the apparent identity to be real. The matrix is largely composed of rhyolite in rolled fragments, one of them exhibiting minute spherulites with irregular edges; quartz, felspar, a chloritic mineral, and an iron peroxide are also present.

The contents of these three slides prove that either a district of Archæan rock supported the rhyolitic volcanos, or the latter had been gashed by denudation to their crystalline cores when the conglomerate was formed.

(12) *Pebble from Cambrian Conglomerate, Moel Tryfaen.*—This is not in a condition very favourable for examination, but it appears to be one of the above-described granitoid rocks, with its felspar much decomposed, which may have been crushed and recemented before it was broken away from the parent rock.

(13) and (14). *Pebbles from Cambrian Conglomerate by shore of Menai Straits, west of Garth.*—These specimens are from rounded pebbles, each rather more than 2 inches long. They do not differ greatly to the eye, and might be readily taken for a granitoid rock, but are really a rather spherulitic quartz-felsite, containing, porphyritically, quartz and felspar. The former sometimes occurs in rounded grains, sometimes shows moderately perfect crystal angles. Inlets and enclosures of the devitrified matrix also occur. Cavities are fairly numerous and of moderate size, the majority containing bubbles, which occupy about one eighth of their volume. The felspar is rather decomposed, but orthoclase and a plagioclase, with rather small extinction-angles, may be recognized. The spherulites, which occupy the greater part of the mass, are not very sharply defined, and appear to consist mainly of felspar. The black cross is very indistinct, but they exhibit a structure which, so far as my experience goes, is rather rare, namely, that considerable portions of a spherulite give, with the nicols, a nearly uniform tint, as though the usual "sheaf" of crystallites had been replaced by a single crystal. Possibly this is analogous to the common change in calcite, when a mass originally cryptocrystalline assumes an ordinary crystalline structure. The only markedly spherulitic rock which I know to occur *in situ* in the district is at Tan-y-Maes, near Port Dinorwig*, where is one which is quite as good an example as the well-known instance at the School House, St. David's. To this, macroscopically, these pebbles bear a great resemblance, but in the Tan-y-Maes rock the radial structure of the spherulites is more perfectly developed, and the fluid-cavities are fewer and smaller. Still I have little doubt that these pebbles have been connected with the great masses of rhyolitic lava from which the conglomerates of the district have derived so much of their materials; though from what I know of spherulitic structure, I should think it more probable that they (like the rock at Tan-y-Maes) have been formed from a dyke or a part of a flow, cooled before reaching the surface of the ground.

To the above description of Dr. Hicks's specimens I shall venture to append a few remarks as to the nature of the evidence for the existence of representatives of the Archæan series in North Wales; because, as it appears to me, some geologists are unable to realize how strong it is, and regard the question as a still open one. This perhaps is due to the fact that, partly owing to the novelty of the investigation and partly to the nature of the case, the evidence can only be appreciated by those who have devoted themselves to its

* Geol. Mag. dec. ii. vol. vii. p. 301.

study. Lithology, now that the microscope has become an essential in the study, makes its appeal not *ad populum* but *ad clerum*. It is quite true that in this, as in every rapidly progressing science, the most qualified experts are not infallible; mistakes have been and will continue to be made; there are many points on which cautious observers are obliged to speak with hesitation; but there are far more on which no one who has worked steadily for some years, both in the field and with the microscope (for the two methods of research are inseparable), feels the slightest doubt*.

With regard, then, to the existence of Archæan rocks in Wales, the following summary may, I think, fairly be given of the results of the investigations up to the present time:—

(1) If there be any signs by which a rhyolite, produced by a Tertiary or still active volcano, can be recognized, then the great mass of "felstone" about Llyn Padarn and that between Port Dinorwig and the neighbourhood of Bangor exhibit these, and only present such differences as can be explained by their greater antiquity. While I will not assert that it is always possible to distinguish between an igneous rock which has once been a subaerial lava and a rock of the same chemical composition when it has solidified under the surface of the ground, *i. e.* between some *coulées* and some dykes, yet, upon consideration of the whole question, I have no doubt whatever that these felstones are old lava-flows.

(2) That the pebbles in the masses of conglomerate (be these one or, as I think, more than one in number) mentioned in this and other papers on the district† are fragments of old rhyolite (in some cases, perhaps, bits of scoria), and that they have either been derived from extensions of the above masses or from rocks in all essential points identical and contemporaneous with them.

(3) That in the present state of our knowledge it is difficult to decide whether the granitoidite at Twt Hill and Llanfaelog is an igneous or a metamorphic rock. If the former, it is a rather abnormal granite; if the latter, metamorphism could hardly go much further. This difficulty, however, is not peculiar to these Welsh rocks; it exists also at the Wrekin, at Malvern, in the north-west of Scotland, in the Alps, and in many other parts of the world. In short it is one likely to confront us wherever the most ancient group of metamorphic rocks (call it Laurentian, Hebridean, Malvernian, Fundamental Gneiss, or what not) presents itself for examination. In Anglesey, however, as in most of the above localities, this granitoid

* It would be thought unreasonable to reject the conclusions of palæontologists relating to stratigraphical geology because they cannot always decide with certainty upon the species or even the genus of a fossil, or because such forms, for instance, as *Stromatopora*, *Calceola*, and *Hippurites* have oscillated between different classes or even subkingdoms of the Invertebrata. But the geologist who settles difficult questions in petrology without an appeal to the microscope, is certainly, to say the least, as unreasonable as one who fifty years since had solved stratigraphical problems without regard to fossils.

† See Quart. Journ. Geol. Soc. vols. xxxiv., xxxv., xxxix. s. v. Hicks, Hughes, and the author.

rock is in close association with indubitable coarse gneisses of the oldest type, and seems to be inseparable from them.

(4) That the Anglesey granitoid rocks and some at least of the schists had assumed in all important respects their present mineral condition when the conglomerate of Llanfaelog (which, if not Cambrian, must at least be extremely low in the Ordovician *) was formed, and that some fragments in the basal Cambrian conglomerate of the Llyn Padarn district were derived from a rock substantially identical with that of Twt Hill, where also a conglomerate, certainly not newer than basal Cambrian, rests on the granitoid rock itself †. The only conceivable alternative hypothesis (which is inapplicable to the last instance) is that these granitoid blocks were portions of fundamental rock ejected among the ash and scoria by very early Cambrian volcanos; and this, I think, could hardly be seriously entertained by any one well acquainted with the circumstances.

(5) That when the conglomerates so often referred to by Dr. Hicks, Professor Hughes, myself, and others, were formed, there existed in the neighbourhood either (*a*) a tract or tracts of Archæan rocks upon which groups of volcanos ejecting rhyolite had been built up; or (*b*) that an ancient volcanic district had previously been in places so deeply gashed by agents of denudation that the granitic cores of some of its extinct craters were already exposed; and on a review of all the circumstances, I think the former far the more probable, for the latter takes no account of the schists which have contributed to the conglomerates of Anglesey and, to some extent, of Twt Hill. But in either case we are forced to the conclusion that between the commencement of the sequence of sediments which all agree in calling Cambrian, and the formation of certain lavas and schists and granitoid rocks, there was a distinct interval of time, which, in the case of some of these, must have been a very long one. Hence it follows that we are fully justified in asserting the existence of Archæan rocks in North Wales, even if we admit that the rocks immediately below the conglomerate, taken by Dr. Hicks and Prof. Hughes as the base of the Cambrian, are not separated from it by so wide an interval as, perhaps, some authorities would demand; for, if the granitoid rock at Twt Hill and all at Llanfaelog be granite, it must certainly be Pre-Cambrian in date; and if a metamorphic rock, it must be referred to the oldest known Archæans—the "Fundamental Gneisses."

* It is coloured Lower Silurian on the Survey Map; but this was issued prior to Prof. Hughes's identification of Tremadoc and Arenig rocks considerably above the conglomerates of Anglesey. Quart. Journ. Geol. Soc. vol. xxxvi. p. 239.

† The one which I erroneously referred to the Archæan series, entertaining opinions as to the action of selective metamorphism which I now see cannot be so readily assumed. I think, however, the exact position of the conglomerate is open to question, but that at any rate "basal Cambrian" is the latest possible date that can be assigned to it. See Geol. Mag. dec. ii. vol. ix. p. 18.

Discussion.

Mr. Lydekker remarked on the similarity of these rocks to those in the Himalayas. But in that district it was certain that a Pre-Cambrian rock, which supplied pebbles to the Palæozoic schists, could not in many cases be distinguished from granitic intrusive rocks of post-Silurian age.

Mr. Topley said that the Director-General of the Geological Survey had dealt in his paper with the St. David's area, and was not bound to follow Dr. Hicks into the collateral issues he had raised. He said that Sir A. Ramsay had fully described these beds of conglomerate, and had stated that the metamorphic and granitic pebbles, though apparently derived from the rocks of the district, were not of local origin, as he considered there was evidence to prove the later metamorphism and intrusion of the rocks. The speaker stated that the Cambrian quartzose conglomerate of St. David's was very different in character from that now described, and he invited Dr. Hicks to produce pebbles of the St. David's Dimetian from that conglomerate.

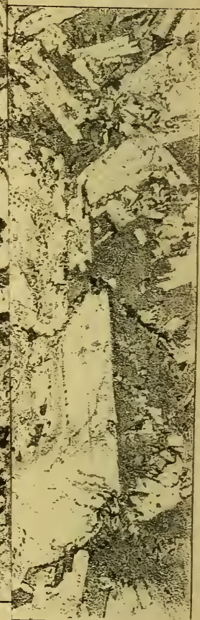
Prof. Seeley said that Sir Andrew Ramsay had recognized the presence of pebbles in the Cambrian conglomerates as proof of the existence of rocks older than the Cambrian; and he had also described an actual passage in Anglesey by metamorphism through schists into true granitic rocks. In these North-Welsh areas the succession of a central mass of granite surrounded by felsite, with ashes further away, was so like the condition described by Professor Judd in the central masses of the Grampians, that he asked whether Prof. Judd's interpretation of the Scotch areas might not apply in Wales. And when there were no ashes, he thought the granitic and felsitic rocks were situated in these Pre-Cambrian masses as they would be if due to metamorphism. The denudation of such rocks might have furnished the pebbles described.

Mr. Marr said that Prof. Sedgwick had recognized the fact that his Cambrian strata were underlain by older deposits. He denied the existence of metamorphism in the conglomerates—such metamorphism, *e.g.*, as that described by Reusch in the conglomerate of Norway. He insisted on the exact similarity between the pebbles of the conglomerates and the different varieties of Pre-Cambrian rocks in the immediate neighbourhood.

Dr. Hicks agreed with Mr. Marr that the existence of Pre-Cambrian rocks had been recognized by Prof. Sedgwick. He admitted the great value and importance of Sir A. Ramsay's work in North Wales. He had not evaded the question as applying to the St. David's area, but would very shortly deal with it, and bring forward also from that area evidence as conclusive as that which he now placed before the Society from North Wales. The Director-General and his assistants were entirely wrong in their conclusions about the St. David's conglomerates.

Prof. Bonney said he thought that it was not so difficult as Mr.

Lydekker supposed to distinguish between the more ancient and modern granitoid rocks. But the objection raised did not apply to North Wales, where we have no later intrusive granites. He expressed his high regard for the work of Sir A. Ramsay; at the same time he must protest against appealing to authority in the discussion of questions, when, since statements had been made, new methods of investigation had been devised and knowledge greatly increased. Dr. Hicks had been attacked generally as well as particularly, and he had a right to choose on what issue he would first reply. He did not see how the argument of Prof. Seeley bore upon the question at issue.



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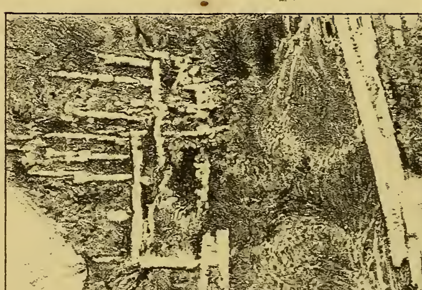


W. H. Wesley lith.

West Newman & Co imp.

ROCKS OF NORTH-OF-ENGLAND DYKES.

H. M. Teall del.

J. W. Watson. del et lith.

ROCKS OF NORTH OF ENGLAND DYKES

Watson & Son lith. 93. Gt Charles St Birmm.

13. Petrological Notes *on some* North-of-England Dykes. By J. J. H. Teall, Esq., M.A., F.G.S. (Read December 19, 1883.)

[Plates XII. & XIII.]

The object of the present paper is to give a petrological account of some North-of-England dykes. The specimens on which the observations are based were mostly collected by myself during the winter of 1881–82; a few, however, were given me by Prof. Lebour and other friends.

In the microscopic work I have derived great assistance from my friends Mr. I'Anson of Darlington and Dr. Trechmann of Hartlepool. To Mr. I'Anson I am indebted in another way; for he kindly handed over to me the analysis of the Great Ayton rock which was prepared for him by Mr. Stock. My indebtedness to the latter gentleman, and also to Mr. Stead of Middlesborough, will appear in the sequel. Without the valuable chemical work communicated by these gentlemen my paper would indeed be incomplete. It is no part of my purpose to describe the mode of occurrence of these dykes, and therefore the general course of each is indicated mainly by reference to works already published. One or two new facts of importance are, however, given; especially in relation to the dying-out of dykes beneath the surface.

The dykes are first of all described in the order of their occurrence from south to north, and at the conclusion of the paper some general remarks on their mutual relations are given.

The Cleveland, Cockfield, and Armathwaite Dyke.

Literature.

Young & Bird. Geological Survey of the Yorkshire Coast. Whitby, 1822, p. 171.

Sedgwick, Rev. Adam. "Geological Relations and internal Structure of the Magnesian Limestone," Trans. Geol. Soc. 2nd series, vol. iii. part i. p. 62.

——. "On the Phenomena connected with some Trap Dykes in Yorkshire and Durham," Trans. Cambr. Phil. Soc. vol. ii. pp. 21–40.

Winch, N. J. "Observations on the Geology of Northumberland and Durham," Trans. Geol. Soc. 2nd series, vol. iv.

Phillips, John. Illustrations of the Geology of Yorkshire. Part i. 1st edit. 1829, 3rd edit. 1875, 190.

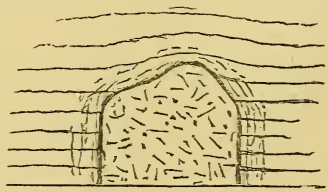
Tate & Blake. Yorkshire Lias, 1876, p. 210.

Handbook to Middlesborough and District, 1881, p. 50.

This dyke crosses the following one-inch Ordnance Maps: 95 N.W.; 96 N.E.; 104 S.W.; 103 S.E. and S.W.; 102 S.E., N.E., and N.W.

Before proceeding to describe the petrological characters of this remarkable dyke, it will be necessary to give some account of its mode of occurrence; this account will be compiled mainly from the works cited above. The most easterly exposure is near Maybecks on Sneaton High Moor, about six miles south of Whitby. From this point it may be traced, with occasional interruptions, in a W.N.W. direction by Silhowe Cross, Egton Bridge, Ainthorpe, Castleton, Commondale, Kildale, Eastby Moor, Rye-hill, and Ayton to Nunthorpe in the vale of Cleveland. At Maybecks it is 18 ft.* in thickness and at Silhowe Cross, 30 ft. At Great Ayton it is 80 ft.† thick at the base and 20 ft. at the top, which is 350 ft. higher. Throughout that portion of its course described above, a distance of over 20 miles, it is intrusive in Oolite and Lias, and the adjacent rocks are in many cases much altered. At many parts of its course the dyke forms a conspicuous feature in the landscape, as, for instance, on the Moors east of Silhowe Cross ‡, and at Cliff Ridge near Ayton. West of Nunthorpe it may be traced by Stainton and Preston to Coatham Beck, near the village of Elton, in the county of Durham. Between Nunthorpe and Stainton it is shifted about half a mile to the south; and at Preston it makes an abrupt bend at right angles to its usual direction. West of Cotham there is no exposure until we reach a point about a mile east of the village of Bolam (Ordnance Map 103 S.W.). In this interval the Magnesian Limestone occurs, so that the dyke is nowhere seen in contact with that formation. From Bolam it may be traced by means of surface outcrops and colliery workings to Cockfield Fell. Near the village of Bolam it expands laterally in the form of a "sill" or bed which is approximately parallel with the stratification, and attains a width of 200 or 300 yards. Mr. Howell, now Director of the Geological Survey of Scotland, was kind enough to conduct me to the various exposures in the neighbourhood of Bolam and Cockfield; and it may be interesting to place on record one or two of the facts which we observed. At the time of our visit (Jan. 1882) three quarries were being worked in the neighbourhood of Cockfield; and in the most easterly of these we saw a phenomenon which must be

Fig. 1.—*Dying-out of Dyke in Quarry near Cockfield.*



* 'Yorkshire Lias,' Tate & Blake, p. 210.
† Middlesborough Handbook, p. 50.
‡ Illustrations of the Geology of Yorkshire, 3rd ed. p. 191.

of frequent occurrence, but which cannot very often be directly observed, viz. the vertical dying-out of the dyke beneath the stratified rocks. The whinstone was seen to terminate upwards very abruptly in the form of a low and somewhat irregular dome, over which the coal-measure shales passed without any fracture and only with a slight upward arching (fig. 1).

West of this face and for a distance of about half a mile the dyke has been quarried, and its course is therefore marked by a deep trench. At one point it has been shifted laterally by a fault a little more than its own thickness. The next working-face is the largest one in the district. The width of the dyke at the time of our visit was 66 ft., and the depth of the working-face about 40 or 50 feet. Here the dyke was quite vertical.

In the next quarry to the west, the width of the entrance was about 15 feet, and at the working-face, 170 yards further east, 29 feet. Here the dyke hades to the S.S.W. at an angle of 70°. The adjacent rocks are shales and sandstones, and the zone of alteration extends to a distance of 20 or 30 yards. At the north side of the main dyke, near the entrance to this quarry, is a narrow dyke, about 4 feet wide, of similar material.

West of this point the dyke does not appear at the surface for some distance; but Mr. Howell informed me that it has been proved in colliery workings; and there can be no doubt that the dyke crossing Woodland Fell in an east-and-west direction, which can be traced to a point about 1 mile east of Middleton, is the same one.

The above facts prove that the dyke in question varies very much in thickness both in a vertical and in a horizontal direction, that it frequently dies out before reaching the surface, and that it is liable to lateral shifts. Absence of continuity in the outcrop is thus seen to be no proof of a want of continuity underground.

Until quite recently it has never been suspected that this remarkable dyke could be traced any further to the west than the neighbourhood of Middleton. The work of the Survey, however, has rendered it almost certain that the well-known dyke in the Eden valley, extending at intervals from the neighbourhood of Renwick to Armathwaite, is a portion of the same igneous outburst.

Between the most easterly exposure of the Eden-valley dyke and the most westerly exposure of the Cockfield dyke, near Middleton, no less than nine exposures, all lying very much in the same general direction, are now known. Mr. Howell was kind enough to mark these exposures on my maps, and I was thus enabled to visit two of them—one about $1\frac{1}{2}$ mile north-east of High Force Inn, where the dyke crosses the Bowles Beck, at the junction of two streams, and another about one mile south of Tyne Head, where it is also seen crossing a stream. In both these exposures the rock presents the macroscopic and microscopic peculiarities about to be described.

From Bolam to the edge of the escarpment overlooking the Eden valley the dyke is intrusive in the various members of the Carboniferous formation. In the Eden valley it enters once more on Secondary ground. It has been traced by Renwick and Ruckcroft to Armathwaite, where it crosses the Eden at the weir about half a mile above the bridge. There are many good exposures in the neighbourhood of Armathwaite. Its thickness in the railway-cutting is about 18 yards.

It thus appears that a dyke having characters which are constant and at the same time different from those of any other igneous rock known to me in the north of England may be traced at intervals from Maybecks in the east to Armathwaite in the west, a distance of about 90 miles; that it keeps on the whole a general W.N.W. direction but is liable here and there to lateral shifts and local deviations; and that it may be seen in one place, and proved by colliery workings in others, to die out before reaching the surface; so that in districts where it is not actually seen it may reasonably be supposed to exist underground.

Doubts have been expressed as to the continuity of the Cockfield and Cleveland dykes. When, however, we see that the petrological characters of these two dykes are not only alike, as has been remarked by Prof. Sedgwick and others, but also peculiar, a point which is, I believe, now insisted upon for the first time, there can, I think, be no longer any hesitation in admitting their continuity, especially as they follow each other very much in the same straight line. And if we admit the continuity of the Cleveland and Cockfield dykes, we are compelled by the same kind of evidence to regard the Armathwaite dyke as a portion of the same igneous outburst.

What is the age of this dyke? The latest formations intersected and altered by it are the oolitic sandstones of the Yorkshire moors. It must therefore be post-Jurassic. The only period subsequent to the Jurassic in which volcanic action is known to have taken place in Western Europe is the Tertiary, and especially the Miocene; and inasmuch as the dyke in question points by its direction to the north of Ireland, and west of Scotland, districts celebrated for the enormous development of Miocene volcanic rocks, we seem compelled to regard it as of Miocene age.

It has been suggested by some that there may be a connexion between the Great Whinsill of Teesdale and the dyke in question. This seems to me in the highest degree improbable. There are marked chemical and physical differences between the two rocks, even where, as at Tyne Head, they occur in close proximity, and where the Cockfield Dyke has in all probability cut through the Whinsill. The Whinsill is composed of a rock of more basic composition and higher specific gravity than that of the dyke. It is moreover holocrystalline, whereas the dyke contains a considerable amount of imperfectly individualized matter. It is interesting to note that the Whinsill is similar in composition, structure, and mode of occurrence to the diabase (? dolerite) which is so extensively developed in the Triassico-Jurassic strata of Nova Scotia, Massachusetts, Connecticut, New Jersey*, Pennsylvania, and North Carolina, and which possesses throughout the whole of its enormous range,

* See E. S. Dana, 'American Journal of Science,' 1874, ser. 3, vol. viii. p. 390, and G. W. Hawes in the same Journal for 1875, vol. ix. p. 185.

that is for a distance of 1000 miles, the same composition and structure. In a future paper I hope to give an account of the Whinsill, when these points will be more fully discussed.

I now proceed to describe the rock of the Cleveland, Cockfield, and Armathwaite dyke. The facts recorded are based on the observation of numerous specimens collected by myself at Ayton, Preston, Bolam, Cockfield, Bowles Beck, Tyne Head, and Armathwaite. Many sections* have been prepared of the rocks from each of these localities, and several chemical analyses have been placed at my disposal by my friends Messrs. Stead and Stock. I have also made a large series of specific-gravity determinations. All these observations prove the essential uniformity of the rock along the whole line of outcrop.

Petrology of the Cockfield and Armathwaite Dyke.

The rock is usually of a dark grey or bluish grey colour when freshly broken, but it becomes darker after exposure to the air. It is porphyritic in texture, and frequently, though not invariably, possesses a subconchoidal fracture. The porphyritic crystals are glassy-looking felspars, which occasionally show on their cleavage-faces the striations due to repeated twinning. The crystals are sometimes whole, sometimes fragmentary, the fragmentary condition evidently indicating that they were not developed where we now see them. Sections more or less parallel to the basal plane are usually long in proportion to their width; whereas those which are parallel to the brachypinakoid have tolerably uniform dimensions in the different directions. These facts doubtless show that the crystals are less developed in the direction of the macro-diagonal than in the directions of the other two crystal axes. The sections, when measured across, vary from 1 mm. to 5 mm. These porphyritic crystals are distributed throughout the ground-mass with considerable regularity along the whole length of the dyke. Three or four conspicuous ones usually occur on a square inch of surface, thus giving the rock of this dyke a definite macroscopic character, by means of which it can be distinguished from that of any other dyke known to me in the north of England. The ground-mass varies according as the specimen is taken from the margin or from the centre of the dyke. At the margin and for a few inches inwards it appears to the unaided eye compact and homogeneous, and the large porphyritic crystals, which are just as well developed here as in the centre, stand out very conspicuously; beyond this, however, it becomes finely and, in a few cases, where the dyke is thick, even coarsely crystalline.

The rock, especially at the margins of the dyke, frequently effervesces freely with hydrochloric acid; this indicates the development of carbonates by secondary processes, and marks the first stage of decomposition. A further stage may be well seen at the

* I have had 27 sections prepared from my own specimens, and several others have been placed at my disposal by my friends Messrs. I'Anson and Trechmann.

north margin of the dyke, in the large quarry at Cockfield, and at the base of the intrusive sheet at Bolam. In the former locality the actual margin consists of a brown layer about an inch in thickness, and evidently rich in iron oxides. This is sharply divided from a light grey band in which kaolinized felspars are very conspicuous. This band is several inches in thickness and shades off gradually into the main mass of the dyke. It does not effervesce with acid; but the dark and, to the eye, comparatively unaltered-looking rock which adjoins it does effervesce. Carbonates are thus seen to be present in the dark rock, but absent in the light-grey band, which therefore represents a further stage of decomposition. My friend Mr. G. E. Stead, of Middlesboro', to whose kindness and generosity I am indebted for most of the analyses which appear in this paper, found the white substance occurring beneath the whin at Bolam to contain:—

	Per cent.
Silica	54·00
Alumina	30·93
Iron oxides	0·78
Lime	0·47
Magnesia	0·74
Potash	1·11
Soda	2·75
Loss	8·95
	99·73

It is thus seen to consist mainly of hydrated silicate of alumina, and to have been formed from the original rock (see analysis on p. 224) by the removal, doubtless as carbonates, of the iron, lime, and magnesia. It appears remarkable that the alkalies should have been left. Now the light-grey band at Cockfield is evidently similar in composition to this white substance, although probably the removal of lime, iron, and magnesia has not been quite so effectually carried out. The brown band which forms the actual margin is certainly rich in iron-oxides, so that there appears to have been here as at High Green (see p. 240) a removal of the iron from the interior of the rock and a concentration of it along a bounding surface.

Narrow veins of calcite may occasionally be seen traversing the rock, and these sometimes contain pyrites. Dr. Veitch, of Middlesboro', gave me a specimen of the rock showing a joint surface coated with a radiating fibrous zeolite, which Dr. Trechmann determined to be pectolite.

Angular and subangular portions, which appear homogeneous to the unaided eye, are frequently seen lying in a finely crystalline ground-mass. As these fragments resemble very closely the rock formed by rapid consolidation at the sides of the dyke, I am disposed to regard them as having been portions of the side which were broken up and carried along by subsequent movements of the igneous matter. Inclusions of foreign rocks are not common. The only specimen which has come under my notice was found by Dr. Trechmann among the road-metal at Hartlepool; it is an angular fragment of what is now a light-grey quartzite. The sharpness of the angles of this specimen appears remarkable when one takes into consideration the evidence of extreme metamorphism which the microscope affords.

The inclusion, as a whole, is now composed of extremely irregular grains of crystalline quartz, which fit together so as to leave no interspaces. Here and there, however, more or less oval spaces occupied by the magma of the igneous rock may be recognized, and in much of the quartz secondary glass inclusions similar to those described by Chrustschoff* and Dölter† occur.

The other macroscopically recognizable constituents are blebs of quartz (Ayton, Preston, and Cockfield), small agates, usually associated with calcite (Bowles Beck), and irregular patches of pyrites. These, however, are not uniformly present, but occur rather as local peculiarities.

I have made 23 specific-gravity determinations on specimens taken from widely separated localities, including Great Ayton, Preston, Bolam, Cockfield, Bowles Beck, Tyne Head, and Armathwaite, with this general result that, when care is taken to select unaltered or but slightly altered specimens, the specific gravity is found to lie between 2·765 and 2·788. The best observations indicate 2·77 as the mean. Altered specimens have a lower specific gravity: thus two from Cockfield and Tyne Head respectively gave 2·63 and 2·62.

The microscopic as well as the macroscopic characters are remarkably constant along the whole length of the dyke, so that in describing the rock from a microscopic point of view it will not be necessary, except in a few special cases, to refer to separate localities. Two important structural types may be observed; the one characteristic of the main mass of the dyke, the other of the few inches which form the margin. These will be referred to again when the separate constituents have been described.

The original constituents may be considered under the following heads:—(*a*) porphyritic felspars, (*b*) felspars of the ground-mass, (*c*) augite, (*d*) magnetite and ilmenite (?), (*e*) biotite, (*f*) apatite, (*g*) interstitial matter with globulites, longulites, microlites, &c.

The two varieties of felspar will be referred to simply as the large and small felspars; they belong, of course, on the whole to two different stages in the process of consolidation, although it is probable that the outer zone of the large felspars was frequently added during the formation of the felspars of the ground-mass. Biotite occurs sparingly, and has only been observed in certain sections from Ayton and in one from Armathwaite. Apatite does not seem to be abundant; indeed its presence is inferred rather from the chemical than from the microscopic analysis. By interstitial matter is meant

* Chrustschoff, "Ueber secundäre Glaseinschlüsse in den Gemengtheilen gefritteter Gesteine," Tschermak, Min. u. petr. Mitth. 1882. Neue Folge iv. p. 473.

† Dölter and Hussak, "Ueber die Einwirkung geschmolzener Magmen auf verschiedene Mineralien," Neues Jahrbuch, 1884. Bd. i. p. 18.

that portion of the rock which cannot be resolved into distinct crystals or crystalline grains by the aid of the microscope; it may be glassy, micro-felsitic (Rosenbusch), crypto- or even micro-crystalline. It usually gives a decided reaction with polarized light, a true glass having been distinctly recognized only in one instance, viz. in that of a specimen from Armathwaite. The secondary constituents comprise (*a*) quartz, (*b*) calcite, (*c*) chloritic alteration-products, (*d*) limonite, (*e*) pyrites. Some of the quartz may be original.

In order to form some notion of the relative importance of the different constituents of the ground-mass, I selected two fairly characteristic photographs, and, having cut out the portions representing the different constituents, weighed them separately. The following is the percentage composition of the rock as thus determined:—Augite and magnetite 11·4 per cent., small felspars 29·1 per cent., interstitial matter 59·5 per cent. It is difficult to cut out the parts exactly, so that a liberal margin for error must be allowed. It must also be remembered that the interstitial matter contains microlites of augite and felspar, which cannot be cut out and weighed separately. The magnetite was taken with the augite because it was found impossible to separate the two in the photograph; magnetite, however, forms only a very small proportion of the entire mass of the rock. The relative abundance of the different constituents is a fairly constant feature of this and also of the other dykes to be described; so that the application of this method, originally due to Dr. Sorby, I believe, becomes of considerable importance.

Large Felspars.—These occur, as already stated, in a tolerably constant proportion, and give the rock of this dyke a macroscopic character which enables one to recognize it at once wherever it occurs. Sections more or less parallel to the brachypinakoid appear as large flat plates, having tolerably equal dimensions in the different directions, and polarize in a uniform tint, or else show striations due to twinning on what may be assumed to be the pericline type. This twinning is very irregular as regards the length and breadth of the lamellæ. Sections out of the zone of the brachydiagonal axis are frequently much longer than broad, and they show the striation due to twinning on the albite plan. This twinning is also irregular so far as the width of the bands is concerned. Sometimes the section is divided into two well-marked halves: but when this is the case each half usually contains a few very narrow bands which extinguish simultaneously with the other half, thus showing that the crystals are twinned on the albite and not on the Carlsbad plan, as might at first sight be supposed. The large felspars are frequently in the condition of fragments; and sometimes a crystal may be seen to be fractured and to have had its parts slightly displaced, but not actually separated from one another. The fragmentary state of many of the large felspars, as also the fact that they occur in the same condition at the sides and in the centre of the dyke, proves that they have not been formed *in situ*, but have been brought into their present position from below.

It is difficult to obtain cleavage-flakes of these felspars for optical examination; but after many failures I have succeeded in preparing one reliable slide. The section is approximately at right angles to the twinning-plane and parallel to the edge $o\,P \mid \infty \breve{P}\infty$. Two separate determinations of the extinction-angles of adjacent lamellæ, with reference to the trace of the twinning-plane, gave (*a*) 5° 10′ and 7° 20′, (*b*) 5° 35′ and 7° 10′. This shows that the section is not exactly perpendicular to the twinning-plane, because if it were, the extinctions would be symmetrical; nevertheless it may be regarded as sufficiently near for the purpose of comparison with the table given by Messrs. Lévy and Fouqué ('Minéralogie Micrographique,' p. 230). We find on referring to that table that in labradorite the extinction-positions of adjacent lamellæ in the plane passing through the edge $o\,P \mid \infty \breve{P}\infty$, and normal to the twinning-plane, lies between 10° and 14° 30′, and differs markedly from the corresponding angle in the other well-defined species of felspar. In the case in question it may be taken as about 12° or 13°, and we are therefore led to the conclusion that the felspar is labradorite. It is perhaps hardly safe to infer that all the large felspars belong to the same species; indeed the results obtained by observing the angle between the extinction-positions of adjacent lamellæ in the felspars exposed in the rock-sections seem to indicate the presence of a felspar more nearly allied to anorthite. The large felspars contain inlets and inclusions of the ground-mass, and frequently show the most exquisite zonal banding (see Pl. XII. fig. 3). In one typical case which is now before me this banding is due to brownish, more or less spherical or elliptical, granules, which vary in size from the smallest specks visible with a magnifiying power of 270 diameters up to those which measure ·02 mm. × ·01 mm. The larger granules are markedly elliptical, and their longer axes are set parallel to the longer edge of the crystal section. They keep this parallelism throughout the zone, a fact which shows that the elliptical form was determined by the unequal rate of growth of the crystal in different directions. There are also larger irregular inclusions which do not lie in definite zones. It is worthy of note that the distance between contiguous zones is greater in the direction of the length than in that of the breadth of the crystal section; another fact indicative of the unequal rate of growth of the crystal. Sometimes the large felspars are completely honey-combed by irregular ramifiying inclusions; at other times the centre only contains such inclusions. Not unfrequently they are surrounded by a narrow outer zone, which extinguishes at a slightly different angle from the rest of the section. Thus, in one case in which the extinction-angles of the main mass of the crystal were 30° 35′ and 33° 20′ on either side of the twinning-line, those of the outer zone were some 3° or 4° greater on either side. If we assume* that this difference is due to difference in composition, and that the optical properties are related

* In 'Comptes Rendus' for 23 Jan., 1882, M. Lévy points out that the variations in the angles of extinction in successive zones need not necessarily indicate variations in chemical composition. His mathematical investigations

to the chemical properties in the manner laid down by Schuster (Min. Mitth. 1881, p. 117), then it indicates that the outer portion of the crystal approaches more closely to the composition of anorthite than that which forms the main mass. It is worthy of note that in this crystal, as in most of, if not all, the others which show the same character, although the outer angles are tolerably sharp, those of the internal portion (the nucleus, as it may be termed) are more or less rounded. In another section three zones may be recognized ; the outer and inner ones extinguish simultaneously, but the middle one extinguishes at an angle which shows a nearer approach to anorthite. The outer edges of crystals zoned in this particular manner are frequently ragged owing to inlets of the ground-mass; these inlets, however, are limited to the outer zone and do not penetrate the central portion. It is clear therefore that the outer zone was added during one of the later stages in the process of rock-consolidation, and probably after some of the constituents of the ground-mass had separated out.

Small Felspars.—These vary in character according as the section is taken from the main mass or from the margins of the dyke. In the latter case they consist for the most part of small microlites, whereas in the former they may be (*a*) fairly well developed crystals, not very long in proportion to their width, (*b*) imperfectly developed and skeleton crystals, (*c*) long narrow acicular microlites. The more perfectly developed crystals are frequently ragged at their extremities, and sometimes run out into the long narrow microlites, thus proving the felspathic nature of the latter. The sections of the more perfect crystals are often lath-shaped in form, and usually lie between the following dimensions :— × ·1 mm. × ·35 mm. and ·2 mm. × ·5 mm. The small felspars are distinguished from those which give the rock its porphyritic character by the general absence of inclusions, and of zonal banding, as well as by their size. They occasionally show the repeated twinning characteristic of plagioclase, but more frequently occur as binary twins and simple individuals. The following numbers represent a series of measurements of the extinction-positions of adjacent lamellæ, with reference to the twinning-line, those crystals being selected which gave approximately symmetrical extinctions: 21° and 34°, 22° and 35°, 26° and 29°, 33° and 28°, 21° and 19°. Another series of observations in which the angle between the extinction-positions of adjacent lamellæ alone was recorded, gave 27°, 19°, 6°, 58°, 36°, 46°, 22°, 41°, 44°, 47°. It thus appears that 58° was the maximum observed. The maximum for labradorite in the zone which gives symmetrical extinctions with reference to the twinning-line is 62° 30′, that for oligoclase 37°, for albite 31° 30′, and for anorthite over 74° 42′. The measurements therefore appear to indicate the presence of labradorite, but they can of course tell us nothing as to the presence

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lead him to the conclusion that they may be accounted for, in certain cases, on the assumption that the crystals are built up by the association of submicroscopic twin lamellæ.

or absence of oligoclase or albite. The researches of M. Fouqué on the mineralogical composition of the Santorin augite-andesite lava of 1866, led him to the conclusion that the porphyritic felspars of that rock were mainly labradorite, but that they comprised also anorthite, sanidine, and oligoclase, and that the felspars of the ground-mass were albite and oligoclase. It is highly probable that the rock we are considering, which appears to be a fairly typical augite-andesite, though not so rich in silica as the lava of Santorin, also contains a mixture of different felspars.

In the description of the remaining felspathic constituents of the ground-mass it will be convenient to begin with the microlites. These may be either straight or curved. The majority of them lie between the following dimensions:—width ·002m. to ·004 mm.; length ·06 mm. to ·35 mm. As a rule, these microlites are not sharply defined from the interstitial matter; thus, the interstitial matter of the rock which occurs at the old quarry at Barwick, on the right bank of the Tees, near Preston, shows under a high power (270 diameters) a sort of mottled appearance due to the irregular interlacing of darker and lighter portions. In places these lighter portions assume a linear form, and take on the characters of the microlites (see Pl. XII. fig. 4 *b*). Curved microlites are common in the same rock; they are sometimes clustered together so as to give rise to curious plume-like forms. The straight microlites extinguish in the direction of their length. The curved microlites have the same optical properties, and do not therefore extinguish simultaneously in any one position, only that portion of any particular microlite appearing dark which happens to lie parallel with one of the two vibration-planes. Not unfrequently the microlites show a tendency to unite with each other at definite angles; and this leads to the building-up of curious skeleton-like forms. The rectangular mode of junction is the most common. When the primary microlite is curved, then the secondary microlites converge like the spokes of a wheel.

The skeleton felspars (see Pl. XII. fig. 4 *a*) constitute an intermediate group between the microlites and the more or less perfect felspars, and they exhibit a very great diversity of form. Commencing with those which consist of a primary microlite to which secondary microlites have attached themselves at right angles, we may pass, by means of those which consist of two parallel microlites, joined, either at their centres or at their ends, by transverse microlites, to broad rectangular felspar sections, bounded by sharp straight edges, or else running out at their ends into acicular microlites. These skeleton forms are best studied in sections from the Barwick and Armathwaite quarries. I have observed somewhat similar forms in the dolerite of Sababurg, in Hesse, and in that of Dalmahoy Hill, near Edinburgh, also in some of the other dykes to be hereafter described. Bořický has described similar forms in the melaphyres of Bohemia (Petrographische Studien an den Melaphyrgesteinen Böhmens, p. 9, pl. i. fig. 7).

Augite.—This mineral, like the felspar, occurs in two conditions,

(1) as fairly large (·55 mm. × ·75 mm.), and more or less perfectly developed crystals of the common form; and (2) as minute crystals or crystalline granules (·05 mm.). The former show fairly good cleavages, which appear in the sections as lines running parallel to each other, or else belonging to two series which intersect at various angles according to the direction of the crystal section, up to about 90°. They are not numerous, but in the slides in my possession may be recognized the eight-sided, six-sided, and four-sided forms characteristic of sections more or less at right angles to the principal axis, parallel to the ortho-pinakoid, and parallel to the clino-pinakoid respectively. By far the larger portion of the augite occurs in the form of minute crystals and crystalline grains. A green chloritic substance, having a fibrous appearance in thin sections, sometimes wholly or partially replaces the augite. In some of the sections from the Barwick quarry the augite crystals are entirely replaced by calcite pseudomorphs, giving aggregate polarization. These are especially interesting, as the forms of the replaced augite were evidently very perfect. Augite does not, at any rate as a rule, occur as inclusions in the large porphyritic felspars. Many of the very small augite grains when examined with a magnifying power of 500 diameters, are seen to have their edges ill defined and ragged like the felspar microlites, and seem to be connected with the brownish substance which appears as indistinct granules and fibres in the interstitial matter. This very interesting feature will be again referred to in describing the microscopic character of the interstitial matter.

Magnetite (*and Ilmenite?*).—This occurs in the form of fairly well-developed crystals, and also as skeleton crystals and small granules. The crystals show the usual quadratic, triangular, and hexagonal forms. Now and then a lath-shaped section occurs, such as might be formed by cutting a tabular crystal of ilmenite at right angles to the basal plane. The occurrence of this latter mineral must, however, be regarded as doubtful; for the microscopic evidence is not clear, and the small quantity of titanic acid revealed by analysis may be contained in the magnetite. On heating a thin section for some time with hot hydrochloric acid, the black opaque mineral entirely disappears.

Biotite.—This mineral is not constantly present. It has been observed in specimens from Armathwaite and Ayton. It shows a tendency to alteration, and is frequently represented by green chloritic fibres.

Quartz.—This may be recognized in most of the slides, either in the form of definite crystals or as crytalline grains, which usually show a polysynthetic structure. It may, in part, be an original constituent; but from its frequent association with calcite, I am inclined to class it under the secondary minerals.

Calcite.—This mineral occurs in irregular crystalline plates, giving definite extinctions, and is also scattered throughout the slide in the condition of crystalline powder. The last-mentioned mode of occurrence indicates, however, a very advanced stage of decomposition, and is usually found only in those slides in which the augites have been replaced by calcite. The irregular crystalline plates occur in comparatively unaltered rocks, and they are here seen to be almost invariably associated with quartz. Both quartz and calcite also occur in thin veins. Small spherical amygdules containing calcite and chalcedony occur in certain localities, and especially at Bowles Beck, where my attention was first called to them by Mr. James I'Anson.

Pyrites.—This mineral occurs abundantly in certain localities, but is not distributed throughout the rock with any definite regularity. It owes its origin, no doubt, to local causes. Under the microscope it appears as irregular ragged plates, the true nature of which can, of course, only be recognized by reflected light.

The Interstitial Matter.—This is in some respects the most interesting portion of the rock. It forms, as a rule, about one half of the ground-mass, and presents a number of remarkable structural variations. Although giving, in the majority of cases, a decided reaction under polarized light, it consists of a number of imperfectly individualized substances. In order to study the characters of this substance, it is absolutely necessary to have the thinnest possible sections and to use a magnifying power of not less than 500 diameters. We will consider first of all the case of a somewhat exceptional variety of the rock, which occurs at Armathwaite. The ultimate base is a clear isotropic glass containing a large number of extremely minute brownish granules. With a magnifying power of 500 diameters the smallest granules appear as mere specks, while the larger ones have frequently a globular or elliptical form. Clusters of granules may frequently be seen, and these appear to show a tendency to a linear arrangement, The granules are without action on polarized light. They belong to the *globulites* of Vogelsang (Die Krystalliten). In addition to the globulites, there are also long, more or less conical needles of the same substance. The thin ends of these needles are usually clear and transparent, and the external surfaces smooth; but the thick ends are rough, and evidently made up of globulites which have not entirely lost their individuality in the attempt to form these needle-like bodies. The bodies in question give no reaction with polarized light, and they correspond therefore with the *longulites* of Vogelsang. The smaller ends of the longulites rarely, if ever, lie free in the glassy base, but are in contact with minute augite granules, around which they are arranged in a rude kind of radial manner (see Pl. XII. fig. 2 *a*). In short the smaller augite grains may be described as bristling with longulites. It is worthy of note that the felspars of the ground-mass appear to have exercised no influence whatever on the grouping of the globulites and longulites.

The conical needles which occur in a slag figured by Vogelsang (Die Krystalliten, pl. ii.) are described by him as having been formed by a double process of growth, the pointed end having been produced by the coming together of the very smallest spherical elements (" die kleinsten constituirenden Kugelelemente "), and the opposite or shank end by an aggregation of globulites. In the Armathwaite longulites it appears probable that the growth has always been in one direction, that is from the end in contact with the augite granule. At first the conditions were such that an intimate union of the constituent elements took place, and the smooth rod-like portion was produced. After a time, however, the conditions became more and more unfavourable to the individualization of distinct substances. Larger globulites were produced and brought together by the action of the attractive forces; but these did not become perfectly united, and thus the rough portion of the longulite was formed.

That the longulites are intimately connected with the globulites is proved by the occurrence of every possible kind of intermediate form. Thus one may pass from single globulites to a linear grouping due to the coming together of two or more globulites without actual union, and from this, again, to an elongated form which has evidently been produced by the union of distinct globulites at their points of contact. These, again, may be connected with the more perfectly developed longulites by intermediate forms. As will naturally be anticipated from the facts already described, the spaces surrounding the longulites are free from globulites; the material of the globulites has been abstracted for the purpose of forming the longulites. What substance is it whose crystallizing force has led to the formation of these non-crystalline bodies? It is impossible to demonstrate the fact, but I have little doubt that it is augite. A suspicion of this is aroused when one notices that the longulites cluster round the augite grains, which they resemble in colour and general appearance, but not round the felspars; and this suspicion is confirmed when one studies carefully the structure of some of the least perfectly developed augites. These have sometimes a fibrous look, and occasionally run out into microlites which cannot be distinguished from the longulites without the use of polarized light. I consider, therefore, that if we could isolate these globulites and longulites for separate analysis we should find them not to consist of pure augite substance, but of material richer in augite substance than the surrounding glassy base; just as in Vogelsang's experiments with sulphur and Canada balsam (Die Krystalliten, p. 8) the globulites and longulites consisted of Canada balsam containing more sulphur than the surrounding mass.

As a rule, the felspars of the ground-mass are entirely free from globulites and longulites. It does sometimes happen, however, that a portion of the base gives the reaction of felspar under polarized light, and at the same time contains these bodies.

We are thus led to the conclusion that the magma which remained fluid after the formation of the large felspars, the magnetite and many of the augite crystals and grains, still contained the chemical constituents of felspar and augite, and that the peculiar structures of the ground-mass owe their origin to the crystallizing power of these constituents acting under unfavourable circumstances. In short they may be regarded as the final attempts of these constituents to assume a crystalline condition. Mr. Stock found (see his note, p. 225) that 35·57 per cent. of this rock remained insoluble after treatment with hydrochloric acid in a pressure-tube for one month, and that the insoluble residue yielded, on analysis, SiO_2 70·76 per cent.; Al_2O_3 10·93; Fe_2O_3 3·59; CaO 3·29; MgO 4·21; Alkalies 7·22. This may be taken as representing approximately the composition of the base with its various devitrification-products. It is, as one would naturally expect, highly acid; the silica here, as in other cases, having served as a sort of solvent medium out of which the other minerals have crystallized.

So far I have been referring to the prevailing type of interstitial matter in the Armathwaite slide. Here and there, however, in the same slide it puts on a very different aspect. It becomes deep brown in colour and is traversed by numerous ill-defined felspar microlites. The longulites and globulites are no longer to be recognized, and the whole patch gives a vague reaction on polarized light. This is the common type of devitrification, and may be well studied in sections taken from the rock which occurs at Barwick quarry, near Preston. Here the ill-defined felspar microlites occur in great abundance; but as they have already been described it will be unnecessary to refer to them at greater length. In the thinnest possible sections the brown colour is seen to be due to a kind of indistinct granulation which has evidently been produced by the imperfect individualization of a brownish substance. This substance appears as minute specks and ill-defined fibres. It is occasionally aggregated into irregular patches and narrow bands, which give the vivid polarization-tints characteristic of the small augite granules. I have not been able to recognize any clear transparent glass in the Preston slides; but some of the base containing indistinct fibres and granules appears isotropic, and may therefore be regarded as consisting of the micro-felsite of Rosenbusch. There is yet a third type of devitrification, also very common, which may be well studied in the specimens from Great Ayton. Indistinct granules, fibres, and ragged patches of a brownish substance which may be connected by intermediate forms with the augite granules, and which give the same reaction on polarized light, together with specks of opacite (? magnetite) lie intermixed with a substance which also reacts on polarized light. Thus, it splits up under crossed nicols into irregular patches of considerable size, which extinguish in definite positions, but whose boundaries are by no means well defined. Long, sharp, colourless microlites, and black hair-like bodies (trichites) may be observed in the base of the rock from certain localities.

Structural Variations of the Rock.—As already stated, only two well-marked structural types can be recognized, one characteristic of the main mass, the other of the margins of the dyke. They differ from each other merely in the extent to which crystalline growth has been carried in the ground-mass of the rock; for the porphyrite felspars are alike in both varieties. In the marginal part of the dyke the ground-mass is composed of minute felspar microlites (see Plate XII. fig. 2), indistinct brownish granules (? augite), and specks of magnetite imbedded in a clear isotropic glass. In the rock from the central portions of the dyke the felspars of the ground-mass and augite grains are much more fully developed, and the base itself also appears completely devitrified. The rock from the margin of the dyke bears a striking general resemblance to many of the so-called augite-andesites of Hungary and Santorin.

Chemical Analyses of the Cockfield and Armathwaite Dyke.

	I.	II.	III.	IV.
Silica	57·57	58·07	59·25	56·10
Alumina	14·25	13·22	16·75	17·24
Ferric oxide	6·04	10·10	4·00	4·76
Ferrous oxide	3·95		4·82	
Manganese oxide	·27	...	...	...
Lime	6·87	7·04	6·88	11·20
Magnesia	4·24	4·46	3·81	2·29
Potash	1·08	1·58	1·92	1·38
Soda	2·98	2·59	2·56	2·04
Sulphur	·19	...	..	...
Carbonic acid	·30	..	trace	3·60
Phosphoric acid	.15	...	...	...
Titanic acid	trace	...	...	...
Water	1·25	1·50	...	1·55
	99·14	98·56	99·99	100·16

I. Specimen from Great Ayton. Analysis by W. F. K. Stock, Esq., of Darlington*.

II. Specimen from Armathwaite, about 60 miles from Ayton in a direct line. Analysis by W. F. K. Stock, Esq.

III. Specimen from Great Ayton. Analysis by J. E. Stead, Esq.

IV. Altered specimen from the margin of the dyke at Preston. Analysis by J. E. Stead, Esq.

Note on the Action of Hydrochloric Acid on the Rock of the Cockfield and Armathwaite Dyke. By W. F. K. Stock, Esq., Darlington.

The following investigation was suggested by the apparent ease with which a notable quantity of the Cockfield Armathwaite rock was acted upon by hydrochloric acid in open flasks, and by the fact communicated to me by Mr. James I'Anson, of Darlington, that sections cut by him showed a large proportion of matter wanting in definite form. The Ayton rock was first examined. A portion was reduced to an extremely finely divided condition by long-continued trituration in an agate mortar. About 2 grammes of the fine powder were sealed up in a pressure-tube of strong Bohemian glass along with 20 c.c. of hydrochloric acid of sp. gr. 1·16. The tube with its contents was exposed in an air-bath to a

* This analysis of the Ayton rock was originally prepared for Mr. I'Anson; but, thanks to the kindness of the latter gentleman, I am able to give it in this paper.

temperature ranging between 220° and 240° Fahr. for 24 days; at the end of that time the tube was opened under water and the contents filtered off. The insoluble portion was washed off the filter and treated with a ten-per-cent. solution of caustic potash to remove deposited silica. The washed residue was dried and heated to near redness and weighed. It was again ground down for a long time in the agate mortar, and an aliquot part sealed up once more with hydrochloric acid and exposed for fourteen days as before. It was found that in the second treatment only about 16 per cent. by weight had been dissolved, which seemed to afford good evidence that what remained was quite insoluble in hydrochloric acid under these conditions. The quantitative results obtained were that 39·33 per cent. of the Ayton rock was *insoluble in hydrochloric acid*, and that on determining the silica in this residue it was found to amount to 77·66 per cent. These results were verified by repetition.

After the analysis of the Armathwaite specimen had been completed, it was thought desirable to subject a portion of this rock also to the foregoing treatment. This was done; but the time of exposure was extended to 31 days, and the temperature was raised to 316°·4 Fahr. Under these conditions several tubes were lost by explosion. The insoluble residue amounted to 35·57 per cent. It was analyzed and furnished the following:—

Silica	25·17	70·76
Alumina	3·89	10·93
Ferric oxide	1·28	3·59
Lime..........	1·17	3·29
Magnesia	1·50	4·21
Alkalies	2·56	7·22
	35·57	100·00

Mr. I'Anson examined portions of the insoluble residue from time to time, duplicate tubes being prepared for that purpose, and in the final residues he found the doubly refracting matter to be reduced to a minimum.

Deducing an opinion from the almost total insolubility of these residues, their highly acidic character, and the absence of any marked amount of doubly refractive matter, I think we may regard them, at any rate approximately, as representing the base of the rock. This view is much strengthened by the results from the Armathwaite specimen which Mr. Teall handed to me as a rock with "a true glassy base;" nothing could much better represent a glass than the composition of this residue.

It may be of interest to state that in these tube-experiments it was conclusively proved that the hydrochloric acid took up none of the silica from the decomposable silicates, but that the whole of it was deposited in a pulverulent form in the tube, and was filtered off with the insoluble residue, from which it was, of course, separated by the treatment with caustic potash. This is a point which I have not seen noticed previously.

General Relations of the Rock forming the Cockfield and Armathwaite Dyke.

The rock has generally been considered a basalt; but it differs from typical basalts in many ways: thus olivine is entirely absent, and the bisilicate constituent plays a very subordinate part in the mineralogical composition of the rock. Then, again, the silica percentage (57 to 59) is much too high, that of true basalts averaging about 50 or less, and the specific gravity (2·77) is too low. The presence in considerable quantity of a highly acid base is also another point which distinguishes this rock from true basalts. Now in all these points the rock approaches the andesites and trachytes; and if the term augite-andesite is to be used at all, it seems fairly applicable to this rock, which, be it remembered, is almost certainly of Tertiary age.

I append a Table of analyses of recognized augite-andesites to show that there is a close correspondence between them and the rock now under special consideration:—

	I.	II.	III.	IV.	V.
Silica	57·80	59·70	58·76	57·51	56·582
Alumina	18·07	16·16	17·34	16·83	18·379
Ferric oxide	8·98	7·97	7·77	10·40	1·112
Ferrous oxide	......	0·83	......	......	5·995
Manganese oxide	......	......	......	......	0·108
Lime	4·69	8·01	7·46	6·54	11·053
Magnesia	1·12	1·16	2·67	1·89	3·239
Potash	2·61	1·56	0·93	2·21	0·912
Soda	4·60	3·12	2·36	3·86	2·589
Loss	1·18	1·09	2·10	0·43	......
	99·05	99·60	99·39	99·67	99·969

I. Augite-andesite Lava, Polsiegy near Szkaros.—Dr. C. Dölter, "Ueber einige Trachyte des Tokaj-Eperieser Gebirges," Min. Mitth. 1874, Heft iii. p. 213.

II. Augite-andesite from Köhegy near Bogdanz Garbocz.—Dr. C. Dölter, Min. Mitth. 1874, Heft iii. p. 207.

III. Porphyritic Augite-andesite from Tuhrina.—Dr. C. Dölter, Min. Mitth. 1874, Heft iii. p. 205.

IV. Lava of Pariou, ending at Fontmort, Clermont Ferrand.—Von Lasaulx, "Petrographische Studien an den vulkanischen Gesteinen der Auvergne," Neues Jahrbuch, 1871, p. 682.

V. Lava of Masaya Mindiri, Central America.—H. R. Marx, "Beitrag zur Kenntniss centralamerikanischer Laven," Zeitschr. d. geol. Ges. xx. p. 526 (1868).

The bulk analysis of our rock also bears a close resemblance to that of many of the so-called melaphyres, as will be seen at once by referring to the collection of analyses published in Zirkel's 'Lehrbuch der Petrographie,' vol. ii. p. 55. It should be borne in mind that the rocks to which the term melaphyre has been applied on the continent have, as a rule, a higher silica percentage, a lower specific gravity, and a larger proportion of felspar than the basalts.

The affinities of melaphyre are therefore rather with the augite-andesites than with the true basalts.

Many of the so-called augite-andesites contain a rhombic pyroxene; and it has been suggested by Mr. Whitman Cross ('Amer. Journ. of Science,' Feb. 1883), in a paper on the andesite of Buffalo Peaks, Colorado, that this rhombic pyroxene (hypersthene) is the predominating bisilicate in these rocks *. If this should turn out to be correct then they would have to be termed hypersthene-andesites, and the question would arise as to whether the term augite-andesite should be retained at all. I think in any case, however, the term augite-andesite is useful to indicate such a rock as the one described above, that is a plagioclase-augite-magnetite rock, having more or less a trachytic or andesitic structure, a silica percentage considerably higher than that of normal basalts, and a specific gravity of about 2·7. At the same time it must be admitted that such a rock is not separated from basalt by any hard-and-fast line; and from this point of view it might be called an andesitic basalt, except that this term has been used in a somewhat different sense by Bořický ('Basaltgesteine Böhmens,' p. 543).

A rock having essentially the same chemical and mineralogical composition has been described by Prof. A. Geikie, in a paper on the so-called Pitchstone of Eskdale ('Proceedings of the Royal Physical Society of Edinburgh,' vol. v. 1880). The Pitchstone of Jameson is shown to be merely a glassy form of this rock. My attention was called to this paper by Mr. Topley, after the above description of the microscopic character of the Cockfield and Armathwaite rock had been written. I mention this because there is a very striking resemblance between the way in which Prof. Geikie has described the devitrification-products of the so-called pitchstone and the manner in which I have described the precisely similar bodies in the Armathwaite specimen. The figure which Prof. Geikie gives in the paper above quoted, and also in his 'Text-book of Geology,' p. 100, exactly represents the special features of the base of the Armathwaite specimen (compare Pl. XII. fig. 2 *a*).

It may be as well to quote the bulk-analysis of the Eskdale rock:—

Silica	58·67
Alumina	14·37
Ferrous oxide	6·94
Ferric oxide	1·64
Manganese oxide	trace
Lime	7·39
Magnesia	4·65
Potash	1·42
Soda	3·01
Water	2·02
	100·11

* See also Bulletin of the U.S. Survey, no. 1.

The Hett Dyke.

Literature.

Sedgwick, Rev. Adam. "Geological Structure and internal Relations of the Magnesian Limestone," Trans. Geol. Soc. 2nd ser. vol. iii. part i.

———. "On the Phenomena connected with some Trap-dykes in Yorkshire and Durham," Trans. Cambr. Phil. Soc. vol. ii.

Bell, I. Lowthian. "On some supposed Changes Basaltic Veins have suffered during their passage through and contact with Stratified Rocks, and on the manner in which these rocks have been affected by the heated Basalt," Proceedings of the Royal Society, 1875, p. 543.

This dyke crosses the following 1-inch Ordnance Maps: 103° N.E., N.W., and S.W. Its course is thus traced by Professor Sedgwick * on the authority of Mr. Wharton, of Oswald House, Durham:—"It ranges from the escarpment of Magnesian Limestone (at Quarrington Hill, a few miles to the east of Durham), through the great coal-field, in a direction about W.S.W. It is found along this line at Crowtrees, Tarsdale, Hett, Tudhoe, Whitworth, and Constantine Farm. From the last-mentioned place it passes along the same line of bearing through the collieries of Bitchburn and Hargill Hill to a spot near the confluence of the Bedburn Beck and the river Wear, where it is well exposed at the surface of the ground; and it is known to pass up the Bedburn-Beck valley to Egglestone Moor." The author also states that the dyke increases in width in its progress westward from 6½ feet at Crowtrees to 15 feet at Bitchburn Beck.

The dyke has formerly been quarried on an extensive scale between the villages of Tudhoe and Hett. At present (1882) it is worked by means of shafts at Tudhoe, near the Darlington road, and at Hett village. Between the Darlington-road shaft and Hett village its course is marked by a nearly continuous trench, the result of old quarrying operations, which terminates at the village in a vertical face of rock. The direction of this trench is nearly east and west. At Hett the dyke is 10 feet wide, and hades to the north at a very high angle. The adjacent rocks are coal-shales which have been baked and indurated by the action of the igneous mass. A rude spheroidal structure has been brought to light by the action of the weather. This dyke, like the one already described, appears to keep its character for great distances; and although I have only examined it between Tudhoe and Hett, I have no doubt that the following petrological description will apply to it throughout its entire length.

Macroscopically it is a fine- or medium-grained crystalline rock of a dark grey or bluish-grey colour and a subconchoidal fracture. It can be at once distinguished from the rock of the Cleveland dyke by the absence of any porphyritic crystals of felspar. Here and

* Trans. Cambr. Phil. Soc. vol. ii. (1827).

there small spherical amygdaloids, for the most part filled with calcite, may be recognized. The texture of the rock does not vary in any marked manner, the individual constituents being, as a rule, just recognizable by the naked eye. On applying acid, a slight effervescence may frequently be observed, and this naturally becomes more marked near the edges of the dyke and in the neighbourhood of joint-planes.

Under the microscope the rock is seen to consist for the most part of felspar, pyroxene, and magnetite. There is, however, also a small quantity of cryptocrystalline matter (Pl. XII. fig. 5).

Felspar.—This occurs in forms which give lath-shaped sections, whose dimensions lie, as a rule, between the following limits:— ·08 × ·3 millim. and ·02 × ·14 millim. The length of a section is, on the average, about five times its width. I am not able to recognize more than one generation of felspar, so that the rock would be granular in the sense in which that term is used by Prof. Rosenbusch *. Under crossed Nicols the sections are seen to consist of two or more lamellæ; but simple individuals are by no means uncommon. When the thin sections are exposed for some hours to the action of hydrochloric acid at a temperature of 100° C. the felspars lose their individual action on polarized light; and I conclude from this, as well as from the bulk-analysis of the rock, that they belong to a species allied to labradorite.

Pyroxene.—This mineral rarely, if ever, presents definite crystalline boundaries. It occurs in isolated grains, granular aggregates, and irregular plates, which are frequently interpenetrated by the lath-shaped felspars. There is no doubt, therefore, that it consolidated after the felspar. The prismatic cleavages are the only ones that I have observed. Twinning is not uncommon.

Magnetite occurs in grains and crystals scattered uniformly through the rock, the sections measuring about ·12 or ·1 millim. across. That it is magnetite and not ilmenite appears to be proved by its tendency to give rise to limonite decomposition-products, and by the readiness with which it is attacked or removed by hot hydrochloric acid.

The elements already described make up perhaps nine tenths of the mass. As already stated, however, there occurs also a small quantity of interstitial matter which gives an indistinct reaction under crossed Nicols; it is brown in colour, granular in aspect, and usually charged with minute colourless acicular microlites. This doubtless represents the highly acid residue which remained after the separation of the definitely crystalline constituents. The secondary minerals are calcite and quartz. Green alteration-products are very rare in the specimens examined by myself.

The specific gravity of the unaltered rock varies from 2·94 to 2·96. Its chemical composition, as given by Mr. I. Lowthian Bell, F.R.S., is as follows:—

* "Ueber das Wesen der körnigen und porphyrischen Structur bei Massengesteinen," Neues Jahrbuch (1882), Band ii. p. 1.

Silica	51·35
Alumina	17·61
Ferrous oxide	12·04
Lime	9·65
Magnesia	5·68
Potash	1·40
Soda	0·56
Carbonic acid	1·53
	99·82

About 2 miles to the north of the Hett dyke is another dyke of almost identical composition (see Mr. Bell's paper, p. 546); and between the two there occurs, at a depth of about 60 fathoms beneath the surface, a horizontal sheet of similar material, which was proved, by the mining operations of Messrs. Bell Brothers, to cover an area of at least 15 acres, and to be in one place 19·75 feet in thickness. Mr. Ernest Bell forwarded a piece of this rock to Dr. Trechmann; and to the latter gentleman I am indebted for the specimen on which the following statements are based. The rock is identical in appearance with the more coarsely crystalline varieties of the Hett dyke. Microscopically, also, there is the closest resemblance, the principal difference being the almost entire absence, in the case of the intrusive sheet, of any interstitial matter. The specific gravity of my specimen is 2·96, and the chemical composition of the sheet, as given in Mr. Bell's paper, is:—

Silica	51·90
Alumina	15·46
Ferrous oxide	12·87
Lime	13·80
Magnesia	4·02
Potash	1·21
Soda	0·48
Carbonic acid	1·02
	100·76

Of what age are these dykes? To this question no definite answer can be given. There is no evidence that either of them penetrates the Magnesian Limestone, although they are known to occur in the Coal-measures beneath. Prof. Sedgwick remarks that the Hett dyke can be traced to Quarrington Hill, but that it does not pass up into the Permian; and from this fact he is inclined to regard it as of Palæozoic age. It is worthy of note that the rock of which these dykes and the accompanying "sill" are composed differs in a marked manner from that of the Cleveland dyke; it is more basic in composition, of higher specific gravity, and much more largely composed of crystalline constituents. In all these points it approaches in character the rock of the Great Whinsill, with which I am strongly inclined to regard it as contemporaneous.

The Hebburn Dyke.

Literature.

Winch, N. J. "Observations on the Geology of Northumberland and Durham," Trans. Geol. Soc. vol. iv. (1827).

Lebour, Prof. G. A. Outlines of the Geology of Northumberland (1878), p. 48.

Ordnance Maps (1 inch). 105 S.E. and S.W.

This dyke is described by Prof. Lebour as emerging from beneath the Magnesian Limestone near Cleadon, and passing in a W.N.W. direction by Hedworth and Hebburn to the Tyne at Walker, where it enters Northumberland. There is, so far as I know, no exposure of this dyke at the surface now known; but Winch describes a quarry which was formerly worked about 1 mile north of the Boldon Hills. "The rock," he says, "was fine-grained, nearly black, and filled with small globules of milk-white chalcedony not bigger than a mustard-seed."

The course of this dyke, as marked on the Survey maps, has therefore been traced by means of the data supplied by the numerous colliery workings in the district. Prof. Lebour regards the celebrated Coley-Hill dyke, which was formerly worked on such an extensive scale to the west of Newcastle, as a continuation of the Hebburn dyke; but as the former agrees very well in direction with the Tynemouth dyke, with which it has also very close petrological affinities, I am inclined to regard it rather as a continuation of the latter than of the former. When speaking of the relations of the dykes of Coley Hill, Walker, and Boldon, Mr. Winch says:—"It is by no means ascertained that they are portions of the same dyke connected together below the surface, since no trace of that of Coley Hill could be discovered in the very extensive and ancient collieries of Montagu and Kenton, situated in its course at a short distance to the east of it; nor was the Walker dyke found in any other quarry."

The only locality where I have had an opportunity of examining

Fig. 2.—*Dyke in Coal-measures, Boldon Pit.*

A. Bad coal, slightly charred, 8 yards. B. Greyish black cinder, 12 yards. C. Greyish black cinder.

the Hebburn dyke is in Boldon pit. To this exposure I was conducted through the kindness of Mr. Walker, who also supplied me with a sketch from which the diagram (fig. 2), expressing the relation of the whinstone to the Coal-measures, is constructed. The section crosses the dyke about 22° from a right angle.

The actual thickness of the dyke in the "blue metal" is thus seen to be 44′ 6″, and in the coal 49′.

Macroscopically the rock is dark, almost black in colour and uniformly crystalline in texture, *i. e.* porphyritic elements are wanting. At the margins it is compact. In the central parts it effervesces slightly, and in the marginal parts freely with hydrochloric acid. Here and there occur small spherical amygdaloids, measuring on the average about 1 mm. in diameter; these are occupied by calcite and quartz. The specific gravity of the unaltered rock is 2·84.

Under the microscope the rock is seen to consist of magnetite (? ilmenite), felspar, pyroxene, and a considerable quantity of interstitial matter, which has a decided though indefinite reaction on polarized light. This ground-paste is rendered in places almost opaque by a large quantity of brown granular matter. It also contains skeleton felspars and acicular microlites of felspar, which do not always appear to be sharply separated from the paste.

The felspar sections are usually very long in proportion to their width, a feature which characterizes many of the dykes now about to be described (Pl. XII. fig. 6). Binary twins are most numerous. The pyroxene is almost colourless, frequently twinned and evidently monoclinic; it occurs in irregular plates of secondary consolidation and rarely, if ever, shows definite crystalline boundaries in those sections which are taken from the main mass of the dyke.

The mutual relation of the felspar and pyroxene is that so eminently characteristic of the German and Swedish diabases, but which is also found in certain typical dolerites.

The secondary products are calcite, quartz, and a greenish serpentinous mineral giving aggregate polarization. The latter mineral occurs sparingly, and may possibly be a pseudomorph after olivine. Calcite and quartz occur in the spherical amygdaloids already mentioned, the former mineral making up the central and larger portion of the amygdule, and the latter occurring as detached crystals or crystalline granular aggregates near the periphery. It is especially worthy of note that the lath-shaped felspar sections are frequently arranged with their longer axes parallel to the boundaries of the amygdaloids, a fact which can only be explained by supposing that the cavities were produced when the rock was plastic. The presence of gas-cavities in a rock which was evidently produced under great pressure is somewhat anomalous.

The marginal portion differs in texture from the main mass of the dyke. It is micro-porphyritic; but, owing to the enormous amount of alteration which has taken place, it is somewhat difficult to make out its original character. The larger constituents are irregular grains of magnetite, lath-shaped felspars, frequently having bifid and ragged terminations, and green pseudomorphs after a pyroxene having definite crystalline boundaries; both the six- and eight-sided forms characteristic of sections of augite parallel to the orthopinakoid, and at right angles to the vertical axis, may be easily recognized. The ground-mass is a confused aggregate of extremely minute felspar microlites, specks of opacite, and indistinct brownish granules. Isotropic glass may or may not be present; a considerable amount of calcite in the form of crystalline powder is scattered throughout the mass.

The absence of well-formed augites in the main mass of the dyke, and their presence in the more rapidly cooled marginal portions, is a fact of some considerable importance, as apparently showing that the period of consolidation of the augite is dependent rather upon physical than upon chemical conditions. In microscopic structure the rock of the Hebburn dyke differs from that of either of the dykes already referred to and approximates very closely to that of several dykes now to be described.

Is this dyke of Tertiary or pre-Tertiary age? No definite answer can be given to this question. It is not known to cut any formation of later date than the Coal-measures.

The Tynemouth Dyke.

Literature.

Winch, N. J. "Geology of Northumberland and Durham," Trans. Geol. Soc. vol. iv.

Lebour, Prof. G. A. Outline of the Geology of Northumberland (1878).

Ordnance Maps 105 N.E. and N.W.

This dyke is exposed at the base of the Castle Rock, Tynemouth. It may be examined on the shore in the angle formed by the meeting of the breakwater and the coast-line, where it is seen in contact with Coal-measure strata on the north, and with the wall of the breakwater on the south. Permian strata cap the hill on which the Priory stands; but the dyke is not seen in contact with these beds. It is about 10 feet wide, and separated into two portions by a quartzose vein which is 6 inches wide. The same dyke was also admirably exposed during the construction of the new railway station at Tynemonth in the winter of 1881 and 1882.

The most interesting feature connected with this exposure was the evidence of a breach in the continuity of the dyke, accompanied by a lateral shift in the outcrop, amounting to 17 yards. The width of the dyke was about 11 or 12 feet, and it possessed a hade to the north. Further west the same dyke has been met with near Biddy Mill * by Mr. Flavell, F.G.S., during the construction of works by the North Shields Water Company. Still further to the west, near

* Lebour, 'Geology of Northumberland,' p. 48.

Newcastle, occurs the well-known Coley-hill dyke, which was formerly worked on a very extensive scale for road-metal, and the course of which is now indicated by a deep trench. This dyke agrees very well in direction with the Tynemouth dyke, and Winch appears to have regarded the two as connected.

I was not able to find the Coley-hill rock *in situ*; but some large angular fragments were found in the trench at one point, and as these agree with the description gived by Winch, I have no doubt that they were portions of the dyke. If so, they prove that the petrological characters of the Coley-hill dyke agree with those of the Tynemouth dyke, and differ from those of the Hebburn dyke, a fact which seems to establish the connexion of the two former.

I now proceed to describe the rock of the Tynemouth dyke. It varies in aspect according to the presence or absence of (*a*) porphyritic crystals of anorthite and (*b*) small spherical amygdaloids. The porphyritic crystals frequently measure more than 1 centim. in cross section; they are, as a rule, very irregular, and consist rather of crystalline aggregates than of simple crystals; nevertheless sections parallel to the basal plane, showing the forms $\infty \breve{P}\infty$, $\infty P'$, and $\infty 'P$, are not uncommon. These sections show also the striation characteristic of plagioclase. The crystals are glassy in texture, but they frequently show a slight tinge of yellow. Isolated fragments of these felspars were analyzed by my friend Mr. Stead, with the following result:—

Silica	47·30
Alumina	31·50
Ferric oxide	1·85
Lime	14·88
Magnesia	0·93
Potash	38
Soda..................	1·22
Loss	1·80
	99·86

It is impossible to obtain the felspar in a state of absolute purity, on account of the numerous inclusions which it contains; and it will also be shown further on that the outer zone of felspar substance possesses optical properties somewhat different from the central portion; nevertheless the analysis clearly proves that the felspar is closely allied to anorthite. A section of the felspar specially prepared and approximately parallel to the basal plane gave 55° 10′ as the angle between the extinction-positions of adjacent lamellæ. The corresponding angle in anorthite, according to Lévy and Fouqué, lies between 57° and 74°, and in labradorite between 10° and 14° 30′. Assuming Schuster's interpretation of Tschermak's theory to be correct, then this figure corresponds to about 90 per cent. of anorthite in the mixture. The above facts with regard to the Tynemouth felspars have appeared in the Geol.

Mag. decade ii. vol. x. p. 252 ; but they are again inserted here in order to make the description of the Tynemouth rock complete.

The spherical amygdaloids, like the porphyritic crystals, are very abundant in certain specimens and almost entirely absent in others; they vary in size from that of a mustard-seed to that of a pepper-corn, and, as a general rule, where the amygdaloids are most numerous the porphyritic crystals are least numerous, and *vice versâ*. The amygdules effervesce freely with hydrochloric acid and are thus seen to be largely composed of calcite.

The ground-mass of the rock in which the above elements occur is crystalline in texture and of a very dark colour. Fractured surfaces are somewhat uneven. A bulk-analysis of the rock yielded to Mr. Stead the following result:—

Silica	58·30
Alumina	16·14
Ferrous oxide	4·50
Ferric oxide	4·76
Lime	10·96
Magnesia	2·68
Potash	0·94
Soda	1·74
	100·02

Three separate determinations of the density gave 2·844, 2·845, 2·839.

Under the microscope (Pl. XIII. fig. 1) the ground-mass is seen to be identical with that of the Hebburn dyke; it is therefore unnecessary to describe it in detail. In two out of the seven slides examined the serpentinous mineral appears to form a pseudomorph after olivine; and we may conclude, I think, that olivine was sparingly present in the original rock. The large porphyritic crystals call for more detailed description. Under polarized light they are at once seen to consist, as a rule, of crystalline granular aggregates, as many as 7 or 8 crystalline grains going to make up one of the larger porphyritic masses. The different individuals in a complex mass are not orientated in any definite manner with regard to each other, *nor do the interior boundaries of the crystalline particles show definite faces, although the external boundaries usually do.* Another feature of great interest is to be found in the fact that a narrow peripheral zone of felspar substance is usually present, which extinguishes at a different angle from the central kernel, and that it is this peripheral zone which gives the definite crystalline form to many of the grains. I have never seen this zone continued between two individual grains of one and the same aggregate.

It appears, then, that granular aggregates of anorthite were first formed without external crystalline faces, and that, during the later stages of consolidation, additional felspar substance of somewhat different composition was added, so as to give definite form to the external portions of individual grains—that is, to those portions which were in contact with the consolidating magma (Pl. XIII. fig. 1).

The porphyritic felspars frequently contain large numbers of minute (·004 mm.) elliptical inclusions of a brownish glass, and sometimes large, irregular, and nearly opaque masses of the ground-paste. Augite granules are not uncommon in the peripheral zone. Under crossed Nicols two types of twinning may be recognized, the lamellæ of the prevailing type being usually broad and frequently terminating in the centre of a crystal or crystalline grain.

The microscopic structure of the amygdaloids has been already described in connexion with the Hebburn dyke.

An experiment was made to ascertain the relative fusibility of the ground-mass of this rock and the porphyritic crystals. Several pounds weight were placed in a crucible, and subjected to the heat of a brass furnace. It was found that this was sufficient to melt the ground-mass; but the large felspars remained intact, so that after rapid cooling they were found imbedded in a brown isotropic glass. In a second experiment the cooling was prolonged for fourteen hours, and it was then ascertained that dense spherulites similar to those of the tachylite (? hyalomelan) of Sababurg had developed themselves, and that a similar mode of devitrification had taken place round each of the porphyritic crystals.

Brunton Dyke.

Literature.

Lebour, Prof. G. A. Geology of Northumberland.
Ordnance Map 106 N.E.

The course of this dyke in thus described by Prof. Lebour:—"The Brunton dyke, known in west Allendale, near Whitfield, crosses the South Tyne first to the west of Haydon Bridge, then between that little town and Wharnley, and lastly to the east of the latter place; it crosses the North Tyne near Wall, is well exposed by St. Oswald's Chapel, near Brunton, and is last seen in the Bingfield Burn on the east side of the Watling Street. Two small dykes run close to and parallel with this one near its easternmost extremity. Of these one is well seen in the Bingfield Burn, and the other in the bed of the Pont, where that little stream crosses the Watling Street."

The general trend of the main dyke appears to be nearly N.E. and S.W. On Feb. 2, 1882, I had the opportunity of examining two of the dykes above referred to in company with Mr. I'Anson. We were directed to the spot by Prof. Lebour. They are exposed in the small burn which crosses the Watling Street about half a mile W.S.W. of Bingfield. Leaving the road at this point and working up the stream for a quarter of a mile, or rather less, we see the main dyke exposed on the south side of the stream, where it is intrusive in encrinital limestone. The main mass is composed of a dark grey, or greenish-grey, finely crystalline rock, portions of which bear a very close resemblance to the ground-mass of the Tynemouth dyke. Porphyritic crystals of felspar are very rare, but not entirely absent. At the north-west margin there occurs a considerable thickness, perhaps 12 or 14 feet, of what appears to be highly altered whinstone. This varies in colour from a light grey to a dark greenish grey, with narrow zones of brown due to the segregation of iron oxides along bounding surfaces and joint-planes. The altered portion usually effervesces very freely with hydrochloric acid; and cracks and amygdaloidal cavities filled with calcite and chalcedony are very abundant. The total thickness of the dyke is about 20 or 25 feet.

Under the microscope the central and comparatively unaltered portions are seen to consist of long narrow lath-shaped felspars, irregular crystalline grains and plates of a nearly colourless pyroxene, and a small quantity of nearly opaque interstitial matter. The iron oxide does not seem to have separated out, but to have remained in solution in the paste until the final act of consolidation took place. This is probably only a local peculiarity (Pl. XII. fig. 6). The marginal portions of the dyke are so much altered that it is difficult to make out their original characters under the microscope. It is worthy of note, however, that the felspars are comparatively fresh even when the other constituents have lost all their original characters. The amygdaloids and veins of calcite and chalcedony do not call for any special description. The specific gravity of the rock is 2·9.

The Seaton and Hartley Dykes.

Literature.

Lebour, Prof. G. A. Geology of Northumberland, p. 48.
Ordnance Maps 105 N.E. and N.W.

In this district there are several parallel dykes running at short distances from each other in a direction slightly N. of W. and S. of E. They are exposed on the shore between Seaton and Hartley (one near the northern angle of the shore and another near the spring which rises on the shore), in the small valley to the west of the village, where they are now (1882) being quarried for road-metal, and also in the Shankhouse collieries further west. At page 48 of his 'Geology of Northumberland,' Prof. Lebour writes:—"In some cases the actual natural top or vertical dying-out of a dyke may be seen, as on the coast a little to the south of Seaton Sluice. Here, near a spring on the beach, a dyke, at least 12 feet in width where it rises at the foot of the cliff, is finely shown ending off in two tongues of basalt, the longest of which, after curving amongst disturbed and contorted shale, dies out about 11 feet from the ground beneath a bed of sandstone, which it had not the force to break through. The fault along which this dyke was injected is well seen continuing its upward course." At the time of my visit this section was obscure, but the same feature was exposed in a small quarry on the east side of the dene, a few hundred yards inland. The dyke here was about 10 feet wide at the bottom and 5 feet at the top of the quarry, the depth exposed being about 20 feet; it terminated upwards in an abrupt manner, and the indurated shales which were continuous over the top showed a slight upward arching. Macroscopically and microscopically the rock bears the closest resemblance to that last described.

Through the kindness of Messrs. Linsby and Ormsby, I was conducted to two exposures in the Shankhouse pit. The south dyke was here seen to be 7 or 8 feet wide, its centre being occupied by a rubbly mass containing angular fragments of whin and Coal-measure strata; Mr. Paterson, the overman, informed me that this was a common feature in the dykes of this district. I presume that the centre has in many cases been a plane of weakness, owing to cooling from opposite sides, and that subsequent movement has taken place along this plane, giving rise to a fault-breccia. The northern exposure in this colliery showed two parallel dykes, one measuring several feet and the other only 11 inches in thickness. These two dykes run together into one within the limits of the same royalty. The coal was much charred in the neighbourhood of the igneous rock, which was seen in one case to send off narrow irregular veins. The narrow dykes and veins were altered to the condition of "white trap" *.

Numerous specimens from these dykes as they are exposed on the shore near Seaton, in the dene, and in the Shankhouse pit have been examined both macroscopically and microscopically. Everywhere they present the same features. The rock is dark, in some cases almost black in colour and finely crystalline in texture. Porphyritic elements are very rare, but now and then crystals of felspar, similar to those of the Tynemouth rock and doubtless belonging to the same species, may be recognized. In some specimens the small spherical amygdaloids are not uncommon. Alteration at the surface gives rise to the characteristic brown colours; but in the pit these are never observed, the large amount of organic matter causing the water to act as a reducing, instead of an oxidizing agent. The specific gravity of the rock varies from 2·81 to 2·824.

Under the microscope one recognizes long narrow sections of plagioclase, irregular grains and plates of a colourless pyroxene, and a certain amount of interstitial matter rendered more or less opaque by various devitrification-products, and especially by small crystals, rods, and granules of magnetite. In some cases the ultimate base is seen to be a rich brown isotropic glass. The secondary products comprise, as usual, calcite, quartz, pyrites, and a yellowish-green substance giving aggregate polarization. The latter product, however, is by no means invariably present. A section of the white altered rock from the pit shows the felspar fresh, and the pyroxene replaced by calcite.

* Jukes, 'South Staffordshire Coal Field,' 2nd edit. p. 118.

Morpeth Dyke.

Literature.

Lebour, Prof. G. A. Geology of Northumberland, p. 48.
Ordnance Map 105 N.W.

Specimens of this dyke have been kindly given to me by Prof. Lebour. It crosses the Wansbeck a few yards below the viaduct of the North-Eastern Railway near Morpeth ('Geology of Northumberland,' p. 48). The rock is somewhat blacker and more closely crystalline than that of the dykes hitherto described; it is also denser, its specific gravity lying between 2·88 and 2·89. Crystals and crystalline granular aggregates of felspar (? anorthite) occur as porphyritic elements; but as they do not differ markedly in size from the larger felspars of the ground-mass, they are not so easily recognized in the hand-specimen as in the thin section.

Mr. Stead has analyzed the rock with the following result:—

Silica	51·20
Alumina	20·03
Ferric oxide	7·57
Lime	10·52
Magnesia	6·75
Potash	0·51
Soda	1·71
Water	1·70
	99·99

Under the microscope the rock is seen to have very close relations with that of the Tynemouth and the related dykes. There are the same porphyritic felspars and amygdaloids, although these are not nearly so abundant or so large as in the Tynemouth rock, and the same long lath-shaped felspar sections, irregular grains and plates of pyroxene, and interstitial matter, with its various devitrification-products. There is, however, one important point of difference: olivine, both fresh and in the form of a green and brown serpentinous pseudomorph, is comparatively abundant in this rock. This occurrence is of some interest, on account of the rarity of this mineral in the rocks described in this paper; indeed this is the only rock here referred to in which I have detected the mineral in an unaltered condition.

It must not be supposed, however, that this fact differentiates the Morpeth dyke from the dykes of Hebburn, Tynemouth, Brunton, Seaton, and Hartley; for in all other points there is the closest resemblance between them; and, moreover, pseudomorphs after olivine occur sparingly in the Tynemouth and probably also in the other dykes.

High-Green Dykes.

Literature.

Lebour, Prof. G. A. Geology of Northumberland, p. 50.
Ordnance Map 108 S.E.

Two dykes, presenting a type of structure in some respects different from that of any of those previously described, are exposed on the east side of the Tarret, near High Green, a farmhouse about 5 miles N.N.W. of Bellingham. My attention was first called to these dykes by Prof. Lebour, and subsequently Mr. Howell was kind enough to mark them in for me on my maps.

The first to be described strikes W. 10° S., E. 10° N., and crosses the Tarret Burn at a point W.S.W. of High Green. It is well exposed in the bed and along the sides of the stream, where it is about 50 feet thick. The central portions are coarsely and uniformly crystalline in texture; but the margins, where not highly altered, are finely crystalline or even compact. The only elements which can be distinctly made out with a hand-lens are felspar and pyrites, the latter mineral occurring very sparingly and only in certain specimens.

Its specific gravity lies between 2·9 and 2·93, and its chemical composition, as determined by Mr. Stead, is as follows:—

Silica	53·70
Alumina	18·21
Ferric oxide	10·64
Lime	6·66
Magnesia................	5·24
Potash	0·99
Soda	2·65
Water	1·55
	99·64

One of the most interesting features connected with this dyke is its mode of alteration at the north margin. The rock there shows a cellular structure, evidently connected with its mode of jointing. The walls of the cells are formed of a deep brown and comparatively hard substance, evidently rich in hydrated ferric oxide, while the cells themselves are filled with a friable white or cream-coloured material. On analysis these two substances yielded to Mr. Stead the following results:—

	Cell-walls.	Cell-contents.
Silica	43·50	66·20
Alumina	14·61	23·92
Ferric oxide......	31·14	0·78
Lime............	0·44	0·95
Magnesia	0·11	0·33
Carbonic acid	....	traces
Potash	0·09	0·04
Soda	0·26	0·57
Water	9·50	7·00
	99·65	99·79

On comparing these analyses with each other, and with the analysis of the comparatively unaltered rock, we see that the effect of the alteration has been to remove the alkalies and alkaline earths, to introduce water, and to concentrate the iron in the form of hydrated peroxide along the margins of the joint-planes. It is not difficult to trace the probable steps by which these results have been brought about. In the first place the silicates would be decomposed by the action of water charged with carbonic acid; and the carbonates of lime, magnesia, and iron thus formed would be in part held in solution by an excess of carbonic acid. This solution would come into contact with oxygen along the joint-planes, and hydrated ferric oxide would be precipitated. Diffusion would tend to cause the carbonate of iron held in solution in the interior of the cells to move outwards, and thus fresh portions would be brought under the influence of the oxygen, obtaining access by means of the joint-planes, and a further precipitation of ferric oxide would take place. This process would be continued until the whole of the iron had been removed from the interior of the cell, and concentrated in the neighbourhood of the joint-planes. In short the action would be analogous to that described by Prof. Judd as having taken place in the case of the Northamptonshire iron-ore*. The carbonates of lime and magnesia would of course also be removed from the interior of the cells; but as there would be no chemical action tending to separate the lime and magnesia at the joint-planes, these bases would be completely removed by the percolating waters. Here, then, we witness the result of an interesting chemical operation: iron is separated from lime and magnesia by the action of oxygen on a solution of the carbonates; iron is precipitated as ferric oxide, while the carbonates of lime and magnesia remain in solution.

We return now to the description of the unaltered rock. Under the microscope (Pl. XIII. fig. 2) one recognizes felspar, pyroxene, and large plates of an opaque mineral, which appears to be ilmenite †, also colourless prisms of apatite. The rock is composed almost entirely of crystalline elements, and in structure is eminently diabasic (*structure ophitique* of Lévy and Fouqué and *diabasisch-körnig* of Rosenbusch).

Felspar.—This mineral occurs in lath-shaped sections, usually three or four times as long as broad. In the Tynemouth dyke and its associates the corresponding felspars, as we have seen, are very long in proportion to their width. Another point of difference lies in the fact that the felspars in the High-Green dyke are more or less altered, while those in the altered portions of the Tynemouth dyke are comparatively fresh. This probably indicates an important difference in chemical composition. Under polarized light, and in cases where the alteration has not proceeded so far as to destroy all individual action, the crystals are seen to consist of binary, or more frequently of multiple twins.

Pyroxene occurs as isolated crystalline grains and irregular plates;

* 'Geology of Rutland,' p. 133.

† Titanic acid was not estimated in the analysis, and is therefore weighed in part with the silica and in part with the alumina and iron.

but more frequently as crystalline granular aggregates. It appears, in the thin section, of a pale brown colour. Twinning is common, and the prismatic cleavages are usually well marked. The lath-shaped sections frequently interpenetrate the pyroxene, thus giving rise to the diabasic structure.

Ilmenite.—This occurs in large opaque plates of great irregularity, interpenetrated by the other crystalline elements. The habit of this mineral in the High-Green rock is exactly the same as in the diabases of the Hartz, Nassau, and Saxony, except that it is not altered into the white silico-titanate of lime.

The most important secondary product is a greenish serpentinous mineral containing specks and veins of opacite. This may possibly be a pseudomorph after olivine.

Rather more than a mile to the north of the dyke just described is another having a somewhat similar character. It is well exposed in an old quarry on the east side of the Tarret Burn, where it is 20 or 30 feet wide, and weathers in a markedly spheroidal manner. The rock is black in colour and distinctly crystalline in texture. Porphyritic elements are not distinctly recognizable by the naked eye; but under the microscope two generations of felspar are at once seen to be present.

The original constituents are felspar, pyroxene, ilmenite, apatite, and possibly also olivine. A very small quantity of a pale brown isotropic glass is present. If we except the earlier generation of felspars and the small quantity of isotropic glass, then there is the closest resemblance between this rock and that of the more southern dyke. The other constituents have the same individual characteristics and are similarly related to each other; they do not therefore call for any special description.

The felspars which give the porphyritic character to the rocks are few in number, and may be distinguished from the others by their form and by the presence of a large number of irregular ramifying inclusions of the ground-mass. The specific gravity of the rock is 2·92.

Acklington Dyke.

Literature.

Lebour, Prof. G. A. Geology of Northumberland, p. 49.
Ordnance Maps 109 S.W. and 108 N.E.

The course of this dyke is thus described by Prof. Lebour:—"It stretches across the entire width of the country from the coast at Boudicar, near Acklington, cutting through Coal-measures, Millstone Grit, the whole of the Bernicians, the Tuedians, and the Cheviot porphyrites. . . . . it runs on for many miles across the south of Scotland. It is well seen at numberless places along its course, notably at Debdon, Cartington Castle, and the road along the Coquet, near Shillmoor. At Acklington it is 30 feet wide."

I have examined it myself at the point where it crosses the Coquet, half a mile above the Mill, near Acklington Park, and again at two points near Newton and Clennel, 17 or 18 miles further west. Also on the hills about 2 miles north-west of Alwinton, at the point where it crosses the Usway, half a mile above Shillmoor Farm, and, lastly, in the road along the Coquet, one mile above Shillmoor. At the two last-mentioned exposures the dyke is intrusive in Cheviot porphyrites.

Observations based on numerous specimens collected from the above localities prove that the rock of this dyke, like that of the Cleveland, Cockfield, and Armathwaite dyke, is remarkably constant, both in its macroscopic and microscopic characters, throughout the entire length examined. It is distinctly crystalline in texture, and of a bluish-grey colour when freshly broken. The colour, however, rapidly changes to black on exposure. Porphyritic crystals of felspar are not to be recognized by macroscopic examination; and in this respect there is a marked difference between the Acklington and Cleveland dykes. Determinations of the specific gravity of specimens from each of the above localities were made, with results varying from 2·805 to 2·817. The average may be taken as 2·81; and the deviations from this average, therefore, do not appear to reach more than two fifths per cent. Mr. Stead has analyzed the rock with the following result:—

Silica	57·80
Alumina	16·18
Ferric oxide*	10·07
Lime	6·18
Magnesia	4·68
Potash	0·77
Soda	2·38
Water	1·70
	99·76

Under the microscope the original constituents are seen to comprise felspar, pyroxene, magnetite, and interstitial matter, with various devitrification-products. The general structure reminds one of the ground-mass of the Cleveland, Cockfield, and Armathwaite dyke, except that the interstitial matter in this case is much less abundant.

Felspar.—The prevailing felspar occurs in lath-shaped sections similar in every respect to the small felspars of the Cleveland dyke. A detailed description is therefore unnecessary. In the majority of slides examined these are the only felspars to be recognized; but in one or two other forms occur which belong to an earlier generation, and therefore give the rocks a porphyritic character. These give sections more equal in the different directions; they contain numerous inclusions, and are usually composed of a central nucleus and a peripheral zone, which extinguish in slightly different positions.

Pyroxene occurs in crystalline grains and small imperfectly developed crystals, the latter sometimes elongated in the direction of the

* Total iron reckoned as Fe_2O_3.

vertical axis. Twinning is common, and cleavages are sometimes well shown. In thin sections this mineral is almost colourless.

Magnetite is present as small crystals, grains, and skeleton-crystals.

The interstitial matter is similar in every respect to that which is so common in the Cleveland dyke, and does not therefore call for special description. The secondary products are calcite and quartz. Pyrites also occurs. Amygdaloidal cavities containing a crystal of calcite surrounded by a narrow zone of chloritic material are found both at Debdon and Clennel.

The dyke is not known to intersect any formation of later date than the Coal-measures; but from the fact that it bears a close resemblance in character and direction to that of Cleveland, I am disposed to regard it as of Tertiary age.

Conclusion.

If we reconsider the facts recorded above, it will appear that the dykes to which reference has been made fall into four more or less distinct groups:—

1. (*a*) Cockfield, Cleveland, and Armathwaite dyke.
   (*b*) Acklington dyke.
2. The Hett and related dykes. including the "sill" in the Browny and Page-Bank collieries.
3. (*a*) The Hebburn dyke.
   (*b*) The Tynemouth dyke.
   (*c*) The Brunton dyke.
   (*d*) The Seaton and Hartley dykes.
   (*e*) The Morpeth dyke.
4. The High-Green dykes.

Groups 1 and 3 resemble each other in chemical composition and specific gravity; so also do groups 2 and 4. The former have a silica percentage varying from 57 to 59, if we except the somewhat abnormal Morpeth dyke (which appears in other respects to belong to group 3), and a specific gravity of about 2·7 or 2·8; the latter have a silica percentage varying from 51 to 53, and a somewhat higher specific gravity. Groups 1 and 3 are distinguished from each other by certain peculiarities of microscopic structure, which may or may not be related to a difference in geological age.

Groups 2 and 4 are closely related both in composition and structure, the principal difference being a pathological one. Alteration-products abound in group 4, but are for the most part absent from group 2.

If we consider the dykes with reference to the structures indicated by the terms "porphyritic," "granular," and "holocrystalline," as these are used by Prof. Rosenbusch, we find that the Hett and the High-Green dykes are almost, though not entirely, holocrystalline and granular; whereas the others contain a considerable amount of indistinctly individualized matter. All the dykes show occasional traces of two generations of felspar; but the only ones which are conspicuously porphyritic are those of Cleveland and Tynemouth.

The observations which have been made on the Cleveland, Acklington, and Hett dykes prove that the minute characters, both of composition and structure, are constant throughout great distances, and bear no relation to the surrounding rocks. These observations do not lend any support to the view that the igneous matter has taken up any appreciable portion of the sedimentary material into which it has penetrated. If we endeavour to give names to the rocks here described we are met by the difficulty arising from the absence of unanimity among petrologists as to the use of such terms as basalt, dolerite, augite-andesite, augite-porphyrite, diabase, and melaphyre.

In this country we find it quite impossible to apply any system of classification which primarily depends on a distinction between pre-Tertiary and post-Tertiary rocks, for the following reasons:—(1) The age of many of our eruptive rocks, including some of the dykes here referred to, cannot be determined by field-evidence; (2) rocks identical both in structure and composition, and belonging to the basic, intermediate, and acidic groups, have been formed at widely separated intervals of geological time.

If we assume, for the purpose of indicating the relations of our rocks with those of thec ontinent, that groups 2, 3, and 4 are of pre-Tertiary age, then the Hett and High-Green dykes would have affinities with the diabases and augite-porphyrites, but would be more allied to the former than the latter. The High-Green dyke might almost be called a typical diabase; for the interstitial matter is hardly present in recognizable quantity, and the porphyritic felspars are very few and far between; they cannot be recognized without the microscope. In the mode of alteration of the rock and the character of the ilmenite it exactly resembles many of the continental diabases. The dyke to the north of High Green is more distinctly porphyritic, and indicates, therefore, a transition from the diabases to the melaphyres.

The dykes of group 3 would, on the continent, be described as melaphyres; indeed Prof. Rosenbusch speaks of a rock from Newcastle-on-Tyne, probably a portion of the Tynemouth and Coleyhill dyke, as a true melaphyre ('Massige Gesteine,' p. 410).

It is worthy of note that many of the rocks to which the term "melaphyre" has been applied have a higher silica percentage (about 56 per cent.) than dolerites and basalts. Thus they are described in the older petrology as consisting essentially of oligoclase and augite, whereas the felspar in the basalts is described as labradorite (Zirkel, Lehrb. d. Petrogr. 1866, Band ii. p. 39). If this view were generally accepted, then the melaphyres would bear the same relation to the augite-andesites as the diabases do to the dolerites.

The Cleveland, Cockfield, and Armathwaite dyke in composition, structure, and geological age is a pyroxene-andesite; and as the pyroxene is monoclinic, it may fairly be called an augite-andesite.

The classification of the rocks referred to in this paper would be greatly facilitated if we had a ready method of determining the felspars. Unfortunately we appear to have no such method. I have tried both alterability by acid and the method of extinction, as recommended by Messrs. Lévy and Fouqué. The results, however, have not been such as to give me confidence in their general applicability. When the crystals are sufficiently large to enable one to isolate fragments, then specific-gravity determinations and optical tests yield results which are doubtless thoroughly reliable. In conclusion I would remark that any system of classification, to be natural, should take into consideration all the characters of igneous rocks—chemical composition, mineralogical composition, microscopic structure, and mode of occurrence; and that in estimating the relative value of these characters great importance should be attached to the fact that the chemical composition of unaltered specimens is that of the original magma, by the consolidation of which the rock in question has been produced.

EXPLANATION OF PLATES XII. & XIII.

Plate XII.

Fig. 1. Cleveland dyke, centre: ×50. Portion of a porphyritic felspar in top right-hand corner. The remainder of the figure illustrates the general structure of the ground-mass. Crystals of felspar, grains and granular aggregates of augite, magnetite, and interstitial matter may be recognized.

2. Cleveland dyke, margin: ×50. Broken and corroded felspar in the top right-hand corner. General structure of the ground-mass shown in the remainder of the figure. Compare with fig 1.

2 *a*. Armathwaite dyke: ×350. Portion of glassy base showing a small augite surrounded by longulites and globulites. Longulites formed by the coalescence of globulites. The small augite runs out into microlites.

3. Cleveland dyke, Preston: ×20. Large felspar zoned by inclusions and penetrated by inlets of the ground-mass.

4 *a*. Cleveland dyke, Preston: ×170. Skeleton felspars in the ground-mass.

4 *b*. Cleveland dyke, Preston: ×170. Structures observed in the interstitial matter.

5. Hett dyke, Hett village: ×40. Illustrating structure of the Hett and related dykes. Augite, felspar, and magnetite make up almost all the whole mass of the rock, and may be recognized in the figure. A patch of augite granules occurs in the centre.

6. Brunton dyke, Bingfield: ×40. Illustrating structure of the ground-mass of the Tynemouth and related dykes. The figure shows long narrow felspar sections, irregular grains and granular aggregrates of augite, and interstitial matter, rendered nearly opaque by imperfectly individualized magnetite.

PLATE XIII.

Fig. 1. Tynemouth dyke. Nicols crossed: ×20. A portion of one of the granular aggregates of anorthite is represented in the bottom right-hand portion. It is partially zoned with felspar, having different optical properties; but this zone is not continued between two contiguous grains of anorthite. Two amygdaloids occur in the top left-hand portion of the figure. The outer zone of the larger amygdaloid is formed of quartz. The ground-mass is composed of long lath-shaped felspars, bright-coloured augite grains, and dark interstitial matter, which is nearly opaque in this section, even when viewed with ordinary light. The figure illustrates the typical structure of the Tynemouth and related dykes.

Fig. 2. High-Green dyke, High Green: ×30. Ordinary light felspar, augite, and ilmenite. Structure that of a typical diabase. Brown tint of the augite somewhat exaggerated.

DISCUSSION.

The PRESIDENT remarked upon the exhaustive treatment of his subject by the Author.

Mr. TOPLEY pointed out that very little had been done by previous authors in describing these dykes. He said that in the Acklington dykes chlorophæite had been detected for the first time in England. Some of the dykes are probably of Miocene age, while of others the age is doubtful. The question of the absorption of the aqueous rocks by igneous rocks, especially basalt, is one of very great interest to geologists—the stratigraphical and chemical evidence seeming to be at variance.

The Rev. E. HILL pointed out the difference between the cases when the dyke was simply filled from below, and when the fissure formed a channel for the upward passage of the molten matter.

Mr. MARR referred to the existence of diabase dykes in Bohemia, in which fragments of Orthoceratites were found intact.

Prof. JUDD congratulated the Author on his very valuable contribution to petrographical science. He pointed out some of the difficulties in accepting the theory of the absorption of stratified material by igneous rocks.

The AUTHOR called attention to an angular fragment of sandstone included in the rock of the Cleveland dyke. It did not lend any support to the view that absorption of sedimentary rocks had taken place. He admitted that certain stratigraphical facts appeared to point to an opposite conclusion, and instanced the manner in which certain dykes terminate beneath the surface. He considered, however, that the balance of evidence at present was against the idea of absorption to any appreciable extent.

14. *The* Droitwich Brine-springs *and* Saliferous Marls. By C. Parkinson, Esq., F.G.S. (Read December 19, 1883.)

The valley of Droitwich lies in the lowest part of a trough, the Upper Keuper Marls partly filling up a deep depression in the lower Trias and Permian rocks. The geographical direction of the valley is from N.E. to S.W., taking a westward turn through the town of Droitwich itself. It is in the Red Marls that brine-springs are met with—a source of considerable wealth to the surrounding population, but, on the other hand, the cause of great depreciation in the value of land and house property within the borough of Droitwich.

As we pass through the town by the Birmingham and Bristol line of the Midland railway, a strange scene of dilapidation lies before us. Every chimney is out of the perpendicular; houses appear to be sinking in, and signs of active subsidence show themselves on every side; the very ground over which the line passes hardly seems safe from a sudden collapse. Standing in the churchyard of Dodderhill*, an eminence nearly overlooking the town and valley, it is possible to trace the line of country which is so affected by the extraction of salt, the probable area of the brine-basin of this locality. From the evidence afforded by this subsidence, and from experimental borings, the width of this area does not exceed 300 yards, while the length, so far as has been ascertained, is about 6 miles—this length extending from Stoke, 4½ miles N.E. of Droitwich, to a point not far beyond the town, S.W. or W. This area represents the district productive of brine-springs or rock-salt in quantity or quality which may be worked at remunerative cost. The saliferous marl, however, passes in a line just missing Worcester; and on Defford Common, 12 miles south-west of Droitwich, weak brine-springs have been tapped. The same may be said of Bromyard, on the Hereford side of the county; all attempts have failed to extract the salt anywhere west or south-west of Droitwich. In a N.E. direction, at Stoke works, the brine is even stronger than at Droitwich.

That further mischief in the way of land-subsidence may be expected in Droitwich and some outlying farms &c. is evident from an examination of the centre of the town itself. In High Street, between the parish church and a point where the Worcester road joins the street, a deep depression occurs. Twenty years ago water ran down this street in exactly the opposite direction; and recent cracks in the Royal Hotel and other houses (in fact every one) show that a gradual subsidence still goes on; the canal-level has sunk 4 feet 9 inches in the five years. Further than this, at a place below the last lock from the Stoke side there are 20 feet of mud on the original bed of the canal, showing a subsidence which has occurred chiefly within the last 15 years. I think that in this immediate vicinity considerable danger exists of some extensive and

* Both church and vicarage being in a most insecure position.

sudden fall. Again, south-west of the town, over Yew-Tree Hill, the fields subside so rapidly that a farmer informed me he could no longer cultivate his land at that part (a strip from 10 to 15 yards across). For $1\frac{1}{2}$ mile a subsidence appears in this direction, showing that brine is extracted from underneath this hill, or that a cavity exists here. Across the garden of the Venerable Archdeacon Lea, nearer to Droitwich, the same depression may be noted. Twenty feet from the surface, a well in his garden * has a crack across it into which a man can crawl; this is in the Keuper Marls; and a similar cavity may be seen in a well at Rashwood, on the other side of Droitwich. As a man can insert his body into this cavity, it cannot be less than 2–3 feet.

The saliferous Red Marl is numbered A 2 in the Triassic series, as shown in the Geological Survey Report †. In order to understand the position of these Keuper Marls of the Droitwich district it is necessary to examine slightly the succession of Trias and Permian strata from the ridges of the Lickey and Clent hills, which form the southern boundary, to the Dudley Coal-fields. The Lickey Hills are of Permian rocks, which, having a southerly dip, disappear beneath the New Red Sandstones (Lower Keuper, A 3) of the Trias series, in the direction of Bromsgrove. A fine section of this Lower Keuper Sandstone is exposed in the railway-cutting at Bromsgrove station. In these beds, I believe, the peculiar fossil fish *Dipteronotus cyphus* was discovered, and was described by Sir Philip Egerton ‡ as forming a new genus. The Lower Keuper Sandstones dip slightly to the south, and are bounded east and west by marked faults, the Upper Keuper Marls filling up a trough, Droitwich being at about the lowest part. The total fall from the higher Lickey Hills, through Bromsgrove and Stoke, is not less than 800 feet, a point of some importance in connexion with the brine-springs of Droitwich. A small stream, the Salwarpe, rising in the Lickey Hills, passes through the valley. There is also a branch canal through Droitwich from the Worcester and Birmingham Canal, running almost parallel with the railway. The gradient of the Midland line from Droitwich to the top of the Lickey incline cannot be less than 1 in 70, the section from Bromsgrove station to the Lickey being one of the steepest inclines on any line of railway in England.

From Stoke works to Droitwich there are twelve canal-locks, each having a fall of about 6 feet, the distance being $4\frac{1}{2}$ miles. These details afford us some means of estimating the difference in level from the Lickey to Bromsgrove, to the Stoke works, and on to Droitwich.

For over a thousand years salt has been extracted from the marls of this locality. Salt-furnaces are mentioned in ancient records from A.D. 816 ‖. It is certain, however, that the salt supply

* The Archdeacon kindly offered me a seat in the bucket to inspect this crack or cavity.

† Hull, Geol. Survey Reports, vol. viii. Trias and Permian Rocks, p. 10.

‡ Quart. Journ. Geol. Soc. vol. x. p. 369.

‖ Nash, Hist. Worcester, vol. i., Section on Droitwich.

in early days was only such as could be worked at or near the surface. It was not till 1725 that salt-springs below the gypsum bands were discovered; and Dr. Nash, the historian, states that for a long time fully nine tenths of the natural supply ran to waste through the Salwarpe into the Severn. In 1779 one Richard Norris sank a well through the Red Marl and gypsum, striking a brine-spring, apparently 80 feet from the surface. With such force did the water rush upwards that either one or two workmen lost their lives, being unable to escape the flowing spring; the force of the water is, I think, a point to be noted. Of this well Dr. Nash gives the following rough section:—

5 feet	Mould.
35 ,,	Marl.
40 ,,	Talc.
22 inches	Brine-river.
75 feet	Talc.
5 ,,	Rock-salt.

The talc mentioned is no doubt gypsum, which occurs in veins of different thickness in the Red Marls.

Within the last twenty-five or thirty years the character of the brine-pits has completely changed. The old pits, Walker's, Walwyn's, Romney's, Stuckey's, and Farley's, named by Mr. Horner, F.R.S., in his paper *, are entirely lost sight of. Even twenty-five years ago the brine welled up to the surface in certain pits, a great quantity running to waste. It is now pumped up by engines from a depth of 210–220 feet in Droitwich, and at Stoke works from a depth of from 800 to 1000 feet, showing a remarkable difference, when we consider the fact of the two places being within 5 miles. At the surface, therefore, we find no traces of brine at the present time, while many of the old pits are either closed or abandoned. No doubt the supply of brine nearer the surface failed as soon as steam-pumps tapped the lower source of the springs. About 36 borings have been worked, but a few only remain in full activity.

The section I now give may be taken as a representative one in the immediate valley of Droitwich, since the newer machinery has been used in boring and pumping. The area is limited where a sufficient supply of brine can be reached; it is, indeed, within the narrow strip before mentioned, 300 yards wide, running through the centre of the town, where the signs of subsidence are most evident; a natural reservoir, 210–220 feet below the surface, has been discovered here. Repeated borings have clearly proved where the deepest cavity exists, which gradually shelves off at each side, while, outside of this area, a boring of over 300 feet † fails to touch either a cavity or brine-springs, though several feet of rock-salt are found in places.

My section commences with a black peaty soil followed by quicksands and gravel base; the black alluvial soils are only met with in the valley watered by the river Salwarpe. The quicksands are

* Leonard Horner, "Account of the Brine-springs at Droitwich," Trans. Geol. Soc. ser. 1, vol. ii. p. 94.

† I think a deeper boring would probably reach rock-salt.

not always present; they average 6 feet, sometimes being as much as 10 feet. Springs are always found here, and extend down 60–70 feet into the marls. These springs are fresh, occasionally brackish. The real work of boring commences some 30 feet from the surface; but away from the valley the Red Marls are much nearer to the top. The quicksands, it should be stated, occur also in Cheshire *.

Section of most recent boring at the works of the Droitwich Salt Company. (Details supplied by the engineer and the man who actually assisted in the work.)

	15–20 feet.	Black peaty soils, varying in thickness in different parts of the valley.
	6 feet.	Quicksands, with fresh springs.
	3 feet.	Base of gravel, loose stones and sand.
	40 feet.	Red Marls, alternating with shaly greyish beds of a few inches; few, if any, traces of salt.
210–220 feet.	140 feet.	Springs to 60–70 feet from surface. Bands of gypsum occur irregularly. Red Marls with traces of salt crystals. Irregular accumulations of rock-salt. Lower marls, intermixed with sand of a harder texture.
	1–1½ foot.	Intensely hard crust of gypsum.
	6–9 feet.	Salt springs from a cavity.

The Red Keuper Marls (an admirable section is exposed in the cutting at Rainbow Hill, Worcester station), through which the real boring-operations commence, are bright in colour, friable and regularly stratified; some bands appear to be of an inferior sandstone, shaly in character, and intermixed with thin bands of greyish or micaceous sandy beds, also shaly. As far as fresh springs are met with, salt appears to be absent. Bands of gypsum occur irregularly; these are intermixed with red marls, having traces of salt crystals.

Accumulations of rock-salt of several feet are met with in some borings. The lower marls become harder in texture and are mixed with sand and gypsum. At about 210 feet the hard crust above the brine occurs, a sure indication that the springs are reached. The steel bore rebounds again from its contact with this hard, gypseous bed, from 1 foot to 1 foot 6 inches thick.

Immediately the hard band is pierced the steel rods fall through a cavity; in the instance I inquired into, a drop of 9 feet. The

* Section, Geol. Survey Report, vol. viii. Hull's Trias, chap. ix. p. 110 (1864).

brine at once flows up with great force. Fourteen feet is the deepest part as yet discovered; at either side of the 300 yards depression the spring cavity is about 4 feet. Underneath this a boring has never yet been made, and we can only judge, from the deeper shafts at Stoke works, the probable strata over which the brine-cavity exists. The extent of the natural brine-river, or reservoir, can hardly be ascertained; but it cannot be less in breadth than 200 yards, and half a mile in length; that other cavities are under Yew-tree Hill, Rashwood, and other parts is certain from the rapid subsidence. Possibly some communication by a small stream exists between each basin, in a line already indicated, viz. N.E. to S.W. What are now empty cavities have, no doubt, previously been solid accumulations of rock-salt.

In the section given by Dr. Nash we find that a brine-spring was struck some 80 feet from the surface, a cavity of 22 inches only being met with; but the boring was apparently continued another 80 feet to rock-salt. This was a spring which must have forced its way upwards before the more recent borings tapped the deeper supply; no trace of a brine-spring now remains at that depth. I am of opinion that some considerable beds of rock-salt exist at a greater depth than 210–220 feet, lying more in the N.E. direction towards Stoke works. This is somewhat proved by the remarkable difference in the wells at Stoke*.

At first when the salt at Stoke was discovered, it was from the rock-salt beds that the salt was extracted, and not from the evaporation of brine-springs. In beds of red marl, grey marl, and gypsum, of 800 feet (at the least), several bands of excellent rock-salt are found.

270 feet down a bed 15 feet in thickness is passed of intensely hard sandstone, which tests the strength of the steel rods and renders progress extremely slow. I think that this is probably the immediate base of the brine-cavities at Droitwich ($4\frac{1}{2}$ miles further down the valley), and that the seam of rock-salt above is absolutely carried away by brine-springs at Droitwich and remains solid at Stoke. Several hundred feet below this hard portion, 25 feet are bored through softer marls, sandstones, and rock-salt, till brine-springs are tapped at least 800 feet from the surface. Even at this depth the salt was formerly got by mining operations, till the brine-springs (as Mr. Corbett, M.P., has informed me) suddenly broke through, rendering further extraction of rock-salt impossible; this supply of brine has never failed. I have remarked on the manner the brine wells up with such great force both at Droitwich and Stoke when the springs are struck. This leads to the question of the water-supply necessary to permeate the rock-salt and produce such a remarkable pressure.

In the first place the supply never varies. On the other hand the Droitwich water-works, the supply of water being from the Keuper Marls and surface springs, cannot always keep up their supply.

* Information of which has been placed at my disposal through the kindness of J. Corbett, Esq., M.P., Droitwich.

In dry seasons their water fails, and at this very time (September 1883) only a partial supply is obtainable. The brine-springs remain as strong as ever. This fact, together with the force noted in the brine-springs, affords strong evidence that the water-systems are separate. I believe the brine-springs are derived from the Bunter Sandstones of the Lickey Hills, where the immense supply of pure water is obtained for Birmingham, and where the river Salwarpe, flowing through Stoke and Droitwich, rises. The great difference in elevation at once gives us an explanation of the force which permeates the rock-salts intervening, and supplies the brine-springs of such remarkable force.

Turning to the chemical composition of the brine, the extraordinary strength of it is at once noticeable. Taking the solid constituents contained in 10,000 parts of sea-water, we find:—

Mediterranean	410	grains.
English Channel	380	„
German Ocean	325	„
Baltic	168	„

The Dead Sea 24·6 per cent. solid matter*.

Droitwich brine, 38–40 per cent. at Droitwich and Stoke respectively.

As 42 is the absolute saturation-point of common salt, the strength of the brine is apparent. Mr. Corbett further informs me that he has known the Stoke brine to be of such strength that salt would not dissolve in it, a proof of the brine being absolutely saturated.

At Droitwich the strength of the brine varies slightly. If the springs are worked incessantly for two or three days, the brine will be perhaps half a degree less strong: this is explained by the surface-springs getting mixed with the brine-water if the pressure from below becomes less. At Stoke, where the boring is better protected and cased with iron, to prevent the surface-springs getting in, no variation occurs in the brine.

The Cheshire brine contains, I believe, from 34 to 36 per cent. of solid salt. The explanation of the decrease between the strength of the Cheshire and Worcester springs is, that the former have been overworked, the rock-salt not having been so thoroughly dissolved by the springs.

Analyses of Droitwich brine, showing the solid constituents in the imperial gallon, have been made by various authorities. I give the more recent as follows:—

Northcote, Phil. Mag. 1855, ser. 4, vol. ix. p. 33:

Chloride of sodium	19392·570
Carbonate of magnesia	33·501
Carbonate of soda	115·123
Sulphate of lime	307·282
Sulphate of soda	309·097
Traces of bromide of magnesia	......
Salts in imp. gallon	20157·573

* Mr. Bainbrigge, Droitwich Springs, chap. i.

D. W. Taylor, 1854:

Chloride of sodium	21509·77
Chloride of magnesium	101·22
Sulphate of lime	302·15
Sulphate of soda	319·50
Silicate of soda	1·36
Traces of bromide of magnesium	......
,, iodide of sodium	......
,, protoxide of iron	......
Salts in gallon	22234·00

As far back as 1815 (*vide* Trans. Geol. Soc. ser. 1, vol. ii. p. 107) Mr. Horner gave an analysis with somewhat similar proportions.

Dr. H. Swete informs me that his analysis, as County Analyst, agrees with those above given, except in unimportant details.

The chemical action of the brine on most metals is very strong. A strong iron pipe corrodes to such an extent that the piping can be cut through with a knife like so much soap. Marble slabs gradually become pulverized by the brine, and all cements are eaten away. If mixed with ordinary water (3 of water to 1 of brine) and boiled in a copper vessel, it produces a precipitate, the water coming out a brilliant blue, while the vessel remains discoloured.

No traces of organic life have been discovered in the Droitwich Keuper Marls, although the small Crustacean bivalve *Estheria minuta* (Brown) belongs to the uppermost Keuper sandstones * and has been found in Worcestershire; the same fossil occurs in the Muschelkalk of the continent †, and probably existed in the Keuper-Marl period. Four Saurians are also named by Sir Charles Lyell as Upper Keuper fossils. The *Hyperodapedon*, discovered near Warwick, in Devon, in Central Asia, and South Africa, in rocks of the Triassic period (the Warwick and Devon rocks being of Keuper age), has been referred by Prof. Huxley to a terrestrial reptile closely allied to the New-Zealand living *Sphenodon*‡. At the base of the Cheshire rock-salts and Marls we find the "waterstones," both ripple-marked and having the footprints of reptiles. I do not know whether the "waterstones" have been observed in Worcestershire; but as the Cheshire and South Midland Saliferous Marls must have been one before the upheaval of the Permian and Bunter ridges across the country, the reptilian footprints and ripple-marks, taken with the reptiles of the uppermost Keuper Sandstones, afford us some slight indication of the fauna of that period and the conditions under which the animals lived. The ripple-marks give evidence, I suppose, of a tidal waste, occasionally covered by the sea-water, when the impressions or footprints of reptiles have been covered with mud and preserved to us in the Cheshire waterstones. The existence of reptiles would seem to point to some considerable tracts of land during the Upper Keuper period (the sandstones of Upper Keuper

* Lyell, 'Elements of Geol.' p. 358. † Ibid. p. 369. ‡ Ibid. p. 358.

age, named by Sir Charles Lyell, must have been nearly, if not quite, of the same period as the marls).

It is probable that at the close of the Bunter period in Britain a marked elevation took place, raising the Triassic formation above the ocean, this explaining the entire absence of the Middle Trias or Muschelkalk series *.

In the Keuper age this area was again submerged, a sedimentary deposit being formed which is now the Lower Keuper. It was probably in a series of inland lakes, or lagoons separated by barriers from the sea, that the saliferous red marls and rock-salts were formed. The red Keuper deposits were perhaps detritus from older gneiss and mica-schists † carried down by rivers containing salts. The salts spread in a sediment with the detritus in the lake-bottom from which the waters evaporated ; subsequent changes might easily account for the solid formation of rock-salts, the nature of the waters explaining the curious absence of organic remains in the saliferous marls. The Droitwich brine-springs being of even greater strength than the waters of the Dead Sea, indicate some similar conditions as to their origin, the Great Salt Lake of America giving even a better example of what was the origin of the Keuper lakes.

Deposits of salt occur in other formations, such as Magnesian Limestones and the blue clays of Sicily, but I cannot think that there is a general cause accounting for their occurrence. Certainly in some of the continental beds the origin has more likely been from hot springs. With regard to the red Keuper saliferous marls being for the most part unfossiliferous, an observation of Sir Charles Lyell's is of interest ‡, that no stratified rocks containing a very large amount of oxide of iron have many fossil remains ; when we find fossils it is more in the grey or calcareous bands. Possibly the oxide of iron becomes an agent of destruction as it permeates the deposits. An instance bearing on the point came under my own observation in the Greensands of the Isle of Wight. In the Atherfield brown clays and grey cracker-rocks the Mollusca are beautifully preserved : at the base of the Shanklin sands, which are strongly impregnated with oxide of iron, most of the Atherfield Mollusca occur ; but casts only remain, no traces of a shell ever being found ; and even the casts crumble away immediately they are exposed to the atmosphere. So in the Keuper age, if crustaceans, mollusks, or any organic structure could exist in the waters of the saliferous marls, they would probably be destroyed by the oxide of iron ; any remains left would in all probability be from grey bands or gypsum ; in fact I believe certain Foraminifera have been discovered in the gypsum, though not in the neighbourhood of Droitwich.

There is one more remarkable point which calls for mention in the stratification of the red saliferous marls. Marked lines are visible in exposed sections, showing the many subdivisions and different-coloured bands. The red marl bands mostly show signs of some

* Hull, memoir before referred to, p. 106.

† Sir C. Lyell, 'Elements of Geol.' p. 362.

‡ Elements of Geol. p. 363.

violent fracture, as if, in some sudden upheaval (such as must have occurred when the Cheshire marls became separated from the Southern Midlands), the less compact bands were dissevered at right angles to the lines of stratification; the harder sandstones do not show any such indications. I have noticed something similar to this in the limestone districts of North Wales.

In conclusion, the calculation has been made that some 2 million tons of salt have been extracted at Droitwich and Stoke in the last 20 years through the working of the brine-springs, a further proof of the empty cavities which have been gradually created beneath the town, and showing how such spaces are constantly enlarging and extending all round.

In this paper I have merely attempted to show:—

1. The extent of the brine-cavities beneath Droitwich, and the consequent insecurity of the greater part of the town.

2. The probable sourse of the brine-water system, as distinct from the Keuper springs.

3. The probability of extensive beds of rock-salt lower than the present brine-cavities, and to the N.E. of Droitwich, partly proved by the deeper borings at Stoke works.

4. The details of more recent borings at Droitwich and Stoke works.

Discussion.

Capt. Douglas Galton said that for every ton of salt at Droitwich 900 gallons of water were pumped, a quantity sufficient to exhaust the rainfall of about six square miles, and that whilst formerly the Droitwich brine-springs overflowed at the surface, the brine is now pumped up 200 feet. He remarked on the difference of level between the Droitwich and Stoke deposits—the highest bed of rock-salt at Droitwich being about 120 feet below mean sea-level and the lowest 170 feet; whilst at Stoke the first bed, which is very thin, is at 170 feet below sea-level, and the lowest yet reached at 300 feet. He suggested the existence of a great fault between Stoke and Droitwich. He thought the question of the existence of deeper supplies of brine at Droitwich a doubtful one.

Prof. Judd expressed his regret that, owing to ill health, the Author was not present to reply to questions which had been asked concerning his paper.

15. *On further* Discoveries *of* Vertebrate Remains *in the* Triassic Strata *of the* South Coast *of* Devonshire, *between* Budleigh Salterton *and* Sidmouth. By A. T. Metcalfe, Esq., F.G.S. (Read January 9, 1884.)

My special object in making this communication is to bring under the notice of the Society some further vertebrate remains which have been obtained by my friend H. J. Carter, Esq., F.R.S., of Budleigh Salterton, from the Triassic strata of the south coast of Devon, between Budleigh Salterton and Sidmouth, and are now deposited in the Geological Department of the British Museum of Natural History, at South Kensington.

In order to fix the precise geographical and stratigraphical position of these extremely rare and interesting specimens, I propose to commence with a brief reference to the coast section (fig. 1, p. 258).

The Upper Sandstones (following Mr. Ussher's classification of the Triassic rocks of Devonshire), in which the before-mentioned fossils were found, crop out in the cliffs at Budleigh Salterton. Near their outcrop the beds are coarse and conglomeratic, but they become less and less so as we follow them along the dip towards Sidmouth, which lies about six miles to the east.

About two miles before Sidmouth is reached, the cliffs suddenly rise to the height of 513 feet at a spot called "High Peake Hill," where the sandstones are capped by the Upper Marls (Triassic), the Upper Greensand, and supracretaceous gravel. The section at this point is approximately as follows:—

		feet.
Supracretaceous Gravel and Upper Greensand		113
Trias	Upper Marls	200
	Upper Sandstones	200
		513

On the Budleigh Salterton or western side of High Peake Hill is a steep slope leading to a stile on the brink of the cliff, whence a stratum in the sandstones, somewhat lighter in colour than the rest, may be seen dipping to the east. This stratum is very near the junction with the Upper Marls, and I am informed is more distinctly observable from a short distance out at sea.

On the beach, and immediately under the stile, is a talus consisting of fragments of sandstone of all sizes, varying from blocks of many tons in weight to mere sand-grains. In composition and colour these fragments are, in the opinion of Mr. Carter and myself, identical with the lighter-coloured stratum before referred to; and upon such grounds *only* are they assumed to be part of it. From this talus, Dr. Johnston-Lavis, F.G.S., procured, in the autumn of 1875, the remains called by Prof. Seeley *Labyrinthodon Lavisi* (see Q.J.G.S. vol. xxxii. page 274). In the following year Mr. Carter

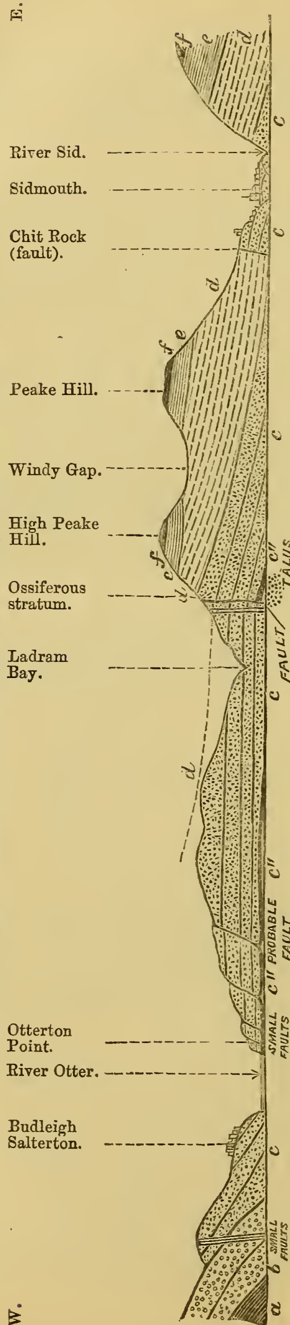


Fig. 1.—*South Devon Coast Section, from Budleigh Salterton to Sidmouth.*

a. Lower Marls. *b.* Pebble-beds. *c.* Upper Sandstones. (*c''*. Conglomeratic beds.) *d.* Upper Marls. *e.* Upper Greensand. *f.* Clay, with flint or chert stones.

found in it a large number of bone fragments, including several portions of jawbones of reptiles, with teeth *in line*. In the autumn of 1882 I myself visited High Peake Hill, and succeeded in finding in the talus numerous fragments of fossilized bone, including one flat one (probably dermal), 3 inches by 2 in size. In this specimen the bone structure is remarkably well preserved and distinctly visible to the naked eye. I was also particularly struck with the presence of numerous isolated small white fragments of irregular shape, both thick and thin, in the blocks of sandstone, most of them no larger than a florin, and many as small as a sixpence. Fragments of a similar character have been examined under the microscope, by Mr. Carter, whose statement is as follows:—

"Where the consistence is firm the bone structure is visible throughout, although there may be no form for identification. In other specimens which have become soft, chalk-like, or pulverulent when dry, the presence alone of little thin plates of translucent material (somewhat like mica in appearance, but calcareous in composition), dispersed irregularly throughout the mass, preserves the bone structure, and that so unmistakably, that they can be thus satisfactorily identified, even without form. These fragments are occasionally more or less replaced by red clay, and also more or less charged with crystalline grains of quartz, a circumstance which appears to arise from a metamorphic transposition of the surrounding material in which the carbonate of lime of the fossilized bone has been removed by aqueous solution previous to the deposit of the foreign ingredients."

On careful search I also found in the harder beds of the sandstones, at numerous spots near Budleigh Salterton and Otterton Point, small white (and occasionally red) fragments similar in outward appearance to those in the talus at High Peake Hill, but, of course, from lower horizons. Mr. Carter has carefully examined such fragments, and informs me that he is clearly of opinion that they also are, or represent, *bone* fragments. Mr. Carter thus observes:—"Concentric lines may be seen in them precisely similar to those in the fragments from the talus at High Peake Hill, but no bone structure or form is identifiable, while the white calcareous material, of which they are chiefly composed, is hardened, and the whole more or less reddened by the presence of red clay, and altered by that of crystalline grains of quartz similar to those found in the specimens from High Peake Hill, in which the bone-structure *is* distinctly visible." It was in the hard conglomeratic beds of one of these lower horizons close to Budleigh Salterton that Mr. Whitaker, F.G.S., of Her Majesty's Geological Survey, in 1868, found the specimen to which Prof. Huxley afterwards gave the name of "*Hyperodapedon*" (Q.J.G.S. vol. xxv. pp. 146, 156); and I am further informed by Mr. Carter, who has seen the specimen in the Museum of the School of Mines, at Jermyn Street, that but for *form* there is here also, probably, no bone structure for identification.

In a small quarry in the sandstones, close to Shortwood Hill (on the Tidwell Estate), about four miles west from High Peake Hill, are similar white fragments, chalky and structureless in character generally, but still containing, as Mr. Carter has proved, the plates of bone structure above mentioned, together with a large quantity of concretionary carbonate of lime in the upper strata, in which, of course, there is no organic structure whatever.

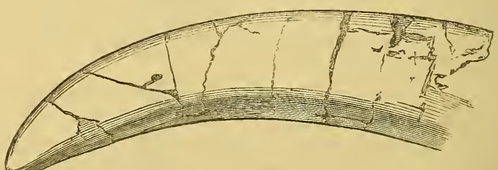
Mr. Carter has also deposited, with the remains before mentioned, carefully prepared specimens and sections of the bone fragments illustrating the foregoing observations. There can be no doubt that the great blocks, from the surface of which he chiefly obtained the remains, do contain, interiorly, many more of the same kind, which are soon washed out by exposure to the weather and the waves, being, as was before stated, of a soft or chalky nature when moist. Unless, therefore, the blocks are broken open, the chance of finding in them further traces of such organic remains becomes daily less; although, of course, a rich find might at any time follow a fall from the same bed of the cliff.

I carefully examined the length of the Triassic rocks exposed on the coast from the Upper Marls of Seaton to the breccia in the neighbourhood of Torquay (30 miles); but only in the Upper Sandstones were these peculiar bone fragments visible. The Upper Sandstones, as exposed on the coast between Budleigh Salterton and High Peake Hill, are remarkable for the presence of curious, irregular, branch-like masses of a very hard character, which are weathered out and form a prominent feature in the cliffs; they seem to defy all weathering and wave-friction, thus giving the cliffs, in some parts, quite a rugged aspect. These masses appear to be calcareous concretions; and it has been suggested that their calcareous material may be largely due to that removed from fossilized bones and other organic remains. I do not think, however, that much weight can be given to the suggestion. It must be borne in mind that towards Bishops Lydeard and Crowcombe (Somersetshire), the Upper Sandstones become so exceedingly calcareous that they might locally be almost considered a limestone, and, indeed, are largely quarried to be burned for lime; this excess of calcareous matter, Mr. W. A. E. Ussher, F.G.S., of the Geological Survey, in his valuable paper on the Triassic Rocks of Somerset and Devon (Q.J.G.S. vol. xxxii. p. 370), attributes to the denuding agents of the Triassic period having transported calcareous sediments derived from the occasional limestones occurring in the shales and grits of the Devonian and Culm-measure strata of the south-west of England. It is probable that a similar origin must be ascribed to the hard calcareous masses between Budleigh Salterton and Sidmouth. Nevertheless it is manifest that, by the process described by Mr. Carter, a large number of remains may have become wholly "removed" and lost to the palæontologist; while the presence, at numerous spots, of isolated bone fragments such as I have described, bespeaks the fact that a comparative abundance of vertebrate life was maintained during the Triassic period, and suggests that the rareness of Triassic fossils may be due, not so much to the paucity of animal life during that period, as to the fact that the strata then formed afforded no suitable conditions for the *preservation* of organic remains.

The following are the most noteworthy of the remains obtained by Mr. Carter and deposited by him in the British Museum, Cromwell Road, South Kensington; those numbered 1 to 11 inclusive were found in the talus under High Peake Hill, and the last (No. 12) came from the quarry at Shortwood Hill:—

1. Spine. Curved like a boar's tusk, bluntly pointed, $3\frac{1}{2}$ inches in the arc, by $\frac{1}{2}\frac{3}{5}$ inch in greatest diameter when entire. Solid, with bone structure throughout (fig. 2).

Fig. 2.—*Curved Spine from talus under High Peake Hill.* (Natural size.)



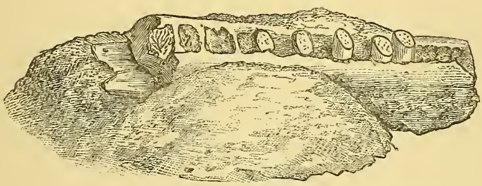
2. Portion (? middle) of jawbone, bearing the "honeycomb-like

ornament" on one side, similar to that of *Labyrinthodon Lavisi* (*op. et loc. cit.* pl. xix), probably also of the *Labyrinthodon*, 4 inches long, $2\frac{5}{8}$ inches high, 2 inches thick in its greatest dimensions. Fragment found loose, and rounded by exposure on the sea-shore. No teeth. Bone structure throughout.

3. Small jawbone of *Labyrinthodon* (?), with fragments of opercular bone (?) *in situ*, in the matrix. There is something like remains of teeth on the anterior extremity of the jaw.

4. Ramus of jaw of Reptile (?), imperfect, with several teeth in line, some broken off. $2\frac{3}{4}$ inches long, $\frac{4}{12}$ inch broad at alveolar margin; 25 teeth, the largest of which are posterior, about $\frac{5}{12}$ inch above jaw, pointed and suddenly expanded at base, where they are compressed antero-posteriorly, and about 3 inches by $\frac{1}{12}$ inch in greatest diameter, minutely grooved longitudinally from the base upwards, and anchylosed to the jaw. Bone structure throughout (fig. 3).

Fig. 3.—*Ramus of Jaw, with teeth, from talus under High Peake Hill.* (Natural size.)



5. Fragment of jaw of small animal, bearing three pulps; $1\frac{1}{2}$ inch long by $\frac{2}{3}$ inch in thickness. Bone structure throughout.

6. The same with 2 teeth more advanced, showing the layer of enamel $\frac{1}{2}$ inch long. Bone structure.

7. Fragment of (?) hollow bone or tooth. Bone structure throughout.

8 & 9. Two fragments of jawbone, containing remains of teeth. Bone structure throughout.

10. Fragment of subcutaneous bones of *Labyrinthodon* (?). Bone structure throughout.

11. A great number of other shapeless fragments, some of which appear to have been "scutes," illustrating both their nature and that of the matrix in which they are imbedded.

12. Fragment of bone from Tidwell-Estate Quarry. Bone structure confined to little opalescent thin plates or scales dispersed irregularly through the rest of the chalky substance.

I should mention that in a geological diagram of the strata between High Peake Hill and Sidmouth inclusive, prepared and presented to me by Mr. P. O. Hutchinson, a Local Secretary of the Society of Antiquaries, the bone-bed is placed considerably lower down in the sandstones than the lighter-coloured stratum to which I have directed special attention. Mr. Hutchinson has long resided at Sidmouth, and observed the geological features of his locality;

his opinion is therefore deserving of attention. To indicate, however, the precise position of the ossiferous horizon whence the bones found by Mr. Carter, at High Peake Hill, were derived, is necessarily a matter of difficulty. The Sandstones forming the lower portion of the cliff, at that spot, are not only homogeneous in character, but quite vertical and only accessible at low tide. Researches in other and more accessible sections in the neighbourhood may hereafter set this matter at rest.

While treating of the foregoing locality, I would call attention to the interesting fact that, in the Transactions of the Devonshire Association (vol. xi. page 383), Mr. Hutchinson has figured and described the remains of several plants found by him, half way between High Peake Hill and Sidmouth, at the very base of the Upper Marls, and now deposited in the Exeter Museum. These interesting specimens bear every appearance of belonging to some one of the subdivisions of the Calamiteæ, but it does not seem possible to say to which. As the true Calamite seems to have disappeared in the Permian period and to have been replaced by *Equisetites* and other forms more nearly allied to the living Equisetiform type, the probability is that the remains represent some one of these. It is manifest that the remains had a verticillate ramification, which presupposes a verticillate foliage—facts pointing towards the Equisetiform type. As, however, the specimens are structureless their precise character cannot be determined with certainty. Mr. Hutchinson thus describes the specimens:—"Stems of lacustrine plants, discovered in May 1878, by a fall of some of the cliff. The appearance on the slab of soft clayey and sandy rock was that of a number of reed-like stalks, lying across one another, as if they had fallen into the water as they grew. I secured a few pieces of the stems with a joint or two in each, and the waves destroyed the slabs soon after. The stems are an inch to an inch and a quarter in diameter, oval by pressure; joints at every six or seven inches, with indications that 8, 9, or 10 side-branches grew out of each joint. The interior of the fossils is soft sand rock, and the outside is clay of a greenish colour."

In conclusion, I have to thank Mr. Carter for having afforded me an opportunity of previously examining the vertebrate remains now deposited in the British Museum, as well as for his kind assistance in the preparation of this paper. The rareness of fossils in Triassic strata seemed to me to demand a note of Mr. Carter's discovery and observations.

Discussion.

The President said that the author, in this interesting communication, had proved that there was an abundant vertebrate fauna in the Triassic strata of Devonshire, and we could only regret that the specimens found up to the present time were all so fragmentary and imperfect.

16. *A* Delta *in* Miniature—twenty-seven Years' Work. By T. Mellard Reade, Esq., C.E., F.G.S. (Read February 6, 1884.)

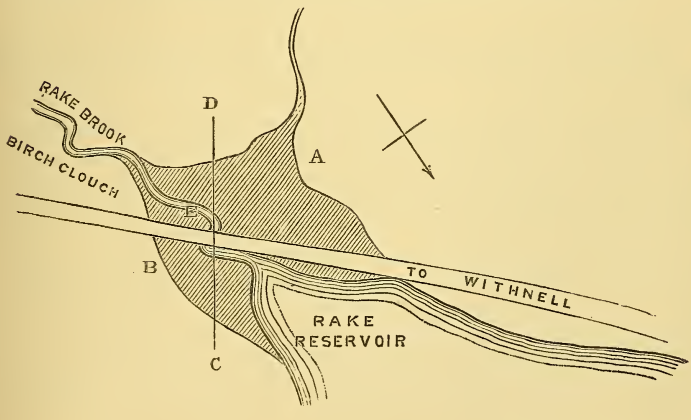
Introductory.—The rate of sedimentary accumulation has in all cases that I know of been calculated from the amount of sediment held in suspension in river-water and the mean annual discharge of the river.

It is true, history has furnished examples of towns that have once been sea-ports becoming inland towns through the extension of river-deltas *; but the information has not been sufficient or accurate enough to found an estimate of the rate denudation has proceeded at in the river-basins in question.

The Rake-Brook Delta.—In June 1883 Mr. Joseph Parry, C.E., who has charge of the Rivington Waterworks supplying Liverpool, called my attention to the great amount of deposit that had taken place in the Rake reservoir since 1856, the year it was filled.

On visiting the locality in his company, I found that where the two forks of the Rake Brook joined the reservoir, a corner of the reservoir was cut off by the public road from Bolton to Withnell, the communication being by a culvert, stated to be 8 feet high under the road, but then nearly silted up with deposit. The following plan will explain my meaning more fully. The whole corner of the reservoir on the south side of the road, at A on plan (fig. 1), was

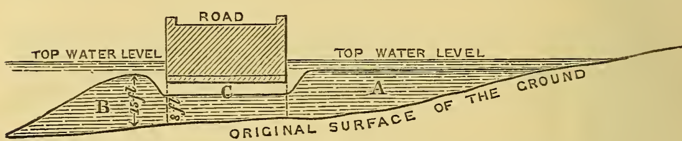
Fig. 1.—*Sketch Plan of Miniature Delta, Rake Reservoir.*



* Adria was a sea-port in the time of Augustus; it is now about 20 Italian miles inland. Ravenna was also a seaport, and is now about 4 miles from the main sea. Lyell's 'Principles, vol. i. p. 425 (10th edition).

filled to considerably above the level of the crown of the arch of the culvert (fig. 2) with a beautifully stratified deposit of peaty matter,

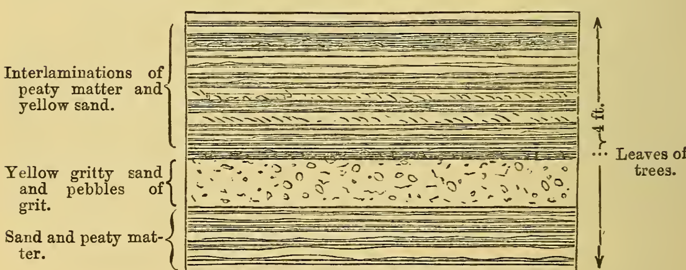
Fig. 2.—*Section in line* C–D *of fig.* 1.



A, B. Deltaic deposits. C. Culvert.

gritty sand, gravel shingle and boulders, as shown in the section below (fig. 3).

Fig. 3.—*Enlarged Section at* E *on Plan, fig.* 1.



Deposit unbottomed.

The layers of peaty matter and sand were generally from ¼ inch to 1 inch in thickness, one bed of gritty yellow sand being 9 inches thick.

This section was exposed by the excavations then going on to remove the deposit, advantage having been taken of the exceptionally dry weather and the lowness of the water in the reservoir. Part of the sand was being riddled with the object of using it in the filter-beds. About 5 feet thick had been removed off the whole area, there being still 8 feet in thickness at the mouth of the culvert. After consultation with the man in charge, I averaged the thickness over the entire area of 2508 yards at 2 yards. The bed of the Rake Brook had cut a devious course through this delta (for such it was), and its bed was strewn with boulders of Millstone Grit, the largest I measured being 1 foot across. On the north side of the road and in the open reservoir, marked B on plan, was another delta formed by the matter washed through the culvert. Five feet thick of this had been removed from the front of the culvert. It consisted principally of fine sand with a small proportion of peaty matter mixed with it. There was still 10 feet deep of deposit immediately opposite the culvert. The area of this delta I estimated at 430 yards and the average thickness at 3 yards.

Rake Brook.—On walking up one fork of the Rake Brook and coming down the other I found the brook-beds full of large Millstone-grit boulders; in places the rock *in situ* formed the bed of the brook.

The banks, largely cut down vertically, showed a drift composed entirely of the débris of the underlying rocks from large stones through boulders to gravel and sand; much of it seemed like subaerial detritus. On the top of this was a peaty soil of considerable thickness. In fact all the materials of the delta were there and nothing more. I observed no erratic stones.

The Drainage-area.—On walking from one fork to the other I passed over the heath, which was extensively covered with the cotton grass, the beautiful tufts of downy cotton looking at a distance like white flowers. This heath, according to the 6-inch ordnance map, kindly furnished by Mr. Parry, constitutes about $\frac{2}{3}$ of the drainage area; it can hardly be called a "basin" as it occupies the side of the hill. The reservoir is about 550 feet above O.D., and the highest point of the watershed about 1200 feet above O.D. I estimated the drainage-area or "gathering-ground" at 3,643,000 square yards $=1{\cdot}176$ square mile. The delta I estimated at 6,306 cubic yards; and as the time of accumulation was 27 years, the rate of removal or denudation over the whole surface was $\frac{1}{432}$ of an inch per annum or 1 foot in 5184 years. The mean rainfall of the Rake-Brook watershed was, during the last 10 years, according to information supplied me by Mr. Parry, 49·57 inches per annum.

Observations.—No doubt some of the finer mud has been distributed over the bottom of the reservoir and is not taken into account in my estimate. It is interesting to note that the rate is nearly the same as that of the Mississippi*. It is also perhaps more instructive to note what a close agreement there exists between the relative amounts of peaty matter and sand in the deposit and on the surface of the gathering-ground. The example also forcibly impresses on the mind the importance of causes at work, which, but for exceptional circumstances which direct our attention to their accumulated results, would not be noticed. If the reservoir had not been made, the matter would have passed out to sea through the river Douglas without notice; as it was, the matter intercepted seemed so exceptionally great for the time as to attract the attention of the engineer; but, on measurement, we find that the rate of denudation accords well with what has been calculated in other ways. Being in miniature, we are enabled to directly inspect and explore all the processes of nature leading to the result, both on the gathering-ground and in the deposit itself. We also see very beautifully displayed those puzzling alternations of fine laminated beds and coarse sand with boulders resulting from the varying conditions in

* See 'Text book of Geology' by Dr. Archibald Geikie: given at 1 foot in 6,000 years. The mean rainfall of the whole Mississippi valley is, according to data given by Humphreys and Abbott, about 30 inches.

fine weather and flood of the same agent, a running stream, modified, no doubt, by the height to which the reservoir rose at the time,—conditions often repeated on a larger scale in nature all over the world.

Discussion.

Mr. J. Evans pointed out that the rainfall in the district of the Rake river was a high one, so that the denudation might thereby be increased. It would be interesting to have results where the rainfall was of a more average character. He was disposed to think that, under similar conditions, the denuding effect of the rainfall would vary as some higher power than unity with the amount.

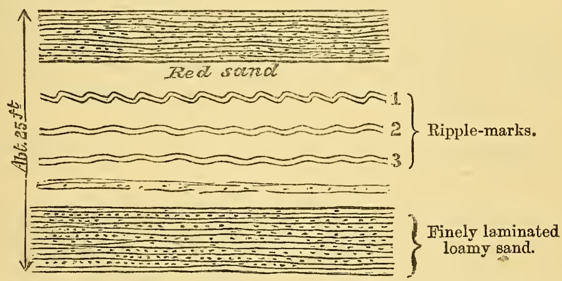
Prof. Judd said that Mr. Mellard Reade had found that in higher regions the harder character of the rock balanced the increased amount of rainfall.

17. RIPPLE-MARKS *in* DRIFT *in* SHROPSHIRE *and* CHESHIRE. By T. MELLARD READE, Esq., C.E., F.G.S. (Read February 20, 1884.)

AMONG all the published notices of drift deposits that I have read, I cannot call to mind any description of ripple-marks as forming features in that formation*. Of course if the drift was formed under land-ice we should not expect to see them; but if, as I maintain, a very large part of it has been laid down in water, then, under favourable conditions, they should be found.

I was much pleased on examining, in the early part of 1883, a section in the Old-Park-Field sand-hole, at Ketley, near Wellington, Shropshire (to which I had been directed by my friend Dr. Callaway), to notice in a stratified deposit of drift-sand three distinct beds of ripple-marked laminæ, most beautifully displayed in section. The following is a sketch of the deposit (fig. 1). The position of this sand-pit is

Fig. 1.—*Section at Ketley, near Wellington, Shropshire.*



on the south side of Watling Street. I measured one of the ripple-marks in bed No. 1, and found it was 9 inches from crest to crest, and $1\frac{1}{4}$ inch high; the fall of the wave indicated that the wind producing it was from the N.W. The figure below (fig. 2), drawn to a scale of $\frac{2}{3}$ inch to the foot, will more fully explain its form.

* *Note* (March 1884).—Mr. Mackintosh, describing a section of Boulder-clay (Low-level Boulder-clay) at Egremont, Cheshire, says, "The surface of this bed ['Middle sands' according to him, but an included sand bed according to my classification] 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 typical upper clay."

Mr. Jukes-Browne informs me that there is at South Ferriby, in Lincolnshire, a bed of indurated sand a few inches thick beautifully ripple-marked on the upper surface, which underlies the Boulder-clay and overlies a thin bed of gravel resting on the chalk. It was previously described by Mr. Searles Wood (Q. J. G. S. vol. xxiv. p. 150), who states that there is a similar bed below the Hessle clay in the Hessle quarry.

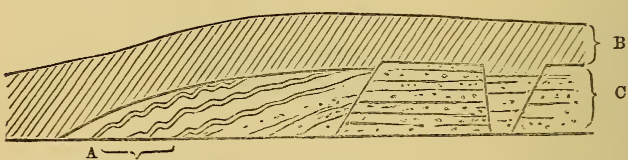
Mr. Lamplugh, in reply to an inquiry, says, "Ripple-marks are by no means uncommon in our cliff sections [about Bridlington], being generally in beds of sand and sandy clay, interstratified with the Purple Boulder-clay." He has given an example of one of the best of them in the Geol. Mag. for Sept. 1879.

Fig. 2.—*Ripple-marks at Ketley.*

In July 1883 I had the further pleasure of seeing in a cutting in Low-level Boulder-clay and Sands at Tranmere, Cheshire, in one of the approaches to the Mersey Tunnel, ripple-marks in hard fine loamy brown sand, forming the flank of what must have been a submarine bank, and *covered* with a compact mass of Boulder-clay many feet thick *. These also were displayed in section, in a perfectly distinct and unmistakable manner, though, through being formed on a sloping bank, they did not possess the perfect regularity and symmetry of form of those previously described †.

The following (fig. 3) is a sketch-section.

Fig. 3.—*Ripple-marks at Tranmere, Cheshire.*



A. Ripple-marks in brown loamy sand. B. Boulder-clay.
C. Yellow sand, containing shell fragments.

The sand was faulted, as shown, with throws of from 2 to 4 inches. I found shell fragments in the bed of sand, among which I could distinguish *Turritella terebra*, *Cardium edule, Tellina balthica*, and a *Pholas*.

The position of this section being in an embayment between higher lands must have been favourable for the preservation of such markings. The clay was remarkably free from stones, and no doubt this arose from the same cause, viz. the protecting embayment. The beds are undoubtedly of the same series as those to which I have given the name of the Low-level Boulder-clays and Sands.

These ripple-markings would not be seen except when developed by weathering. From the nature of the material they could not be displayed except in section.

Discussion.

Mr. Clement Reid said that he believed similar phenomena had been often observed before, and he did not exactly see the bearing

* See 'Drift Beds of the N.W. of England,' part ii.

† *Note* (March 1884).—I have not the least doubt that these are genuine ripple-marks, and that the faulting of the sand has no connexion with them. They are distinct phenomena, and not due to any common cause. They were also observed by several members of the Liverpool Geological Association.

of the paper. On the east coast of Norfolk ripple-marks were of common occurrence in drift deposits.

Dr. Woodward, on behalf of Prof. Lapworth, suggested that these were not all true ripple-marks, but due to pressure, especially in the example adduced at Tranmere, where the drift sands were faulted close by.

Prof. T. Rupert Jones thought that the facts observed by the author at Ketley might very well indicate ripple-marks, and that ripple-marks and the effects of pressure could hardly be mistaken one for the other. He thought that it was just as interesting to find ripple-marks in the drift on the west as on the east coast.

Mr. Lamplugh corroborated the remarks of Mr. Clement Reid with regard to the common occurrence of ripple-marks in the drifts of the Yorkshire coast.

The President suggested that the idea which Mr. Mellard Reade wished to convey was, that if the phenomena observed by him were ripple-marks, they could hardly have survived the passage of land-ice over the district, as implied by extreme glacial theories.

18. *Further* Notes *on* Rock-fragments *from the* South *of* Scotland *imbedded in the* Low-level Boulder-clay *of* Lancashire. By T. Mellard Reade, Esq., C.E., F.G.S. (Read February 20, 1884.)

In my paper on the Drift-beds of the North-West of England, Part II.*, I gave certain identifications of granites from Criffel and the neighbourhood of Dumfries made by Mr. Patrick Dudgeon from specimens I forwarded to him in 1882, these being confirmatory of Mr. Mackintosh's previous discovery of Criffel granite in the Lancashire Drift. In August of this year I had an opportunity of travelling from Dumfries through Kirkcudbright to Wigtonshire, when I paid special attention both to the rocks *in situ* and to the boulders lying about the country, with the following results.

In Kirkcudbright there are two large and distinct masses of granite, rising through the Silurian strata, which generally rest nearly vertical and are repeated in fold after fold. The easternmost of these granite masses rises 1800 feet above the sea, and forms the grand isolated mountain called Criffel. The westernmost mass, occupying not less than 50 square miles †, rises to 2331 feet in the mountain called Cairnsmore of Fleet, which is also an isolated granite boss; but the surrounding Silurians rise to a higher level than at Criffel. The Cairnsmore granite is of a coarser nature than that of Criffel; though in a vein at Creetown, no doubt connected underground with the main granitic mass, is a quarry, belonging to the Mersey Docks and Harbour Board, which has supplied for many years the granite used in the construction of the Liverpool Docks, which is of a more compact nature and finer grain.

All round Criffel in the low country and near the coast are to be found numerous granite boulders, all of them more or less rounded, and none showing marks of glaciation either by plane surfaces or striations. At Kirkbean I took chippings of several, which were used in the building of a field-wall; among them were a dark granite and a reddish-coloured granite, no doubt all variations of Criffel granite, and such as I could match from the Lancashire Drift. Close by a road-stone quarry in the Silurian Greywackes, about 5 miles S.E. of Dalbeattie, there were many boulders of a dark red granite, which I can also match by specimens from the Lancashire Drift; and I take these also to be local variations of the Criffel granite.

The Dalbeattie grey-granite quarries are also in the Criffel-granite mass, and I believe we have all these varieties of granite rocks in the Lancashire Drift.

The granite of Creetown is very similar to the Dalbeattie granite; and here can be seen the junction between the granite and the

* Quart. Journ. Geol. Soc. vol. xxxix. p. 119.

† This is only a very rough approximation. The Survey explanation of sheet 4 says—30 square miles of it are exposed in sheet 4 (p. 18).

Silurians, and specimens of granite veins penetrating the Greywacke can be taken with the altered Silurian adhering to both sides. This fine-grained vein granite can also be matched by granite fragments in the Drift about Liverpool.

In ascending the Moneypool Burn from Creetown I found among the boulders a granite with light pink felspar not unlike the Eskdale granite. This has, no doubt, been derived from Cairnsmore of Fleet, in which the burn rises.

In Palnure Burn, at Talnotry, a splendid junction of the granite and metamorphosed Silurians can be seen, and specimens taken showing the granite and gneiss adhering. I ascended Craignelder, a spur of Cairnsmore, 1971 feet high. The mountain is literally covered with splendid granite boulders which weather white. I cannot help remarking that here is a sublime study for a painter in the harmony existing between the mountain and its fragments,—no erratics—all one grand harmony of granite. I am led to believe from what I saw, that many of the coarser grey granites of the Lancashire Drift have come from Cairnsmore of Fleet.

But I was most interested in the Silurian Greywackes, for here were undoubtedly the parent rocks which have yielded many of the fragments found in the Low-level Boulder-clay about Liverpool. The identifications I consider unmistakable, and I exhibit specimens side by side from the Boulder-clay and from the Greywackes of Wigtonshire. These rocks seem never before to have been identified with Lancashire drift rocks; and before I traversed them from Kirkcudbright to the Isle of Whithorn and Luce Bay these numerous fragments, partly distinguished by the small veins of the carbonates of baryta and lime traversing them, were a puzzle to me. The colour of the Greywacke ranges through dark blue and grey to a deep purple red*. "It varies in texture from a fine-grained mudstone to a coarse gritty sandstone, and occurs in beds from 6 inches to 6 feet thick." The Survey memoir explanatory of sheet 4 says (p. 13):—"The section which perhaps best shows the characteristic features of these thick grits and massive greywackes (the Queensbury Grit Group) runs along a line of cliffs called the Craigs of Garheugh at the side of the road from Glenluce to Port William." I have compared a specimen I took from these "Craigs" with some obtained from the Low-level boulders of Great Crosby, Lancashire; they are identical. Also a specimen of the red greywacke of the Ardwell group obtained by me at Innerwick fishery, a few miles north of Garliestown, is matched by specimens from Great Crosby, as are some of the rocks in and near the Isle of Whithorn.

But it is the general appearance of the group of rocks, and long familiarity with drift specimens of the Low-level Boulder-clay that most convinces me. Unfortunately I did not ascend to the summit of Cairnsmore of Fleet; but the Survey memoir says of this granite †:—"The general colour of the granite is grey, shading

* These greywackes are well described in the explanations of sheets 1, 2, & 4, Memoirs of the Geological Survey of Scotland.

† Explanation of sheet 4, p. 18.

in places into a flesh-colour or pink tint. The latter is most commonly met with near the edge of the mass, and may be well seen along the south and west slopes of Cairnsmore Hill and up the valley of the Palnure Burn. The general texture of the Cairnsmore mass is extremely coarse; . . . . . . by far the coarsest-grained examples are exposed along the top of Cairnsmore Hill. Here masses of granite may be seen with crystals of quartz and felspar upwards of two inches in length, while the granite consists for the most part of quartz, orthoclase and plagioclase felspar, black and white mica, with occasional hornblende; its lithological character varies, owing to the disappearance of one or more of the ordinary constituents. . . . . . . The felspar is always the chief constituent, consisting for the most part of orthoclase, but numerous striated faces are also met with."

I have a specimen of coarse granite from the Low-level Boulder-clay, Great Crosby, containing a crystal of felspar $1\frac{3}{4}$ inch long. This coarse variety is generally found in a more crumbly condition than the finer-grained granites.

It is only necessary, in conclusion, for me to point out that these further identifications, which go far to complete the series of Low-level Boulder-clay rocks, are a further confirmation of the views expressed by me "that all the stones (of the north-west of England Drift) are confined to the basin of the Irish Sea and the river-basins flowing into it, excepting some stray stones that may have come from the Highlands of Scotland"*.

Discussion.

Dr. Hicks remarked that similar evidence to that obtained on the north-west coast was furnished by the Vale of Clwyd. At St. Asaph the granites and other rocks in the Boulder-clay were to a great extent derived from a distant source, evidently somewhere to the north, only a few from the neighbourhood; but further south the boulders were mainly from the Welsh area.

* "The Drift-beds of the North-West of England," Quart. Journ. Geol. Soc. vol. xxxix. p. 120.

19. *On the so-called* Spongia paradoxica, S. Woodward, *from the* Red *and* White Chalk *of* Hunstanton. By T. McKenny Hughes, M.A., Woodwardian Professor of Geology, Cambridge. (Read February 20, 1884.)

The sea-cliff of Hunstanton in Norfolk offers one of the most interesting sections along our eastern coast. We there have an opportunity of examining in detail all the beds from well down in the Lower Greensand fairly up into the Chalk, and we see that, where we should have expected to find the Gault and Cambridge Greensand, there is instead a conspicuous band of red rock about 4 feet in average thickness, which, when examined closely, seems to pass up into the Chalk above, part of the lowest bed of which is mottled with stains and nests of red earthy oxide of iron, and to pass down through more and more sandy layers into the Lower Greensand underneath, as if it was either largely derived from the Lower Greensand, or the conditions of deposit of the Lower Greensand were still going on while the earlier part of the Red Rock was being formed. When we stand off at a little distance, however, the line of demarcation appears more sharply defined by the results of weathering. Palæontologically, too, it is a section of great interest. The Red Rock and the lower part of the Chalk are full of organisms of various kinds, of which lists have been given by Taylor *, Samuel Woodward †, Rose ‡, Wiltshire §, Seeley ||, and others; and in these lists we find repeatedly the description or mention of a fossil which, from the time of Woodward on, was referred to under the name of *Spongia* or *Siphonia paradoxica*. The bed at the base of the White Chalk is sometimes spoken of as the *Sponge-bed*, from the prevalence of these bodies, which have been supposed to be sponges.

Taylor gives a good section and description of the beds seen (Phil. Mag. vol. lxi (1823), p. 81.) in the Hunstanton Cliff, in which he says, p. 82:—"No. 4. 1½ foot. A stratum of white chalk, more loose than the last, containing no fossil shells; yet is distinguished by a remarkable species of ramifying zoophyte, resembling the roots of trees; about an inch thick, branching and interweaving in every direction. Some of the fragments are not unlike the horns of a stag." And again, "No. 6. 2 feet. Red chalk, of a rough disjointed structure, similar, except in colour, to No. 4, and, like it, though in

* "Hunstanton Cliff," Phil. Mag. vol. lxi.

† Geology of Norfolk, 1833.

‡ "Sketch of the Geology of West Norfolk," Lond. & Edinb. Phil. Mag. and Journ. vols. vii. & viii. 1835–36.

§ "On the Red Chalk of England," Geol. Assoc. Ap. 1859. "On the Red Chalk of Hunstanton," Quart. Journ. Geol. Soc. May 1869.

|| "On the Red Limestone of Hunstanton," Ann. & Mag. Nat. Hist. April 1861. "On the Hunstanton Red Rock," Quart. Journ. Geol. Soc. vol. xx. p. 327 (1864).

a smaller degree, interwoven with the ramifying zoophytes before mentioned."

Woodward mentions the fossils in his 'Synoptical Table of British Organic Remains,' 1830, and in his 'Geology of Norfolk,' 1833, and refers in illustration to the figure given by Webster in his paper on *Alcyonia*, Trans. Geol. Soc. vol. ii. pl. xxvii. f. 1. But on hunting up this reference, we find that Webster is describing what he calls the Tulip Alcyonium, and makes no mention of Hunstanton, or of the Red Rock and associated beds, or of *Spongia paradoxica*; and, moreover, he does not appear to be describing the same fossil. So this appears to be only the reference to a picture of an organism which Woodward thought the *Spongia paradoxica* might have resembled.

Rose (1835–36), describing the Red Chalk of Hunstanton, borrows largely from Taylor. "It is," he says, "a compact limestone coloured by oxide of iron, containing many small dark-green siliceous pebbles, and is divided into two beds: the uppermost, about seven inches in thickness, abounds in organic remains; this bed is intersected throughout by a ramose Zoophite, the nature of which is not satisfactorily determined; and the two characteristic species of Belemnites are in great abundance; *Terebratula biplicata* and *Inocerami* are numerous, and one species of *Nautilus* occurs. The lower bed is three feet five inches in thickness, contains less of the zoophite, and fewer fossils than the upper, but the siliceous pebbles are more numerous" (vol. vii. p. 181).

Again, under the head of '*Chalk without Flints*,' he says (*l. c.* p. 275) "Under this denomination I include all the *Lower* Cretaceous beds. At Hunstanton Cliff, where they are exposed, reposing immediately upon the *red chalk* (as it has hitherto been called), three natural divisions of them may be observed; the lowest is made up almost entirely of a ramose zoophite, which strongly characterizes it; the middle above has a gray colour and arenaceous texture, abounds in organic remains; the gray shale [shade?] forcibly distinguishes this; and the uppermost bed, usually denominated the *lower chalk*, which here forms the upper portion of the cliff, is readily distinguished by its pure whiteness. It has been attempted to separate and arrange these beds by their *zoological* characters; the *zoophitic* bed has been considered the *equivalent* of the *upper green-sand* or firestone; and the *gray* bed that of the *chalk-marl*; but I find the *characteristic* fossils of the *upper green-sand*, and *chalk-marl* so intermingled in the *gray* bed, that it is impossible to draw a line of demarcation between those two strata. . . . . . The *lowest* of these beds (No. 4 of the section of Hunstanton Cliff) reposes upon the thin seam of dark red argillaceous matter which separates it from the red limestone or Gault equivalent. The texture of this bed varies, some portions of it being very loose, others exceedingly hard and compact; its substance is throughout intersected by a ramose zoophite, the original texture of which is so completely obliterated that it appears impossible to determine precisely the nature of what it is the relic: the formation of the stratum is best explained by supposing it originally a coral reef, and its interstices filled with cretaceous mud; it is about eighteen inches in thickness, and contains very few organic remains." He remarks in a footnote that "a nearly corresponding bed composed of ramose zoophytes occurs in Sussex: *vide* Geology of S.-E. of England, p. 384, *note* d."

The name only is handed on by subsequent writers. So few exact observations have been recorded in favour of the fossil being a sponge, that we may fairly reconsider the question; and in doing so, I am led to go further and question whether the object can be referred to any organism.

The beds in which this fossil is most abundant are full of fragments of shells, corals, Bryozoa, sponges, &c., and, therefore, spicules and other indications of sponge-structure may be seen in any part of the mass, just as fragments of any other organism may be found where such remains have not been obliterated by chemical action. But I cannot find in the specimens which I have had cut, any structure associated with or limited by the boundaries of the trailing objects known as *Spongia paradoxica*, in such a manner as to suggest that it represents an original organism of the form of the paradoxical body in question. For fear this might be due to the accident of my having less well-preserved specimens, I have asked many friends who have had opportunities of examining these fossils, whether they have ever seen any structure belonging to the bodies in question. The Rev. O. Fisher, of Harlton, replies—"I have a section, by Cuttell, of what I believe is *Spongia paradoxica*. It does not show any structure that I can see. The mode in which it ramifies over the rock in a network is very curious. The piece from which my slice was cut had a very definite body surrounded by a coating of indurated chalk."

Next, as to the manner of occurrence of the fossil: it is found in beds full of large fragments of *Inoceramus* and other fossils, which have drifted into their present position; and this, as Mr. Starkie Gardner remarked to me on the ground, points to conditions unsuitable for the growth of a slender sponge. Many of the undoubted sponges, Bryozoa, &c., are fragmentary and apparently transported to their present position, while the *Spongia paradoxica* does not, so far as I have observed, ever occur in a fragmentary condition, but always forms part of an apparently complete ramifying body. The interrupted fragmentary appearance sometimes seen in the face of the cliff is due to the breaking away of portions of the cylindrical body after exposure of the rock-surface, or to its running into the mass so as to be lost to sight, because the irregular fossil does not all lie in the plane of the section. It occurs most commonly in layers along the bedding-planes, but very frequently extends up through the whole thickness of what we may call a bed, *i.e.* about 5 or 6 inches, and runs on into the masses which appear to belong to the layer above. Now it is very improbable that it could support this long trailing stem in a vertical or oblique position, or that it grew on while the chalky mud was accumulating around the lower part, while the form does not support the view that it was the root portion of a sponge allied to *Siphonia*; for the masses are of approximately uniform thickness, and terminate in rounded ends in the same plane as the rest of the fossil, or taper off along joints into banded rock, such as is due to infiltration; and in no case can I learn that any head has been seen attached to, or been found in connexion with, these branching anastomosing rootlike masses. It extends in a network uninterruptedly over many yards of rock, apparently, indeed, over the whole bed. The meshes are from 1 to 5 inches across, more or less. It cannot be regarded as representing bounding portions of sarcode round canals, as there is no depth to the structure; it is merely a very open net of a material rarely thicker than a one-inch rope; nor can it be referred to a trailing anastomosing ramose sponge, as it occurs in vertical as well as in horizontal planes; and these vertical or highly inclined planes along which it occurs appear commonly to coincide with the joints.

Another body to which the name *Spongia paradoxica* has been sometimes given is common in the same beds. It consists of masses of more crystalline texture, which exhibit upon the weathered surface a fretted network of small ridges enclosing cuplike depressions of irregular form and size, such as are not uncommonly seen in certain beds belonging to the Mountain-Limestone, or more exactly like some weathered surfaces of gypsum, where they obviously depend not only on the unequal texture of parts of the limestone or gypsum, but also upon the accidents that determine the limitation of drops upon a window, of the dotted moss and lichens that guide the formation of the weathered holes in limestone which are often mistaken for pholas-burrows, or of the cavities in the fretted surface of ice or rock-salt.

These fretted surfaces are seldom found upon the trailing ramose bodies above described, which have a smooth exterior and are of approximately uniform thickness, whereas the fretted masses are tuberous lumps of all sizes up to 4 or 5 inches in diameter; but there is no reason for considering that the fretted masses are organic any more than the others. They show no internal structure, and the peculiarity of form and of surface has been shown to be just like that found in other weathered concretionary bodies.

A microscopic examination of sections cut across these bodies often shows a more compact crystalline structure than that which is seen in the other part of the rock; but in other respects it is the same, and contains the same fragments of shell, &c., and the same grains and pebbles.

Seeing, then, that there are so many and great difficulties in the way of accepting the view that these bodies represent the outlines of sponges, we must next ask whether there is any other probable explanation of them; and an examination of them in place suggests the idea that they may be merely concretions, owing their symmetry of form and regularity of arrangement to rock-structure, which is more obvious in the cliff than in hand-specimens.

First, we notice that in a general way they run along the intersections of joints with the bedding-planes or with one another. At the intersection of three or more such planes they spread out into triangular pieces or irregular flat masses according as these divisional planes have affected the infiltration and concretionary action. When the exterior part which should show the sponge-growth comes across an included fragment, it does not grow round it, as would a sponge, but shows a banded concretionary structure, as seen under similar circumstances in the ironstone concretions of the Lower Greensand or Oolitic series.

The Red Rock itself is a concretionary bed; there is a pink gritty or conglomeratic limestone, with cavities filled with spar and slickensides, pervading it; where circumstances favoured the formation of concretions of uniform size and form, as was the case along the intersections of the joints and bedding-planes, there a symmetrical series was produced; elsewhere the concretionary limestone occurs in large nodular masses in the more sandy matrix. So the occurrence of flint in the overlying chalk is very much regulated by joints and bedding which facilitated, and clayey bands which impeded, infiltration; but we have, in that case, the additional disturbing cause arising out of the fact that the silica was apt to be attracted by the traces of organic matter left in connexion with fossils.

Phosphatic nodules are not uncommon in the lower part of the White Chalk; and it occurred to me that had these paradoxical bodies been sponges, they might have been phosphatized, as is so commonly the case with the sponges of the Cambridge Greensand or basement-bed of the Chalk.

Portions of the specimen exhibited have been analyzed in the chemical laboratory at Cambridge, through the kindness of Professor Liveing, who writes, "My assistant has examined the specimen you sent to the laboratory; he does not find any very obvious difference in composition between the nodular part and the surrounding matrix. Both contain a small quantity of phosphate, but only a very small quantity, and it is as nearly as possible in equal proportion in nodule and matrix.

"As to the green colour about the concretion, it appears to be due to silicate of iron; at the same time it may be due in some slight degree to some phosphate of iron; for there is rather more phosphate in proportion to the whole mass in this green part than in the rest of the matrix; but the whole quantity of phosphate is small in both."

In this respect it agrees with the nodules in the base of the Upper Chalk, near Swindon, some of which have been analyzed by Mr. Phillips, of St. John's College, who informs me that there is nearly as much phosphate in the chalk which forms the matrix as there is in the nodules themselves. The only difference which can be detected is that which can be seen with the naked eye, namely, that the nodules and the so-called *Spongia paradoxica* often have a more hard stony character, due to incipient crystallization of the carbonate of lime.

It is always difficult to prove a negative; but it does seem to me that enough has been said to throw doubt upon the sponge-theory, and further, that in the concretion-theory, another possible explanation has been offered. I am aware that sponges do often perish, so as, in the fossil state, to leave nothing but the form to guide us as to the whereabouts of the whole or certain portions of the organism. In such cases, however, a part of the structure has generally been preserved somewhere; but in the case of *Spongia paradoxica*, I cannot find that any structure has ever been seen in the bodies referred to under that name, nor can I learn that there are sponges known which have the habit and manner of growth of the *Spongia paradoxica*. Therefore it would seem that until those familiar with sponges offer some further evidence, we must abolish the name which assigns to this body a definite zoological place.

Through the courtesy of Mr. W. Johnstone, I am allowed to append the quantitative analyses of the so-called sponge and sponge-bed, which were read to the Society in the discussion upon my paper. They fully confirm the results arrived at by Professor Liveing's examination of my specimens.

	III.	IV.	V.
CaO	53·230	52·050	52·400
CO_6	42·295	41·456	41·283
$Al_2P_2O_8$	0·353	trace	0·477
P_2O_5	0·289	0·268	0·338
Fe_2O_3	0·325	0·635	0·213
MnO	....	trace	trace
MgO	0·748	0·773	0·810
SO_3	trace	trace	trace
NaCl	trace	trace	trace
SiO_2	3·170	5·025	5·057
Organic matter	trace	trace	trace
	100·410	100·207	100·578

No. III. Sponge-bed.
" IV. Sponge-bed (immediately above red bed).
" V. *Spongia paradoxica*.

Discussion.

Dr. J. Gwyn Jeffreys referred to the creation, either through mistake or fraud, of Molluscan genera and species from the gizzard of a common Mollusk, as well as from other organisms not belonging to the Mollusca.

Dr. Hicks spoke of the value of analysis in settling the question. Mr. W. Johnstone had made an important series of analyses, which, by showing about equal quantities of phosphoric acid in the matrix and in the supposed fossils, quite bore out the views of the author.

Dr. G. J. Hinde said that he agreed with Prof. Hughes that it was not a sponge, for no sponge-structure could be detected in it. The form alone would be no argument against it being a sponge. Forms like the *S. paradoxica* have been found at many other localities. The *S. saxonicus* of Geinitz, from the Quader-sandstone, was similar. Göppert thought it a sea-weed, and Zittel has suggested that it might possibly be the cast of a horny sponge. He was not prepared himself to offer a suggestion as to their nature.

Prof. T. Rupert Jones thought that there were no grounds for not regarding them as some kind of organic structure, either sea-weed or sponges, or something else. The absence of structure was no argument against their organic origin; in many fossils the outer form remained, but all structure had disappeared. He did not attach much importance to the proportion of phosphoric acid in the matrix and supposed fossil.

Dr. Woodward recalled a similar case as occurring in the London Clay at Harwich. He stated that similar pseudo-organic forms might be seen in course of formation in the sand at Bournemouth. He referred to the *Harlania* of the Niagara Limestone, and similar forms in the Nummulitic rocks of Egypt. The fact that such forms were found in strata of all ages pointed to their inorganic origin.

The Author said that from its great extent and manner of occurrence the whole mass could not be referred to any organism, though parts might resemble some sponges in form. The position of the branching masses and their sections pointed to a concretionary origin. What most resembled organic structure in *S. paradoxica*, viz. the stag's-horn pattern, was exactly simulated on many limestones and on gypsum, where the fretted surface was produced, not by weathering above ground, but in the red marl in which the gypsum occurred.

20. *On the* Occurrence *of* Antelope remains *in* Newer Pliocene Beds *in* Britain, *with the* Description *of a* new Species, *Gazella anglica*. By E. T. Newton, Esq., F.G.S. (Read March 9, 1884.)

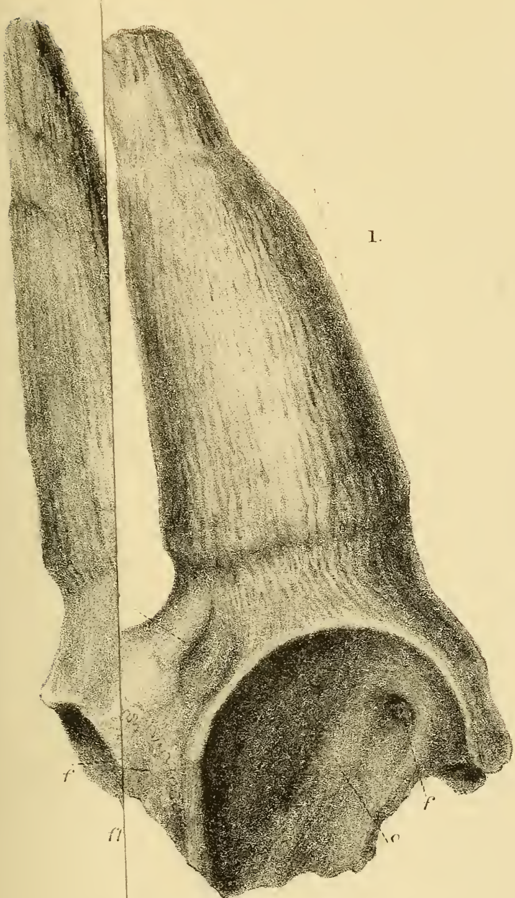
[Plate XIV.]

In the year 1878 Mr. H. B. Woodward, of the Geological Survey, obtained from the Norwich Crag at Thorpe, near Norwich, a fragment of a horn-core closely resembling the corresponding part of a Goat; and although the genus was not known to occur in beds of undoubted Pliocene or Pleistocene age in Britain, I felt justified in calling attention to it by inserting "*Capra*?" in the list of Mammals from these beds, which appeared in the Survey Memoir 'On the Country around Norwich' (1881), p. 55. More recently my colleague has been fortunate enough to get another and much more perfect horn-core from the same place. As will be seen from the description given below, there can be no question as to the close relationship of this specimen to the Antelopes, and more especially to the Gazelles; but it is not certain that the first-found of these horn-cores belongs to the same genus as the second; indeed, the slight impressions of the brain convolutions, which are traceable on the inner wall of the frontal bone, seem to indicate a greater complexity of these parts than is found in the second specimen. However, seeing that we now have undoubted evidence of an Antilopine form occurring in these deposits, it will perhaps be better to refer the less perfect specimen to the Antilopidæ, and not to the genus *Capra*.

The second and more perfect specimen (Pl. XIV. fig. 1) consists of a right horn-core with its frontal bone and a fragment of the parietal bone still attached. The frontal suture is perfectly preserved, and consequently the direction and amount of divergence of the horn-cores can be clearly made out (fig. 2). More than half of the orbit remains, although its upper border is broken away. On the inner side the frontal bone retains very perfectly the impressions of the convolutions of the right anterior cerebral lobe.

The upper part of the horn-core is broken, and in its present condition seems to be much tapered; but other specimens, to be presently noticed, show that this is largely due to the abrasion which it has undergone. The horn-core is supported upon a smooth pedicle, which, on the inner side at its middle part, has a height of about 10 millims. The core itself is rugose, and, being at its base larger than the pedicle, forms a kind of burr. A cross section in this region gives an oval outline (fig. 3), the front and back being rounded, without any trace of a sharp edge or keel having existed; neither is there any indication of twisting. Judging from the relative positions of the brain-cavity, orbits, and other parts, it is probable that the horns were held almost erect, with a slight curve backwards.

1.



9.

GAZELLA ANGLICA.

Mintern Bros. imp.

The bases of the two horn-cores were not set parallel upon the skull, but diverged posteriorly. It is evident that the skull was very narrow, a space of not more than from 14 to 16 millim. intervening between the bases of the two horn-cores; and the orbits must have very nearly met below the brain. The pedicle extends downwards in front of the orbit, and towards the middle line the frontal bone recedes, so as to form a hollow forehead. Close to the frontal suture the bone thickens again, so that when the two frontals were together, there must have been a median ridge. On the front and inner side of the pedicle, quite at its lower extremity, a deep triangular depression, or fossa, is seen (fig. 2, *ff.*), from the upper part of which a large foramen pierces the frontal bone and passes directly into the upper and inner side of the orbit. Above and behind the orbit there is a well-marked pit, which indents the hinder fourth of the pedicle (fig. 1, *pp.*). No air-cavities can be seen in the frontal bone, and indeed the inner and outer tabulæ are so near together as to render it probable that only cancellated bone intervenes between them.

Measurements in Millimetres.

Height of horn-core from margin of orbit	84·0
Antero-posterior diameter of ditto at base	33·5
Lateral ,, ,, ...	21·5
Probable diameter of orbit	31·0
Greatest width of specimen from frontal suture to the present outermost part of orbit	35·0
Diameter of frontal foramen	4·5

The frontal bone being almost perfect and having the impressions of the cerebral convolutions preserved on its inner surface, it has been possible to take a plaster cast, which reproduces the form of the right frontal lobe and shows clearly the characters of its convolutions, thus enabling us to compare these important parts with those of the recent Antelopes. The remarkable compression of the brain in the orbital region is one of its most marked characters. The outer side of the frontal lobe, which rested upon the orbital plate, is almost plane (fig. 5), but two longitudinal sulci are traceable. The upper one is the more distinct, and towards the front it curves upwards and ends in a depression; posteriorly it deepens, and, passing upwards, forms the Sylvian fissure (*sf.*). Viewed from above (fig. 4), one convolution (*a*) is seen to follow the contour of the outer edge. This convolution at its hinder part is pushed upwards by the Sylvian fissure (*sf.*). More towards the middle line are two other convolutions of a sigmoid form (*b*, *c*), or rather one broad one with a sulcus along its middle incompletely dividing it into two parts. On the inner side of the hinder end of the last-mentioned convolution is a portion of another one (*d*), small but deeply curved. In front of this, and next the middle line, is a roughened space, probably indicating another convolution (*e*), the somewhat enlarged termination of which (*g*) is seen at the front of the brain just above the olfactory lobe, the position of which is shown in fig. 5, *of.*

During the time that I have been working at this Norwich-Crag Antelope, two other examples from the same horizon have come under my notice, so that the occurrence of the Antelope in these beds does not rest upon one specimen. The second example is in the Geological Department of the British Museum at South Kensington. It is labelled as belonging to the Wigham collection, and from the Norwich Crag of Norfolk (No. 33516). This also is a horn-core and frontal, somewhat smaller than Mr. Woodward's specimen, with rather more of the horn-core preserved. The two have a somewhat different appearance, both being imperfect; but they agree in all their principal characters, such as the position and form of the frontal fossa and its foramen, the position of the pit at the back of the pedicles, and also in the arrangement of the brain-convolutions.

The third example was among a number of bones from the Thorpe Crag Pit, which Dr. Arthur King, of Aspley Guise, Woburn, presented to the Museum of Practical Geology. This specimen, like the other two, consists of a horn-core and frontal; it repeats so closely the characters of the two already noticed that I have no doubt as to all three belonging to the same species. Dr. King's specimen (Pl. XIV. fig. 6) is somewhat smaller than that found by Mr. Woodward, and is more mutilated; but the portion of horn-core preserved is little abraded and indicates only a slight tapering, thus confirming the opinion above expressed, namely, that the more rapid tapering of Mr. Woodward's specimen is largely due to abrasion.

There is one other specimen which should be noticed, as it may possibly belong to this Pliocene Antelope; it is the distal half of a left tibia, preserved in the British Museum and labelled "Wigham Collection, Norwich Crag, Norwich." The proportions and structural details of this bone correspond with those of the tibiæ of some of the smaller Antelopes. As no other form is known from these deposits to which this tibia is likely to have belonged, it is better for the present to include it under the same species as the horn-cores already described.

A comparison of this Pliocene Antelope with the Antelope skulls in the British Museum and Royal College of Surgeons shows that, both in size and conformation, it agrees most closely with the Gazelles. Several of the nearly allied genera agree with the fossil in possessing a deep frontal fossa, from which the supra-orbital foramen passes directly into the orbit; but with none is the agreement so close as it is with the Gazelles. The three forms which seem most nearly to resemble the fossil are *Gazella dorcas*, *G. subgutturosa*, and *G. Bennettii*. *Gazella dorcas*, from Abyssinia, has the frontal fossa and its foramen, as well as the form of the horn-cores and pedicles, much as in the fossil; but the pit at the back of the pedicle is neither so deep nor so far forward as it is in the fossil.

The brain of this species, as shown by a specimen in the Museum of the Royal College of Surgeons, labelled *Gazella dorcas*, Egypt (No. 1327. c, *b*.), has the frontal convolutions more complex than they are seen to be in the cast of the fossil. The brain of *Gazella subgutturosa*, from Persia, in the same Museum (No. 1327. c, *c*.), has the convolutions of the frontal lobe much like those of the fossil, the three longitudinal convolutions (*a*, *b*, *c* in figures) being distinctly traceable; but the brain of *G. subgutturosa* has not the lateral compression of the fossil; and consequently, although the same convolutions are seen, they are proportionately wider. In addition to this the external features of the skull are different, *G. subgutturosa* having the horn-cores more upright and more curved, whilst the pit on the pedicle is further back and shallower.

Gazella Bennettii is the species most like the fossil in the form of the exterior of the skull, the greatest observable difference being in the shape of the frontal fossa, the inner margin of which is less distinct than it is in the fossil; and the pit on the pedicle of the horn-core is shallower and placed quite at the back. Mr. R. Lydekker has kindly lent me a skull of *G. Bennettii*, with permission to bisect it and take a cast of the brain-cavity; and I find that its brain (fig. 8) more closely resembles this Pliocene fossil than does that of any other species with which I am acquainted; and indeed it requires a close examination to trace any difference between them. However, although the same three longitudinal convolutions (*a*, *b*, *c*) are to be seen, it will be noticed that the sulcus between the convolutions *b* and *c* is continued backwards, so as to separate these two convolutions at their back part; while in the fossil (fig. 4) they are joined at this point. There are other slight differences in the convolutions of the orbital region*. I am also indebted to Mr. Lydekker for the opportunity of examining the skull and cast of the brain of the Tibetan *Gazella picticaudata*; but both these parts have fewer characters in common with the fossil than have been shown to exist in the species above noticed.

It now remains to be seen whether the Norwich-Crag Antelope will agree with any of the known fossil forms; for although no species of Antelope has hitherto been recorded from British strata, yet more than forty fossil species have been named from other parts of the world. Only a few of these, however, show sufficient resemblance to our fossil to render it necessary to call special attention to them †; and some, having been established on parts of the skeleton other than the skull and horn-cores, cannot be compared with the parts of the British Antelope at present obtained.

All the fossil Antelopes from the Siwalik Hills which have been made known to us are larger than this British example, the one which comes nearest to it, *Antilope porrecticornis*, being at least half as large again, and having the horn-cores directed more outwards, with their inner sides definitely concave from end to end, while the frontal fossa is pyriform and not triangular.

* It was thought that possibly different individuals might vary as to the characters of the skull or brain, and Mr. W. T. Blanford has very kindly placed at my disposal the skulls of two additional specimens of the Indian *Gazella Bennettii* for examination. Having taken casts of the interiors, I find that in their internal as well as external characters they agree exactly with Mr. Lydekker's specimen.

† A list of all the known fossil species, with references, is given at page 285.

Gazella brevicornis, from the Miocene of Pikermi, has the horn-cores strongly curved and not so much flattened as in our fossil, and at the same time they taper more rapidly towards the summit.

Antilope deperdita, from the Miocene of Mont Léberon, very closely resembles the last-named species, having the horn-cores strongly curved. The brain also of this species, as described by Gaudry, has the frontal convolutions more complex than they are in our fossil.

Antilope hastata, from the Pliocene (?) of Montpellier, besides being three times as large, has the horn-cores reclinate with a strong anterior and posterior limiting ridge.

Tragoceros Valenciennesi, from the Miocene of Pikermi, seems to have been about the same size as our fossil ; but the horn-cores are too reclinate, show no basal pit, and are set wider apart on the skull.

Palæoryx parvidens, also from Pikermi, is larger than the Crag species, has the horn-cores more curved, and more nearly round in section.

This comparison of the remains of the Norwich-Crag Antelope with the recent and fossil forms shows that it agrees more closely with some of the Gazelles of the present day than with any of the known fossil species. And seeing that almost all its known characters, including the triangular frontal fossa and supraorbital foramen, as well as the arrangement of the brain-convolutions, are to be found in one or other of the recent Gazelles, there is ample justification for placing it in the same genus. But inasmuch as this English Gazelle differs in certain points from each of the forms which it most nearly resembles, a new specific name must be found for it ; and that of *Gazella anglica* is suggested as being most appropriate.

The following Note on the horizon from which these specimens were obtained has been kindly appended by Mr. H. B. Woodward, who is so well acquainted with these East Anglian deposits; and further information will be found in his Survey Memoir 'On the Country around Norwich,' to which allusion has already been made. Mr. Woodward says:—

"The specimens described by Mr. Newton were obtained from the lower portion of the Norwich Crag at Thorpe, near Norwich. The basement-bed of this deposit, as is well known, generally consists of a bed of flints, of which the majority are more or less rolled, though some appear unworn. Pebbles of quartz and quartzite are occasionally met with in the bed; and at Thorpe I found in it a worn fragment of *Gryphæa dilatata*. At this locality the Crag Mollusca appear abundantly in the bed; and they even occur in crevices of the Chalk beneath, the surface of which, in places, is bored by marine shells and Annelides. This basement-bed has been called the Mammaliferous Stone-bed by Mr. John Gunn, because it is held that most of the mammalian remains of the Norwich Crag have been obtained from it. During a residence of four years at Norwich I frequently visited the

Thorpe pit, and as the Stone-bed was at times extensively worked away, I learnt from the workmen that while bones were found among the flints in all situations, they were most abundant immediately above the Stone-bed. In this position above the Stone-bed there was found a portion of an Elephant's tusk, 4 feet 6 inches in length; and in the same situation occurred most of the bones I had the good fortune to obtain, including the specimens now described by Mr. Newton. It is true that the Stone-bed is only from 1 foot to 18 inches or 2 feet in thickness; but the situation of the fossil bones is important in indicating that they belong to the Norwich-Crag period as much as do the Mollusca and other organic remains, although this opinion has been questioned."

FOSSIL ANTILOPIDÆ.

Antilope arvernensis, Bravard, MS. *Vide* A. TORTICORNIS, Aymard, MS.

ANTILOPE BOODON, Gervais.

Miocene Lignite of Alcoy, Spain.

Bull. Soc. Géol. Fr. sér. 2, vol. x. p. 157, pl. v. 1853.

Miocene, Pikermi ?

Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 84, 1878: possibly Gaudry's unnamed species (Anim. Foss. et Géol. de l'Attique, p. 277, pl. xlviii. f. 1, 1862) may be this.

[*A. Massoni*, Forsyth Major, possibly belongs to this species.]

A large species near *A. boodon*, found in Miocene? of Perpignan, Gervais, Zool. et Pal. Générales, p. 155, 1869.

Antilope brevicornis, Wagner. *Vide* GAZELLA BREVICORNIS, Wagner.

Antilope Christolii, Marcel de Serres. *Vide* A. RUPICAPRA, Pallas.

ANTILOPE CLAVATA, Gervais.

Miocene, Sansan.

Gervais, Zool. et Pal. Françaises, p. 78, 1848–52.
Lartet et Blainville (fide Gervais), Comptes Rendus, vol. v. p. 426, 1837.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 84, 1878 (?=*A. cristata*, Biedermann).

ANTILOPE COMPRESSA, Gervais.

Horizon? *Cucuron, Vaucluse.*

Zool. et Pal. Françaises, p. 178, 1848–52.

ANTILOPE CORDIERI, Christol (=*A. recticornis*, Gervais).

Pliocene, Montpellier.

Christol, Ann. d. Sci. Nat. sér. 2, vol. iv. p. 231, 1835, Ann. sci. et industr. du midi de la France, vol. ii. p. 20, 1832 (fide Gervais).
Gervais, Zool. et Pal. Françaises, p. 78, pl. vii. figs. 3, 11, 1848–52, id. Zool. et Pal. Générales, p. 148, pls. xx. & xxi. f. 1–3, 1869.

Lower Miocene, Casino, nr. Siena, Tuscany.

Forsyth Major, "Fauna Mamm. plioc. e post-plioc. d. Toscana," Atti della Soc. Tosc. Sci. Nat. p. 229, 1875.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. pp. 83, 87, and 180, 1878.

ANTILOPE CRISTATA, Biedermann.

Molasse of North Switzerland.

"Petrefacten aus der Umgegend von Winterthur," Heft iv. p. 14, pls. viii. & ix. 1873.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 84 and 87, 1878 (?=*A. clavata*, Gervais).

ANTILOPE DEPERDITA, Gervais.

Miocene, Mont Léberon, Cucuron, Vaucluse.

Zool. et Pal. Franç. p. 78, pl, xii. 1848–52.
Gaudry, Animaux Fossiles du Mont Léberon, 1873, p. 57, pls. xi. & xii.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 83, 1878.

ANTILOPE DICHOTOMA, Gervais.

Diluvial Sands of Lectoure.

Comptes Rendus, vol. xxviii. p. 549, 1849.
Zool. et Pal. Franç. p. 78, pl. xxiii. f. 4, 7, 1848–52.

ANTILOPE HASTATA, Gervais.

Pliocene ? Montpellier.

Zool. et. Pal. Gén. p. 149, pl. xvii. fig. 5, 1869.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 180, 1878.

ANTILOPE JÄGERI, Rütimeyer.

Württemberg ("Bohnerzgruben").

Jäger, Foss. Säug. Württemb. 1839, p. 22, pl. v. f. 43–54; at p. 201, called *A. major.*
Rütimeyer, "Natürliche Geschichte des Rindes," Neue Denkschr. schweiz. Gesellsch. vol. xxii. mems. 2 and 3, p. 89, Zürich, 1867.
Id., "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 88, 1878.

ANTILOPE MAILETI, Gervais.

Caverne de Mailet, Département du Gard.

Zool. et Pal. Gén. pp. 67, 68, pl. xvii. f. 1, 3, 1869.

ANTILOPE MAQUINENSIS, Lund.

Cave, Lagoa do Sumidouro.

'Blik paa Brasiliens Dyreverden,' Kjöbenhavn, 1841, p. 86, fide Rütimeyer (who places little reliance on this determination), "Rinder Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 90, 1878.

ANTILOPE MARTINIANA, Lartet.

Miocene, Sansan.

"Notice sur la Colline de Sansan," 1851, p. 36. Extrait de l'Annuaire du Département du Gers, Auch, 1851.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 84, 1878.

ANTILOPE MASSONI, Forsyth Major.

Lower Miocene, Casino, Tuscany.

"Consid. sulla Fauna dei Mamm. plioc. e postplioc. d. Toscana." Atti della Soc. Tosc. Sci. Nat. vol. i. p. 223, 1875.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 87, 1878.

[Vide *Antilope boodon*, q. 285.]

ANTILOPE PALÆINDICA, Falconer.

Siwaliks.

Pal. Mem. vol. i. p. 290, pl. xxiii. 1869.
Lydekker, "Crania of Ruminants," Pal. Indica, ser. x. p. 154, 1878.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. pp. 88 and 181, 1878.

ANTILOPE PATULICORNIS, Lydekker.

Siwaliks.

"Crania of Ruminants," Pal. Indica, ser. x. p. 157, pl. xxv. f. 3, 1878.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 181, 1878.

ANTILOPE PORRECTICORNIS, Lydekker.

Siwaliks, Potwar (N.-W. Punjab).

"Crania of Ruminants," Pal. Indica, ser. x. p. 158, pl. xxv. f. 4, 1878.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. pp. 181, 1878.

Antilope recticornis, Gervais. *Vide* A. CORDIERI, Christol.

ANTILOPE (ANTIDORCAS) ROTHI, Wagner.

Miocene, Pikermi.

Abhandl. baier. Akad. Wiss. vol. viii. p. 154, pl. vi. f. 20, 1857.
Gaudry, Bull. Soc. Géol. Fr. sér. 2, vol. xviii. p. 397, 1861; id. Anim. Foss. de l'Attique, p. 297, pl. lii. figs. 2, 3, 1862.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 83, 1878.

ANTILOPE RUPICAPRA, Pallas (= *A. Christolii,* Marcel de Serres).

Now living in Europe.
Caverne à Sallèles, Cabardés.

Marcel de Serres, "Notice sur de nouvelles cavernes, Département de l'Aude," Journal de Géologie, vol. iii. p. 260, 1831, Paris.

Caverne de Bize, near Carcassonne, Aude.

Marcel de Serres, "Notice sur les Cavernes à Ossemens du Département de l'Aude," p. 84, pl. v. f. 5, 1839 (fide Gervais).

Gervais, Zool. et Pal. Franç. p. 77, 1848–52; id. Zool. et Pal. Gén. p. 60, 1869.

Cave at Mentone.

Rivière, Comptes Rendus, 1872, vol. lxxiv. p. 1597.

Thayinger Cave, Schaffhausen.

Nehring, Zeitschr. deutsch. geol. Gesell. 1880, p. 491.

Trou du Sureau, Belgium.

Nehring, ibid. p. 507.

(sp. ?) *Langenbrunn, Sigmaringen.*

Nehring, ibid. p. 493.

(sp. ?) *Cave near O. Ruzsin, N.W. of Kaschau, Hungary.*

Nehring, Zeitschr. f. Ethnol. 1881, p. 102.

Antilope saiga, Pallas. *Vide* Saïga tatarica, Linn.

Antilope sansanensis, Lartet.

Miocene, Sansan.

Notice sur la Colline de Sansan, 1851, p. 36.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 84, 1878.

Antilope sivalensis, Lydekker.

Siwaliks of Kangra.

"Crania of Ruminants," Pal. Indica, ser. x. p. 154, pl. xxv. figs. 1, 2, 1878.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 181, 1878.

Antilope strepsiceros, Pallas.

Now living in S. Africa and Abyssinia.

Quaternary of Algeria.

Gervais, Zool. et. Pal. Gén. p. 92, pl. xix. f. 4, 1869.
Bayle, Bull. Soc. Géol. Fr. sér. 2, t. xi. p. 343, 1854 (fide Gervais).

Antilope torticornis, Aymard, MS. (fide Rütimeyer).

Auvergne.

Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 84, 1878.

Puy-de-Dôme.

[*A. arvernensis*, Bravard, MS., on a specimen in the British Museum, said by Rütimeyer to be the same as *A. torticornis.*]

Antilope, sp.

Banks of the Irawady, Burmah.

Clift, Trans. Geol. Soc. ser. 2, vol. ii. p. 374, pl. xli. f. 21, 25, 1829.

Quaternary of Algeria (probably *A. dama*).

Gervais, Zool. et Pal. Gén. p. 94, pl. xix. f. 5, 1869.

(? gen.) *Diluvium; Magdeburg, Quedlinburg, and near Nürnberg.*

Nehring, Zeitschr. deutsch. geol. Gesellsch. 1880, pp. 473, 475, 488.

GAZELLA ANGLICA, new species.

Norwich Crag, Thorpe, near Norwich.

GAZELLA BREVICORNIS, Roth and Wagner.

Miocene, Pikermi.

Abhandl. baier. Akad. der Wiss. vol. vii. p. 452, non pl. vii. f. 4 & 6, 1854.
Gaudry, Bull. Soc. Géol. Fr. ser. 2, vol. xviii. p. 397, pl. viii. f. 6–8, 1861; id. Anim. Foss. de l'Attique, p. 299, pl. lvi. figs. 1–4, and pl. lvii. 1862.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. Pal. Gesellsch. vol. v. pp. 83 & 87, 1878.

HIPPOTRAGUS FRAASII, Rütimeyer.

Württemberg ("Bohnerzgruben").

"Natürliche Geschichte des Rindes." Neue Denkschr. schweiz. Gesellsch. xxii. Mems. 2 & 3, p. 89, pl. i. f. 78, Zürich, 1867.
Id. "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 88, 1878.

PALÆOREAS LINDERMEYERI, Wagner.

Miocene, Pikermi.

Abhandl. baier. Akad. Wiss. vol. iii. pt. 2, p. 366, pl. iv. figs. 2, 5, 1848.
Gaudry, Bull. Soc. Géol. Fr. sér. 2, vol. xviii. p. 395, pl. ix. figs. 4, 6, 1861; id. Anim. Foss. de l'Attique, p. 290, pl. lii. to lv. 1862; id. 'Enchaînements du Monde Animal,' p. 82, 1878.

Miocene, Mont Léberon.

Gaudry (? species), Anim. Foss. du Mont Léberon, Paris, 1873, p. 64, p. xii. fig. 13.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 83, 1878.

PALÆORYX MENEGHINI, Rütimeyer.

Italy, horizon doubtful.

"Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 87, pl. vii. f. 13, 14, 1878.

PALÆORYX PALLASII, Wagner (=*P. speciosus*, Wagner).

Miocene, Pikermi.

Abhandl. baier. Akad. der Wiss. vol. viii. p. 149, pl. vii. f. 21, 1857.
Gaudry, Bull. Soc. Géol. Fr. sér. 2, vol. xviii. p. 393, pl. ix. f. 1–3, 1861 (*A. speciosus*, referred to *A. Pallasii*); id. Anim. Foss. de l'Attique, p. 271, pl. xlvii. figs. 1 to 5, 1862.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 83, 1878.

PALÆORYX PARVIDENS, Gaudry.

Miocene, Pikermi.

Bull. Soc. Géol. Fr. ser. 2, vol. xviii. p. 395. pl. ix. figs. 4, 6, 1861.
Id. Anim. Foss. de l'Attique, p. 276, pl. xlvii. figs. 6, 7, 1862.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 83, 1878.

Palæoryx speciosus, Wagner. *Vide* P. PALLASII, Wagner.

PALÆOTRAGUS ROUENII, Gaudry.

Miocene, Pikermi.

Bull. Soc. Géol. Fr. sér. 2, vol. xviii. p. 389, pl. vii. figs. 1, 2, 3, 1861.
Gaudry, Anim. Foss. de l'Attique, p. 264, pl. xlv. 1862.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 83, 1878.

PORTAX NAMADICUS, Rütimeyer.

Narbada.

"Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 89, pl. vi. figs. 7, 8, 1878.
Lydekker, "Crania of Ruminants," Pal. Ind. ser. x. p. 180, 1880.

PORTAX, sp., Lydekker.

Siwaliks.

"Crania of Ruminants," Pal. Ind. ser. x. p. 180, 1880.

SAÏGA TATARICA, Linnæus.

Now living in Eastern Europe and Western Asia.
In several European Caves.

Lartet, Comptes Rendus, vol. lviii. p. 1201, 1864.
Woodward, Geol. Mag. vol. vi. p. 58, 1869 (the possible English specimen referred to in this paper was doubtless part of a Goat).
Dupont, L'Homme pendant les Ages de la Pierre, &c., p. 169 and Table, Bruxelles, 1872.
Gervais, "Matériaux hist. de l'homme," sér. 2, vol. iv. pp. 270, 271, 396, 1873.
Lartet and Christy, 'Reliquiæ Aquitanicæ,' pp. 95, 172, 287 (edited by T. Rupert Jones), 1875.
Gaudry, Matériaux pour l'Histoire des Temps Quaternaires, p. 65, 1880.
Dawkins, 'Cave Hunting,' pp. 336, 348, 399, 1874; id. 'Early Man in Britain,' p. 98, 1880. (Possibly some of the remains alluded to by Nehring as *Antilope*, sp., should be placed here.)

TRAGOCEROS AMALTHEUS, Roth & Wagner (= *T. arcuatus*, Gervais).

Miocene, Pikermi.

Abhandl. baier. Akad. der Wiss. vol. vii. p. 453, pl. vi. fig. 2, 1854.
Gaudry, Bull. Soc. Géol. Fr. sér. 2, vol. xviii. p. 390, pl. viii. figs. 1, 2, 3, 1861; id. Anim. Foss. de l'Attique, p. 278, pls. xlviii. to li. 1862.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. pp. 83 & 87, 1878.

Miocene, Mont Léberon, Cucuron, Vaucluse.

Gervais, Zool. et Pal. Franç. édit. 2, 1859, p. 343.
Gaudry, Anim. Foss. du Mont Léberon, p. 50, pl. ix. figs. 8–11, and pl. x. Paris, 1873.

? *Horizon. Near Vienna.*

Süss, Sitzb. d. kais. Akad. d. Wiss. Wien, Bd. xlvii. Abth. i. p. 314, 1863.

Tragoceros arcuatus, Gervais. *Vide* T. AMALTHEUS, Roth & Wagner.

TRAGOCEROS VALENCIENNESI, Gaudry.

Miocene, Pikermi.

Bull. Soc. Géol. Fr. sér. 2, vol. xviii. p. 393, pl. viii. figs. 4, 5; id. Anim Foss. de l'Attique, p. 288, pl. xlviii. figs. 2, 3, 1862.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 83, 1878.

TRAGOCEROS, sp. unnamed, Gaudry.

Miocene, Pikermi.

Animaux Foss. de l'Attique, p. 289, pl. 52, f. 1.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 83 (line 17), 1878.

N.B. The following species have been founded on insufficient data:—

Antilope gyricornis, Falconer, MS.

Siwaliks.

Pal. Mem. vol. i. p. 281, 1878.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 181, 1878.

Antilope major, Jäger.

Württemberg ("*Bohnerzgruben*").

Foss. Säugeth. Württ. 1835–39, p. 201, pl. v. f. 46, 54, & 57–61, and pl. x. f. 49. At page 22 described but not named (figs. 43 to 54 have been called *A. Jägeri* by Rütimeyer); id. Foss. Säug. Württ. Nachtrag, Nova Acta Acad. Naturæ curiosorum, vol. xxii. pp. 793 & 812, 1850.

Antilope minor, Jäger.

Württemberg ("*Bohnerzgruben*").

Foss. Säugeth. Württ. 1835–39, p. 201, pl. v. figs. 55, 56, & pl. x. fig. 48. Described but not named at p. 22; id. Foss. Säug. Württ. Nachtrag, Nova Acta Acad. Naturæ curiosorum, vol. xxii. pp. 793 & 812.

Antilope molassica, Bronn.

Molasse of Württemberg.

This name is given by Bronn, Index Palæontologicus, 1848, p. 84, with the reference to Jäg. Säugeth. 8, t. i. f. 32; but at this reference Jäger mentions two astragali from the Molasse, one of which he thinks closely resembles *Antilope cervicapra*, and the other may be *Cervus* or *Antilope*; no name is given to either of them.

Antilope picta, Pall. (=*Portax picta*).

Living in India.
Siwaliks.

Falconer, Pal. Mem. vol. i. p. 281, 1869.
Rütimeyer, "Rinder d. Tertiärepoche," Abhandl. schweiz. pal. Gesellsch. vol. v. p. 181, 1878. There is no good reason for thinking that this living form has yet been found fossil, but two forms of the genus *Portax* are recorded by Mr. Lydekker.

EXPLANATION OF PLATE XIV.

All the figures are of the natural size.

Fig. 1. *Gazella anglica*, n. sp. From the Norwich Crag, of Thorpe, near Norwich. In the Museum of the Geological Survey. Right horn-core and frontal bone seen from the outer side.

2. Same specimen seen from the front with left side reproduced in outline, to show the direction of the horn-cores.
o. orbit; *pa.* portion of parietal bone; *ff.* frontal fossa; *f.* its foramen passing into orbit; *pp.* the pit on side of pedicle.

3. Section of horn-core at its thickest part.

4. Cast taken from the interior of the frontal bone, seen from above, showing the convolutions of the frontal lobe of the brain.

5. Same cast seen from outer side.
sf. sylvian fissure; *a, b, c, d, e, g.* convolutions; *o.f.* position of olfactory lobe.

6. *Gazella anglica*, n. sp. A left horn-core and frontal bone from the Norwich Crag, Thorpe, presented to the Museum of the Geological Survey by Dr. Arthur King. Seen from the outer side. Letters as in fig. 1.

7. Cast of interior of frontal bone of specimen fig. 6.

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8. Cast of the right frontal lobe of the brain taken from the skull of the recent Indian species, *Gazella Bennettii*, for comparison. Letters as in fig. 4.

9. Similar cast taken from the skull of the recent Tibetan species *Gazella picticaudata*.

Discussion.

Mr. Lydekker agreed with the author that the species was a Gazelle. He remarked that the Hyæna occurring in the Crag was an African type, and that further comparison of the present species with African Gazelles was desirable. There was very little difference between the genera *Antilope* and *Gazella*; and in the case of fossil forms, our knowledge of which is necessarily imperfect, he thought the recognition of a single genus would suffice.

Mr. Blanford remarked that the present paper was the outcome of an excellent piece of palæontological work, and complimented the author upon the perseverance with which he had deduced such valuable results from such exceedingly scanty materials. He remarked, however, in connexion with the affinities of this fossil Antelope, that the author stated that he had compared his specimen with the Abyssinian Gazelle, as well as with the Indian species, but the Abyssinian animal is regarded by some of the best authorities as forming a distinct species from the typical *Gazella dorcas*, which inhabits northern Africa and, as a dweller in the Mediterranean and Palæarctic region, comes nearer than any other in geographical range to the species described. After noticing the present distribution of the genus *Gazella*, he pointed out that nearly all the species were inhabitants of plains, and most of deserts, and that the occurrence of this species in the Crag might perhaps indicate the condition of England in Pliocene times.

Prof. Prestwich said that this species was particularly valuable, because the specimen was not derived. He noticed that a species of Antelope, belonging to the genus *Saïga*, already found in France and Belgium, occurred in Britain in Pleistocene times. Its remains were found a few years since, it was said, near Bedford.

Mr. H. B. Woodward remarked on the valuable corroboration furnished by the specimen subsequently obtained by Dr. A. King from the same locality, and expressed his opinion that the Mammalia found in the Norwich Crag belonged as much to the period as the Mollusca with which they are associated, the former being borne down by streams or tumbling over the chalk cliffs which in places bounded the Crag sea.

The Author in reply said that he had not been able to examine the recent North-African forms so thoroughly as he could have wished; but none of the Dorcas-Gazelle skulls in the British Museum, or of those in the Royal College of Surgeons, were so like the fossil as was that of *G. Bennettii*: and the brain of an Egyptian Dorcas Gazelle in the latter collection also showed less resemblance to the fossil than did that of *G. Bennettii*. He thought the fossil species came nearer to *G. Bennettii* than to either form of the Dorcas Gazelle.

21. *On the* Volcanic Group *of* St. David's.

By Rev. J. F. Blake, M.A., F.G.S. (Read January 9, 1884.)

The discordant views which at the present moment prevail on the subject of the oldest rocks in the St. David's district, and the interest which attaches to these rocks according to one at least of the interpretations, induced me, after a visit to the Highland regions on which the same discordance is shown (but where nature seemed to differ widely from her earlier and disputant interpreters), to attack the St. David's problem independently, and to stay in the district long enough to come to a conclusion as to the true nature and age of the rocks.

Finding myself in accord neither with Dr. Hicks on the one hand, nor with Dr. Geikie on the other, but led irresistibly to the more simple results so ably shadowed forth by Mr. Hudleston *, I cannot refrain from offering to the Society the evidences on which my conclusions are based; as I cannot suppose that the reply which Dr. Hicks will doubtless produce, will represent the same and, as I believe, the true view of the question.

The result of my observations may be thus briefly stated:—all the rocks which have been designated Dimetian, Arvonian, and Pebidian, round and near the city of St. David's, belong to one volcanic series, whose members are those usually recognized in eruptive areas, and whose age is anterior to and independent of the true Cambrian epoch.

An *a priori* argument in favour of this view is, that it unites the essential features of both the other interpretations; it has the advantage of simplicity, and renders a reason for the constant association in the other Pre-Cambrian areas of three types of rock which may be interpreted in the same manner. Nevertheless, were the foeman deemed worthy of the steel, it would doubtless meet with strong resistance from the holders of either of the previous views, as it coincides with neither.

The first point that stands in need of proof is the entire independence of every member of the volcanic series and the Cambrian rocks from the conglomerate upwards. Their junction can be studied in one way or another round most of the circuit, as seen in the map (fig. 1), and can only be satisfactorily explained by the occurrence of a series of bounding faults, such as would be produced when the underlying mass was forced up amongst the newer rocks at the time when their nearly vertical position was assumed.

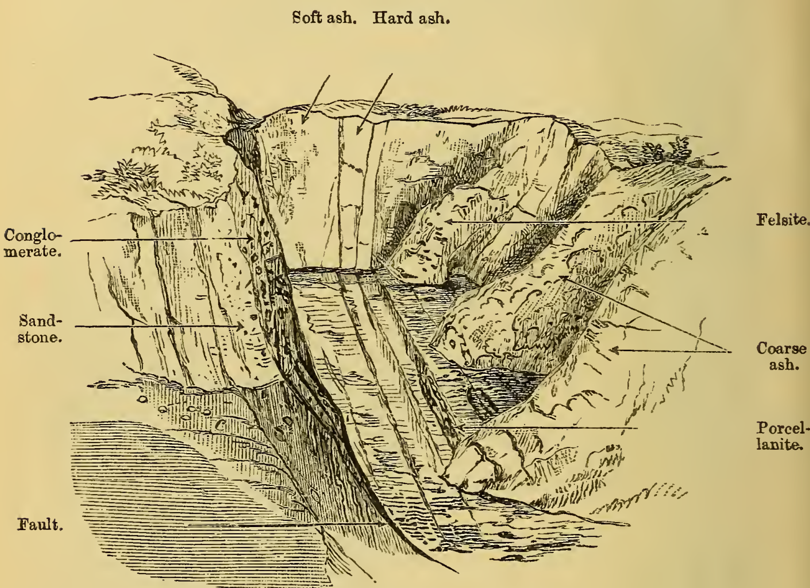
On some parts of this circuit I need but briefly touch, merely corroborating what has been said by Dr. Hicks and others. Starting at the south of St. David's, the line of junction first comes to day in a little bay to the west of the ruins of Nun's Chapel, where

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 167.

Fig. 1.—*Geological Sketch-map of the St. David's District.* (Scale 2 miles to 1 inch.)

the following view may be seen (fig. 2). Here the conglomerate, which passes up into grey sandstone and has none of the intercalated tuff-like material which is found in the next westward cove, lies on

Fig. 2.—*View west of Nun's Chapel, looking west.*



a mass of tuffs and ashes, some of which are indurated by siliceous infiltration into the "porcellanites," and others have intrusions of the spherulitic felsite. The line of junction, which is perfectly clear on the shore, is actually a faulted one, the conglomerate coming against and being entirely cut out by the ashes at that particular spot; and these latter seem to increase in thickness as they pass up the cliff next to the former. Such a fault, standing alone as evidence, would, I admit, be of very little consequence; but it is certainly satisfactory to find that in one of the very few places where a knife can be passed between the surfaces of junction, that junction is a fault. It is not, however, on the character of such isolated spots that the relations of two series are to be judged; but we must inquire whether they cling to each other or not as they are traced across the country.

Now we know that to the west, at Porth Clais, the conglomerate itself is cut out, all the ashes have disappeared, and the granite comes into contact with and has been pushed over the slate *. In the bay below Nun's Chapel we have beneath the conglomerate, first, the fine ash, porcellanized in bands, then the coarser ashes, all nearly vertical, and finally in the recesses of the caves the massive spherulitic felsite without proof of intrusion; and all this is included in less than a hundred yards. When next, however, we come across a section in Caerbwdy valley, a red ash underlies the conglomerate, which is partly composed of its fragments; then is seen a massive felsite; below comes a wide space containing thin-bedded porcellanites, next ashes, and finally the massive felsites of the cave, separated by nearly a quarter of a mile from the conglomerate. All the upper part of this series has been introduced here between the surfaces of junction, we can scarcely suppose by original deposition. Here then is unconformity or fault, or both, but certainly independence.

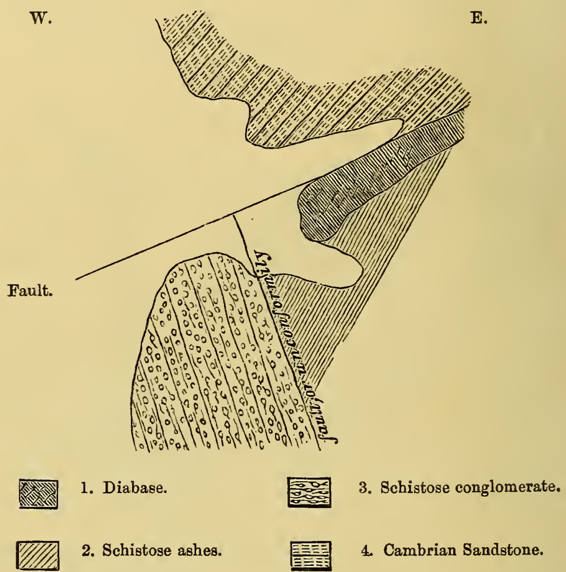
The country hence to Solva valley is obscure, and what justification there may be for the boundary-line I cannot say. In that valley the mass marked as felspar porphyry is overlain both on the north and on the south by a conglomerate, or rather, a very coarse grit, which occupies the same place in the series as the other conglomerates. These felspathic rocks I take therefore to be still part of the volcanic series, but certainly different in character from the beds already seen next the conglomerates. Further up the river, where the valley runs east, it coincides with the line of junction. Yet on the north side we pass successively from felsites to ashes and agglomerates; on the other from the purple slates through the Menevian to the Llandeilo. The break here, again, is at the same place in the series.

Of the northern boundary I know nothing; it has always been marked as a fault. On the west, in the upper reaches of the Alan, near the farm of Trehenliw, we have, on one side, silvery ashes of peculiar character not seen elsewhere, on the other Cambrian slates; again no regular sequence. On the coast the junction is first seen at Ogof Golchfa, where silky ashes associated with dark-coloured crystalline rocks strike at the conglomerate and are nearly parallel to the Cambrian slates, appearances which I interpret as due to a forked fault (fig. 3); but the locality will doubtless be more fully described by Dr. Hicks, who directed my attention to it. The conglomerate here is of a different character compared with that on the eastern side, being well supplied with porcellanite as well as quartzite pebbles, and having a highly schistose matrix, possibly derived from underlying silvery schists which have been destroyed. South of this spot the conglomerates nowhere reach the coast till near Castell, but are cut out by repetitions of the overlying purple beds, as indicated by Dr. Geikie's map. The nature of the junction is not directly observable along this line; but when the conglomerate is seen on the coast its strike and that of the overlying beds is about 45° inland, or directly at a boss of lavas and ashes which is not 40

* This account of what is seen there is, of course, at present assumed to be the true one.

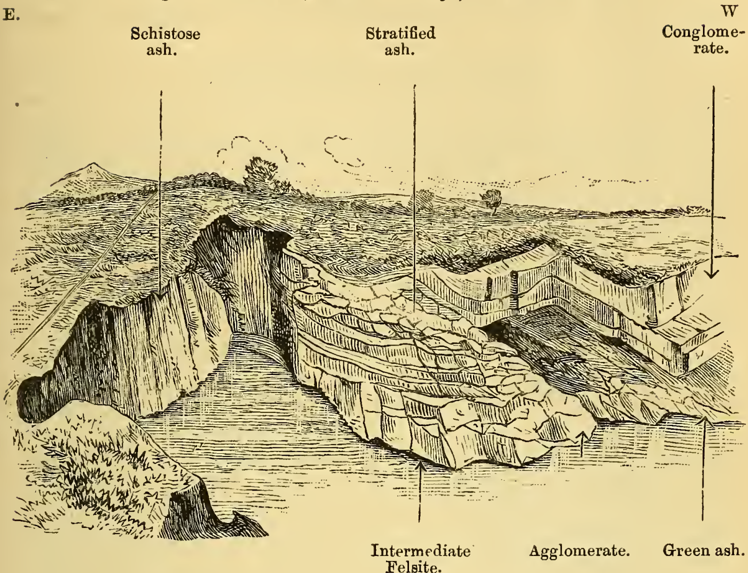
yards distant. Here the junction looks like a faulted one, and the nearest beds to the conglomerate are not the silvery schists. These, indeed, come on further south in an unconnected manner, and

Fig. 3.—*Plan of Ogof Golchfa.*



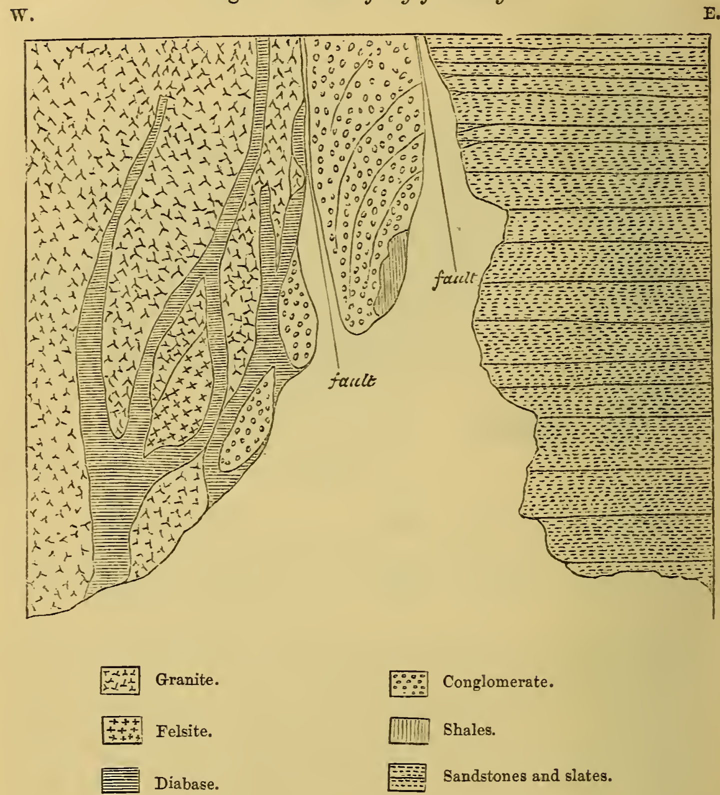
occupy much of the coast till we come to the important section of Carn-ar-wig, where is a landing-place and crane. Here the following view is seen (fig. 4) :—On the east are vertical silvery schists with a north and south strike; they form the boundary of a little inaccessible bay, which apparently contains a fault; associated with which there is probably a mass of an amygdaloidal rock, of which numerous fragments lie about; on the other or west side of the bay are great masses of felsite at the base, covered with evenly bedded ashes dipping N.N.E. at about 20°, and forming part of a mass which is almost agglomeratic in parts. This is followed to the west by smooth green hummocky ashes; and the last two rocks are overlain quite unconformably by typical conglomerate dipping N. W. at about 45°, with large pebbles of quartzite at the base. Though there is no fault here, all the rocks being laid quite bare, no better proof could be desired, derived from one spot, of the perfect independence of the conglomerate and the volcanic series and in particular the silvery schists. This is the end of the circumference, until we reach the eastern side again, and come to those interesting spots in which the granite plays an important part.

Fig. 4.—*View of Carn-ar-wig from the north.*



Of these the rocky inlet of Ogof-Llesugn is doubtless the key; it has been brought forward as a crucial test of the true relations of the two series of rocks, and held to prove the idea of a Pre-Cambrian granite to be a delusion. This being the case, it ought to be described with care. I am at a loss how to characterize the description that has actually been given of it without offence; but I must at least say that the essential feature has been missed. A plan of the spot is presented below (fig. 5):—On the west side of the inlet we have the granite mass, on the east side the nearly vertical beds of the Cambrian some way above the base, striking straight at the granite. In the angle between these is a projecting mass of conglomerate, also apparently vertical and striking nearly at right angles to the other Cambrian beds, so far as can be ascertained, the stratification being obscure. This projecting mass is bounded on either side by a fault which has given rise to a cavern; that on the east side, between the conglomerates and the slates, extends $\frac{3}{4}$ mile inland, or to about the position of the Porthclais mill; both are characterized by their fissure-like straight aspect, their slickensides, and the discordance of the adjacent beds. There is some bending round of the slates near the fault, as if to get into the same strike as the conglomerate, which contains some tuff-like masses, but is unaltered from its usual appearance on this side. On the western side, where the granite is, the line of fault has been invaded by a considerable quantity of dark-green rock, "diabase," which has fissured and streaked the granite by its intrusions, and has torn off fragments of this rock, of felsite, and of conglomerate, in-

Fig. 5.—*Plan of Ogof-Llesugn.*



discriminately, and borne them upwards. It is only, therefore, by chance that the granite and conglomerate ever come together, *i. e.* where the diabase has not intruded between them. There may be a foot or two of such a conjunction on the sides of the fissure; but the greater part of this is bounded by the "diabase." The masses on the foreshore are absolutely not in contact with the granite at all, but surrounded by the "diabase," and altered by it to a much more solid rock. The granite and felsite are treated in the same way. It seems to me an interesting spot to compare the appearances of an intrusive and a faulted junction, since both are so plainly shown and so clearly contrasted, that the truly faulted nature of the junction between the granite and the Cambrian cannot be for a moment doubted. The clear exhibition of a double fault is also instructive as affording the key to the obscurer sections at Porthclais.

Of these, the one on the east of the stream shows no intrusion; the granite is massive, the slates are massive; but the foot or so between them is rotten and waterlogged; the granite is undoubtedly over the slates in the slanting junction. On the opposite side of the stream the granite is in like manner over the conglomerate, but does not intrude into, or alter it. Both junctions are due to one overthrust fault along the continuation of the line which was traced at Nun's Chapel. In any case the conglomerate is out of place here, and there must be another, no doubt connected, fault to bring it there, as at Ogof Llesugn. In the next small section to the north, where the granite and slate approach, there is 3 feet between the solid rocks, occupied in part by decomposed slate and in part by decomposed granite; here the latter underlies, and the fault is not reversed. On the other side of the granite tongue, where it touches the conglomerate again on the north, there is a complication of faults; next to the solid granite comes a mass partly decomposed, next a mass of the quartz-felsite, and then, on the other side of about 6 inches of broken material, the unaltered solid conglomerate. There is another junction on the opposite side of this conglomerate, where the granite comes on again; but its nature is not seen. Thus the boundaries of the series of rocks in question have been examined at all the chief points in the whole circumference, and there is not a single spot where intrusion is suggested, much less shown, or where the volcanic ashes are bound in any way to the Cambrian conglomerate.

But is there nothing in the idea of an isocline on the western side which should show that the conglomerate always follows the silvery schists or their equivalent? I have rowed round the whole of the coast from Porthlisky to the Penmaen-Melyn, and have examined a large portion of it on land, and have been enchanted with the glorious confusion of the volcanic masses there exhibited. Here are the evenly bedded massive agglomerates, here great hummocks of dark lava protruding into the sea, here columnar and spheroidal dykes, now unstratified agglomerates with beds thrown off on either side, and now nearly horizontal well-bedded purple ashes, overlain by a lava-like rock, but all without a sign of a regular fold, which, amongst such rocks, would be almost impossible to conceive. Nor is the similarity of the two rocks on the supposed opposite sides of the fold so great; on the west they are uniformly silky and pink, on the east, next the granite, they are of all kinds, including many very soft and variously coloured; but these bear only the faintest resemblance to anything on the eastern side of the granite at Caerbwdy, where only the topmost red ashes are at all like them, while the lower ones which tend to become porcellanites, are quite peculiar in the St. David's district.

Such are the proofs that the whole series below the Cambrian conglomerate is quite independent of it, and forms a massive which must be studied by itself. Further collateral proofs will be derived from the manner in which this massive holds together as a whole, not only in this immediate district but elsewhere.

The existence of tuffs above the conglomerate appears to me quite a secondary matter in the question; there might, or might not, be such tuffs without seriously affecting the independence of the lower series, as there are certainly tuffs on higher horizons. Nevertheless, neither the specimens collected, nor the sections said to show inosculation that have been indicated, nor the diagrams of the microscopic slides given in Dr. Geikie's paper yield satisfactory proofs of identity in character between any beds above and any beds below the conglomerate.

We have next to consider the more interesting question as to the true character of these rocks. Are they sedimentary or are they igneous? On this subject I feel that any arguments of mine will have more weight with myself than with any one else; but to me they are overwhelming in favour of the essentially igneous origin of the whole (including, of course, ashes and volcanic mud as igneous rocks). First, with regard to the rock considered to be granite by some, and a metamorphosed aqueous rock by others: I believe we are learning from an improved stratigraphy to be more cautious in regarding many rocks as the metamorphosed representatives of what we are also acquainted with in their unmetamorphosed state: but whether metamorphosed or not, there is no reason why a primitive granitic rock should not be stratified in structure, even if not sedimentary, according to the ordinary sense, in origin. But such stratification is not to be proved by planes of division, which, however constant in direction, may well be joint planes, but by differences in mineral character along definite bands, either on a large or on a small scale. It is true that such bands of a partly calcareous nature have been indicated by Dr. Hicks at Porthlisky Point; but these have not been brought prominently forward, as they should have been, if without any doubt they had the significance assigned to them; and though unable to find such myself, I think it probable they are correctly explained by Dr. Geikie. But elsewhere I could trace no such bands. In the Bryn-y-garn quarries there are varieties of texture; but these do not run in bands, and the finer-grained masses have more the appearance of irregular veins. The microscopic structure of both forms is nearly identical. In the coarser the quartz has crystallized before the felspar; but in the finer the felspar has sometimes crystallized first; and sometimes the two have gone together, producing that micropegmatitic structure which Mr. Davies has noted in the rock from Porthlisky, and which is not uncommon in undoubtedly igneous granites. In both, the third constituent is the same chloritic mineral, more frequently in radiating lines occupying narrow interstices, but occasionally in complete and independent crystals. The structure of the rock at Porthclais is essentially the same. Here and there are inosculations of the two minerals, and both are occasionally characterized by abundance of acicular microliths. This latter feature becomes predominant in the rock of Ogof Llesugn, and is its chief distinction from that at Bryn-y-garn. These characters may point to differences in the circumstances of formation, but do not indicate any difference in material which should satisfactorily characterize a bedded rock. The essentially crystalline character of the rock justifies us, under these circumstances, in considering it, if not a granite, at least a rock formed under similar circumstances, *i. e.* an essentially igneous rock, whose crystals have been formed from a fluid magma. The earlier crystallization of the quartz, indicated by the felspar occupying sinuous interstices, may be accounted for on well-known chemical principles by an excess of the silica in the magma.

Next, we come to the felsitic rocks. The chief stratigraphical feature of these is the complete manner in which they surround the central mass, which, for convenience at least, we may designate, for the present, as granite. There are two principal varieties, which may be called the spotted felsite and the quartz-felsite, surrounding the St. David's granite; but other forms occur in outlying districts. Commencing at the city, these are found, as is well known, one in the Church-School quarry and the other in the Board-School quarry, or, rather, both in the first; they are also associated in the field to the south, and again in the street; near the cross there is the quartz-felsite, and further down the hill, to the west, by the Deanery, and on the road-side the spotted felsite, and, at Rock House, a more doubtful rock. The spotted felsite continues all along the southern side of the Alan from the bridge on the Treginnis road, to the bend in the river, when it crosses to the now western side and lies between the ashes and the granite. At the quarry near Rhoscribed, a piece of the quartz-felsite is let down between the granite and conglomerate, and fragments of the spotted felsite strew the ground in the field above. The character of the rocks on the eastern side is not seen on the road to Caerfai; but on the south side again we have the spotted felsite below Nun's Chapel and also further west at Porthclais farm, where the fault cuts out everything between the granite and the slate. That the Porthlisky tongue is not surrounded by such felsite is accounted for by the fact of its being bounded by faults (as I have shown at Ogof Llesugn, and as I have observed at Porthlisky Bay, where also there is an intrusive dyke of diabase along the line of junction). These relations are difficult to explain on the theory of the felsites being metamorphosed stratified rocks having any definite strike, and are more naturally the result of their being the bounding rocks of the granite. Nowhere have I seen any evidence either of the granite intruding into them or of their intruding into the granite, though neither of these phenomena would surprise me; but they intrude into the ashes below Nun's Chapel.

In intimate structure they are essentially igneous rocks, as has been practically admitted by all. The most interesting feature of the quartz-felsites is, that while the quartz centres are uniformly crystalline, and have therefore crystallized slowly, their boundaries are more or less rounded so as to obscure their regular crystalline form, and they are surrounded by a radiate spherulization, which has therefore formed rapidly; the remainder is composed of intermediate-sized crystals, and has therefore crystallized more slowly. This would seem to suggest that the quartz centres were either derived from some preexisting rock, or formed under peculiar circumstances in the magma before its extrusion as a lava, and that they have acted as starting-points for crystallization on the cooling of the mass; but when their influence ceased, the rest became crystalline more gradually. In the other form the porphyritic crystals are *chiefly* felspar, but they do not form centres, the spherulites being scattered in the ground-mass and smaller in size; there is also quartz developed as a pseudomorph, as better seen in other rocks. Some of these are remarkable for the abundance of pyrites, and all contain minute green radiate crystals. A very distinct rock, however, bounds this group in the Church-School quarries, in which the ground-mass consists of a multitude of small quartz and felspar crystals arranged in an almost graphic manner, but with a few large porphyritic crystals and indications of a few spherulites. This would seem an indication of intrusive character. It is remarkable that a very similar rock (in which, however, the spherulites are more numerous and the minute crystals forced into more regular situations) occurs as a dark-looking rock, resembling a basic lava, at Penmaen Melyn. Another mass of the same group, but flinty and compact in appearance, is found north of the Llanhowel rock. This shows none of the spicular crystals, but the ground-mass is minutely and irregularly crystalline, many individuals being recognizable as quartz, a considerable proportion of which may be of clastic origin; and here and there radiate crystallization has taken place; but besides this there are numerous very round blebs of perfectly clear quartz, the origin of which is obscure. They seem to be preexisting and not to have developed in the rock, but they are so round as to be quite unlike water-worn grains. The idea which suggests itself on a comparison of this with the masses nearer the central granite is, that the quartz grains which are there so large, and often retain their crystalline form, have here been subjected to more complete melting and have nearly disappeared, for they are very like what would be produced by such a process. They would then be too feeble to set up much of the spherulitic structure, if such were originated by the quartz. In none of the rocks which are remote from the granite, so far as I have examined them, are any porphyritic crystals found.

The felsitic mass which bounds the Solva valley, S.W. of Llanhowel, is more like the non-spherulitic portion at the Church-School quarry. It is composed of a network of fine crystals, of which those of quartz are irregular; but the other mineral, possibly mica, is so finely divided into fibres that it gives gorgeous colours in polarized light. Some of this occupies the place of an old felspar crystal.

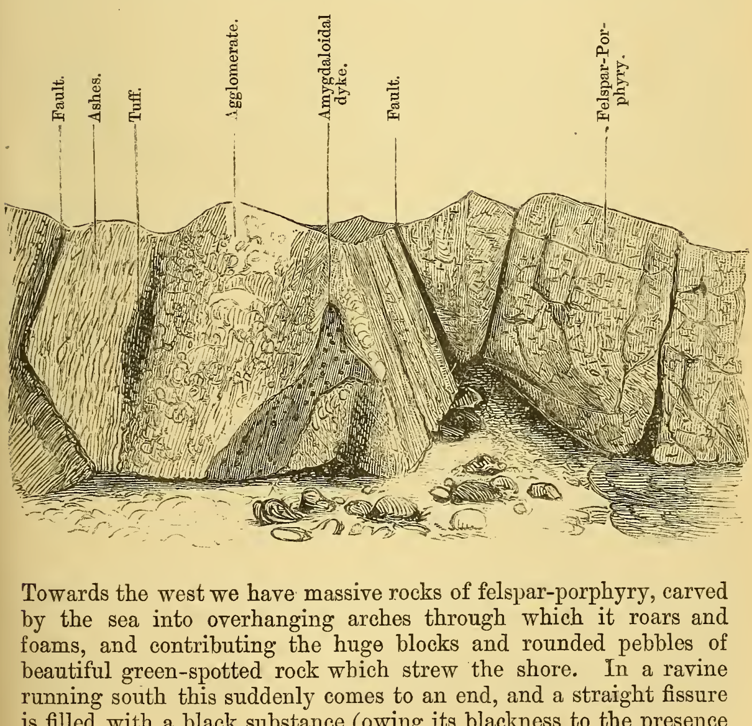
On the ashy rocks nothing need be said in proof of their nature; but their variety is astonishing.

In the nature then of the rocks which compose the Pre-Cambrian mass which has its centre at St. David's, we have proof of its igneous origin, and of the gradual lessening of the magnitude and clearness of the crystals as we approach the boundaries. The spherulitic and other structures are also only to be met with in truly igneous rocks. This being the case, and the relations of the several members recalling those so well described by Prof. Judd in the Island of Mull, we are justified in seeing in this group the natural products of a volcanic area dissected for us by the hand of time.

But however strong may be the argument derived from this particular mass, its force is greatly strengthened by the study of two outlying areas, the one on the west and the other on the east, in both which the association of the rocks and their minute structure suggest, and are explicable by, an igneous origin alone.

That on the west is the remoter part of Ramsey Island, which from a geological point of view presents truly magnificent features. The finest section showing the relations of the rocks is seen on the south side of Porth Hayog, as in the accompanying sketch (fig. 6).

Fig. 6.—*View in Porth Hayog, looking South.*



Towards the west we have massive rocks of felspar-porphyry, carved by the sea into overhanging arches through which it roars and foams, and contributing the huge blocks and rounded pebbles of beautiful green-spotted rock which strew the shore. In a ravine running south this suddenly comes to an end, and a straight fissure is filled with a black substance (owing its blackness to the presence of a small quantity of graphite) which also runs in a kind of horizontal vein through the porphyry. This rock has a very strong resemblance to those portions of the felsite below Nun's Chapel which are destitute of spherulites. There is the same crystalline ground-mass, though the Ramsey rock is clearer and has less secondary quartz, and the same abundance of pyrites and of viridite. In the Porth-Hayog examples, however, there are more of the rounded quartz crystals, as in the Church-School quarry, and still larger crystals of felspar of either kind. There can be no doubt we are dealing with a rock of the same group.

On the other side of the fissure, which is undoubtedly a line of fault, we have vertical glassy-looking rocks with a well-marked banded structure. This I at first thought due to the pressure and dragging which were concerned in the faulting: but the microscopic structure rather contradicts this. Innumerable lines are seen under ordinary light running somewhat irregularly parallel to each other; but under crossed Nicols the minute crystals are often quite independent of these, though others which seem to be felspar have their axis in the same direction. We must regard this, then, as exhibiting a typical fluidal structure, with subsequent devitrification. The truly crystalline character of the constituents, and their only partial dependence on the parallel lines forbids the idea of bedding.

This rock is succeeded by a series of agglomerates, ashes, and tuffs, finally bounded by a broken fault which has let down the fossiliferous Arenig rocks into their midst. The only points of interest in this ashy series are the intrusion into it of a tongue of true amygdaloid, in which nothing but narrow felspar crystals in an isotropic ground-mass is now seen (but the cavities and cracks are lined and sometimes even filled with secondary quartz), and the occurrence amongst the tuffs of a bed of black peperino.

Such a group of rocks as this is as far removed as possible from a sedimentary series, and is typically volcanic.

The north side of Porth Hayog forms the southern boundary of the mass which continues hence to Aber-Mawr and culminates in two peaks called carns. All that is seen of this in Porth Hayog consists of the felspar porphyry, in parts rotted by trickling water into an arkose. The same material forms the bulk of the carns, which are likewise surrounded on the eastern side by a broad band of ashy rocks becoming in places a veritable breccia, but composed essentially of the materials of the felsites or porphyries. In Dr. Hicks's collection in the museum of the Geological Society is a specimen with a fragment of the banded rock. On the eastern side, in limited areas which seem to contract towards the summits of the carns while expanding to form distinct headlands, are the most interesting rocks in the whole district. The most southern is distinctly glassy in aspect, and shows even on the large scale lines of flow which are occasionally contorted in the manner characteristic of semiliquid matter subjected to varying forces. Under the microscope with polarized light the glass is seen to be devitrified; but with ordinary light, the characteristic cracks of perlite are perfectly visible. Of the character of this rock there cannot be the shadow of a doubt; it is the oldest perlite known*. Towards the summit its glassy character is less marked, and a similar flow from the northern summit is also more devitrified in aspect; but I have not examined it microscopically.

In the hollow known as Pwll Hendro the scene is geologically superb. On the remoter southern side, accessible only to the thousand sea-birds who here find habitation, are massive columnar-jointed rocks of, probably, the porphyry; but on the rugged precipitous slopes which lie on the north, the geologist scrambles over apparently vertical beds of finely stratified rock. Each several band, though varying in compactness, consists of a series of spherules of greater or less size, very clearly and beautifully seen on the weathered surface; the finer bands have almost the aspect of a sandstone, but the structure is the same. These rocks, too, are lost in a point as they are traced up the hill, and I doubt whether they are stratified at all. I expected, indeed, to find that these spherules would show a radiate crystallization; but in that I was disappointed. The spherules consist of the same crystalline material as the remainder; but the individual crystals are much larger and resist the weather better. Nevertheless, I think it may be a devitrified rhyolite, as no such structure, I believe, is known in metamorphic rocks, and it would be difficult to account for if it were. There seem, however, to be fragments of crystals included in some portions of the mass here developed, which renders its origin most perplexing. The non-spherulitic rock is rather wide-spread, and is divided by a great vertical slice of conglomerate almost made of it, and let in by faults. If this be the Cambrian conglomerate, the rocks of which it is composed must be pre-Cambrian; and if of more recent date they may be so still. One other amongst several interesting patches of rock here found must be noticed. It is brown in colour, and similar to rocks on the N.-E of St. David's. This is the most basic rock I have seen unassociated with the ashes. It is composed of large crystals of either kind of felspar with little, if any, interstitial matter; quartz is almost absent, but there is no inconsiderable quantity of a highly polarizing acicular mineral, probably representing the magnesian constituent. This is most like the rock which near Whitchurch lies below the conglomerate, and is generally described as a felspar porphyry; but this latter contains far more of the highly polarizing ingredient, and even in some respects suggests the question whether it was not originally a tuff.

In the whole of this series the only doubtful rock is the banded spherulite of Pwll Hendro, the bands of which, by the way, run due E. and W., and not N. and S., as "Arvonian" rocks are supposed to do; but even this in no way removes the series from the essentially volcanic group, both in the lie and in the ultimate structure of the rocks. It must be admitted that as yet no sign of the granite has

* Unless those described by Mr. Allport be of the same age.

been met with in association with the porphyries, which can clearly be massive enough without it. The character, therefore, of the granite stands, at present, on the St. David's evidence alone. But in reality there is much more on the island to be seen yet. Mine was but a rapid and incomplete inspection.

On the eastern side of St. David's is another small area, almost a repetition of some parts of Ramsey Island. It is situated south of Pointz Castle, at the west end of Newgale Bay. On the western side it is brought against Cambrian slates by a fault, and there resembles somewhat the porphyry of Porth Hayog; but I have not examined it microscopically. Here also, in inaccessible spots, very good evidence of apparent bedding is visible; but it is on the eastern side that the most instructive development and section are seen. There we see great crags of banded felsite, looking, at a distance, like gneiss with the bands vertical. This, in structure, is quite comparable to the Pwll Hendro rock, and is equally enigmatical. On the shore, however, we have a second Ogof Llesugn, which has met apparently with a second misinterpretation. There is a deep cave sloping to the north, the upper face of which is Cambrian brown sandstone, the conglomerate not appearing here; the under face is the banded felsite; the line of junction is a fault extremely brecciated: but no hardening has taken place, for there is no dyke. The mass to the south is very much bedded, but with no regularity, some being vertical, other parts in a synclinal; then again is another cave-producing fault, on the south of which the rocks are of an ashy character. This is an admirable confirmation of previous experiences. According to Dr. Hicks, it forms part of a massive, of similar constitution, which stretches away from Roche Castle to Trefgarn. It was inevitable, therefore, to visit the Roche-Castle rock. I came away with the impression that it had nothing in common with the series under examination; and if pre-Cambrian in age, this must be proved independently; and the same must be said of the Brawdy granite, which, to my eye, has little resemblance to that of St. David's. The Roche-Castle rock, however, was so peculiar in appearance and so tough that I have examined it microscopically, and thus am confirmed as to its distinct character. It seems to have been originally a kind of andesite, as it consisted of large felspar crystals in an abundant ground-mass. Now, however, only the forms of the crystals are to be seen in ordinary light, while with crossed Nicols the boundaries become rather obscure, because the original felspar has all been replaced by quartz, which first lined the empty cavity with hexagonal pyramids and then filled the rest with irregular crystallization. The quartz-filling is thus exactly similar to that of the St. David's rocks, though here in excess: but this is a subsequent alteration affecting alike rocks of very different character and possibly of very different age.

Such is the evidence on which I depend in support of the view of the essentially igneous character of the whole series. They here seem united into a connected whole, and such I believe them to be; a belief rendered more probable and, indeed, induced by the known association of similar rocks in other volcanic areas of more recent origin. It is remarkable also that in the areas elsewhere proved pre-Cambrian, the same association of rocks occurs, though the patch may be relatively small. Thus in the Wrekin, associated with the perlite, Mr. Allport describes both ashes and spherulites, but no granitic rocks; while in Anglesey and Caernarvonshire all three forms, according to Dr. Hicks, are associated in no less than three areas. Considering the small size of these exposures, the constant association is remarkable, and in itself suggests a connexion, especially as, though the two upper parts may stand alone, the basal part never seems to do so.

Two general observations are suggested by these results, one with regard to the composition, the other with regard to the distribution of these volcanic rocks.

A marked feature in the composition is the highly acid character. In the central granitic mass this is shown by the abundance of quartz and the almost entire absence of any ferrous or magnesian constituent. In the felsites or porphyries it likewise appears in the abundance of original quartz and the small quantities of any magnesian mineral, pyroxene not being certainly present even in the intermediate rocks. That there are basic rocks amongst the ashes in the form of lavas has been proved; but even in this portion the peculiar feature is the abundance of porcellanite and other highly acid tuffs. But whatever the original nature of the supragranitic rocks, it is certain they have undergone great change in the way of addition of silica. This, we have seen, has been deposited in cavities of former crystals, in interstices and in cracks, a phenomenon reaching its maximum development in the porcellanites and the Roche-Castle rock. Whence is this silica derived, and when was it introduced? Whatever we may answer to this, it must be reckoned with in considering the significance of analyses. It would seem, however, that the rocks of St. David's were at the commencement nearly as acid as now, since the relics of decomposition are not grains of iron-oxide, which, as a rule, are very rare, but kaolin, which is abundantly distributed in every slide: hence the original minerals were mostly felspathic.

In regard to the distribution, we note first the linear arrangement of the centres: an east-and-west line through the central mass of St. David's cuts through Ramsey Island on the one side and the mass at Pointz Castle on the other, and nearly cuts what I think is probably another centre north of Solva; this is in accordance with the modern arrangement of volcanic outbursts. But if these be truly centres, how insignificant they are! Elsewhere the centres of like age would seem to be equally small, and hence their confusion with simple intrusive rocks of subterranean origin.

As we pass up the geological series, the magnitude of volcanic centres, as found in Silurian, Carboniferous or Permian, and Miocene times, seems to increase till we reach the magnificent volcanoes of to-day, which have mostly not more than a Tertiary origin. But while the magnitude has increased, the concentration has *pari passu* progressed; and instead of the numerous Palæozoic centres, and still more scattered Archæan foci, we have the few volcanic areas which now mark the globe, whose limits appear to have forsaken for ever the British Isles.

This is what we might expect if the sedimentary deposits form a damper to the heat within. In the early stages of the earth's history but a slight concentration of explosive force would suffice to break through the external coat and pour the contents of the interior on the surface, where they would be degraded by the atmosphere and increase the thickness of the coat. As this thickening progressed, it would require a greater force to break through, and points or lines of weakness would be more remote from each other; thus the violence, the infrequency, and the circumscription of volcanic outbursts would increase together, though the total sum of the forces in action might at the same time decrease.

One other general question is suggested. The absence of ordinary sediments of Archæan date in these Welsh areas is as remarkable as the rarity of volcanic rocks in the Highland gneiss.

Is this due to a difference in age? or do we see in the one the area occupied by land, in the other that occupied by the sea in that remote, long-extended, but at present little-studied epoch?

Discussion.

Mr. Topley called attention to the discrepancy between the views of Prof. Blake and Dr. Hicks as to the consecutiveness or the separability of the series below the Cambrian conglomerate; also to the difference between their views as to Ogof Llesugn, and as to the character of the Dimetian of Dr. Hicks.

Dr. Hicks said that diversity of opinion among progressive writers did not prove that the stationary party was correct. He appreciated the value of Prof. Blake's paper as regards the stratigraphy, though he could not accept his views as regarded some points in the petrology. Prof. Blake entirely agreed with him that the rocks he had classed as Dimetian, Arvonian, and Pebidian at St. David's were of Pre-Cambrian Age, and also as to the separation of the Pre-Cambrian series from the Cambrian conglomerate. Prof. Blake, he thought, had not succeeded in proving the connexion between the granitoid (Dimetian) and the overlying volcanic series. He observed also that Prof. Blake's map was wrong in that it omitted the Clegyr-Bridge breccias and others near Nun's Well. He pointed out that Prof. Blake was distinctly opposed to the principal tenets of Dr. Geikie, including the evidence of intrusion of the granitoid series and the great fold of the volcanic series.

Mr. T. Davies said that the Dimetian differed mineralogically from typical granites; the quartz and felspar constituents had very different relations from what they had in ordinary granites. Also the behaviour of the rock under the hammer was different.

Mr. F. Drew said that Dr. Hicks had not taken up in detail the differences between his views and those of Prof. Blake, to which

Mr. Topley had called attention. He asked Prof. Blake to explain how the ashy beds could form one series with the granites.

Mr. Hudleston said that the difference of the Dimetian from granite might be from subsequent alteration, as the Roche-Castle rock had been altered. What was wanted was proof of a passage from the Dimetian to the quartz-felsites.

Prof. Bonney said that he should confine his remarks mainly to the petrology, for as regards the stratigraphy it did not appear to him that Mr. Topley's criticisms were serious. It appeared to him not to be so simple a matter as Prof. Blake supposed, to say whether the Dimetian was granite or not; certainly it differed from all typical granites, and the difference could not be explained as Mr. Hudleston suggested. We could not, in questions of this kind, where felsites distinctly broke through granitoid rocks which were in some cases certainly of metamorphic origin, leave other Archæan areas out of consideration, and he certainly thought that, whether granite or not, the Dimetian was much older than the felsites and ashes.

Prof. Blake said that the Dimetian differed much from Hebridean gneiss. He replied to Dr. Hicks's criticisms of his map that they would not affect his views. There might have been intervals between the members of this Pre-Cambrian group, as he could not absolutely prove the passage of one into the other, but still he thought it simpler to regard them as one group. He thought that the unconformity, whether it were above volcanic rocks or not, was important.

22. *On a* Recent Exposure *of the* Shelly Patches *in the* Boulder-clay *at* Bridlington Quay. By G. W. Lamplugh, Esq. *With* Notes *on the* Fossils *by* Dr. J. Gwyn Jeffreys, F.R.S., F.G.S., E. T. Newton, Esq., F.G.S., *and* Dr. H. W. Crosskey, F.G.S. (Read February 20, 1884.)

(Communicated by Dr. J. Gwyn Jeffreys, F.R.S., F.G.S.)

[Plate XV.]

The arctic Molluscan fauna obtained from Bridlington many years ago attracted the attention of many observers, and yielded results of great interest. But though the fauna was carefully studied, the deposit from which it came was comparatively neglected; and as that part of the cliff from which the shells were first obtained was built over, in raising sea-walls for the protection of the town, soon after the bed was discovered, much misconception has arisen as to the nature and position of the deposit. And, the bed being inaccessible to the later workers who established the present system of divisions in our Yorkshire drifts, it came to be described as a *seam or bed of shelly sand in place*, in the *Purple* Boulder-clay*.

Two years ago, however, I was able to show† that neither these shells nor those similarly found at Dimlington, near Spurn Point, had been obtained from beds in place, but from masses of sand and clay occurring as boulders in the *Basement* Boulder-clay. This I endeavoured to prove, not only by evidence collected during the building of a new sea-wall at Bridlington, but also by reference to the accounts of the beds themselves, given by their early investigators.

But as there is still a tendency‡ to hold that the Bridlington shells occurred in place, I am glad to be able to bring forward further evidence bearing on this point, and at the same time to add materially to our knowledge of the fauna of the deposit.

During the early part of the winter of 1882–83 long-continued on-shore gales so far lowered the level of the beach opposite the town of Bridlington Quay, that the shore-deposit of sand and shingle was removed in many places, and the Boulder-clay below it well exposed on the foreshore, a circumstance of rare occurrence of late years, since groynes have been raised across the shore at right angles to the cliff to prevent such excessive beach-scour.

The largest of these exposures was nearly opposite the place where the shells were first found in the cliff, and I have not before had an opportunity of examining this part of the beach.

In this exposure, of which I give a ground-plan on p. 313, the shore-deposit of sand and shingle was, at one time or another, removed

* Wood and Rome, 'Quart. Journ. Geol. Soc.' vol. xxiv. p. 149; Lyell's 'Student's Elements,' 2nd ed. p. 169.

† "On the Bridlington and Dimlington Glacial Shell-beds," in Geol. Mag. vol. viii. p. 535, Dec. 1881.

‡ Mr. S. V. Wood in Quart. Journ. Geol. Soc. vol. xxxviii. p. 683, and letter in Geol. Mag. April 1882.

Sketch-plan of Fore-shore at Bridlington, showing " Basement" Boulder-clay with included masses of Sand and Clay.
January 1883. (Scale, 78 feet to 1 inch.)

X. Position of the so-called " Bridlington Crag " in the cliff.
A. Masses of fine blue or brown clay with a little sand. Shells.
B. Mass containing a large proportion of dark green sand and gravel. Many shells.
C. Fine leaden-coloured silty clay, with a streak of peaty matter and fragments of wood. Freshwater?

from a strip of beach about 120 yards long by 30 wide, stretching from the base of the sea defences, near high-water mark, to a little below the level of half-tide.

The beds exposed formed part of the lowest recognized division in the glacial series of Yorkshire, that to which the term *Basement Boulder-clay* has been applied*. Though the sea defences already alluded to completely mask the cliff immediately abutting, there is, at the time of writing, a wide breach in the terraced wall just north of the groyne, as shown on the ground-plan; and here the Basement-clay is seen to rise to a height of 13 feet above the level of the beach, sinking gently northward. And as there is no reason to infer a sudden change in its level, we may estimate the plane exposed on the shore to be at an average depth of about 20 feet from the top of the clay.

In the section just mentioned, the *Basement Boulder-clay* is overlain by the *Purple Boulder-clay*, with the occasional intervention of a little sand or gravel. The Laminated Clay, which is so well developed between them both north and south of the town, is here absent.

The Boulder-clay in the exposure on the beach was of a dark greenish-blue colour, and generally hard and sandy in texture. It contained a few angular and subangular boulders, none very large in size, and many smaller pebbles, generally well rounded and sometimes scratched. These included an immense variety of rocks of various ages, igneous and metamorphic rocks being especially abundant. I made a collection of them, hoping that at some future time their identification might be possible. Fragments and occasional valves of marine shells occurred in plenty in the clay.

The Boulder-clay also included in it many crushed masses of sand, and sandy gravel and clay, these forming, indeed, a large proportion, nearly one third, of its bulk. These masses, which generally contained marine remains, were of all sizes and shapes, some, as seen on the beach in horizontal section, appearing more or less round and coherent, others occurring as long, thin, sometimes intermittent, streaks between slabs of Boulder-clay, with every form between these extremes. In like manner the lithological character of the masses varied; some consisted of clay alone—blue, brown, or leaden-hued; others of clay with the admixture of sand; others of gravel and sand with little clay. One of the largest of the masses, that marked B on the plan, consisted in part of roughish gravel, the larger pebbles being about the size of a small orange; these were thoroughly water-worn and rounded, and I found amongst them the following rocks:—black flint, sometimes with green coating; red flint; nodules, some apparently Neocomian, others probably Liassic; yellow claystone; several varieties of basalt; brown quartzite; dark volcanic ash, and other igneous rocks unknown to me.

* For cliff-sections and general account of glacial and postglacial beds in the neighbourhood, see my papers on "Glacial Sections near Bridlington" in 'Proceedings of the Yorkshire Geological and Polytechnic Society,' vol. vii. pt. iv. p. 383 (1881); vol. viii. pt. i. p. 27 (1882), and pt. ii. p. 240 (1883).

The fauna of the masses also varied greatly. Some contained many shells throughout; others very few, occasionally none; others had shells in one part, but not in another; and one mass, that marked C on the plan, seemed to be of freshwater origin, as it consisted of very fine unctuous slaty-blue clay without stones or shells, through which ran a thin seam of peaty matter, in which traces of moss, wood, and the seeds of *Potamogeton* were detected.

Further, when marine shells occurred, though a few forms such as *Astarte borealis*, *Astarte compressa,* and *Saxicava rugosa* were rarely absent, the greater number of species were either limited to certain masses, or occurred plentifully in one place and sparingly elsewhere; so that there was generally a well-marked difference between the fauna of adjacent masses.

Most of the clay-patches showed a curious admixture of dark green sand, containing Foraminifera. This was usually diffused through the fine clay in thin and irregular beady streaks, as though thoroughly kneaded in; but here and there, especially in the mass marked B on the plan, isolated patches of this sand occurred amidst the clay; boulders involved in a boulder. Wherever this sand was abundant shells were plentiful, and in these patches they were also best preserved.

The sand itself contained many small black pebbles; waterworn coprolitic-looking fragments of bone and fishes' teeth; and coarse subangular grains of quartz. It is not, in my opinion, such as would form from the waste of any of our Yorkshire rocks.

Although shells were plentiful in the masses, the great majority were so crushed and broken, and the fragments so scattered, that the ordinary method of collecting yielded extremely meagre results. But my friend, Mr. W. B. Headley, of this town, by removing a large quantity of the material and carefully washing, sifting, and examining it, obtained a very large and interesting collection, not only of molluscan, but also of fish and other marine remains. This collection he has very considerately placed at my disposal in working up the subject, and, by the help of the gentlemen elsewhere named, who kindly undertook the determination of the species, the lists which form appendices to this paper have been drawn up. From these it will be seen that Mr. Headley's work has resulted in large and important additions to our knowledge of the fauna of the deposit, the number of known species of Mollusca alone being raised from 67 to 83, five of the additions being new to science; and the lists of fish and other fossils are almost new. There still remain a few fragmentary corals, Echinoderms, and Polyzoa which have not been determined.

Special interest attaches to the state of preservation and mode of occurrence of the shells, as it is their condition which has caused the deposit to be described, and still occasionally considered, as a bed in place*. As I have just mentioned, the great majority of the shells were crushed into fragments, and these generally some-

* Mr. S. V. Wood in Quart. Journ. Geol. Soc. vol. xxxvi. p. 516, and letter *sup. cit.*

what scattered, as if through the shearing of the whole mass after the shells were broken; so that they often occurred as a little streak of angular fragments in the clay. But even where the crushing had been most severe, absolutely uninjured specimens might occasionally be obtained. For instance, I have myself dug out a single specimen of *Astarte compressa*, with valves united and in perfect preservation, from a mass of blue clay of limited area, in which I was unable by the closest search to find another unbroken valve. In a similar manner, at Dimlington I found one perfect specimen of *Tellina balthica* in a small pocket of sand no larger than a man's head, in which I could not discover another shell, broken or unbroken. And I once found in the Basement Boulder-clay itself, on the South Sands at Bridlington, what we may regard as a shell-patch reduced to its lowest dimensions, a complete specimen of the same *Tellina* (single valves are not rare), with valves closed and filled in with sand, but with no trace of sandy matrix outside the shell.

Though, personally, I only obtained unbroken a few of the stronger bivalves, such as one or two species of *Astarte*, *Mya truncata*, *Pholas crispata*, *Saxicava rugosa*, and other species, the thorough and complete mode of research adopted by Mr. Headley brought to light magnificent examples of such shells as *Nucula Cobboldiæ*, *Tellina calcaria*, and several species of *Leda*, as well as a very large number of the smaller shells, especially univalves, which have escaped injury far oftener than the larger individuals.

The mode of occurrence of *Pholas crispata* is worthy of special remark. This shell is chiefly found in the centre of a blunt cylinder of hardened sand, which forms a faithful cast of the lower part of its boring. This cast often includes other shells, and is, of course, a sample of the sea-bottom on which the mollusk lived. The sand, though lighter in colour, has the same general appearance as that which is so generally diffused through the clay masses. In similar casts which I obtained from the beds at Dimlington, thirty-two miles further south, the matrix closely resembles that of the Bridlington specimens, a fact of great importance in considering the origin of the deposit.

I think, from the sharp and delicate nature of most of these casts, that the boring must have been made in stiff clay. The mollusk probably burrowed down from the sandy floor on which it lived into beds of the fine blue clay which now forms the chief part of the masses, and the ice has ploughed through the sandy sea-bottom into these clays, kneading both together and removing them in mass.

Having now stated the chief facts respecting the deposit which came under my observation, I will briefly indicate what seems to me to be their bearing on the question of its origin.

That the beds are not in place will, I think, be clear to most. But if any still deem the evidence insufficient, I would refer to my letter in the 'Geological Magazine' for August 1882, where the case is discussed.

The question arises,—Of what age are the beds; since if they be transported masses they may, like the rest of the boulders, be of any, or all ages. I think, however, there is sufficient evidence to show that this is not so, and that all the masses containing marine remains (at any rate all that have yet been examined) must be, at least roughly, contemporaneous. For, if the beds were of different ages, or derived from widely separated localities, we might expect to find clear and ready proof of this in the fauna; whereas, although the species present vary considerably in the different masses, the general facies is in every case distinctly the same and always arctic. Nor, with the exception of the doubtful *Rissoæ*, respecting which see notes appended to the list in the Appendix A, are any species found save such as might form part of the same life-group, though there is some discrepancy in the depths at which some of the shells now live.

There is also the evidence of the matrix of the shells. I regard the fine tough blue clay as having been a true glacial mud, deposited on a sea-bottom, and the green sand, with its contained pebbles, as having originated either in the dispersion and disintegration of morainic material or in the destruction of preexisting glacial beds. The existence at the time of a sea-bottom strewn with travelled boulders is shown by the occurrence in the Basement-clay of numerous blocks of *various kinds of rock* bored by *Saxicava*, *Pholas*, or *Cliona*, the borings in the former of these cases sometimes still containing the shells and Foraminiferous sand. I also think, from the well-rounded and water-worn appearance of most of the smaller boulders and pebbles in the Basement-clay, that most of these have suffered aqueous erosion at some period of their history after their detachment from their parent rock and before their incorporation in the clay, and that they are the relics of an old shore-line.

On these grounds I conclude that, though the beds are not in place, they have for the greater part had a common origin, and are all of one age, which the fauna shows to be glacial.

It remains to be considered whether this point of origin has been near the place where they are now formed, or at some unknown distance,—that is, whether the masses are the remnants of beds which once existed on this spot, ploughed up and destroyed by the passage of ice over them; or whether they may have been far transported and here abandoned by the ice in its progress.

The evidence, though strongly leaning towards the latter of these views, I regard as still inconclusive. For as we nowhere see far down into the Basement-clay, and have no knowledge of what takes place below the shelly masses (that it is *the* "Basement" bed at all being a surmise), by no means are we able to satisfy the suspicion that actual beds in place may occur lower in the section; the presence of the supposed freshwater patch, which at first seems to negative this idea, could be explained by supposing the existence of a series of early glacial marine and freshwater beds like those in Norfolk.

On the other hand, in strong support of the view that the masses may be far-travelled, is the fact that masses of Secondary beds, which must have been carried for long distances, and also of chalky and other gravels, are not uncommon in the Basement-clay *, one, a patch of Lower-Lias shale observed by Phillips, occurring on the beach within fifty yards of the exposure I have been describing.

The great similarity between the general aspect of the masses in localities so far apart as Bridlington and Dimlington; their ever-varying lithological character; their composition (which renders it improbable that they have been formed from the waste of rocks in the neighbourhood); the composition of the Boulder-clay in which they are enclosed, which is strikingly unlocal, its very flints being such as do not occur in Yorkshire Chalk; the marine débris so plentifully dispersed in the Boulder-clay; all bear in the same direction and point to the probability of the masses having performed no insignificant journey.

Whence came they? Certainly, I should say, from seaward; probably, judging from their pebbles and boulders, from the north-east.

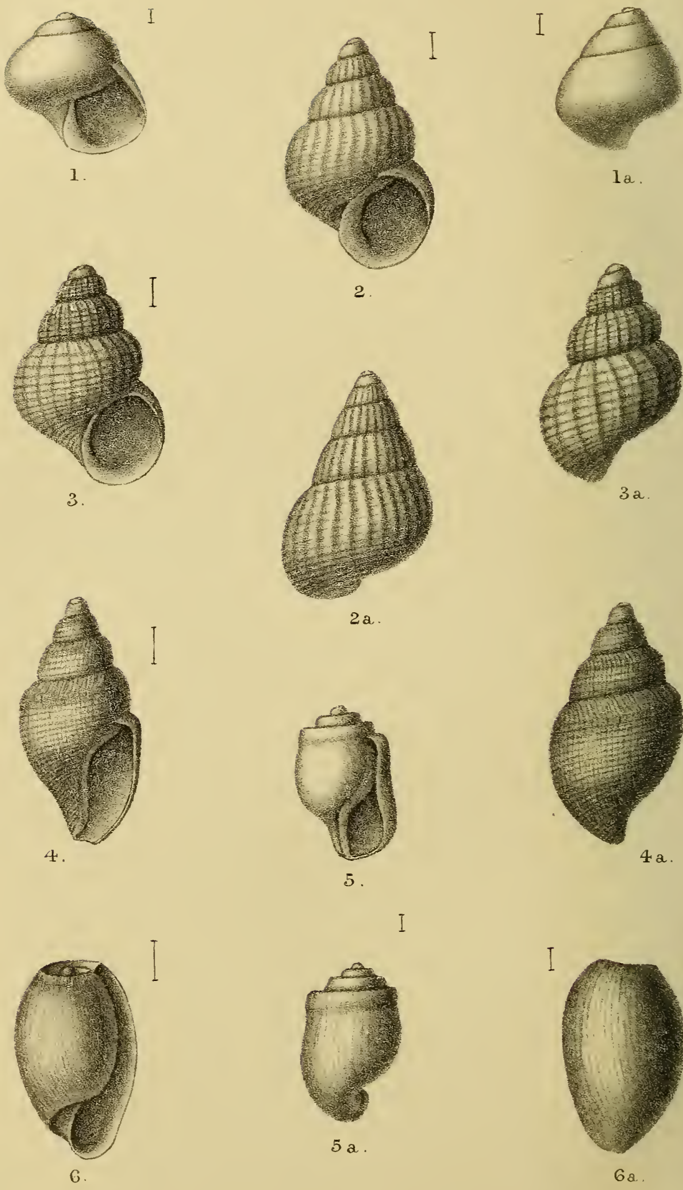
Beyond this, having only a limited and local knowledge of glacial geology, I have no right to express an opinion; but I may remark that to me there seems no reason why portions of a sea-bottom caught up into the base of an advancing glacier should not be carried by detached bergs till stranded on opposite and far-distant shores, and that the position and condition of Holderness prior to the deposition of the drifts, a shallow wide-mouthed bay, well sheltered by the curving Chalk Wolds, might well favour the drifting and stranding of such bergs.

Enough has been said to show that the mere presence of these arctic shells at Bridlington is not, under the circumstances, in itself necessarily a proof that the shells once lived there, or that conditions necessary to their growth existed on the spot at the time of their deposition.

Having drawn attention to the deposit, I trust that some future worker with greater leisure will devote his attention to the subject; for the masses will, I feel assured, amply repay the time spent in examining them, especially at Dimlington, where the conditions are far more favourable for their study than at Bridlington; and I only regret that the distance of that place from Bridlington makes it practically inaccessible to me.

There now only remains to me the pleasant duty of thanking the gentlemen by whose aid alone it has been possible for me to take advantage of so rare and favourable an opportunity of investigating the character of this interesting deposit. My thanks are especially due to Dr. Gwyn Jeffreys, F.R.S., for the kind assistance he has given me in examining and determining the very large number of shells which I have from time to time sent him; to Dr. Crosskey for so willingly undertaking the examination of the microscopic fossils of the deposit; to Mr. E. T. Newton for his kind determinations of and notes on the fish-remains, and to Mr. W. B. Headley, without whose laborious work in collecting, this paper would have been unnecessary and valueless.

* See my letter in Geol. Mag. Aug. 1882 for account of these.



C Berjeau del. et lith.

Mintern Bros. imp.

SHELLS FROM BRIDLINGTON QUAY.

APPENDIX A.

By Dr. Gwyn Jeffreys.

List of Shells obtained from the "Basement" Clay at Bridlington Quay.

Observation.—The species which are not included in the list of Bridlington Post-Tertiary shells furnished by me to the late Professor Phillips, and published in the third edition of his 'Geology of Yorkshire,' p. 274, and which are therefore for the first time recorded, are marked with an asterisk. Among these are five species new to science, which will be now described and figured.

In the column after the names of species the letter A. signifies Arctic, Am. American, L. littoral or shallow water (*i. e.* under 100 fathoms), D. deep sea (over 100 fathoms), and sp. n. new species.

BRACHIOPODA.

Rhynchonella psittacea, *Chemnitz* .... A. L.

CONCHIFERA.

Anomia ephippium, *Linné*, and vars. aculeata and squamula .... A. L.
Pecten islandicus, *Müller*. ... A. L.
*—— pes-lutræ, *L.* .... A. L.
*—— opercularis, *L.* .... A.
Mytilus edulis, *L.* .... A. L.
*Crenella decussata, *Montagu*. A. L.
Leda minuta, *Mont.* .... A. L.
*—— tenuis, *Philippi* .... A. L.
*—— lenticula, *Möller* .... A. L.
—— limatula, *Say* .... A. L.
*—— intermedia, *M. Sars*. ... A. L.
Nucula Cobboldiæ, *Leathes*... Am. L.
*—— nucleus, *L.* .... A. L.
Pectunculus glycymeris, *L.* A. L.
*Montacuta Dawsoni, *Jeffreys*. A. L.
*Axinopsis orbiculata, *G. O. Sars* A. L.
*Cardium groenlandicum, *Ch.* A. L.
—— islandicum, *L.* .... A. L.
Cardita borealis, *Conrad*... L. A. Am.
Cyprina islandica, *L.* .... A. L.
Astarte sulcata, *Da Costa*, and var. elliptica .... A. L.
—— borealis, *Ch.*, and vars. A. L.
—— compressa, *Mont.* .... A. L.
*Venus ovata, *Pennant* .... A. L.
Tellina balthica, *L.* .... A. L.
—— calcaria, *Ch.* .... A. L.
—— pusilla, *Philippi* .... A. L.
Mactra solida, *L.* .... A. L.
*Solen ensis, *L.* .... A. L.
Corbula gibba, *Olivi* .... A. L.
*—— pusilla, *Philippi* .... A. L.
Mya truncata, *L.*, and var. uddevallensis .... A. L.
Saxicava norvegica, *Spengler* A. L.
—— rugosa, *L.* .... A. L.
Pholas crispata, *L.* .... A. L.

SOLENOCONCHIA.

Dentalium entalis, *L.* .... A. L.
—— striolatum, *Stimpson* ... A. L.

GASTROPODA.

Puncturella noachina, *D.* ... A. L.
Trochus varicosus, *Mighels & Adams* .... A. L.
—— cinereus, *Couthouy* .... A. L.
*Trochus groenlandicus, *Ch.*... A. L.
*—— cinerarius, *L.* .... A. L.
*—— zizyphinus, *L.* .... A. L.
*Lacuna divaricata, *Fabricius*. A. L.
*Littorina obtusata, *L.*, and var. A. L.
*—— globosa, *Jeffr.* .... sp. n.
—— rudis, *Maton* .... A. L.
—— litorea, *L.* .... A. L.
*Rissoa costata, *Adams*. .... L.
*—— Wyville-Thomsoni, *Jeffr.* A. D.
*—— subperforata, *Jeffr.* .... sp. n.
*—— parva, *Da Costa*, and var. interrupta .... A. L.
*—— striata, *Ad.* .... A. L.
*—— semistriata, *Mont.* .... L.
Turritella erosa, *Couth.*... A. Am. L.
*Scalaria groenlandica, *Ch.*... A. L.
*Odostomia conspicua, *Alder*. L.
Natica affinis, *Gmelin* .... A. L.
—— groenlandica, *Beck* ... A. L.
—— islandica, *Gm.* .... A. L.
*Amaura sulcosa, *Leche* .... A. L.
*Menestho albula, *Fabr.* .... A. L.
*Trichotropis borealis, *Broderip & Sowerby* .... A. L.
Purpura lapillus, *L.* .... A. L.
Buccinum undatum, *L.* .... A. L.
*—— groenlandicum, *Ch.* ... A. L.
Trophon clathratus, *L.*, and vars. Gunneri and truncata A. L.
Fusus despectus, *L.* .... A. L.
—— curtus, *Jeffr.* .... Am. L.
*Fusus Kroyeri, *Möll.* .... A. L.
Admete viridula, *Fabr.* .... A. L.
Pleurotoma turricula, *Mont.* A. L.

Gastropoda *continued.*

*Pleurotoma exarata, *Möll*.... A. L.
*—— decussata, *Couth*.,... A. Am. L.
*—— simplex, *Middendorff*... A. L.
*—— multistriata, *Jeffr.* ...... sp. n.
*—— bicarinata, *Couth.*, and var. violacea .... A. Am. L.
Pleurotoma elegans, *Möll*.... A. L.
*Cylichna alba, *Brown* ...... A. L.
*—— sculpta, *Leche*............ A. L.
*Utriculus obtusus, *Mont.*, var. pertenuis .... A. L.
*—— constrictus, *Jeffr.* ...... sp. n.
*Bulla crebristriata, *Jeffr*...... sp. n.

The total number of species in the above list is 83, of which 73 are Arctic, 2 are American, 1 only is deep-water, 5 are new to science, and 3 require confirmation as to their being fossil or recent. With respect to *Rissoa costata* and *R. semistriata*, which belong to temperate and southern parts of the North Atlantic, I am not satisfied that they really belong to the glacial bed or deposit above described. Mr. Lamplugh also gives *Thracia pubescens* from similar beds at Dimlington; if correctly identified, this species is not known as living anywhere north of the south of England.

New Species.

1. Littorina? globosa *, Jeffreys. Pl. XV. fig. 1.

Shell globosely conical, thick, opaque, and rather glossy: *sculpture* none: *colour* yellowish brown, whitish about the pillar: *spire* short, compressed at the apex or point: *whorls* 4, convex, the last disproportionately large: *suture* slight: *mouth* roundish, contracted above and curved below: *outer lip* hemispherical, with a sharp edge: *inner lip* filmy: *pillar* broad and thickened at the base; behind it is a small and narrow umbilical chink.

Length 0·1 in. Breadth 0·1 in.

About half a dozen specimens occurred, but all more or less imperfect. In this condition it is impossible to determine whether the shell belongs to *Littorina* or to *Trochus*. If to the former, a littoral habitat must be inferred; if to the latter, a shallow-water or deep-sea habitat might have been the case. The characters of the shell induce me to place it provisionally in *Littorina*.

2. Rissoa subperforata †, Jeffreys. Pl. XV. fig. 2.

Shell pyramidal, rather thick, semitransparent, lustreless in its semifossil state: *sculpture*, numerous longitudinal fine and curved ribs: there are about 25 on the last whorl, which are not continued below the periphery; the labial rib is very thick; all these ribs are crossed by more numerous and close-set spiral striæ, but not so as to produce a decussated or reticulated appearance, because the ribs are stronger and more prominent than the striæ; the base is encircled by half a dozen of these striæ, the lowermost of all forming a strong ridge which encloses the basal groove afterwards mentioned; the two or three apical whorls are quite smooth and polished: *colour* yellowish-brown: *spire* extended and pointed: *whorls* 6, convex, the last occupying at least two thirds of the spire when the shell is placed with the mouth upwards: *suture* distinct and rather

* Globose. † Somewhat perforated.

deep: *mouth* oval, somewhat expanded; the inside or throat is obscurely notched: *outer lip* thin, outside of the labial rib: *inner lip* folded back and adhering to the pillar, continuous with the outer lip; behind the pillar is a deepish semicircular groove, which is indicated by the specific name. Length 0·2 in. Breadth 0·1 in.

Several specimens. I do not know any recent or living species like it in respect of the basal groove.

I also consider it desirable to take this opportunity of having figured for the first time another peculiar species of *Rissoa* (*R. Wyville-Thomsoni*, Pl. XV. fig. 3), which was found with the species now described, and which will be more fully noticed in my forthcoming Part of the 'Lightning' and 'Porcupine' Mollusca in the 'Proceedings of the Zoological Society.'

3. PLEUROTOMA MULTISTRIATA *, Jeffreys. Pl. XV. fig. 4.

Shell oval, moderately strong, semitransparent, and glossy: *sculpture*, very numerous and close-set longitudinal and spiral striæ, the intercrossing of which causes a fine decussation; the first whorl is quite smooth: *colour* pale yellowish-white, with two reddish-brown and rather broad bands, one immediately below the suture, and the other encircling the base of the last whorl: *spire* shortish, turreted; apex bulbous: *whorls* 4–5, convex, abruptly enlarging; the last takes up two thirds of the spire: *suture* deep: *mouth* irregularly oblong: *canal* short and wide, inflected or turning back: *outer lip* angulated at the top, and sloping downwards with a gentle curve: *labial notch* shallow: *inner lip* forming a broad glaze on the pillar and showing the attrition and excavating power of the foot: *pillar* flexuous. Length 0·2 in. Breadth 0·1 in.

Many specimens. *P. novaja-semljensis* of Dr. Leche, from the Kara Sea (Lat. 75° 35′ N.), might, from the figure, be mistaken for this shell; but that is probably a variety of *P. exarata* of Möller, which Leche considered a variety of *P. turricula*. The coloured bands are also peculiar to the present species.

4. UTRICULUS CONSTRICTUS †, Jeffreys. Pl. XV. fig. 5.

Shell oval, deeply constricted in the upper part, and broader in the middle; it is thin, opaque and lustreless: *sculpture*, fine and flexuous longitudinal striæ in the constricted groove, and some irregular striæ in a spiral direction: *colour* dirty white: *spire* produced, but short and turreted: *whorls* 4, rather convex, having a thickened ridge or ledge at the top of each; top whorl inflected: *suture* deep and narrowly excavated: *mouth* long, contracted on the upper part, expanding and oval below: *outer lip* flexuous, commencing at about one third of the last whorl: *inner lip* also flexuous, thick, and spread on the pillar, behind which is a narrow chink. Length 0·1 in. Breadth 0·075 in.

Three specimens. Mr. Lamplugh informs me that other specimens were found, but had been lost. This species differs from *U.*

* Covered with striæ. † Contracted.

obtusus in being much shorter and proportionally broader, deeply constricted in the upper part, and having a narrower mouth.

5. Bulla crebristriata *, Jeffreys. Pl. XV. fig. 6.

Shell cylindrically oval, thin, semitransparent and glossy: *sculpture*, extremely numerous, close-set and fine spiral striæ, besides irregular lines of growth; the spiral striæ are wavy and interrupted by the lines of growth, but are not punctured: *colour* yellowish-brown: *spire* sunken and quite concealed; crown excavated and encircled by a sharp rim: *mouth* long and flexuous, narrower on the upper part and expanding below the pillar: *outer lip* flexuous, slightly projecting above the crown: *inner lip* rather thick; behind it at the base of the pillar is a small umbilical groove. Length 0·2 in. Breadth 0·15 in.

Two specimens, but neither of them is quite perfect.

APPENDIX B.

Cirripedia.

(Determined by Dr. Gwyn Jeffreys.)

Balanus porcatus, *Da Costa.*
—— Hameri, *Ascanius.*
Balanus crenatus, *Brug.*
Verruca Strömii, *Müller.*

Fragments of *Balani* were plentiful in the beds out of which the above have been identified.

APPENDIX C.

Pisces.

By E. T. Newton, Esq., F.G.S.

In Mr. Headley's collection were many teeth and other remains of fish. These were nearly all obtained from the sandy patches, and were in many cases much water-worn and rounded, being sometimes reduced to mere pebbles. Some, however, were quite unworn, and in an excellent state of preservation.

Nearly the whole of the remains of Fishes from Bridlington seem to be either Norwich-Crag, Red-Crag, or London-Clay forms. And seeing that so many of the Crag Vertebrata have been originally derived from the London Clay, it is quite possible that all the Bridlington Fishes have been derived directly from the Crags. I should doubt whether any of them were contemporaneous with the Bridlington deposits, and the mineral condition and polished surface of the specimens are characteristic of Crag fossils.

This would seem to point to the destruction of older Tertiary beds during the formation of the gravelly sand containing the arctic fauna.

Dr. S. P. Woodward, in a note to his list of shells in the 'Geological Magazine,' vol. i. p. 49, 1864, mentions the occurrence of *Platax Woodwardi*, sharks' teeth, and an otolith resembling those of the

* Closely striated.

Haddock. This is the only previous record of fish-remains from the bed known to me.

Carcharodon (teeth), and other sharks.	Oxyrhina (teeth).
Chrysophrys (teeth).	Platax Woodwardi ?
Lamna, sp. (teeth).	Raia batis (teeth).
Myliobatis (teeth).	Otoliths of Gadoid fish.
Notidanus microdon (teeth).	Fish vertebræ. Also a fragment of the tooth of a mammal.

APPENDIX D.

Note on the Ostracoda and Foraminifera of the shelly Patches.
By Dr. H. W. Crosskey, F.G.S.

An examination of the material obtained by Mr. G. W. Lamplugh during the recent exposure of the shelly patches in the Boulder-clay at Bridlington, has both added to the catalogue and confirmed the previously existing evidence of the arctic character of the Ostracoda and Foraminifera contained in that bed.

In making this examination, I have to acknowledge the valuable assistance I have received from Mr. G. S. Brady, with respect to the Ostracoda, and from Mr. H. B. Brady with respect to the Foraminifera. From the facts to be narrated it would appear that the new exposure reveals the same deposit as that to which the name of Bridlington Crag was given when it was first observed; and Mr. Lamplugh informs me that its position on the beach agrees exactly with the early accounts.

Ostracoda.

In order that the general character of the group of Ostracoda may be clearly understood, it is necessary to refer to the investigations that have already been made, especially since the identity of the newer and older exposures is a point of importance.

In the "Monograph of the Tertiary Entomostraca of England," by T. Rupert Jones *, two species of Ostracoda are described, for which Bridlington is the only locality given, viz. *Cythere concinna*, Jones, and *Cytheridea Sorbyana*, Jones. Neither of these species, wrote Mr. Sorby †, "have been met with any where else either living or fossil."

Since the date of these publications both *Cythere concinna* and *Cytheridea Sorbyana* have, however, been found living as far north as Spitzbergen; and they occur in considerable abundance as fossils in the glacial clays of Scotland.

In the "Monograph of the Post-Tertiary Entomostraca of Scotland, including species from England and Ireland," by G. S. Brady, H. W. Crosskey, and D. Robertson, twenty one Bridlington species are described, of which the following analysis has been made ‡ :—

* Palæontographical Society, 1856.

† "On the Crag-deposit at Bridlington, and the microscopic fossils occurring in it" (Polyt. Soc. West Riding, vol. iii. p. 559).

‡ A note by Dr. Crosskey, "On some additions to the fauna of the Post-Tertiary bed at Bridlington, Yorkshire. Proc. Birmingham Phil. Soc. vol. ii. p. 377.

2 are peculiar to Bridlington as fossils, one not being known living, and the other having a high northern range.
1 is found in an English Boulder-clay, but not in Scotland.
5 are most abundant in those Scotch clays in which the fauna is extremely arctic.
11 are common in all Scotch glacial clay.
1 has been found in one Scotch glacial clay only.
1 has been detected in an upper bed only, but is known to live in the Gulf of St. Lawrence.

The whole group is remarkably analogous to that found in the glacial clays of the East of Scotland; and the newly exposed clay has yielded a large proportion of the same species.

The following is a list of the species obtained chiefly from the shelly patches described in Mr. Lamplugh's paper.

Genus Cythere, Müller.

C. concinna, Jones. Common.
C. dunelmensis, Norman. Moderately common.
C. mirabilis, Brady. Common.
C. tuberculata, G. O. Sars. Common.
C. villosa, G. O. Sars. Rare.
C. fimbriata, Norman. Rare.
C. McChesneyi, Brady & Crosskey. Rare.
C. globulifera, Brady. Rare.

Genus Cytheridea, Bosquet.

C. Sorbyana, Jones. Common.
C. elongata, Brady. Rare.

Genus Cytheropteron, G. O. Sars.

C. latissimum, Norman. Rare.

Genus Eucythere, Brady.

E. argus, G. O. Sars. Common.

Genus Krithe, Brady, Crosskey, & Robertson.

K. glacialis, B., C., & R. Common.

With two exceptions the whole of these species are characteristic of the Scotch glacial clays, and especially of those near the eastern coast. *C. mirabilis*, *Cytheridea Sorbyana*, and *Krithe glacialis*, for example, are especially associated with such arctic mollusca as *Pecten grœnlandicus*, *Leda arctica*, and *Thracia myopsis* in the glacial clays of the East of Scotland, and are among the most abundant species in the Bridlington shelly patches. The forms I have excepted from this general statement are *Cytheridea elongata* and *Cythere McChesneyi*. Of these *C. McChesneyi*, Mr. Brady informs me, is "interesting as being the first notice of it on this side of the Atlantic." It was originally discovered in gatherings of glacial clay from Montreal and Saco, which were sent to the writer of this note by Principal Dawson.

Cytheridea elongata "is common enough as a recent species all around these islands" and lives in the Gulf of St. Lawrence also, so that it is not surprising to find it in a glacial deposit*.

The general statement made by Mr. Lamplugh in his paper respecting the fauna of the shelly patches in the Boulder-clay that (with the exception of a doubtful *Rissoa*) no "species are found save such as might form part of the same life-group," accurately represents the state of the case with respect to the Ostracoda.

Foraminifera.

In the Monograph of the "Foraminifera of the Crag," by Prof. T. R. Jones, W. K. Parker, and H. B. Brady†, the following passage occurs:—"Some Foraminifera collected by Mr. H. C. Sorby, F.R.S., from the Bridlington Crag some years ago, and kindly placed at our disposal, have to be noticed. These comprise *Cornuspira*, *Miliola*, *Lagena*, *Dentalina*, *Cristellaria*, *Polymorphina*, *Cassidulina*, *Truncatulina*, *Polystomella*, and *Nonionina*, and are the most conspicuous of a probably more extensive fauna, nearly allied to that of the Suffolk Crag."

As Mr. H. B. Brady points out to me, however, much more is known of the distribution of the northern forms than when this paragraph was written; and, of the 18 Bridlington species described in the monograph, all save one have been discovered in the North Atlantic, and 14 of them in the Arctic seas.

When in connexion with this fact their association with Arctic Mollusca is considered, the application to them of the term "Crag" becomes more than questionable.

The new material has yielded 16 species, with two varieties of species.

Of these 16 species, 8 are catalogued as from Bridlington in the monograph; and the whole of these occur in the Scotch glacial clays. Of the remaining 8, 5 are Scotch glacial fossils; while 3 species and 2 varieties, although catalogued as glacial fossils for the first time, are not improbable members of the same group, so far as climatic conditions are concerned.

The following is the list of Foraminifera; the number of specimens found was far greater than of the Ostracoda:—

Genus Biloculina, D'Orbigny.

B. ringens, Lamk. Moderately common.

Genus Cassidulina, D'Orb.

C. lævigata, D'Orb. Rare.

* Vide "Notes on fossil Ostracoda from the Post-Tertiary deposits of Canada and New England" by G. S. Brady and H. W. Crosskey. Geological Magazine, vol. viii. No. 2, where it is figured and described.

† Palæontographical Society, 1865, Preface, p. v.

Genus Dentalina, D'Orb.

D. communis, D'Orb. Common.

Genus Glandulina, D'Orb.

G. lævigata, D'Orb. Abundant.
*var. *rotundata*, Reuss.
*var. *æqualis*, Reuss.

Genus Gaudryina, D'Orb.

**G. pupoides*, D'Orb. Rare.

Genus Lagena, Walker and Jacob.

L. globosa, Mont. Rare.
L. lævigata, Reuss. Rare.
L. squamosa, Mont. Moderately common.
L. sulcata, W. & J. Common.

Genus Nonionina, D'Orb.

**N. orbicularis*, Brady ? Rare.

Genus Polymorphina, D'Orb.

P. lactea, W. & J. Abundant.
P. compressa, D'Orb. Abundant.

Genus Polystomella, Lamarck.

P. striato-punctata, F. & M. Abundant.

Genus Pulvinulina, Parker and Jones.

**P. Karsteni*, Reuss. Rare.

Genus Quinqueloculina, D'Orb.

Q. seminulum, Linn. Abundant.

Genus Truncatulina, D'Orb.

T. lobatula, W. & J. Common.

With respect to the forms marked *, which have not been previously given in the lists of glacial fossils, the following notes may be made.

Glandulina lævigata is very rare in the Scotch beds; it is abundant at Bridlington, and its varieties therefore (var. *rotundata* and var. *æqualis*) may be expected.

Gaudryina pupoides is described by Mr. H. B. Brady† as a "common deep-water Foraminifer. The list of localities at which it

† The voyage of H.M.S. 'Challenger,' p. 378.

has been found includes fourteen stations in the North Atlantic, the most northerly being about lat. 60° N."

Pulvinulina Karsteni is a Shetland form, and is figured in Mr. H. B. Brady's paper on the "Rhizopodal Fauna of the Shetlands"*.

Several species of *Nonionina* occur in the glacial clays, so that the appearance of a species doubtfully named *N. orbicularis* raises no difficulty regarding the general character of the group.

The Foraminifera, as well as the Ostracoda derived from the new material I have examined, when compared with the Scotch fossils and studied together, give considerable ground for the supposition that these "shelly patches" in the Bridlington Boulder-clay belong very closely to the same period of the glacial epoch as that represented by the fossiliferous clays of the coast of Scotland.

EXPLANATION OF PLATE XV.

Fig. 1, 1 *a*. *Littorina? globosa*, Jeffreys, sp. n.
2, 2 *a*. *Rissoa subperforata*, Jeffreys, sp. n.
3, 3 *a*. —— *Wyville-Thomsoni*, Jeffreys.
4, 4 *a*. *Pleurotoma multistriata*, Jeffreys, sp. n.
5, 5 *a*. *Utriculus constrictus*, Jeffreys, sp. n.
6, 6 *a*. *Bulla crebristriata*, Jeffreys, sp. n.

The short lines indicate the natural size.

Discussion.

Dr. J. Gwyn Jeffreys believed, from a personal inspection, that this was a *remanié* deposit. He had supplied Prof. Phillips with a list of the Bridlington shells for the second and posthumous edition of his 'Geology of Yorkshire.' The present list showed that the total number of species and varieties amounted to 74†, of which 33 were purely arctic forms, 1 a deep-water form (480 to 560 fms.), 2 American forms, 33 shallow-water forms (under 100 fms.), and there were 5 perfectly new species. Besides the peculiarly arctic species, 20 of the littoral species are also arctic, making the total number of the latter 61, or nearly 87 per cent. of the whole. Similar purely arctic forms had been lately found in deposits near Glasgow. These shells were much more arctic in character than those of Moel Tryfaen, which might be referred to a Celtic area of distribution.

Prof. T. M'K. Hughes said that many years ago he had found, with Mr. Lyell, in Dimlington cliff, a lenticular bed of sand with *Nucula Cobboldiæ*, *Astarte compressa*, and other shells, some of the bivalves with the shells in contact. He thought it more probable that the shelly patches were pushed up by the grounding of icebergs and shore-ice from the sea-bottom close by, than that they

* Transactions of the Linnean Society, vol. xxiv.

† After this paper was read 9 more species were discovered, and have been entered in the Appendix A.

had been conveyed from a distance. He thought the shells lived in Glacial times and near the place where they are now found.

Mr. Leonard Lyell did not agree with Prof. Hughes as to the shells found in a sandy bed at Dimlington being of the age of the Boulder-clay. The shells were excessively friable, and were found at various points along the coast. He thought they had been transported from a distance in frozen masses. He asked as to the state of preservation of the different shells in the deposit.

The Author, in reply to the President, said that the presence of deep-sea forms was a bar to the conclusion that they were entirely carried by coast-ice. The difference of this sand from that formed from the waste of rocks on the coast was an argument against the masses coming from the immediate locality. The state of preservation was very different in different patches, and seemed to depend more on the character of the matrix than on the nature of the different species. The patches were more abundant at Dimlington than at Bridlington, owing to the wider exposure of the Boulder-clay containing them.

23. *The* Silurian Species *of* Glauconome, *and a* Suggested Classification *of the* Palæozoic Polyzoa. *By* George W. Shrubsole, Esq., F.G.S., *and* George R. Vine, Esq. (Read June 21, 1882.)

[Abridged.]

The genus *Glauconome*, originally founded by Goldfuss, was so modified by Lonsdale, as to become virtually a new genus, of which *Glauconome disticha* from the Dudley Limestone is the type. Later on came the discovery by Sedgwick of apparently a similar polyzoan from the Bala beds of North Wales. This was regarded by Prof. McCoy* as identical with the Wenlock species, and, as such, has been generally received.

We have been of late examining these Silurian species of *Glauconome*, both as to their identity with one another and their connexion with the Carboniferous and Devonian species, and we find that the Bala and Wenlock species are not even generically related, while the members of the large Carboniferous group have not the least affinity with the type species from the Wenlock beds.

The present Bala, Devonian, and Carboniferous species evidently belong to a modified group of the Cyclostomatous Polyzoa, while the type species from the Wenlock can only be classed in a distinct division of the Polyzoa, for which at present no provision is made.

In coming to this decision, we have been mainly guided by zoarial form, and not outward resemblance. Evidence in this direction has been carefully sought for in the several species. In *Glauconome disticha* from the Wenlock Limestone we find the cell open and exposed throughout its entire length; this, we find, is not accidental, but characteristic. The cells are built up of a series of thick longitudinal walls running parallel with the branch, and divided at regular intervals by cross walls, which go to form the cell or, rather, cell-area, which may be pyriform or quadrangular in shape and depressed in the centre. The keel is normally rounded, having on the elevated portions prominent nodes.

The remarkable feature about the cell is its open character; for out of the many examples we have examined we have not found it otherwise. That this is not due to the wearing away of any part of the structure is apparent from the fact that even more delicate polyzoans associated with it are not so affected. Lonsdale noticed the same peculiarity; for he says "that the nature of the covering and opening of the cells is unknown." This is still the extent of our knowledge.

We turn now to the other species of *Glauconome* from the Bala beds, which McCoy regarded as identical with *G. disticha*. In working out the affinity of this species, we have been favoured with specimens from Glyn Ceiriog, North Wales, in which the cell-features are well shown. The zoœcia are seen to be long and cylindrical in shape, buried in the length of the branch, and the cell-neck bent, and protruded through the branch.

* British Palæoz. Foss. p. 49.

As a natural consequence, there can be no generic relationship between the tubular cell of this Bala *Glauconome*, and the open quadrate one of the Dudley species. The difference between them is considerable; it is even more than generic. The zoarial character, as seen in the Dudley species, can have no place even among the Cyclostomatous Polyzoa. There is an antique arrangement of the cells unlike anything in recent types. Its characteristics are entirely Palæozoic. It is scarcely necessary to say that the numerous species of Carboniferous *Glauconome* with their cylindrical zoœcia can no longer be associated with the Dudley species. The latter is a polyzoan which is not provided for in the existing suborders of the group; and for the reception of it and similar species, a suitable suborder will be requisite. It will remain the type and, so far as at present known, the only representative of the genus *Glauconome*. On the other hand the Bala species is clearly allied by close zoarial affinity with the Devonian and Carboniferous *Glauconome*, and may be included in a new genus to be presently described. We are aware that some years ago * Mr. Etheridge, Jun., proposed to assign this Bala species to *Ramipora*, a genus founded by Toula upon a fragment of a Polyzoan brought from the Arctic regions. The reference mainly rested on a certain outward resemblance, not very marked or reliable, which cannot outweigh its zoarial agreement with the Carboniferous *Glauconome*, or even its outward resemblance to the perfect condition of the zoarium in the same.

The new genus to be now described will include the discarded Bala, Devonian, and Carboniferous species of *Glauconome*.

PINNATOPORA, nov. gen.

GLAUCONOME (pars), M'Coy, Brit. Pal. Fos. p. 49.

Zoarium made up of a series of main stems, having a common attachment, with secondary and tertiary branches, which come off at an acute angle. The tertiary branch may or may not unite with a corresponding branch on the adjoining stem. Zoœcia cylindrical, arranged in longitudinal and alternate series over one half of the surface. Between the row of cells a dividing keel.

PINNATOPORA SEDGWICKII, Shrubsole.

Glauconome disticha (pars), Lonsdale, Brit. Pal. Fos. p. 49.

Ramipora Hochstetteri, var. *carinata*, R. Eth. Jun., Geol. Mag. 1879, p. 241.

Sp. char. Zoarium a series of main, non-bifurcating stems growing from a common base, having alternate, secondary, and tertiary branches, the latter uniting with a corresponding branch on the adjoining stem, so as to connect the entire zoarium. Zoœcia long, tubular; aperture circular, arranged longitudinally in alternate rows, spread over one half of the surface. A dividing keel between the rows of cells. Reverse angular.

Obs. The chief interest of this species is that it is the oldest known

* Geol. Mag. 1879, p. 241.

representative of its class. It is the head of an important genus ranging from the Bala or Caradoc beds to the latest Carboniferous. Although the earliest of its kind, this species was of strong robust growth, exceeding in size the species of later date. Large fragments of it are frequently found in the Bala beds. That so fragile an organism should be found in an almost unbroken condition suggests the fact that the sediment, from whatever cause, must have accumulated very rapidly around it.

Locality. Fairly abundant in the Bala beds of Glyn Ceiriog, Denbighshire, and Cefn Coedog near Corwen.

We would slightly enlarge the characters of the original Dudley species as follows :—

GLAUCONOME DISTICHA, Lonsd.

Glauconome disticha, Goldf. Petref. Germ. Tab. 64, fig. 15 ; Silurian Syst. pl. 15. fig. 12.

Pinniretepora Lonsdalei, D'Orb. Prodr. de Pal. i. p. 45.

Sp. char. Zoarium branched or pinnate, the branches diverging at a sharp angle from the main or central stem. Stem rooted by a strong base. Zoœcia both on stem and branch. When fully developed, two rows of quadrangular or pyriform cell vestibules arranged longitudinally on stem and branch, on either side of a strong keel, which is nodulose when perfect. Three rows of cell-openings may often be seen on the main stem. Aperture of cells unknown.

Obs. In addition to the features already described in this species there is an antique arrangement of the cells that is unlike anything seen in modern types. There is another detail worth mention. In the cells of *Membranipora membranacea* and the Flustridæ generally, the cell is entirely bounded by its own wall. A perpendicular line drawn through the end walls would enclose the cell and its contents. In the Palæozoic types, lines similarly drawn would cut off the true cell from the area, the cell being buried beneath the area operated upon.

Recurring to the present classification of the Polyzoa, it is evident to a large extent that the divisions are founded upon recent types. Of the three suborders (i) Chilostomata, (ii) Cyclostomata, (iii) Ctenostomata, the latter is unknown to us in a fossil state. We know of no genera or species within the British area, in either the Cainozoic or Mesozoic epochs, that may not be included in the first or second of these divisions if slightly modified. When we pass to the Palæozoic forms, it is different. Here we meet with types of Polyzoa essentially different, in which the cells are devoid of stomata, either subterminal or terminal, being concealed beneath what we have called the vestibule. This is often very large and filled with matrix. The concealed stomata may be shown in sections of species of *Ptilodictyæ* and *Ceramoporæ*. To meet the case of these older types of Polyzoa, we propose a new suborder which shall have special reference to the cell and stomata. As yet we have no clear evidence that Chilostomatous types existed in Palæozoic times. The majority of these older species will be found to arrange themselves under the Cyclostomata; the rest will be accommodated in the new suborder Cryptostomata.

Class POLYZOA.

I. Suborder Chilostomata, Busk.

"Orifice of the zoœcium closed by a movable opercular valve. Ova usually matured in external marsupia. Appendicular organs (avicularia and vibracula) frequently present." *Hincks.*

Very few species at present known to us in the fossil state. It is doubtful if they are found below the Cretaceous period.

II. Suborder Cyclostomata, Busk.

"Zoœcia tubular, with a plain inoperculate orifice. Marsupia and appendicular organs wanting." *Hincks.*

Species belonging to this suborder less specialized than recent types range from the Lower Silurian upwards.

III. Suborder Cryptostomata, Vine.

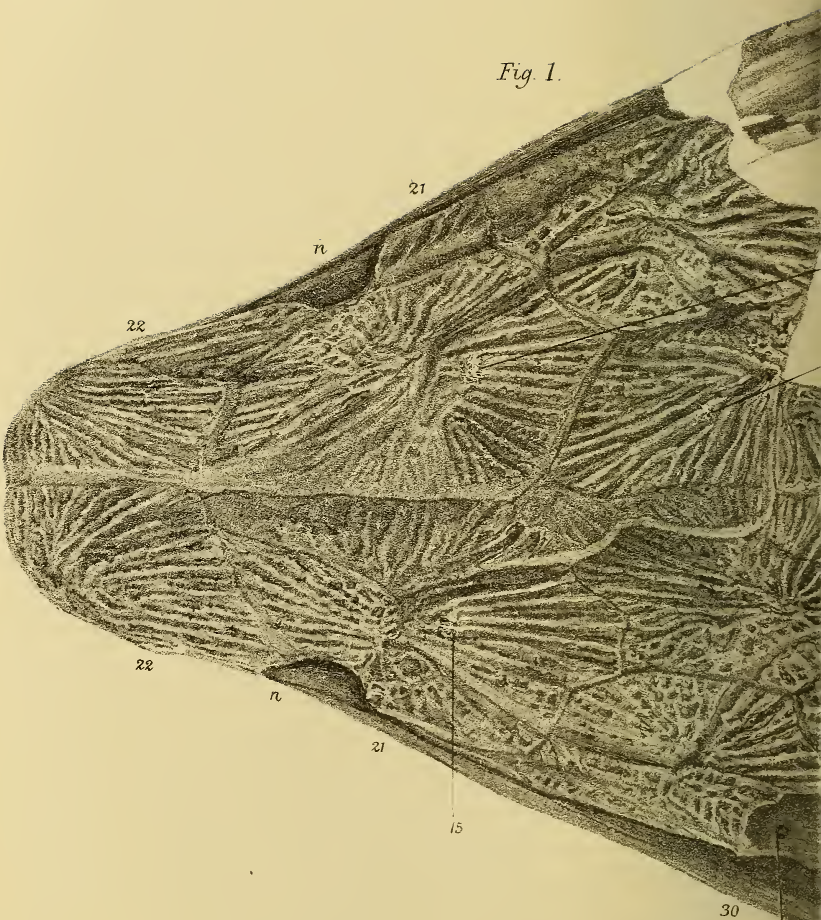
Zoœcia subtubular, in section slightly angular. Orifice surrounded by a vestibule, or otherwise concealed.

To this division we assign the Silurian species of *Glauconome* and *Ptilodictya.*

Discussion.

Prof. Hughes bore testimony to the valuable work which the authors were accomplishing in connexion with the study of a very difficult group of organisms.

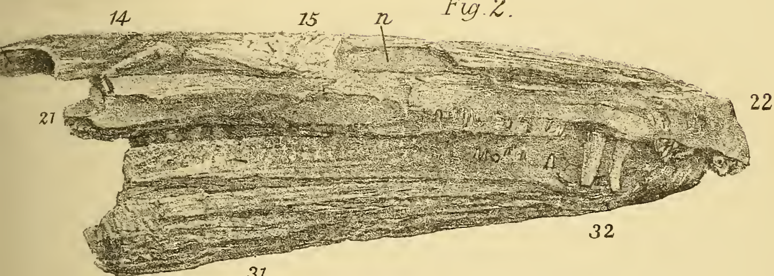
Fig. 1.

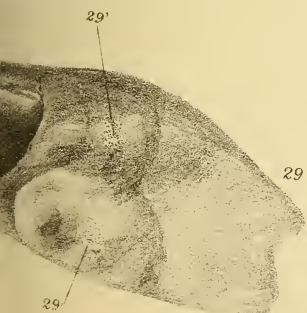


From nat. on Stone by J Erxleben.

RHYTIDOST

Fig. 2.





M&N. Hanhart imp

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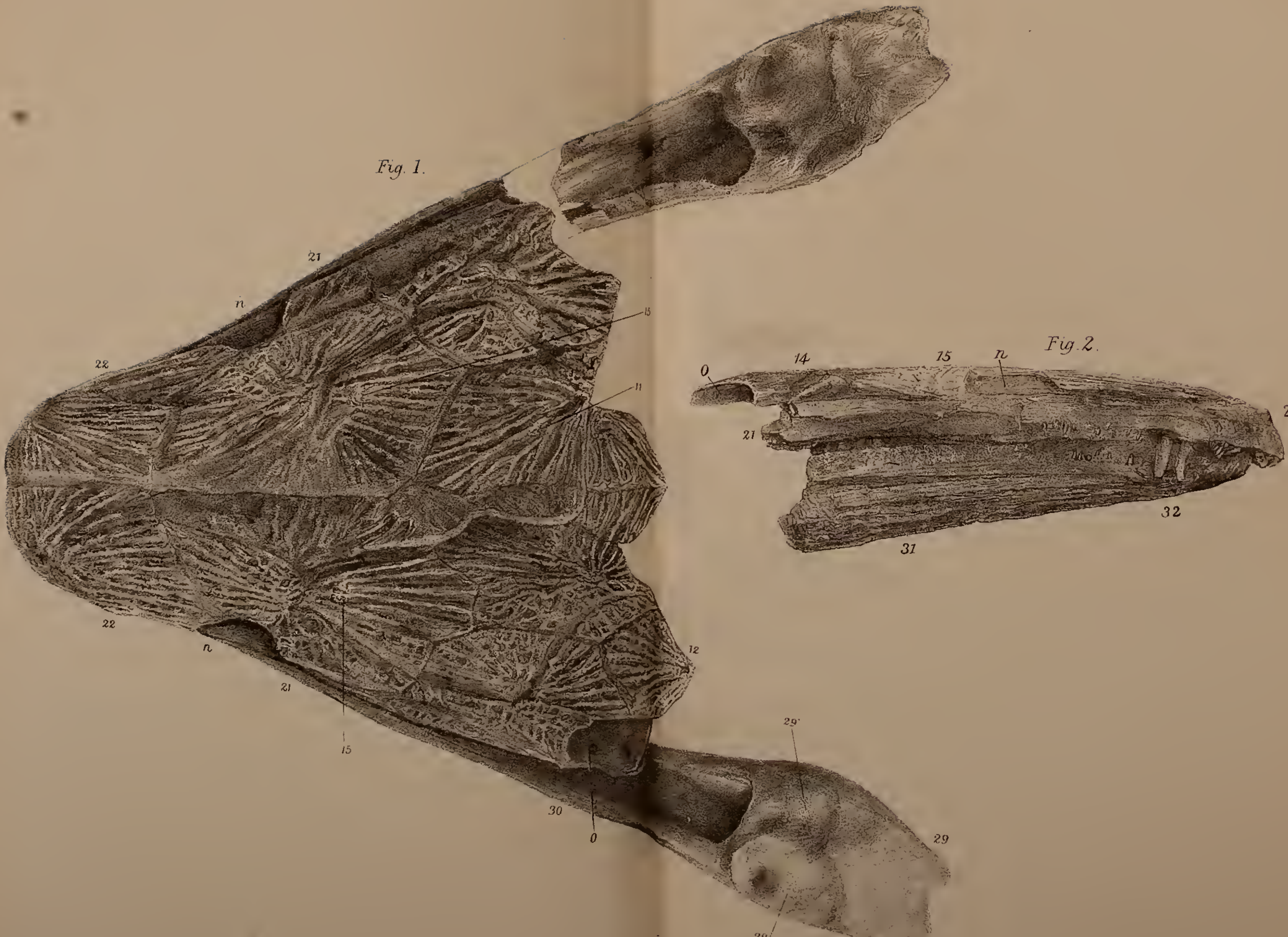
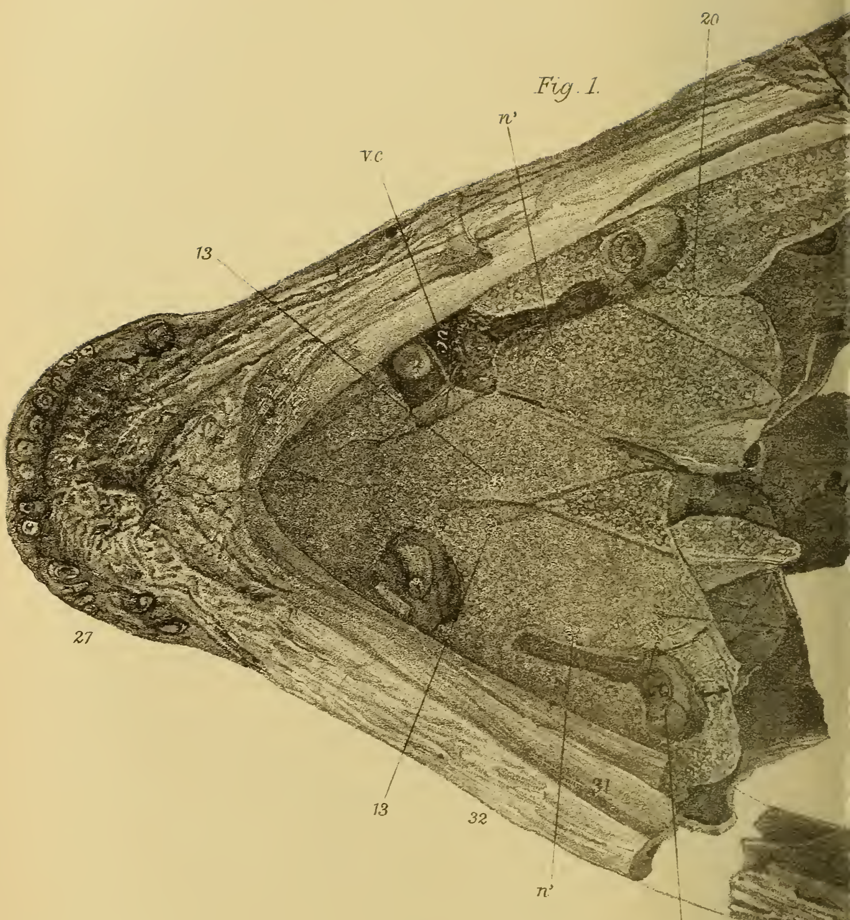


From nat. on Stone, by J. Erxleben.

M. & N. Hanhart imp.

REYTIDOSTEUS CAPENSIS.

2/3 nat. sz.



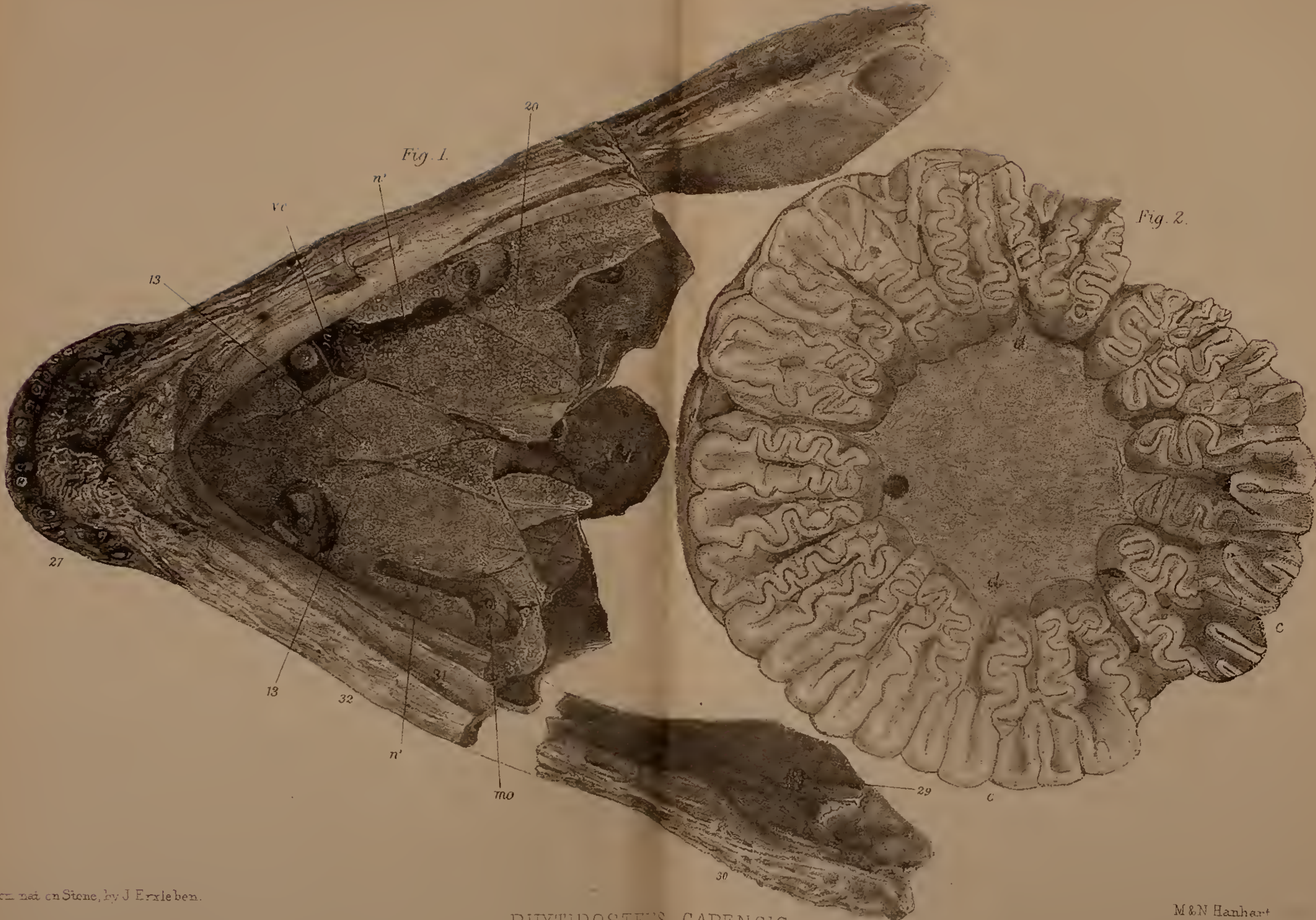
From nat. on Stone. by J. Erxleben.

RHYTIDOS

Fig. 2.

M & N. Hanhart

ENSIS.



From nat. on Stone, by J. Erxleben.

RHYTIDOSTEUS CAPENSIS.

2/3 nat. size

M & N Hanhart

24. *On a* Labyrinthodont Amphibian (Rhytidosteus capensis *) *from the* Trias *of the* Orange Free State, Cape of Good Hope. By Sir Richard Owen, K.C.B., F.R.S., F.G.S., &c. (Read March 19, 1884.)

[Plates XVI. & XVII.]

In the year 1837 I examined, microscopically, the structure of certain teeth from the sandstone of Guy's Cliff, Warwickshire, which had been submitted to me by their discoverer, Dr. Lloyd, F.G.S., of Leamington, the form of these teeth being that of simple canines. The well-marked and peculiar structure, so discovered, and the geological correspondence of the matrix with the Keuper of Germany, induced me to apply to Prof. Jäger of Stuttgart (whose acquaintance, ripening into friendship, I had formed at the Meeting of the German naturalists in 1835, under the presidency of Oken, at Freiburg im Breisgau) for a tooth, or portion of tooth, of a fossil in his collection.

To this I was moved by the fact that Jäger had described certain remains from the Keuper of Württemberg, as of a Saurian reptile, under the name of *Mastodonsaurus*, and it was to the teeth of this species that I wished to apply the microscopic test.

My friend at once transmitted a tooth of this ancient reptile, and I was gratified to find therein the same peculiar structure which had led me to apply the generic term '*Labyrinthodon*' to the extinct species represented by the Warwickshire fossil tooth: this result was communicated to the Geological Society †.

The batrachian or batrachoid character of the extinct possessor of teeth of this complexity was subsequently inferred from the structure of the bony palate in a portion of skull, also from the Keuper of Warwickshire, described and figured in a later paper under the name of *Labyrinthodon leptognathus* ‡. Subsequent knowledge of allied cold-blooded air-breathers has shown the labyrinthodont dental character to be one of an order or, at least, of a group of anallantoid air-breathers of higher value than the genus.

Accordingly, on receiving a cranial fossil from Mangali, Central India, with teeth manifesting the labyrinthic character, I proposed for it, in a paper communicated to the Geological Society in 1855, the generic name of *Brachyops*. Subsequently I recognized in a series of fossils from a Triassic sandstone of the Tafelberg, Queenstown district, Cape of Good Hope, submitted to me in 1875, by Dr. Atherstone, F.G.S., the skull of a smaller labyrinthodont, remarkable for the granulate superficies of

* 'Ρυτὶς, wrinkle, ὀστέον, bone.

† Transactions of the Geological Society, 4to, second series, vol. vi. 1841, p. 503, figs. 1 & 2. Similar fossils from the same locality had been referred by Murchison and Strickland to the Keuper.

‡ *Loc. cit.* pp. 515–543, pl. 43, figs. 1, 2.

the cranial bones. This fossil is figured in plate xx. figs. 13–20, in my 'Catalogue of the Fossil Reptilia of S. Africa, in the British Museum' (4to, 1876, p. 67).

A somewhat larger fossil skull (3 inches 6 lines in length) preserved in the Museum of the Imperial Society of Naturalists of Moscow, and described by Fischer de Waldheim under the name *Rhinosaurus Jasikovii*, I believed, from its shape and the close correspondence of the granulate ganoid superficies of the cranial bones, to belong to the labyrinthodont rather than to the saurian order. Fischer notes, in his account, that this fossil, "quoique découvert dans le Gouvernement de Simbirsk, est sans indication précise de localité" *. If this fossil should yield the structure of the bony palate, and the occipital articulation with the atlas, *i.e.*, whether by one or two condyles, its affinity or otherwise to the Labyrinthodonts would be determined.

The Cape *Petrophryne* revealed the double condyle †, but not the characters of the bony palate.

The fossil of which I have now the pleasure to submit a description, supplies the palatal character; but the occipital part of the skull is wanting.

This cranial specimen (Plates XVI. & XVII.) was obtained, in a fractured condition, by Heer Swanopol, from the Trias of a locality called Beersheba, and was deposited by him in the Bloemfontein Museum. The authorities have confided it to Dr. Exton, of the Orange Free State, S. Africa, in order to be submitted to me with other fossils, including *Tritylodon*.

After readjustment of those parts of this fossil skull of which the true relative positions could be determined, the result was the proportion of the facial division, including the external nostrils (Plate XVI. figs. 1, 2, *n.*) and orbits (*ib.* *o*), with a corresponding part of the lower jaw (*ib.* 29–31), thereto cemented by matrix, which forms the subject of the figures now submitted to the Society. In one of these (Plate XVII. fig. 1) are shown the characters exposed by careful removal of matrix from the bony palate. Detached portions of the mandible, and a few other fragments have helped in the determination of the affinities of the fossil.

The proportions of breadth to length, with general flatness, of the skull being batrachoid rather than saurian, my first step was to submit one of the teeth to the microscopic test. For this purpose I selected the hinder palato-vomerine tusk, from which the apical half of the crown had been broken away (Plate XVII. fig. 1, *mo*).

The subjoined drawing of the section ‡, magnified 20 diameters (Plate XVII. fig. 2), shows the decisive character of the laybrinthic

* 'Bulletin de la Société Impériale des Naturalistes de Moscou,' tom. xx. 1847, p. 14.

† See Cat. Foss. Rept. S. Africa, plate xx. fig. 16.

‡ In this the letter *d* indicates the entry of the 'dentinal' process of the tooth-pulp, the letter *c* the entry of the alternating process of the 'cement,' from the capsule of the tooth-matrix.

interblending of the dental tissues complementary to and confirmative of the batrachian modifications exemplified by the recovered bones of the skull.

As shown by the figure 1 of Plate XVI., the upper surface of the skull is nearly flat, the feeble convexity, transversely, of the outer third parts gradually falling to as feeble a concavity at the middle third. The exposed surface of the bones is sculptured according to the pattern which I have termed "rhytidoganoid" in *Brachyops*. The forwardly converging lateral borders are rounded off into an obtuse fore end, two inches broad about an inch behind that end. The rami of the mandible converge, corresponding with the dentigerous borders of the maxillæ, and seemingly coalesce to form a flattened symphysial end of the lower jaw, having a transversely convex termination fitting into that of the overlapping upper jaw (Plate XVII. fig. 1, & Plate XVI. fig. 2), the animal having become fossilized with its mouth close shut.

The fore end of the upper jaw is formed by the premaxillaries (22, 22); their medial suture is 38 millim. in length; the bones extend laterally backward to contribute to the front border of the outer nostril (*n*, figs. 1 & 2, Plate XVI.), above which they terminate in a point. The pattern of their external sculpturing will be presently described.

The maxillaries, 21, 21, contribute the smallest portion to the upper surface of the skull, where it forms part of the upper border of the nostril. Only on a side view, as in fig. 2, Plate XVI., can the due extent of the outer surface of the maxillary be seen, and the proportion, *n*, it contributes to the under and hinder border of the nostril, whence it extends backward with a decreasing vertical diameter to beneath the orbit *o*. Returning to the upper surface of the skull (Plate XVI. fig. 1), the nasal bones 15, 15, there show their great expanse and triangular shape: their extreme length is $3\frac{1}{2}$ inches (90 millim.), and that of their mid suture is $2\frac{1}{2}$ inches (63 millim. Each nasal expands as it recedes from the premaxillary, and contributes about one third of the upper border of the nostril, beyond which the bone unites with the maxillary, 21, and thence extends further back to terminate in a point wedged between the frontal, 11, and prefrontal, 14. The *frontals*, 11, retaining their mesial suture, form together a subquadrate plate with the anterior angles rounded off; the posterior ones are truncate: the connexions of these bones are, anteriorly, with the nasals, laterally with the pre- and postfrontals. The *parietals*, with which they unite behind, are represented by fragments, the occipital part of the skull being lost. The *prefrontals*, 14, are mesially united with the nasals, the mid frontals and postfrontals; laterally, with the maxillaries, 21: they form the anterior and part of the upper border of the orbits. Of the *postfrontals*, 12, only the angle joining and wedged between the mid and prefrontals is preserved.

The roof of the portion of skull formed by the above-noted bones is almost flat, of subtriangular figure, with the anterior apex rounded off. The outer nostrils, *n*, come partially into view, the orbits, *o*, more directly on this aspect; the latter are remarkable for their small relative size, as this is indicated by the fore and part of the upper boundary; their aspect is obliquely lateral. Each of the above-described bones has a sculptured outer surface of the same pattern. From a central or subcentral space, radiate narrow, almost sharp ridges with wider intervals; similar but shorter ridges rise as the intervals expand toward the periphery of the bone; the ridges become irregularly wavy as they diverge thereto: the intervals are smooth grooves. One or two wider channels, suggestive of having carried mucous canals, indent some of the bones. This character suggested the generic name *Rhytidosteus*. A very small portion of the maxillary bone, 21, comes into view in the upper surface of the skull; it is the part (21, fig. 1, Plate XVI.) which contributes the hind border of the nostril. The firm adhesion of the lower to the upper jaw forbade further attempts at severance; the hardness of the cementing matrix threatened such to be more destructive than expository of determinative characters. In the interval of the diverging rami of the portion of mandible so preserved (Plate XVII. fig. 1) sufficient of the bony palate was exposed to afford the chief batrachian character of the present labyrinthodont genus. The major part of this mouth-roof is contributed by the pair of vomerine bones, 13, of which the mesial suture is conspicuous. Each vomer presents a large subcircular vacuity, *v c*, 20 millim. in longest diameter, from which projected the crown of a laniary tooth, the exposed basal part not exceeding 6 millim. in diameter*. The disproportion between this tooth and the socket or vacuity from which it was emerging suggested that it might be a successor to a canine conforming in size with such socket, and which had been lost. Behind each of the vacuities, *v c*, is the palatal nostril *n'*, *n'*, 28 millim. in length, 8 millim. in breadth; the long axis of the aperture is parallel with the outer border of the bony palate. The anterior and mesial with part of the lateral or outer borders are contributed by the vomer; the rest of the circumference by the palatal plate of the maxillary; and, perhaps, the palatine, 20. Close behind the palatal nostril is the socket or aperture of emergence of a canine, *mo*, similar and but little inferior in size to the vomerine one, *v c*. To this palato-maxillary vacuity and tooth applies the same remark as to the vomerine one.

The vomerine bones diverge from each other after a sutural course of two inches, and the pointed anterior end of a palatal bone undivided by any apparent trace of mid suture occupies the interspace. The breadth of the bony palate at the fractured hind border is 5 inches; the length of the part preserved along the mesial line is $4\frac{1}{2}$ inches.

The mandibular rami, 31, 32, have coalesced at a symphysis, 2 inches in length, 3 inches in breadth at the hind border, thence narrowing forward to a breadth of 1 inch 9 lines (45 millim.); and again slightly expanding to a rounded termination with a feeble mid indentation. The portion of each ramus cemented to the upper jaw

* From this the section, fig. 2, Plate XVII., was taken.

includes the splenial (31) with the dentary (32) elements: the former enters into the composition of the hind part of the symphysis mandibulæ. The ramus so constituted has the form of a stout bony bar, the vertical and transverse diameters being subequal, and the under part thick and convex across. Each ramus is slightly bent outwards as it diverges from the symphysis: its outer surface is sculptured in a pattern similar to that of the skull-bones.

A detached hinder end of one of the rami shows the articular surface, 29 (Plates XVI. & XVII.), divided into a transverse pair of shallow concavities. The part of the ramus supporting these seems also to have developed, as in Crocodilia, the angular projection (Plate XVI. fig. 1, 29) behind the joint 29′, for the tympanic. There is a trace of suture which bounded the angular element, also of the crocodilian pattern. If the mandibular fossil above noticed had been found unassociated with other bones of the skull, its reference to a saurian might be condoned. The extreme depth or vertical diameter of this detached hind end of the mandibular ramus of *Rhytidosteus* is 60 millim., its greatest diameter 48 millim.

Some lost portion of the ramus prevents a close fit of the above portion with the dentigerous part adhering to the upper jaw; but the entire length of the lower jaw may be fairly estimated at from 11 inches to a foot.

Dentition.—This armature is wielded by the premaxillary, vomerine, partly palatine, and mandibular bones. In each premaxilla a single row of from eight to ten small, pointed, conical teeth extend along the alveolar border (Plate XVI. fig. 2, 22; and Plate XVII. fig. 1, 22), to where the crowns of two large teeth, which may be called "canines" (Plate XVI. fig. 1), project from the maxilla. Beyond these a row of teeth, smaller than those of the premaxillary series, extends along the margin of the maxilla to near the orbit. The corresponding mandibular teeth, in the small degree in which they could be exposed, correspond in shape, size, and number, with the maxillary series. The chief weapons of the present labyrinthodont genus are supplied by the vomerine and palato-vomerine pairs of laniariform teeth. From one of the latter was taken the section affording the subject of the drawing (Plate XVII. fig. 2).

Should the present communication be favoured, like that of a British Triassic labyrinthodont, read before the Geological Society in 1840, with illustrations of the natural size, such as those which appeared in plates 43–47, vol. vi., of the then quarto form of our publications, the acquisition by the estimable individuals and Societies in our Cape Colony, of further evidences of *Rhytidosteus capensis* may be aided and stimulated by such figures accompanying the description of the present Triassic anallantoid reptile*.

It would seem that at this geological period, in parts of our globe so remote from each other as Britain, Russia, North America,

* Since writing the above, I have found that a reduction of one third would bring the requisite illustrations within the 8vo form, and probably serve the same purpose.

Hindostan, and S. Africa, the batrachian type of air-breathing vertebrates had reached its highest development.

If I were asked in terms of the present phase of "conjectural biology," "from what antecedent form the labyrinthic structure of tooth had been derived," I should reply that, in the matter of complexity, I know, at present, only the teeth of an extinct member of a lower class, characteristic of the Old Red Sandstone, which are comparable. To the genus of fishes manifesting such dental character, the term *Dendrodus* is applied. For, here, a series of processes of the dentinal pulp radiates transversely toward the cement-clad superficies of the tooth-crown; but, in their course, they send off very numerous side branches which are soon resolved into tufts of dentinal tubules, suggestive of the generic name *. Processes of the cement-forming capsule also penetrate the dentine, but for a short distance only from the periphery, and there is no such interblending of the two tooth-tissues as in the great Triassic Batrachians. Between these and the Old Red Dendrodonts missing links, if such existed, are yet to be found.

Of the extinct Reptilia enjoying life at later than Palæozoic periods, the Liassic Ichthyosaurs show convergence of processes of the dental capsule for a short distance into the substance of the base of the teeth, below or beyond the enamel-clad crown; but these converging processes are short and simple; and there is no reciprocal divergence of dentinal productions of the formative pulp †.

DESCRIPTION OF PLATES XVI. & XVII.

Rhytidosteus capensis.

Plate XVI.

Fig. 1. Upper view of anterior part of the skull.
2. Side view of the same.

Plate XVII.

Fig. 1. Under view of anterior portion of the skull. The above figures are reduced to two thirds of the natural size.
2. Transverse section of a palato-vomerine canine, magn. 25 diam.

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* 'Odontography,' 8vo, 1840, p. 172, plate 62 B.

† *Ibid.* p. 275, plate 73. In both labyrinthodont and dendrodont teeth the fractured surface usually displays a confused interblending of tissues, different from the simple compact dentine so exposed in saurian teeth. Observing this, Von Meyer remarked:—"Höchst merkwürdig ist die innere Struktur der Zähne von Mastodonsaurus; ich habe sie an einem dazu geeigneten Zahnfragment in der Sammlung des Herrn Grafen Münster schon vor einiger Zeit erkannt." Letter to Prof. Bronn, in 'Neues Jahrbuch für Mineralogie,' &c., 8vo, 1838, p. 15. No intimation of the nature of this structure is given. In the subsequent 'Beiträge zur Palæontologie Württemberg's,' 4to, 1844, my exposition and term 'Labyrinthodont' are accepted.

Discussion.

Dr. H. Woodward remarked upon the advantage of the enlightened course taken by the authorities of the Museum at Bloemfontein in sending these exceedingly interesting specimens by Dr. Exton to the British Museum for identification and description. He hoped that further treasures of the same kind might be acquired by that Museum, which was located in a most favourable position for securing such objects, and that the same course would be adopted with them.

Dr. Exton said that the precise locality from which the specimen described by Sir Richard Owen was derived was perfectly well known. It was from a farm called Beersheba, in the neighbourhood of Smithfield. There is sufficient evidence that the strata in which it occurred are Triassic. The skull described in the present paper was from lower beds than the *Tritylodon*. He was exceedingly glad that he had been enabled to bring these interesting specimens to England for description, and he thanked Sir R. Owen for describing them.

Prof. Seeley felt a diffidence in speaking without having seen the specimen. He agreed with Sir R. Owen in thinking that certain South-African fossil Reptilia show Mammalian characters. The diagrams clearly showed the cranial and palatal characters of the present species; but without the teeth the cranium might almost be Chelonian. It seemed to him possible that even such palatal characters as were shown may occur in true reptiles or in forms intermediate between Reptiles and Amphibia. *Ichthyosaurus* shows a divided vomer.

The Author in reply said that the divided vomer and the form of the skull showed decided Batrachian affinities, but that the structure of the tooth, of which a magnified drawing was on the table, was quite conclusive as to the Labyrinthodont relationship of the animal.

25. *On* Strain *in* Connexion *with* Crystallization *and the* Development *of* Perlitic Structure. By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Normal School of Science and Royal School of Mines. (Read March 5, 1884.)

[Plate XVIII.]

In a paper on "The Microscopic Structure of the Vitreous Rocks of Montana, U. S. A.," read in connexion with a paper upon the mode of occurrence of those rocks by Mr. J. Eccles, and since published in the Quarterly Journal of this Society (vol. xxxvii. p. 391), I had occasion to allude to a peculiar phenomenon of depolarization in the little grains of obsidian constituting a rock which was very aptly called obsidian sandstone by the officers of the U. S. Geological Survey. I there pointed out the relation which the depolarization bore to the perlitic structure visible in the little obsidian fragments, and also indicated the probable connexion of these strains in the glass with the development of crystals.

The following notes may serve still more clearly to verify the statements then made.

The present observations were made upon a small but thick slice of obsidian from Java, given me some years ago by Prof. W. Chandler Roberts. On examining this section under the microscope, in plane polarized light, a considerable number of crystals may be seen, and in nearly every instance the surrounding glass, where it comes in contact with the crystal, shows very well-marked depolarization, which I think I might say, without any doubt, is due to the tension or strain produced in the glassy obsidian by the development of crystals or by a strain preceding the development of crystals, as I suggested in the paper already alluded to.

In Pl. XVIII. fig. 1, for instance, we see portions of a crystal around which there is a nimbus of double refraction barred by dark radially disposed brushes. In drawing this and all the other figures the nicols were kept crossed in the position of a St. George's cross (+). Fig. 2 shows a small opaque crystal resembling a cube or an octahedron, I could not ascertain which. Around this, again, there is a fringe of double refraction traversed by a dark cross. In fig. 3, again, the crystal is surrounded by a border of depolarizing glass, glass which depolarizes because it is in an abnormal condition of tension, and the dark arms, as in the preceding figure, are four in number; but in this instance they do not form a symmetrical cross. Some of the strains, as evinced by the depolarization figures in the specimen, are very irregular, and the irregularity appears sometimes to be caused by the proximity of one strain-begirt crystal to another.

In fig. 4, we see a very interesting example of a crystal which is only about one third environed by a perlitic fissure. Where the

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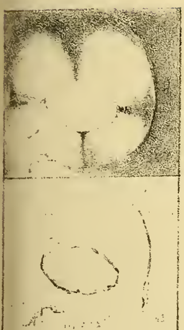
4.



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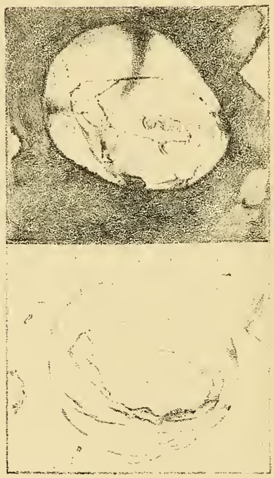

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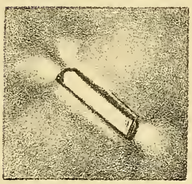

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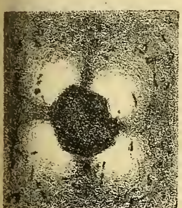

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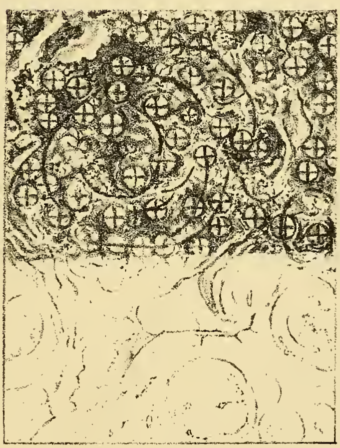


A. S. Foord del et lith.

Mintern Bros. imp.

PHENOMENA, CAUSED BY STRAIN, &c. IN VITREOUS ROCKS.

fissure comes, *there* the depolarization ends abruptly, but the remainder of the depolarizing area shades off gradually.

Fig. 4*a* represents the same crystal as seen by ordinary transmitted light. The extent of the perlitic fissure is shown on the right-hand side of the crystal. This crystal, like some others in the section, has a rounded or spheroidal form.

I may here mention that, in a piece of plate glass given me by Mr. W. Douglas Herman, a distinct depolarization nimbus may be seen around a group of crystallites when the nicols are crossed; and this phenomenon around crystallites in ordinary artificial glass is well known.

In fig. 5 we see a crystal completely surrounded by a perlitic fissure. The perlitic area depolarizes, but the depolarization ends abruptly at the fissure. In examining this section of obsidian with crossed nicols, one can instantly detect the position of the perlitic fissures by the sharp boundaries of the areas of depolarization.

Fig. 5*a* is the same as fig. 5, when viewed by ordinary transmitted light. The perlitic fissure is shown completely surrounding the crystal.

I think that these observations tend to show a definite sequence of events, which we may classify in the following manner:—

A.

1st. Development of Strain.
2nd. „ Perlitic Structure.

Thus we may meet with perlitic structure, without any enclosed crystals, but with depolarization within the perlitic area. Instances of this are seen in the obsidian sandstone of Montana, U.S.A.

B.

1st. Development of Strain } or development of strain and
2nd. „ Crystals } crystals at the same time.

Examples of this are seen in figs. 1, 2, and 3, where the obsidian around the crystals shows depolarization, but no trace of perlitic structure.

C.

1st. Development of Strain } or development of strain and
2nd. „ Crystal } crystal at the same time.
3rd. „ Perlitic Structure.

In such instances we find crystals with surrounding depolarization areas bounded by perlitic fissures as in fig. 5, while fig. 4 represents the incipient development of the perlitic fissure.

The question may be asked, Why in a depolarizing perlitic area may we often find no crystal developed if the strain be so intimately connected with the development of a crystal?

This is not quite an easy question to answer.

We have in this very rock which we are now discussing the most distinct evidence that strain produces perlitic fission and that strain accompanies crystallization.

The perlites of Hungary, Saxony, and other countries are filled with closely packed perlitic fissures; but the perlitic areas seldom environ one particular crystal. They cut indifferently across streams of microliths, and it is evident that the contraction which gave rise to the perlitic structure is quite unconnected with crystallization, so far as we can see, being analogous to the spheroidal structure in basalts and phonolites, as pointed out long ago by Professor Bonney. I think if we regard the development of a crystal as the occasional means of augmenting strain round about it, or of developing strain where all was previously in equilibrium, we shall not be very far from the truth.

Perlitic structure can be set up in a vitreous rock without the intervention of crystallization; but if perlitic structure and sporadic crystals be synchronously developed, an intimate connexion between the one and the other will then, I think, be found to exist.

Then, again, in the perlite of Schemnitz there are crystals of felspar and mica against which the perlitic fissures abut; but these fissures do not traverse the crystals, nor do we find any of these crystals lying within definite fissure-boundaries of their own. There is other evidence also which proves beyond question that these crystals existed in the rock before any perlitic structure was developed. In the porphyritic pitchstone of Spechthausen, near Tharaudt, in Saxony, we may meet with little fragments of rock and broken crystals, and these are very commonly closely wrapped round by minute curved cracks in the contiguous glass, which closely resemble perlitic fissures. Yet in such a case the cracks are more probably due to sudden cooling of the heated glass by contact with colder bodies, such as the fragments of crystals and rocks, which we must regard as volcanic ejecta or as rubbish taken up by the molten lava.

We see that strains may occur in glass without the development of perlitic structure.

It seems to be a question of the extent of the strain, whether or not actual rupture ensues. If the tension be tolerably equal around any particular point, there will be a surface of tension-limit which will be approximately a sphere; and when that limit is reached rupture will follow, and perlitic structure will be the result.

Finally, when the strain is associated with the development of a crystal it may not be sufficiently intense to bring about perlitic structure, and may merely cause a nimbus; but, should it be powerful enough to induce rupture, then the perlitic fissure will encircle the crystal.

In perlites, such as those of Schemnitz, where there is no relation between the perlitic structure and the minute porphyritic crystals, or between the perlitic structure and the fluxion-banding, we shall, I think, find, as I suggested in a paper long ago, and as I believe Professor Bonney did before me, that the perlitic fissures lie packed between rectilinear fissures along which we may assume that cooling has taken place. The main point demonstrated in these notes is, that when a crystal is developed in a vitreous magma, the strain accompanying its development influences the adjacent vitreous mass, reducing it to a condition of permanent tension for some distance around the crystal, and that if this strain be insufficient to cause rupture in the glass, the tension *gradually decreases* and fades away, while if it be strong enough to produce a perlitic fissure, the permanent tension will *end abruptly at the fissure*, the glass which surrounds the perlitic area showing no trace of tension. It seems therefore probable, if not certain, that perlitic structure may be developed in three ways, in each case strain or tension being the primary cause of the perlitic structure, whatever may be the cause of the strain.

1*st way*. Cooling along minute fissures. This seems to be the usual way where the perlitic structure pervades the whole rock, as in perlites.

2*nd way*. Cooling around included fragments taken up in a lava flow. This seems to be merely a marginal structure connected with the fragments, and not affecting the rest of the rock.

3*rd way*. By the tension in the surrounding mass when a crystal is formed; the formation of a crystal not necessarily involving perlitic fission.

Of course there is always the question whether the crystals were developed before, at the same time as, or after, the solidification of the glass. I am inclined to think that a crystal which has a depolarizing nimbus has been developed at the time when the surrounding vitreous matter was in the act of solidifying.

Before, however, expressing a positive opinion upon this point, it is desirable that a large number of observations should be made upon thick slices of vitreous rocks.

At p. 66 of the late Hermann Vogelsang's 'Krystalliten' will be found a very clear record of his observations on the depolarization around certain crystallites which he found in samples of window-glass from the Stolberg works.

With regard to the development of structures in glass along fissures, the following observations may possess some interest. Fifteen or twenty years ago a house was burnt down in the market-place at Dover; a small piece of plate-glass from one of the windows is seen, when closely examined, to be traversed by minute, irregular cracks like those in the artificially cracked, carmine-stained quartz of the French jewellers, known as rubace. When examined under the microscope, between crossed nicols, these cracked surfaces appear to be studded with great numbers of beautiful little spherules with a radiating crystalline structure, each traversed by the usual dark cross. That they follow the cracks is evident, because one has to focus down to them in tracing the crack from the upper surface of the glass downwards. They are, however, really circular crystalline films like little flat wheels lying on the cracked surfaces of the glass.

The phenomenon is superficial and seems only to follow the cracks. We may feel tolerably sure that the glass was not cracked in this manner before the house was burnt. The cracks are precisely such as would be produced in glass or rock crystal by heat, and subsequent immersion in a cold solution; and these conditions would, in this case, be fulfilled by the fire and the play of water from the fire-engines. Whether these little circular crystalline aggregates represent crystallization set up actually *in* the glass, or result from the crystallization of some substance other than that of the glass, introduced in solution into the fissures, I am not prepared to say. How far water has taken a part in the production of spherulitic and perlitic structures in vitreous rocks is a question yet to be ascertained; but it is well known that perlites contain from 2 to 4 per cent. of water. An analysis by Richter of the Spechthausen pitchstone given in Roth's 'Gestein's Analysen' (Berlin: 1861), shows the presence of 5·5 per cent. of water, while another analysis by Erdmann of a spherulite from the pitchstone of the same locality shows only ·3 per cent. of water. It appears, then, that the spherules themselves contain less water than the surrounding glass. To follow this subject one step further, I may mention that in a section of perlite from Buschbad, near Meissen, the perlitic fission is rendered visible between crossed nicols by strings of doubly refracting spherules which closely follow the cracks; while in another section of perlite from Schemnitz the perlitic fissures are also luminous between crossed nicols; but the character and disposition of the crystalline particles cannot be resolved with a $\frac{1}{4}$-inch objective. A section cut from the weathered surface of a specimen of pitchstone from Monamore Mill, in Arran, is very instructive. A spherulitic structure pervades the whole section, but it especially favours very fine cracks which run in different directions but in tolerably straight lines through the preparation, and along these cracks the spherules are very thickly clustered. There are a few felspar crystals in this section, and around them the spherules have also collected in swarms, each crystal, or group of crystals, having a well-defined border of them. The ground-mass of the section consists of a brownish glass thickly charged with fine dusty matter and small spicules. If we assume that access of water along the fissures has had anything to do with the formation of the spherules, we have to face the question how it is that the felspar crystals are also bordered by them, and how it is that isolated spherules occur plentifully in the glassy ground-mass. We may imagine the existence of diminutive fissures close around the crystals of which all evidence is obliterated by the spherulitic crystallization: but we find isolated spherules in obsidians which, in thin section, are as clear as window-glass and where there are no traces of even microscopically small cracks. Clearly, then, we must regard the spherules in the same light in which we regard the individual porphyritic crystals which are formed in a glassy magma in a manner which appears to us utterly capricious. As with the spherules, so with the more definitely developed crystals, there is always a tendency to segregate around some larger body. As for the cracks, those have generally been formed after the porphyritic crystals, but often before the spherules; otherwise why should the spherules cluster along them? We do not always know whether they have been developed exactly where we find them, nor do we know what facilities the rock may have afforded for their locomotion at different periods of its history. What we really do know from actual observation is this:—

That a rock may consist entirely or almost entirely of spherules.

That a rock may have spherules irregularly distributed through it.

That the spherules may range themselves in definite lines without any apparent guide-line, as we see in some vitreous lavas; in fact the spherules floated at certain levels

That the spherules may collect around isolated crystals or around groups of crystals.

That they may collect along cracks.

That in some vitreous rocks their development almost exclusively along cracks indicates that they have been formed subsequently to the solidification of the rock.

In other instances where they are elongated, as in some lava-flows, the evidence is equally strong to prove that they were formed before the lava solidified.

Finally, spherules may cause the the devitrification of a rock after it has solidified and after perlitic fission has supervened. Of this I lay before you the most incontestable evidence in a section of devitrified perlitic obsidian *, now felstone, from the northern end of the Long Sleddale valley, in Westmoreland (Pl. XVIII. fig. 6). It is a lava associated with the Coniston Limestone. In the microscopic section may be seen:—

1. Fluxion-bands.
2. Perlitic structure traversing these bands.
3. Minute spherules constituting the whole rock, so far as spherules can do so, and passing through the perlitic fissures.
4. Subsequent fractures.
5. Formation of quartz veins along these lines of fracture.

EXPLANATION OF PLATE XVIII.

(In each case the nicols are crossed thus, +)

Figs. 1, 2, 3. Depolarization around crystals in obsidian from Java: × 32.

Fig. 4. Depolarization, the depolarization ending abruptly against a perlitic crack, which only partly surrounds the crystal: × 32.

4 *a*. The same crystal and crack seen by ordinary transmitted light: × 32.

5. Crystal completely surrounded by perlitic crack which bounds depolarization-area: × 32.

* Since perlitic structures are met with in all vitreous rocks, it would perhaps be well if the term perlite were abolished as a rock name, and the adjective perlitic prefixed instead to the rocks in which such structure occurs. This, indeed, is suggested to some extent by Prof. Judd and Mr. Cole in their paper upon basalt-glass; but they there propose to retain the noun instead of employing the adjective.

Fig. 5 *a*. The same crystal and crack seen by ordinary transmitted light: × 32.

6. Perlitic obsidian devitrified by spherules, Coniston-Limestone horizion, Till's Hole, Long Sleddale, Westmoreland: × 77.
   Upper portion seen between crossed nicols.
   Lower portion seen by ordinary transmitted light.
   For the sake of clearness the cracks are slightly intensified in the upper half of the drawing.
7. Depolarization around a crystal of ilmenite in obsidian, Mount Shasta, California.
   This crystal had not been observed at the time when the paper was read. The figure is now added as an additional illustration of what is seen in fig. 2. By reflected light the crystal is seen to be partly altered into leucoxene.

Discussion.

Mr. Bauerman asked if there were any evidence of marked dissimilarity in composition between the glass and the crystal in the centre. If there were none, the strain might be the result of surface-tension about the crystal. He remarked on the value of the use of microscopic sections of considerable thickness.

The President had no doubt that in these porphyritic obsidians the crystals were formed before the consolidation of the glass, and were simply floating in it. He thought that perlitic structure can be produced, without the existence of any preexisting cracks, by the contraction of a uniform mass. The contraction of a perlitic granule, with or without a crystal in its midst, would result in a state of stress within it. Spherulitic structures are of two different kinds, namely, with and without definite boundaries; and he pointed out the circumstances under which these would be likely to be produced.

The Author believed that in some cases there might be much truth in the opinions expressed both by the President and by Mr. Bauerman, and was quite ready to admit that similar results might possibly be brought about in various ways.

26. *On a* NEW SPECIMEN *of* MEGALICHTHYS *from the* YORKSHIRE COAL-FIELD. By Prof. L. C. MIALL, F.G.S. (Read April 2, 1884.)

A LARGE and unusually complete example of *Megalichthys Hibberti* was lately found in the roof of the Halifax Hard Bed at Mr. F. B. Ellison's Firebrick Works, Idle, near Leeds, by Mr. Andrew Oldroyd. The fossil, which was presented by Mr. Ellison to the Museum of the Leeds Philosophical and Literary Society, is externally in good preservation and but little disturbed; the ventral surface is uppermost, and the pectoral, ventral, anal, and caudal fins can be more or less satisfactorily made out. The dorsal surface and vertebral column are altogether absent; but nevertheless this specimen gives more information concerning *Megalichthys* than any other which has come to my knowledge. Quite unusual pains were taken by Mr. Oldroyd to recover every fragment of the fish. The remains measure 3 feet 8½ inches in length, of which the head includes about 10 inches and the tail about a foot; 5 or 6 inches appear to be wanting from the end of the tail. The fine skull of *Megalichthys* figured by Agassiz in the Poissons Fossiles *, and still in the Leeds Museum, is a trifle larger than the corresponding part of the new specimen. *Megalichthys* may therefore have attained a length of from 4 to 5 feet.

The skull of the fossil now under description shows the mandible and mandibular teeth, a little of the fore end of the snout, the opercula and the jugular plates; but no novel feature is thereby brought to light.

The pectoral fins are quite distinct and nearly in the natural position. The left fin shows unmistakably the "obtuse lobate" character previously suspected to obtain in this genus †, but not, so far as I know, distinctly seen in any specimen hitherto described. Large basal scales or fulcra (figs. 2, 3, *b*, *b*.) lie on either side of each pectoral fin.

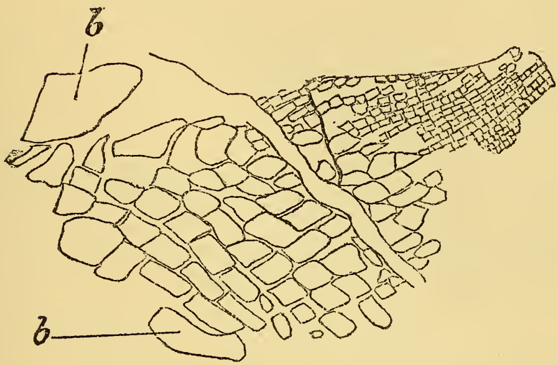
The ventral fins are abdominal, as in all Ganoids which possess them. The right fin is the best preserved, and shows pretty plainly the arrangement of the scales, which in turn gives a clue to the disposition of the underlying bones or cartilages. The base of the fin is invested by large scales, which are continued in a narrow patch along the internal or postaxial border (fig. 4 *m. pt.*); along the outer or preaxial border, which meets the other at an acute angle, is a shorter series of large scales (*p. pt.*). The space between these two rows is occupied by much smaller scales in many parallel series. If we suppose that in *Megalichthys*, as in other fishes with lobate fins, the large scales invest the more rigid, and the small scales the more flexible parts, the skeleton of the ventral fin must have

* Vol. ii. pl. 63 and 63 *a*.

† Huxley, Mem. Geol. Survey, dec. x. p. 12 (1861).

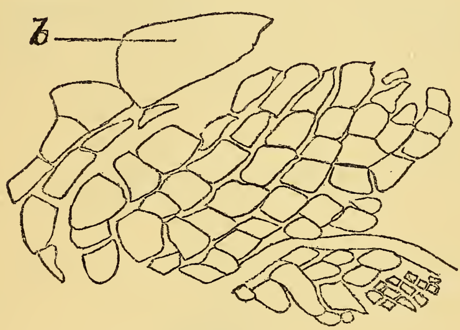
Fig. 1.—*Specimen of* Megalichthys Hibberti, *seen from the ventral surface.*
(One-sixth the natural size.)

Fig. 2.—*Left Pectoral fin of* Megalichthys Hibberti.
(One half natural size.)



b, b. Basal scales or fulcra.

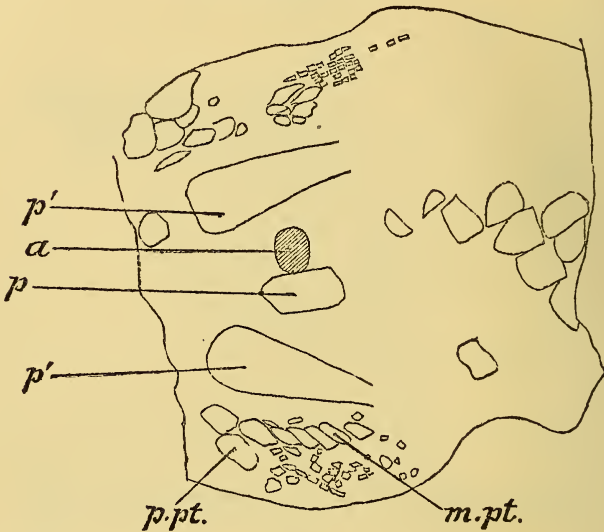
Fig. 3.—*Right Pectoral fin.* (One half natural size.)



b. Basal scale.

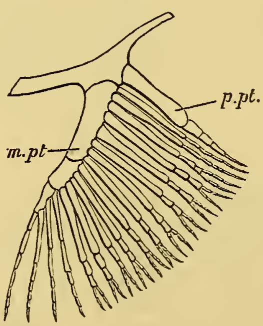
closely resembled that of some Elasmobranchs (fig. 5). The rows of large scales concealed a strong propterygium and metapterygium, while numerous radials, covered by small scales, proceeded from the outer edge of the metapterygium. The Elasmobranch type of ventral fin, thus closely reproduced in *Megalichthys*, may be traced, though with important modifications, in *Polypterus*, *Polyodon*, and *Acipenser*. In other recent Ganoids and in Teleostei the ventral fin differs almost as widely from the Elasmobranch type as does this from the archipterygium of *Ceratodus* or *Dipterus*.

Fig. 4.—*Ventral fins and pelvic scales of* Megalichthys Hibberti. (One half natural size.)



p.pt. Propterygium.
p. Median pelvic scale.
a. Anus.
m.pt. Metapterygium.
p′, p′. Lateral pelvic scales.

Fig. 5.—*Ventral fin of* Torpedo.

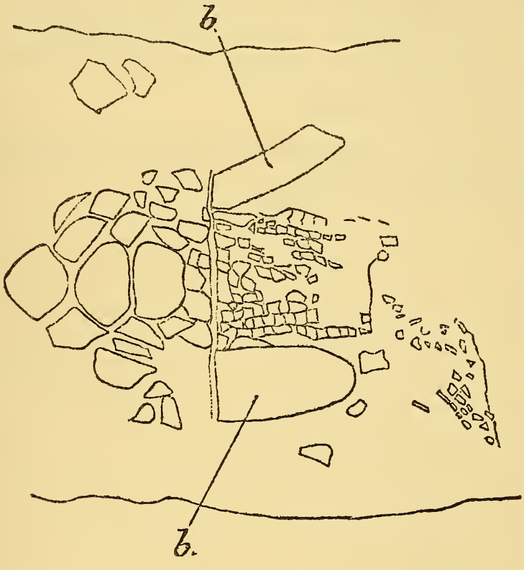


m.pt. Metapterygium.
p.pt. Propterygium.

Between the ventral fins are three large scales, one median and two lateral, which may be called the pelvic scales (fig. 4 p, p', p'). On the left side of the median scale and of the middle line of the body lies what I take to be the anus, distended with fossil fæces. It is quite plain that the anus does not lie immediately in front of the anal fin, as in *Lepidosteus* and other recent Ganoids, but is associated with the pelvis and ventral fins in a manner not uncommon with Teleostei ; in some of which, indeed, the anus follows the ventral fins, even when they are shifted to a thoracic or jugular position.

The anal fin has also its pair of large basal scales (fig. 6 *b*, *b*). Of the caudal fin but little can be made out, and it is uncertain

Fig. 6.—*Anal fin of* Megalichthys Hibberti, *the very convex surface represented as plane.* (One half natural size.)



b, *b*. Basal scales.

whether, as in *Osteolepis* and *Diplopterus*, fin-rays proceeded from the upper as well as from the lower surface*.

There are indications of the underlying skeleton behind the skull and in the neighbourhood of the paired fins; what seems to be the

* Since this paper was sent in, Dr. Traquair has described and figured the tail of *Megalichthys* (Proc. R. Phys. Soc. Edin. vol. viii., and Geol. Mag. March, 1884). It "may be said to be somewhat intermediate between the diphycercal and heterocercal types; at least it is not quite so heterocercal as that of *Osteolepis*, and in general form reminds us of that of *Tristichopterus*. Rays arise from both the upper and lower margins of the body-continuation, but those of the lower side commence in advance of those of the upper."

left clavicle is plainly visible beneath the left pectoral fin; but nothing admitting of definite description can be made out.

All the features of the present fossil confirm the opinion long ago expressed by Pander * and Huxley † as to the near affinity of *Megalichthys* to *Osteolepis* and *Diplopterus*.

Discussion.

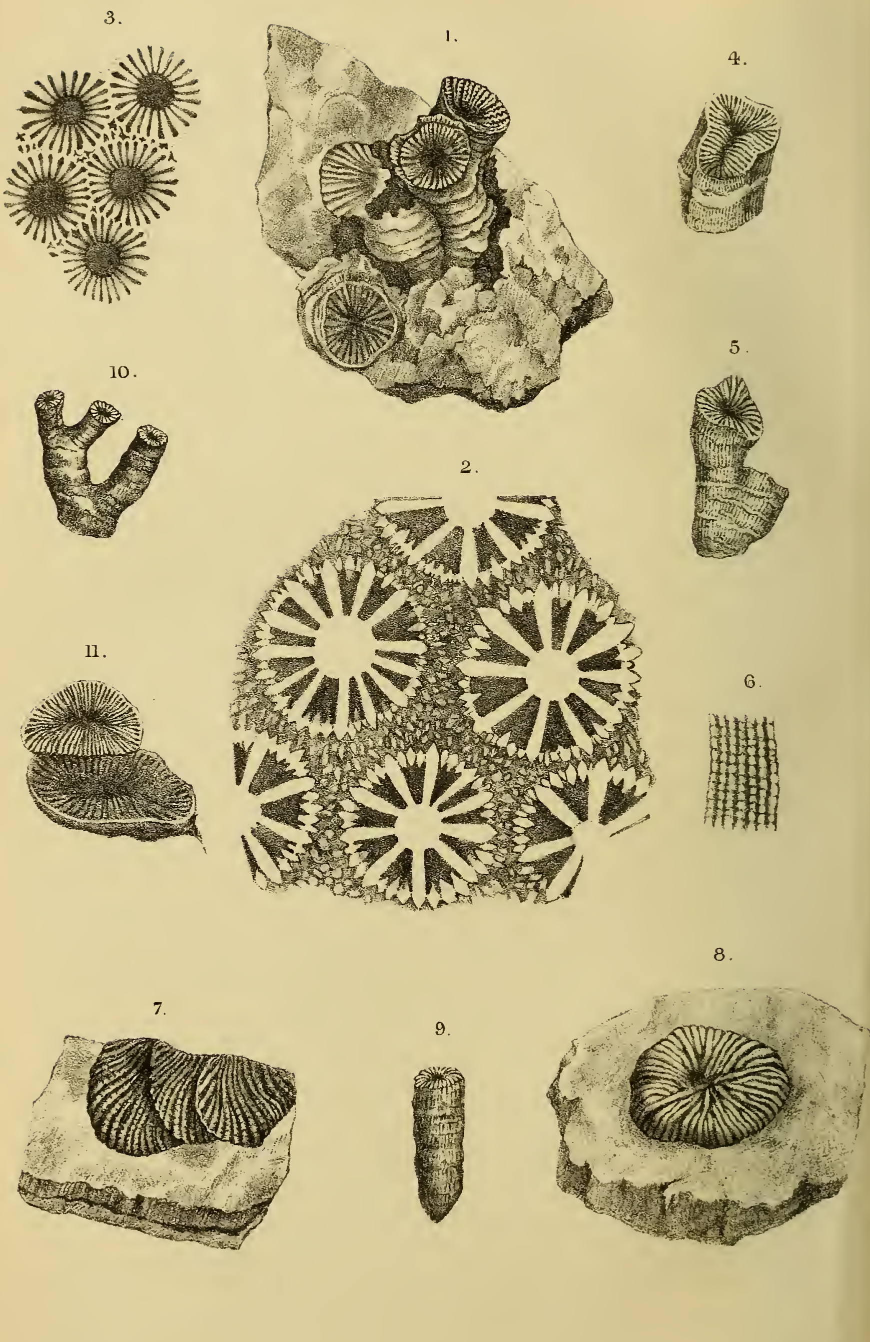
Prof. Seeley remarked, that it was but seldom that so much was added to our knowledge of a long-known type, especially from a single specimen. For his own part, he could only offer his personal thanks to Prof. Miall for bringing so interesting a specimen under the notice of the Society, and for the valuable addition that he had made to our acquaintance with the characters of *Megalichthys*.

Mr. Etheridge expressed a hope that in his paper Mr. Miall would furnish further details of the structure of the fins, to which especial interest attached. Specimens of *Megalichthys* are, as is well known, exceedingly rare; so important a discovery as the present should be fully described and figured.

The Author briefly replied.

* Die Saurodipterinen, Dendrodonten, Glyptolepiden und Cheirolepiden des devonischen Systems, p. 12 (1860).

† Mem. Geol. Survey, dec. x. (1861).



A. S. Foord del. et lith.

Mintern Bros. imp.

SUTTON-STONE AND WHITE-LIAS CORALS.

27. *A* Comparative *and* Critical Revision *of the* Madreporaria *of the* White Lias *of the* Middle *and* Western Counties *of* England, *and of those of the* Conglomerate *at the base of the* South-Wales Lias. By Robert. F. Tomes, Esq., F.G.S. (Read March 19, 1884.)

[Plate XIX.]

The purpose of the present paper is a twofold one—to point out the identity of certain Madreporaria from the Rhætic White Lias of Warwickshire and the Western counties with species from the South-Wales Liassic Conglomerate, and to show that a greater number than has been supposed are identical also with corals from the St. Cassian beds.

In 1878, when my paper on Liassic Corals was published in the Society's Journal*, I thought I had exhausted the whole of the material at command. However, a recent examination of Prof. Duncan's types of species of Madreporaria from the Glamorganshire Lias, collected by the late Mr. Moore, and now in the Bath Museum, and the acquisition of a considerable collection made at Sutton during the present year (1883) by my friends Mr. W. C. Lucy, F.G.S., and Mr. T. J. Slatter, F.G.S., and by myself, has led me to re-examine the several species. The results of such examination I now lay before the Society; but before doing so, it is desirable that I should briefly notice the several papers which have appeared on the subject. Unfortunately the greater part of them are so far controversial, and even contradictory within themselves, as to render their conclusions, to say the least of it, far less valuable than they otherwise would have been.

In 1863 I published, in the 'Proceedings of the Cotteswold Naturalists' Field Club,' a brief notice of the South-Wales Lower Lias, in which, on account of the presence of the supposed Rhætic oyster, *Plicatula intusstriata*, I claimed for the basement-beds a date corresponding to the Rhætic age. A communication on the same subject by the late Mr. Tawney was read at one of the meetings of the Geological Society, in 1865, in which the whole of the conglomerate beds of Sutton and Dunraven and other places in South Wales were declared to be Rhætic †. Shortly afterwards papers on these same deposits were contributed by Mr. Moore ‡, Mr. Bristow §, and Mr. Tate ||, and published in the Journal. In all of them these conglomerate beds, observed at the base of the Glamorganshire Lias, were stated to be nothing more than true Lias. Of these latter contributions, by far the most valuable is the one by Mr. Tate, his conclusions being chiefly derived from palæontological evidence. In

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 179.
† Vol. xxii. p. 69, 1866. Read December 6th, 1865.
‡ Vol. xxiii. p. 449, 1867. Read March 20th, 1867.
§ Vol. xxiii. p. 199, 1867. Read March 20th, 1867.
|| Vol. xxiii. p. 305, 1867. Read May 22nd, 1867.

this paper a list of the Sutton-Stone fossils is given, amended according to Mr. Tate's own determination of the species. These, as decided by him, represent a fauna which is wholly Hettangian.

In none of the above papers was the evidence afforded by the Madreporaria taken into account. That deficiency I now propose to make good; but before doing so, I wish to offer some remarks on the value of the evidence derived from them. Possessed of no powers of locomotion, and being especially impatient of changes of surrounding conditions, corals speedily give way to, and are destroyed by, alterations affecting unfavourably the purity of the sea around them, and in which they have flourished. And supposing that existing coral islands and atolls, such as those of the Pacific, became imbedded in the strata of some future formation, it is obvious that they could not be of the age of such deposit, but that they would be actually contemporary with the surface of the existing sea-bottom around them. Unless, therefore, the layer in which they were imbedded should be broken up, and, with its enclosed organisms, redeposited, such remains as corals should not properly be taken as directly indicating the age of the deposit, but rather as pointing to the date of an interval between the older formation on which they took their growth and the succeeding and overlying stratum in which they would be imbedded. Precisely the same thing would occur with coral-banks or with species scattered over a sea-bottom, as with reef-builders; and it follows as a necessary consequence that corals, unless removed from the place of their growth, cannot properly represent any thing more than a period during which very little deposition took place. Tested by the above considerations, as well as by the affinities of the species themselves, to be hereafter mentioned, many, though not, perhaps, all of the corals found in the Sutton Stone, if not also those of the Brocastle conglomerate, must be assigned to a period antecedent to that at which those beds were formed.

Amongst the genera adopted by Prof. Duncan for the reception of Madreporaria from Brocastle and Sutton are some which, in my opinion, demand considerable revision, and I have accordingly made some changes in their nomenclature. Most of the so-called *Astrocœniæ* from those localities appear to me to appertain to the genus *Stylastræa* of M. de Fromentel. *Cyathocœnia* of Prof. Duncan I regard as identical with the genus *Phyllocœnia*, as applied to a St. Cassian coral by Laube, though quite distinct from the Tertiary and Cretaceous *Phyllocœniæ*. Of course Prof. Duncan's name must be adopted, and, if I am right in my determination, it must henceforth be recognized as a Triassic as well as Liassic genus. Some of the *Montlivaltiæ* from the South Wales deposits, from which Prof. Duncan's figures were taken, are either so young or so ill preserved as to be wholly useless for specific description. Such are *Montlivaltia parasitica*, *M. brevis*, and *M. Murchisoniæ*. The peculiarity observed in the costæ of the last-named species is wholly due to the state of preservation of the specimen from which the description was taken. The supposed costæ are, indeed, nothing more than an infilling of stony matter into the interseptal loculi, which has been laid bare by the removal of the wall, and thus appears in the form of rounded costæ. Specimens of *Montlivaltiæ* in a corresponding condition to that of *M. Murchisoniæ* are by no means uncommon in the Lower *Trigonia*-grit of the Inferior Oolite in the neighbourhood of Cheltenham. *Montlivaltia polymorpha* and *M. pedunculata* are nothing more than fragments of composite genera, which will be hereafter mentioned. *Thecosmilia similis* is another species of which nothing definite can be said, owing to the unfavourable state of preservation of the type specimen. Of *Astrocœnia favoidea* and *A. sinemuriensis*, introduced by Prof. Duncan into the list of British species, I am unable to speak; nor can I give any opinion on the coral described, but not figured, by that zoophytologist, under the name of *Latimœandra denticulata.*

Corals of the White Lias.

Throughout a great part of the area in Warwickshire which is occupied by the Lias, the White Lias, or upper part of the Rhætic formation, is seen underlying it, and in many places is found to be very fossiliferous, the fossils usually being in a bad state of preservation. The few remains of corals observable in it, though in some instances fairly preserved, are much more frequently mere impressions of their calices. That some of these are identical with St. Cassian species I shall endeavour to show, and at the same time point out their identity with species which have been described by Prof. Duncan from the Sutton Stone of Glamorganshire.

The localities in Warwickshire where the White Lias may be most satisfactorily studied are in the neighbourhood of Rugby, Southam, Loxley, and Eatington. West of the river Stour, which passes into the Avon about a mile from Stratford-on-Avon, the White Lias is not seen, excepting at a few points in the county and the adjoining county of Worcester, as at Wimpstone, Crimscot, and Armscot. It is worthy of remark that, whenever in the district above indicated the lower part of the Rhætic deposit has been exposed and examined, it is seen to be of an arenaceous nature and almost wholly without organic remains. At a few places only is this condition reversed, and its usual sandy nature indicates that it was deposited near to a coast-line and in shallow water; while the existence of some highly conglomeratic beds in the lower part of the overlying White Lias points to nearly the same conclusion *. Almost the whole of the Madreporaria I have collected from the last-mentioned formation in Warwickshire have been taken from these lower conglomeratic beds; but I believe that the small discoid *Montlivaltia* I have distinguished by the name of *M. rhætica* occurs a little higher up than the others.

A few miles to the westward, in the neighbourhood of Stratford-on-Avon, the White Lias is wholly wanting, and other beds come

* See some remarks on the slow deposition of the White Lias by the late Mr. C. Moore, in the 17th volume of the Quarterly Journal of the Geological Society, p. 496.

in which do not occur where the White Lias is present. These are the finely laminated shale and stone beds of the *Planorbis* series, and the underlying and subcrystalline *Ostrea*-beds. Immediately below the latter is the "Guinea" bed, which takes exactly the same place at the top of the Rhætic series which the White Lias does, and moreover is, like the lower part of that deposit, often highly conglomeratic. From its position, its lithology, and the occurrence of *Thecosmiliæ* in it, I believe that it corresponds in time with the White Lias, and is, in fact, the attenuated northerly extension of it. I shall further on show, when speaking of the South-Wales Lias, how nearly it also corresponds with a bed of conglomerate quite at the bottom of the formation at the Stormy Cement Works, near Pyle.

I am unable to trace the exact stratigraphical position of the Madreporaria in the beds of the White Lias through the western counties of England, but I may call attention to a section at Steven's Hill, near Long Sutton, Somersetshire, given by the late Mr. Moore, in which a species of branching *Thecosmilia* was found in great abundance in one of the lower beds by my late friend Mr. J. W. Kirshaw and myself *. The position of the coral at that place appears to correspond with the position of the *Thecosmilia* in the White Lias of Warwickshire.

The corals I have met with from the White Lias up to the present time are:—*Montlivaltia rhætica*, Tomes, *Thecosmilia rugosa*, Laube, *Thecosmilia Hörnesii*, Laube, *Thecosmilia confluens*, Laube, and the branching *Thecosmilia* from Long Sutton, to which I am unable at present to give a name. These, it will be observed, are all Rhætic species; none of them, unless it be the last named, ever occurring in the true Lias. With the Mollusca it is quite different, nearly the whole of the species being found also in the zones of *Ammonites planorbis* and *A. angulatus*.

Indeed it may be asserted of the Warwickshire White Lias that while it and the Sutton Stone have a coral fauna much resembling that of the St. Cassian beds, the Molluscan remains in the former, and perhaps also in the latter, are essentially Hettangian. In this respect therefore they have no close relationship with the St. Cassian deposits. But it is desirable to note that in the White Lias of the western counties some of the mollusca are exclusively Rhætic. Yet the stratigraphical position of the Warwickshire and Somersetshire White Lias is the same, and there are not two opinions as to their forming part of the Rhætic formation. Regarded as the upper part of it, and as a transition into the true Lias, such differences are nothing more than may be anticipated.

The Brocastle and Sutton Conglomerates.

I had the advantage of an examination of the conglomeratic bed at Brocastle so long ago as 1863, when I visited the locality under the guidance of the late Mr. Moore; but I failed at that time, as I have since failed, to come to a satisfactory conclusion respecting its real position between the argillaceous beds of the true Lias and the

* See Quart. Journ. Geol. Soc. vol. xvii. p. 492.

Mountain Limestone against which it rests. It appeared then, as during the present year, when I again visited the spot, to be a drifted bed, perhaps only a patch, and very likely derived from the conglomerate beneath the typical Lias of the district, which had been thrown against the slope of the Mountain Limestone previously to the deposition of the Lias proper, and with which the latter became mixed and blended. The woodcut which acompanies the late Mr. Moore's account of the Brocastle beds seems rather to represent such a deposit than a more continuous one. It was probably redeposited where we see it now almost coincidently with the Lias, the fossils of which, such as Gryphites, were then freely mixed up with it. That it differs greatly from the Sutton Stone I shall now proceed to show.

An examination of the Sutton Stone in the coast-section will be attended with much more satisfactory results. The best place for examination is at a spot a few yards westward of "the caves," which are between Sutton and Southerndown, at which place a vertical line would, according to my view, pass through the following series of beds:—

	feet.
1. A series of beds of true Lias and shale, at the bottom of which is the fucoid bed mentioned by Mr. Bristow. Between this series and the following is a thin layer of chert, the fragments of which are overgrown by specimens of *Plicatula intusstriata*...................... about	60
2. Hard conglomeratic stone in layers, and containing a considerable quantity of chert	8
3. Sutton Stone, highly conglomeratic, but sometimes fine-grained. It is divided into two parts, the upper one being about 12 feet, and the lower one about 9 feet in thickness .... about	20
4. Mountain Limestone, on the upturned edges of which the Sutton Stone was deposited.	

Of the beds forming the upper two thirds of the section, I need only observe that their lower limit is clearly defined by the fucoid bed mentioned by Mr. Bristow, and by the line of fragmentary chert noticed both by him and by Mr. Tawney. But of the series numbered 2, it is necessary to state that, although very decidedly conglomeratic, it is unquestionably true Lias, and that it contains characteristic Liassic fossils. The lower series, numbered 3, that is to say the Sutton Stone, is quite distinct from the overlying conglomeratic beds, and contains, according to my observation, a distinct series of organisms. My conclusion, after a careful examination, accords pretty closely with what has been shown by Mr. Tawney in his horizontal illustration of the coast-section, in which the Sutton Stone is seen to occupy but a short distance along the coast-line, and to dip eastward out of sight, only again to become visible when brought up by a fault at Dunraven Point, at which place it is dark in colour and hard*. At a spot only a very short distance from Dunraven Point eastward the same sequence of beds may be seen as at the caves near Sutton. It is not essential to my purpose to enter at length into the details of the physical geology of this coast-section, my present object being in great measure answered by the

* Mr. Bristow also, in the paper already referred to, substantiates the eastward dip of the Sutton and Southerndown beds.

establishment of two distinct series of conglomeratic beds at the point mentioned. Nor will my conclusions be much affected if at some other point these two series should be found blended, either with each other or with some other beds, so long as I am able to show that the Sutton Stone at Sutton is distinct from the conglomerate immediately overlying it. But as I differ so essentially in my interpretation of the coast-section from the readings of such very high authorities as Bristow, Moore, and Tate, who have declared their convictions that the whole from top to bottom and, I might even say, from end to end, is true Lias, I ought perhaps to enter somewhat more fully into the reasons for this difference of opinion. If I am right in considering with Mr. Tawney that the true Sutton Stone is only exposed for a short distance horizontally, it is obvious that the conglomerate which is seen further to the east, that is at Southerndown, is not Sutton Stone but the Upper Conglomerate, which has dipped down to the shore-level; and as it contains undoubted Lias fossils, such as Ammonites and Gryphites, these would certainly be observable, at that spot, from the top to the very bottom of the cliff. It must, I think, have been this part of the section which engaged Mr. Bristow's attention when he spoke of the rocks being so hard that "even with the help of so experienced a collector as Mr. Gibbs, the number of specimens procured is but scanty." According to my views, therefore, fossils obtained from any spot other than at or near Sutton are not Sutton-Stone fossils; and unless I am assured that the lists of species have been drawn up from specimens actually collected at that place, I must still venture to doubt their value as evidence.

My own examination of this fine section, unsupported by other evidence, would lead me to the conclusion that the Sutton Stone holds a position at the base of the Liassic series corresponding to that of the White Lias or Upper Rhætic beds. But there are other reasons for regarding it as holding a position below the true Lias. Mr. Bristow has stated his belief that a conglomerate bed in the bottom of the excavation at the Stormy Cement Works, about two miles from Pyle, is the thinned-out representative of the Sutton Stone, and that the bed upon which it rests represents the White Lias. Mr. Tawney also attributes this lower bed to the White Lias, but appears to have overlooked the Conglomerate bed. The following is the section at that place, on which I wish to make a few remarks:—

	ft.	in.
1. Drift, with boulders of Millstone Grit	2	6
2. Rubbly stone, much broken up, and containing *Lima gigantea*, Ammonites, and a discoid *Montlivaltia*	0	6
3. Rubbly stone, similar to the last	0	6
4. Stone much resembling the last	0	6
5. Compact beds like the last, but divided by thin layers of shale	12	0
6. Compact beds like the last, but containing a few examples of *Ostrea liassica*	6	0
7. Compact stone, harder than the preceding, and containing *Ostrea liassica* in great abundance	1	0
8. Hard and subcrystalline stone, very closely resembling the *Ostrea-*		

	ft.	in.
bed or "firestone" of Binton and Grafton, and containing an abundance of *Ostrea liassica*	1	0
9. Hard conglomerate, in all respects like the "Guinea" bed of Binton ... 2 to	3	0
10. Fine-grained nodular limestone, with a conchoidal fracture, and very much resembling the *Estheria*-bed ... 1 to	2	0
11. Dark grey Rhætic shale	1	6
12. Greenish compact Keuper marl forming the bottom of the pit.		

In this section the regular succession of the lower beds of the Lias and of the upper ones of the Rhætic formation is very clearly shown. The conglomerate takes exactly the place *beneath* the *Ostrea*-beds, and, if I am right in my determination, the precise position *above* the *Estheria*-bed, which is proper to the White Lias or its admitted equivalent. At any rate, the mere fact of its occurrence *under* beds which cannot be other than the *Ostrea*-beds, must be taken as indubitable evidence of its position below the Hettangian series of beds. My own conviction is, that the conglomerate bed is the true representative of the Sutton Stone of Sutton and West, of the "Guinea" bed of Binton and Grafton in Warwickshire, and of the White Lias of that county and the West of England. A comparison of the section at Stormy with the lower part of the section I have elsewhere given of the Binton Lias will show how considerable is the resemblance between the two †. It will also point out the position of the bed numbered 10 as corresponding with that of the *Estheria*-bed.

At another locality, Laleston, similar evidence to that of Stormy may be found. The churchyard quarry is now nearly filled with rubbish, and the conglomerate is hidden; but the beds which are yet visible near the top of the opening are unquestionably the *Ostrea*-beds, and their presence proves that at this place also the conglomerate is inferior to the Hettangian series ‡.

I will now give an amended and comparative list of the Madreporaria of the White Lias, Sutton Stone, Brocastle conglomerate, and of the St. Cassian beds; but I refrain from adding for comparison those from the Azzarola beds, because none of them have as yet been met with in this country.

	St. Cassian.	White Lias.	Sutton Stone.	Brocastle.
Montlivaltia capitata	*			
—— obliqua	*			
—— recurvata	*			
—— acaulis	*			
—— crenata	*			
—— perlonga	*	......	*	
—— radiciformis	*			
—— granulata	*			
—— cellulosa	*			
—— Walliæ	......	......	......	*
—— simplex	......	......	......	*

† Quart. Journ. Geol. Soc. vol. xxxiv. p. 182.

‡ See Moore, Quart. Journ. Geol. Soc. vol. xxiii. p. 536, for particulars of the position of the conglomerate at Laleston.

Table (*continued*).

	St. Cassian.	White Lias.	Sutton Stone.	Brocastle.
Omphalophyllia gracilis	*			
—— boletiformis	*			
—— cyclolitiformis	*			
—— deformis	*			
—— pygmæa	*			
Peplosmilia triassica	*			
Calamophyllia cassiana	*	......	*	
Rhabdophyllia recondita............	*	......	*	
Thecosmilia Hörnesii	*	*		
—— Zietenii	*			
—— granulata	*			
—— rugosa	*	*	*	
—— confluens	*	*		
—— irregularis, *Laube*	*			
—— neglecta............................	*			
—— major	......	......	......	*
—— suttonensis	......	......	*	
—— mirabilis	......	......	*	
—— serialis	......	......	*	
—— Terquemi	......	......	......	*
—— Brodiei	......	......	......	*
—— dentata	......	......	......	*
—— Duncani, *Tomes* (=irregularis, *Duncan*)	......	......	......	*
—— from Long Sutton	......	*		
Cladophyllia subdichotoma.........	*	......	*	
—— sublævis	*	......	*	
—— gracilis	*			
Isastræa sinemuriensis...............	......	......	......	*
—— globosa	......	......	......	*
—— Gümbelii	*	......	*	
—— Haueri	*			
—— splendida	*			
Latimæandra Bronni	*			
—— labyrinthica	*			
—— plana...............................	*			
Stylina Reussi	*			
Elysastræa Fischeri	*	......	*	
Stylastræa sinemuriensis	......	......	......	*
—— Martini.............................	......	......	......	*
—— plana	......	......	*	
—— gibbosa	......	......	*	
—— reptans	......	......	*	
—— parasitica	......	......	*	
—— insignis	......	......	......	*
—— pedunculata	......	......	......	*
—— dendroidea	......	......	......	*
—— minuta	......	......	......	*
Cyathocœnia decipiens	*	......	*	
—— dendroidea	......	......	......	*
—— incrustans.........................	......	......	......	*
—— costata	......	......	......	*
Astrocœnia Oppelli	*			
Microsolena ramosa..................	*			
—— plana	*			
——, sp.	......	......	*	
Septastræa excavata	......	......	......	*

On looking over the foregoing list, it will be seen that nearly all the species hitherto determined from the White Lias are also St. Cassian species, the only exceptions being *Montlivaltica rhætica*, and the branching *Thecosmilia* from Long Sutton; also that a certain number of St. Cassian and White-Lias corals are common to those formations and to the Sutton Stone, but that none of them occur in the Brocastle coralline conglomerate. Furthermore, a most important difference will be observed between the coral faunas of the Sutton Stone and Brocastle, not a single species being common to both. One species, however, which may be mentioned here, has been determined by me, though from rather doubtful specimens, to occur both at the latter place and in the conglomeratic beds overlying the Sutton Stone. It is the *Septastræa excavata*, and its association in both these localities with *Gryphæa arcuata* may, perhaps, be taken as evidence in favour of the identity of the two deposits. To this I shall again refer in my concluding observations.

Conclusion.

At p. 359 of the present paper an opinion has been advanced that the White Lias of the midland and western counties of England, the so-called Guinea-bed of the western extremity of Warwickshire (Binton, Grafton, Wilmcote, and Bickmarsh), the conglomerate of the Stormy cement works, and the Sutton Stone of Sutton and West, are nearly or perhaps precisely of the same geological age. I wish now in conclusion to briefly confirm, but at the same time slightly to modify, that statement.

The late Mr. Moore, in the paper from which I have already quoted, has expressed the opinion that a great thickness of conglomerate exists below the Sutton Stone. This he believed might have been accumulated contemporaneously with Liassic beds elsewhere. Furthermore he has made the remarkable statement that the shaft of the Langan lead-mine was sunk, first through beds of fine conglomerate, afterwards through the Sutton Stone, and then to a depth of 150 feet into an unstratified conglomerate, the bottom of which was not reached. This latter was supposed by Mr. Moore to be identical with beds observed by him under the Sutton Stone in the coast-section. Bearing this statement in mind, I made a most careful examination at Sutton; but could not perceive the least evidence of any deposit in the position indicated by him. What Mr. Moore observed at Cave number 2 (see p. 528 of his paper) was, I believe, nothing more than a part of the Sutton Stone itself, which, as Mr. Bristow observes, becomes hard and blue near that place. Taking into consideration the great difference of opinion respecting the age of the beds at the bottom of the cliff at Sutton and Southerndown, it will be well to base our conclusions on such stratigraphical evidence as may be derived from other localities, where the relationship of the conglomerate to the overlying and underlying beds can be more certainly traced. Such a locality is Stormy (and perhaps also Laleston), where we know that the Conglomerate lies directly between the *Ostrea*- and *Estheria*-beds.

Palæontological evidence of the age of the Sutton Stone would, no doubt, be conclusive, if no uncertainty existed respecting the precise spot from which the fossils were obtained. But the difficulty of collecting specimens, excepting corals, and the doubt as to their position, owing to the diversity of opinion of the several collectors respecting the definition of the Sutton Stone proper, diminishes very greatly the value of their evidence. Moreover, as I have already stated, the upper Rhætic beds of some localities, as in Warwickshire, contain such a very large percentage of Hettangian Mollusca, as to render it quite necessary that a very complete collection should be examined. Unless this is done the small number of characteristic species would probably be overlooked. The Hettangian character of the Mollusca at present recorded from the Sutton Stone, is not therefore sufficient proof of its non-Rhætic relationship; while the corals, like those from the Warwickshire White Lias, unquestionably indicate a Rhætic period. At the same time, however, that which I have stated at p. 354 respecting the value of the evidence afforded by the presence of corals may apply here, and point to a period during which they flourished on the upturned edges of the Mountain Limestone prior to the deposition of the Sutton Stone.

Of the Brocastle corals it may be distinctly affirmed that their affinity is with Infra-Liassic or Hettangian forms, some of them having been described in the works of Martin, Dumortier, and Terquem, although they are at present associated with organisms of a later date. When, however, we remember that a conglomerate has, so to speak, two dates, one when first deposited, and another when redeposited, we shall experience less difficulty in explaining the apparent anomalies presented by both the Sutton and Brocastle conglomerates.

ZOANTHARIA APOROSA

Family ASTRÆIDÆ.

Subfamily Astræinæ.

Genus Montlivaltia, Lamx.

Montlivaltia perlonga, Laube, Fauna St. Cassian, Abth. i. Denkschr. k.-k. Akad. Wiss. Wien, Bd. xxiv. p. 249, Taf. iii. fig. 13. (Pl. XIX. fig. 9.)

A few flattened and otherwise ill-preserved specimens of a *Montlivaltia* of small size have been met with in the Sutton Stone at Sutton. Of these the most that I can say is, that in the general form of the corallum they bear considerable resemblance to the *Montlivaltia perlonga* of Laube, and that, as in that species, they were attached by a small space, and have a rudimentary epitheca which scarcely conceals the costæ. From Laube's figure, however, they differ in being rather less tall.

MONTLIVALTIA SIMPLEX, Duncan, Suppl. Brit. Foss. Cor. pt. iv. p. 9, pl. iii. figs. 16–17.

A single example of this coral, consisting of a polished section imbedded in the stone, which was taken by me from the Brocastle coral deposit, presents exactly the same peculiarities which are shown in Prof. Duncan's figure 17. I wish, however, to remark that the much elongated form of the calice, and the angle observable in some of the septa, are merely the result of pressure. I have observed the same thing in some other species.

MONTLIVALTIA WALLIÆ, Duncan, *loc. cit.* p. 7, pl. viii. figs. 5, 6, & 7.

Prof. Duncan remarks of this species that there is a double wall in some places, and that the rudimentary septa "which are barely visible in the true calice are distinct in the outer rim." He might further have noted the continuity of the older septa from the outer rim, through the inner wall in the calice proper. This is well shown in Prof. Duncan's figure, and is a good illustration of rejuvenesence. The habitat is Brocastle.

MONTLIVALTIA RHÆTICA, Tomes, Quart. Journ. Geol. Soc. vol. xxxiv. p. 180.

This species, as I have already stated in my original description, is characterized by a very thin discoid form, and by the great size and relative prominence of its primary septa.

MONTLIVALTIA, sp.

A young and imperfectly preserved specimen of a species of *Montlivaltia*, which was parasitic on a *Modiola*, was found by me in the black shales of the Rhætic formation during the construction of the Penarth Docks in 1860. Although I am able to state definitely that it was found low down in that formation, I cannot fix its precise position further than to say that it occurred at no great distance either above or below the bone-bed. It is included here because I believe it to be the most ancient representative of the genus which has been met with in this country.

Genus THECOSMILIA, Edw. & Haime.

Of the species appertaining to this genus which come within the scope of the present paper, some have been said to increase by gemmation, and others by fissiparity. And there are a certain number which, like the St. Cassian species, have a great many septa, and others, again, in which the number of septa is very small. The latter would seem to have a more truly Liassic affinity than the others. Those which have very short and stunted forms, and more especially such as increase by gemmation, are possibly only the peduncular portions of species which, in their ultimate growth, constitute genera quite distinct from the present. They might readily, except for their well-developed epitheca, bear some relationship to the genus *Chorisastræa*. *Thecosmilia Martini* and *T. Michelini* are omitted from the present list because they do not occur, to the best of my belief, either in the White Lias or in the conglomerates of Glamorganshire. Of the species which are characterized by a small number of very irregularly developed septa and a stunted form, such as *Thecosmilia Terquemi*, *T. Brodiei*, and *T. dentata*, but little can be said definitely, and it is even possible that they represent only the immature state of some species which, by aftergrowth, would assume a different form. These present very little affinity with the multi-septate St. Cassian and Sutton-Stone species.

Thecosmilia Hörnesii, Laube, *loc. cit.* p. 255, Taf. v. fig. 1. (Pl. XIX. fig. 8.)

Impressions of the calices of a coral occur in the White Lias of Warwickshire which I do not hesitate to refer to this species. For the purpose of direct comparison, I have taken casts from these impressions, which, when compared with veritable specimens of *Thecosmilia Hörnesii* from the St. Cassian beds, are so exactly similar as to leave no doubt of their specific identity. The two woodcuts (5 & 6) at p. 68 of Prof. Duncan's 'Supplement to the British Fossil Corals,' were, I have no doubt, taken from unfavourable examples of such casts, though they are considerably larger than is usual.

Thecosmilia rugosa, Laube, *loc. cit.* p. 256, Taf. v. fig. 4. (Pl. XIX. fig. 1.)

Fragments of this species are not rare in the White Lias of Warwickshire and the adjoining parts of Worcestershire, but they are usually in a very bad state of preservation, and rarely possess anything more of the characteristics of the species than is seen in the rugose portions of broken-up corallites. One example only shows a well-preserved calice. It was taken by me from a quarry in an outlier of White Lias at Meer Hill, near Loxley, about two or three miles north-east of Stratford-on-Avon, and was very near to the bottom of the excavation. This is the position in which I have found all the specimens in this as well as other localities.

In the Sutton Stone of Sutton and West, the present species is not rare; but occurs only in fragments which possess the same peculiarities as the White-Lias and St. Cassian specimens.

Thecosmilia confluens, Laube, *loc. cit.* p. 257, Taf. v. fig. 5. (Pl. XIX. fig. 7.)

Cyathophyllum confluens, Münst. Beitr. iv. p. 37, tab. ii. fig. 16.

I have met with a fragment only of this species lying amongst the rubbish in the bottom of a quarry of White Lias at Stoneythorpe, in Warwickshire. Although partially enclosed by stone, the foliaceous character of its calicular surface is well shown. It differs from Laube's illustration (fig. 5 *c*) only in having the lobes more crowded, so that the folds almost overlap each other, and in having the septa more distinctly denticulated.

Amongst the same rubbish was found the specimen of *Hemipedina*

Tomesii from which Dr. Wright's original description and figure of the species were taken, and around were countless numbers of *Plicatula intusstriata*, which were either lying disengaged from the soft shale between the stone beds, or cemented together into lumps. There was evidence of an oyster-bed, overlain, so far as I could observe, by the bed from which the *Thecosmilia* and *Hemipedina* were derived.

THECOSMILIA SERIALIS, Duncan, *loc. cit.* p. 12, pl. iv. figs. 10–12.

I have met with several specimens of this coral, but always in a fragmentary state, and did not for some time determine them satisfactorily in consequence of their being, in every case, either in contact with, or surrounded by, corallites of *Elysastræa*. The direct evidence of fissiparity observable in some of the elongated calices led to their distinction from those of *Elysastræa*, with which I had confounded them. Hitherto it has only been met with in the Sutton Stone of Sutton and West.

THECOSMILIA, sp.

As already mentioned, a tall branching species of *Thecosmilia* occurs abundantly in a bed quite low down in the White Lias at Steven's Hill near Long Sutton, Somerset. It appears as hollow tubes running vertically through the stone, and showing with great accuracy the epithecal and costal markings of the corallites which have occasioned them. The impressions of the epitheca exhibit an excessively rugose character; but as fragments only of the corallites remain in these hollow casts, the septal characters cannot be made out.

THECOSMILIA SUTTONENSIS, Duncan, *loc. cit.* p. 11, pl. iv. figs. 7–9.

Except for the method of increase, which is by gemmation, the present species would not have been considered by the original describer as a distinct species. If gemmation were found to be its sole mode of increase, it would not only be specifically distinct, but very possibly generically also. Fragments are by no means rare in the Sutton Stone, and are nearly always found denuded of their epitheca, which appears to have been very thin.

THECOSMILIA MIRABILIS, Duncan, *loc. cit.* p. 12, pl. ii. figs. 10, 11.

This multiseptate species altogether conforms to the St. Cassian type; but appears to be specifically distinct from any of the species figured by Laube. So far as I can observe from the figures and description given by Prof. Duncan, it increases by gemmation and not by fissiparity, and a specimen in my own collection shows a much more rapid increase in the diameter of the corallum than appears in the figures just mentioned, and the calicular surface is consequently of greater extent than the same part of the specimen from which Prof. Duncan's figure was taken.

THECOSMILIA TERQUEMI, Duncan, *loc. cit.* p. 16, pl. iii. figs. 7–12.

Prof. Duncan's description of this species was taken from Brocastle specimens in Mr. Moore's collection; but he afterwards figured some very immature *Thecosmiliæ* from my own collection, taken from the "Guinea" bed of Binton; and as these latter were actually found attached to and growing upon shells forming the upper or exposed surface of the bed, there can be no doubt whatever about their horizon. But the low septal number which characterizes them is quite as probably the mere result of immaturity as of their identity with a species which possesses, even with greater age, only a few septa.

THECOSMILIA BRODIEI, Duncan, *loc. cit.* p. 13, pl. x. figs. 1–4.

I am only acquainted with this coral by a very cursory examination of the type specimen. Its calicinal peculiarities distinguish it as a species; but there seems to be little evidence of its generic claims.

THECOSMILIA DENTATA, Duncan, *loc. cit.* p. 16, pl. iv. figs. 21–23.

So far as can be ascertained from the examination of the type specimen, which is not, however, a very satisfactory one, the present species possesses more strongly marked specific characters than some of the other species of *Thecosmiliæ*, occurring also in the Brocastle conglomerate, which have a smaller number of irregular and ill-developed septa.

THECOSMILIA DUNCANI, Tomes.

Thecosmilia irregularis, Duncan, *loc. cit.* p. 15, pl. iii. figs. 1–6 (not pl. x. fig. 5), not *Thecosmilia irregularis*, Laube, *loc. cit.* p. 257, Taf. 6. fig. 6.

Like so many (probably all) of the Brocastle *Thecosmiliæ*, the present species increases by fissiparity. Figure 5 of plate x. of the work above quoted, represents a coral which I cannot regard as identical with the one figured on plate iii. under the same name, either specifically or generically. The very remarkable form shown on plate x. is, I have no doubt, the result of excessive and repeated rejuvenescence. I have seen precisely the same thing happen, though not in the same degree, in *Montlivaltia rugosa*, and I possess specimens of the latter species which show that when the sudden contraction takes place, the epitheca advances and obliterates the calice, leaving uncovered only a circular space of greater or less extent, from which afterwards arises the new portion of the corallite. This is precisely what has taken place in the specimen attributed to the present species, in which, as may easily be observed in the figure, the upper or final calice has become covered by a thick and wrinkled epitheca. As the specific name *irregularis* had been already made use of, the name of *Duncani* may be here applied to the present species.

THECOSMILIA MAJOR, H. de Ferry, in Dumortier, Etude Paléont. Dépôts Jurass. du Bassin du Rhône, p. 173, pl. xxviii. fig. 1, 2, 3, 4 (1864).

Montlivaltia polymorpha, Duncan, *loc. cit.* p. 8, pl. vii. figs. 14, 15, pl. viii. figs. 1, 2, 3, 4, 14, 15 (not Terquem et Piette) (1866).

After the examination of the specimens figured by Professor Duncan as *M. polymorpha*, now in the Bath Museum, as well as a number of others in my own collection, all from the Brocastle conglomerate, I am fully satisfied of the necessity for placing them in the genus *Thecosmilia,* and referring them to the *Thecosmilia major* of M. de Ferry. The larger and more perfect specimens consist of two corallites supported by a rather tall peduncle, and the latter part, in all the specimens I have seen, is longer than is represented by figure 13 of plate viii. in Prof. Duncan's work. Moreover the corallites separate from each other much less rapidly. As the calicular surface, in the specimen from which that figure was taken, is wholly hidden in the matrix, it is difficult to determine with certainty to what species it should be referred. There is a tendency in the present species to a rapid increase in diameter of the corallite, just at the calice, which gives the latter great openness. This peculiarity is slightly shown in figure 15 of the plate above referred to.

Genus CLADOPHYLLIA, Edw. & Haime.

CLADOPHYLLIA SUBLÆVIS, Laube, *loc. cit.* p. 259, tab. iv. f. 5.

At one place only in the Sutton Stone, to the best of my knowledge, has the present species been found. My friend Mr. T. J. Slatter discovered it in an abandoned quarry close by the side of the road leading from Sutton to the river Ogmore, quite at the western extremity of the Sutton Stone, and, as far as could be ascertained, nearly at its base. It was observed to lie in a thin seam, in which were a number of ill-preserved and crowded fragments. Unlike most of the corals which are common to the St. Cassian beds and to the Sutton Stone, the corallites of this one have not a greater diameter than is shown in Laube's figures.

CLADOPHYLLIA SUBDICHOTOMA, Laube, *loc. cit.* p. 258, Taf. iv fig. 2. (Plate XIX. figs. 10, 11.)

Montlivaltia pedunculata, Duncan, *loc. cit.* p. 10, pl. ii. figs. 12, 13.

A considerable number of fragments of a bush-shaped coral occur in the Sutton Stone, which usually present swellings and constrictions, and, generally speaking, have a shallow calice, which has a sublobate outline. It is only, however, occasionally that the calices are sufficiently preserved to permit satisfactory examination. More frequently the calicular surface resembles that shown in Prof. Duncan's figure of *Montlivaltia pedunculata* (pl. ii. figs. 12, 13), which is, in fact, the representation of such a fragment, which has been broken off inferiorly at a constricted point, and has lost its calicular termination.

The figure of *Montlivaltia pedunculata*, given on plate viii., from Brocastle, is distinctly referable to another species.

As in other Sutton-Stone corals, which have also been found in the St. Cassian beds, the corallites of this species have a greater diameter than is observable in the Alpine representatives.

Genus ELYSASTRÆA, Laube.

ELYSASTRÆA FISCHERI, Laube, *loc. cit.* p. 262, Taf. v. fig. 6; Duncan, *loc. cit.* p. 29, pl. vi. figs. 5–9.

Elysastræa Moorei, Dunc. *loc. cit.* p. 30, pl. vi. figs. 10–15.

Of all the Madreporaria which occur in the Sutton Stone, this is by far the most abundant species. It is, however, very unequally distributed, appearing in some places in great masses, the corallites of which, either more or less closely packed, or in disjointed branches, penetrate the stone through and through. In other places scarcely a fragment can be seen. Notwithstanding a very careful examination, I have not in a single instance met with the *Elysastræa* growing on the floor of Mountain Limestone beneath the Sutton Stone, nor indeed have I seen any of the Madreporaria so placed. But I have found many specimens of immature growth attached to rounded lumps of that rock, as well as to lumps of conglomerate.

This is a very variable species, and the closest investigation has failed to satisfy me that there are two species in the Sutton Stone. On the contrary it has convinced me that the characters attributed to the two species may be seen in different parts of the same corallum. I have not hesitated, therefore, to place the name of the one as a synonym of the other. Of the generic character supposed to be presented by the appearance of a ring of septa within the ordinary ones, I may remark that it is nothing more than one stage of rejuvenescence. Nevertheless that mode of growth is so unusual in the compound Astræidæ, as to constitute a marked feature, as I have elsewhere stated that the same thing sometimes takes place in *Confusastræa* *. But there is one characteristic which deserves especial notice, and which seems to denote some affinity with *Latimæandra*; I allude to the existence of elongated and compound calices amongst the circular and simple ones.

Genus RHABDOPHYLLIA, Edw. & Haime.

RHABDOPHYLLIA RECONDITA, Laube, *loc. cit.* p. 255, Taf. iv. fig. 3.

Notwithstanding that a very diligent search has been made for this species in the Sutton Stone, no other specimen has been met with. The one figured by Prof. Duncan, though only a fragment, fully identifies the species, but differs from Laube's figures just as

* Quart. Journ. Geol. Soc. vol. xxxviii. p. 423.

the other St. Cassian species do which are found in the Sutton Stone, that is to say, in having a greater diameter in the individual corallites.

Rhabdophyllia, sp.

A polished piece of the Brocastle conglomerate reveals a horizontal section of a corallite of a species of *Rhabdophyllia*, with a small diameter and twenty-six short and stout septa, the alternate ones being stouter and longer than the others, and a columella which occupies fully one half of the entire diameter of the calice, and the papillæ of which are far apart and irregular in size.

Genus Calamophyllia, Blainv.

I have followed Laube in attributing to the genus *Calamophyllia* a coral from the Sutton Stone which is evidently identical with one from the St. Cassian beds. It is the *Calamophyllia cassiana* of that author. But it is worthy of note that the naked costulated walls which constitute an important feature in *Calamophyllia*, are also observable in other forms from the St. Cassian beds, and in some of those figured by Stoppani from the Azzarola beds of Lombardy. Such are *Cladophyllia subdichotoma*, Laube, *Rhabdophyllia recondita*, Laube, *Rhabdophyllia langobardica*, Stoppani, and *R. Meneghini*, *R. De-Filippi*, and *R. Sellæ* of the same author. In all of these, with the exception of the last, the corallites are characterized by alternately swollen and attenuated portions; and all have calices which differ so much from the usual circular form as to become sublobular. Bearing these peculiarities in mind, and remembering that the corallites of *Calamophyllia* are jointed rather than swollen, it may perhaps be desirable that the present genus should be adopted provisionally.

Calamophyllia cassiana, Laube, *loc. cit.* p. 254, Taf. iv. fig. 1. (Plate XIX. figs. 5–7.)

At present my knowledge of this as a Sutton-Stone species is confined to fragments which were taken by my friend Mr. T. J. Slatter and myself from the exposures at Sutton These, however, are in a sufficiently perfect state to render their identification a matter of no uncertainty.

Genus Stylastræa, Fromentel.

This genus was created in 1860 by M. de Fromentel for the reception of two species of composite corals from the *Amm.-angulatus*-beds of the Lias of the Côte-d'or. It is characterized by circular calices which are not united by their walls, but by cœnenchyma having costæ which are non-confluent and denticulated, by septa which are exsert and strongly denticulated, and by a well-develo and styliform columella. That some, if not all, of the so-called *Astrocœniæ* from the Sutton-Stone and Brocastle deposits in South Wales, are referable to this genus, whatever may be its affinities, I do not entertain the least doubt. In some of the species in which the calices are more closely placed than in some of the others, the calices, by contact with each other, become more or less polygonal, and have the appearance of those of *Astrocœnia*; yet even in such specimens portions will be observed which have more distinct calices (which are therefore separated by more cœnenchyma), the calices of such portions being always circular.

Stylastræa sinemuriensis, E. de From. in Martin, Infra-Lias du Département de la Côte-d'or, p. 94, pl. viii. figs. 6–7.

Astrocœnia costata, Duncan, *loc. cit.* p. 21, pl. ix. figs. 15, 16, 17.

Any doubt that may exist as to the identity of *Strylastræa sinemuriensis* with *Astrocœnia costata* will be readily removed by comparison of fig. 7 of the former with fig. 16 of the latter species, in the works above quoted. It has only been met with in the Brocastle conglomerate, so far as I know.

Stylastræa Martini, E. de From. *loc. cit.* p. 49, pt. vii. fig. 18.

Astrocœnia superba, Duncan, *loc. cit.* p. 21, pl. ix. figs. 3, 4, 5.

After an examination of the type specimen of *Astrocœnia superba*, I am perfectly satisfied of its identity with the previously described *Stylastræa Martini*, to which species I therefore refer it. The specimens examined have been obtained from Brocastle.

Stylastræa plana, Duncan, sp. (Plate XIX. fig. 2.)

Astrocœnia plana, Duncan, *loc. cit.* p. 19, pl. v. fig. 1.

The want of figures showing sections of the corallites and of other details of this species renders its identification much less easy than that of *S. gibbosa*, which has received at the hands of the describer more ample representation. Yet the present is the more typical species, and a magnified figure corresponding with the enlarged one of *Stylastræa gibbosa*, given by Prof. Duncan (pl. v. fig. 5), would show corallites which are more distinct, having walls much more clearly defined and circular, and a much more abundant cœnenchyma. An enlarged figure, which I now give, will explain the differences thus pointed out.

Stylastræa gibbosa, Duncan, sp.

Astrocœnia gibbosa, Duncan, *loc. cit.* p. 18, pl. iv. fig. 3, pl. v. figs. 2, 3, 4, 12, pl. vi. figs. 1, 2, 3, 4.

The present species, as well as the foregoing, is to be found in the Sutton Stone at Sutton, and both appear to be equally common; but I have seen specimens from no other locality.

Stylastræa reptans, Duncan, *loc. cit.* p. 20, pl. iv. figs. 4, 5, 6, 15.

A single specimen from Sutton, by no means in a good state of preservation, is all I have met with. The peculiar septal arrangement distinguishes it from the foregoing species; but I may observe that the union of the shorter with the longer septa is sometimes also observable in some of the calices of *S. gibbosa*, as is, indeed, shown in Prof. Duncan's enlarged figure. The calices of this species are more polygonal than in most others, which is due to their being rather more closely placed. Nevertheless there are some parts of the corallum where they are wider apart and circular.

Stylastræa parasitica, Duncan, sp.

Astrocœnia parasitica, Duncan, *loc. cit.* p, 20, pl. v. figs. 5, 6.

I am only acquainted with this species through the means of Prof. Duncan's description and figures. The great distance of the calices from each other, as well as their circular outline, and the obviously great amount of cœnenchyma between them, indicate a form which cannot be at all nearly related to *Astrocœnia*, which is characterized by corallites closely connected by their walls.

Stylastræa insignis, Duncan, sp.

Astrocœnia insignis, Duncan, *loc. cit.* p. 19, pl. ix. figs. 1, 2.

This is a well-marked species, and not uncommon in the Brocastle conglomerate, from which I obtained some fine specimens in 1862.

Stylastræa pedunculata, Duncan, sp.

Astrocœnia pedunculata, Duncan, *loc. cit.* p. 20, pl. v. figs. 7, 8, 9.

I am only acquainted with the species through Prof. Duncan's figures and a very cursory inspection of the type specimen. It is remarkable for the wide spaces between the calices.

Stylastræa dendroidea, Duncan, sp.

Astrocœnia dendroidea, Duncan, *loc. cit.* p. 22, pl. ix. figs. 10, 11.

Many fragments of this coral occur at Brocastle, all of which present much the appearance of the specimen from which Prof. Duncan drew up his description. It is rather remarkable that no dendroid species either of this genus or of *Cyathocœnia* have been recorded as occurring in the Sutton Stone.

Stylastræa minuta, Duncan, sp.

Astrocœnia minuta, Duncan, *loc. cit.* p. 22, pl. ix. figs. 18, 19, 20.

Of unfrequent appearance in the Brocastle conglomerate, the present species is readily distinguishable from all the others by the small size of the calices and the presence of a paliform tooth on each septum in close proximity to the columella. The latter peculiarity appears also in a species from the Azzarola beds, which is evidently allied to the present, and which has been described by Stoppani as a *Stylina*. Both show a remarkable resemblance in the above respect to the coral from the Greensand of Haldon which has been made the type of the genus *Haldonia* by Prof. Duncan.

? STYLASTRÆA, sp.

A specimen in my own collection, consisting of a few calices only, bears a very strong resemblance to a *Stylina*. It was taken from the Brocastle conglomerate by my late friend Mr. J. W. Kirshaw, on the occasion of a visit to that locality made by him and myself in company with the late Mr. Moore.

Genus CYATHOCŒNIA, Duncan.

Phyllocœnia, Laube (not Edwards & Haime).

To this genus, which was created by Prof. Duncan, in 1867, for some corals from the Liassic conglomerate of South Wales, and for one species from the *Amm.-angulatus*-zone of the Lower Lias of Worcestershire, must, I believe, be referred the *Phyllocœnia* of Laube. Although in the figure given by him of *Phyllocœnia decipiens* the septa appear to have entire edges, and are therefore consistent with those of the Tertiary and Cretaceous *Phyllocœniæ*, yet in the letterpress they are distinctly mentioned as being serrated. This alone supplies sufficient grounds for the removal of the species from the genus *Phyllocœnia*. The greater part of the *Cyathocœniæ* from the Glamorganshire Lias have lost their septal denticulations; and that the specimen from which Laube's *Phyllocœnia decipiens* was taken had similarly suffered will become exceedingly probable if we compare the figures of that species with Prof. Duncan's of *Cyathocœnia costata* *.

CYATHOCŒNIA DECIPIENS, Laube, sp. (Plate XIX. fig. 3.)
Phyllocœnia decipiens, Laube, *loc. cit.* p. 264, Taf. vi. fig. 1.

My knowledge of this as a Sutton-Stone fossil is confined to the examination of a single specimen taken by myself from one of the small excavations between Sutton and West. The septa and costæ of this example are wholly without denticulations. As will be seen on reference to the figure here given, these parts, as well as the general conformation of the calices, very closely resemble those given by Laube for this species.

CYATHOCŒNIA DENDROIDEA, Duncan, *loc. cit.* p. 27, pl. ix. figs. 6, 7, 8, 9.

Fragments of this species are not rare at Brocastle, from which place I have received several specimens.

CYATHOCŒNIA INCRUSTANS, Duncan, *loc. cit.* p. 28, pl. iv. figs. 1, 2.

The specimen from which Prof. Duncan's illustration of this species was taken was found incrusting an oyster; and the only other one I have seen, which was taken by me from the Sutton Stone, is similarly incrusting a shell of the same species.

* Supp. Brit. Foss. Cor. pt. iv. pl. v. figs. 10, 11.

CYATHOCŒNIA COSTATA, Duncan, *loc. cit.* p. 29, pl. v. figs. 10, 11.

Of this well-marked species I have never met with a specimen, and I insert it here on account of its undoubted specific distinctness.

Genus ISASTRÆA, Edw. & Haime.

ISASTRÆA GÜMBELII, Laube, *loc. cit.* p. 263, Taf. vii. fig. 2.

Impressions of a few calices which, from their size as well as from their details of structure, are probably referable to the above species, were found by me in the Sutton Stone. With the exception of these, I have failed to discover any indications of an *Isastræa* in that deposit.

ISASTRÆA SINEMURIENSIS, E. de From. in Martin, Paléont. Stratigr. Infra-Lias, p. 93, pl. vii. figs. 16, 17; Duncan, *loc. cit.* p. 30, pl. vii. figs. 1–9.

On referring to the original figure of this species it will be observed that it has one calice which is much in excess of the others in size. No such discrepancies can be seen in the calices of any of the specimens from Brocastle; and, moreover, they are all, generally speaking, smaller than those shown in the figure alluded to, and approximate in this respect those of *Isastræa Gümbelii* of Laube, a species to which the present also bears considerable resemblance in the shape and size of the corallum.

ISASTRÆA GLOBOSA, Duncan, *loc. cit.* p. 31, pl. viii. figs. 17, 18.

In the small size and globular and subpedunculate form, as well as in the thickness of its septa in relation to the interseptal loculi, this species bears a decidedly St. Cassian aspect. It appears to be a less abundant species than the last, and has been met with only in the Brocastle conglomerate, from which I obtained a very characteristic example some years since.

Genus SEPTASTRÆA, d'Orbigny.

SEPTASTRÆA EXCAVATA, From.?

In the conglomerate overlying the Sutton Stone and associated with Gryphites and Ammonites, the latter undeterminable, are the remains of compound corals, which are most likely *Septastrææ*. One specimen only was seen by me very near to the caves, which I believe is referable to this species. A greater number were observed not far from Dunraven Point. These may have been *Septastrææ* or one or other of the known species of *Isastræa* which occur in the *Amm.-angulatus*-zone of the Lower Lias. I have also some fragments, apparently of this coral, taken from the Brocastle conglomerate.

ZOANTHARIA POROSA.

Family PORITIDÆ.

Subfamily Poritinæ.

Genus Microsolena, Lamx.

Microsolena, sp.

Two specimens have been taken by me from the Sutton Stone, which though unquestionably referable to this genus, are not well enough preserved to permit of description. Both of them are imbedded in stone and can only be observed at the weathered surfaces or by recent sections. It is evidently a tall species, one specimen, though incomplete, being fully 5 inches high. The calices are large, round, and far apart, and when their septa meet those of other calices there is no disposition towards a parallel arrangement. No trace of columella is observable. The septa are thin and their perforations numerous. The synapticulæ are simple and not much developed.

EXPLANATION OF PLATE XIX.

Fig. 1. *Thecosmilia rugosa*, Laube: natural size; showing the dwarfed and clustered character of the species. Taken from a specimen from the White Lias, at Meer Hill, Loxley, two miles N.E. of Stratford-on-Avon.

2. *Stylastræa plana*, Duncan, sp. A greatly magnified representation of a horizontal section immediately under the calices, taken from a specimen from the Sutton Stone. This shows very satisfactorily the cylindrical form of the corallites, with their thin wall; the abundant cœnenchyma and the well-developed columella. These are characters which distinguish the genus *Stylastræa*, of which this appears to be a typical species.

3. *Cyathocœnia decipiens*, Laube, sp. Some calices, magnified, from a specimen taken by me from the Sutton Stone.

4 & 5. *Calamophyllia cassiana*, Laube: natural size, from specimens taken by me from the Sutton Stone.

6. —— ——. Some of the costæ of fig. 4: magnified.

7. *Thecosmilia confluens*, Laube. The representation of a fragment, natural size, taken from the White Lias, at Stoneythorpe, near Southam, Warwickshire.

8. —— *Hörnesii*, Laube. The cast of a calice from the White Lias, at Wimpstone, near Stratford-on-Avon.

9. *Montlivaltia perlonga*, Laube: natural size; from a specimen taken by me from the Sutton Stone.

10. *Cladophyllia subdichotoma*, Laube. Represents a fragment from a confused mass of broken-up corallites from the Sutton Stone, most of which have a much more parallel arrangement than is shown in the portion figured. The corallites in this species are for the most part placed much more closely side by side than as shown in the figure.

11. —— ——. Some magnified calices of the same. In these the greater thickness of the primary cycle as compared with the other cycles is not sufficiently shown.

Discussion.

Dr. Duncan regretted the absence of the author of the paper. The corals brought from South Wales by Mr. Tawney were examined by the speaker, and several of them were recognized as St. Cassian forms. The mollusca and other corals, however, indicated a Hettangian age. He saw no reason from the paper for altering his opinion as to the age of the deposits. They were not Triassic or even Rhætic, but belonged to the Infrà-Lias. He knew of no examples of fossil coral-atolls, and he could not accept the peculiar views of the author, but believed that the corals were of the same age as the limestone in which they are found. The classification he had adopted for the *Astrocœniæ* and allied forms years ago he still maintained. He did not agree in the value of a genus like *Stylastræa*, which was founded upon its denticulate septa alone; and the form described by Laube was neither *Phyllocœnia* nor *Cyathocœnia*. He pointed out that Mr. Tomes, in his critical essays, had made some errors which diminished the value of his criticisms upon Milne-Edwards and the speaker. Thus Mr. Tomes, in his last paper, had stated that *Astrocœnia* and *Isastræa* bud from the wall, which is wrong. In a former paper he accused Milne-Edwards of error in relation to the septal number of a *Montlivaltia*; yet Mr. Tomes's own figures proved that the distinguished French zoophytologist was correct. On one occasion when the speaker protested against *Thamnastræa* being placed in the Perforata, Mr. Tomes insisted and persisted. But Mr. Tomes, in his next communication, put the genus back into the Fungidæ, having found out his own error. Pratz had disposed of the ideas of Milaschewitsch about *Thamnastræa* belonging to the Perforata. It was to be regretted that Mr. Tomes had not studied recent corals, and that his experience was confined to the fossil forms from a limited area in the west of England.

Mr. Etheridge considered the question of the age of the Sutton beds as still an open one. Mr. Tawney had been satisfied that he was wrong in his original views, and that the beds were truly of the age of the zone of *Amm. angulatus*. He bore testimony to the care and labour bestowed on the study of corals by Mr. Tomes. He agreed with Dr. Duncan as to the non-existence of coral-reefs in the Jurassic deposits.

The President pointed out the difficulty of believing in the existence of coral-reefs of Keuper age in the part of South Wales referred to, under the conditions which we know to have characterized that period in England.

28. Observations *on the* Geology *of the* Line *of the* Canadian Pacific Railway. By J. W. Dawson, LL.D., F.R.S., F.G.S., &c. (Read April 23, 1884.)

Having had an opportunity last summer of passing over the line of this railway, and of examining some of the sections exposed on the road and in its vicinity, it may be useful to note the facts observed.

All of the country on both sides of the line has been more or less explored by the officers of the Geological Survey, more especially by Dr. Selwyn, Dr. G. M. Dawson, and Dr. R. Bell; and without repeating what they have published, I shall confine my remarks chiefly to facts discovered or brought into greater prominence in the construction of the road.

Between Ottawa and Port Arthur the road was only partially opened last summer, though it had penetrated into the region of typical Huronian rocks north of Georgian Bay. Next summer it will be opened throughout, or at least to Algoma Mills, whence steamers will run on Lake Superior to Port Arthur. This section of the road will be of great geological interest, as it abounds in cuttings through Laurentian and Huronian rocks, and will also expose the Kewenian or Upper Copper-bearing series and other formations which, though newer than the Huronian, are believed to be Pre-Cambrian. Last summer, travellers were conveyed by steamer from Collingwood to Port Arthur, through Lakes Huron and Superior, and it was at Port Arthur that their geological experiences began.

Port Arthur is at the head of Thunder Bay, and opposite it are the grand trappean masses of Thunder Cape and of the islands in front of it—masses which are associated with the Kewenian series.

Near the town of Port Arthur the rocks exposed are dark-coloured quartzites and quartzose slates, having occasional veins of white quartz and of amethyst. These beds are believed to underlie the Kewenian series, but to be newer than the true Huronian *. Their surfaces show a few peculiar markings, which may be of organic origin, but are not determinable.

From Port Arthur to Rat Portage the country is at first low, with many swamps and ponds; but occasional rock-cuttings show different varieties of Laurentian gneiss and bands of greenish schistose beds, probably Huronian. In the latter occur the veins now being worked for gold in this vicinity. I did not visit any of the mines; but I saw specimens, more especially from the "Huronian Mine," about 70 miles from Port Arthur. They consisted of white quartz holding visible gold and sylvanite in a rock which appeared to be chloritic slate. Several of these veins are now being worked on the shore of the Lake of the Woods, and are very accessible from Rat Portage. In approaching the place last named, fine sections

* Animiké series of Hunt.

are seen of grey Laurentian gneiss with red felspathic veins, and at Rat Portage itself is a faulted junction of the Huronian and Laurentian, described by Dr. G. M. Dawson, in his Report on the 49th Parallel, and to which the Falls of the Winnipeg river at that place are due.

It has been remarked by previous observers that the Huronian of this district is somewhat different in mineral character from that of the typical district of Georgian Bay, and that it presents a more highly crystalline aspect and an appearance of conformability with the Laurentian. These characters, which are very manifest in some of the railway-cuttings, suggest the possibility that it may be a lower member of the Huronian, partly filling the gap indicated by the great unconformability of the Laurentian and Huronian on Lake Huron itself. Neither of these series has yet been brought into any direct stratigraphical connexion with the Norian or Upper Laurentian formation of Eastern Canada.

It may be well to remark here, in connexion with this western extension of the old crystalline rocks of Canada, on the uniformity of mineral character which they present over 40 degrees of longitude, from Labrador to the Winnipeg river, and after a space of 27 degrees further, in the mountains of British Columbia. Their similarity to the older Eozoic rocks of Brazil, Scotland, Scandinavia, and Southern and Eastern Europe, is equally well marked; and I have the pleasure of placing this evening on the table a collection of similar rocks from the neighbourhood of the first cataract of the Nile, so similar to the Laurentian of Canada that any geologist familiar with these rocks, and placed before the sections of gneiss and micaceous and hornblende schist, traversed by veins of granite and syenite, which are exposed in the vicinity of Assouan, might be excused for imagining that he was examining one of the cuttings on the Canadian Pacific. At Assouan there is also an overlying unconformable series, consisting apparently largely of igneous products, and which may represent the Huronian of Canada. These rocks, with my notes of the sections of the Egyptian Laurentian, I propose to leave in the hands of Prof. Bonney, who has kindly consented to report on them to the Society at a future time *.

Beyond Telford Station the old rocks disappear and are succeeded by muskeg or swamp country, which here forms the border of the Great Red River plain. This vast swamp, 20 miles in width, and extending north and south for a great distance, with a depth of peaty matter stated at nine feet, affords a modern illustration of the formation of the beds of brown coal which occur in the Laramie and Cretaceous further west; and in the somewhat monotonous character

* In the Collection of the society there is a suite of specimens from Assouan, presented by Mr. Hawkshaw, in which there are specimens from both of the crystalline formations above mentioned; but he does not seem to have distinguished between these in his published paper, which is so valuable as a description of this interesting locality. See Quart. Journ. Geol. Soc. vol. xxiii. 1867.

of its vegetation and the absence of large trees, illustrates also the paucity of vegetable fossils by which these beds are sometimes characterized.

In the region above referred to, glacial striæ are often observed upon the hard rocks uncovered in railway excavations; and there are glacial deposits of two kinds, though they are not very continuous or of great depth, the indications being that the region was, in the Pleistocene period, an area rather of denudation than of deposition. One marked variety found between the ridges of crystalline rock is a stratified red clay sometimes with greenish bands. This kind of deposit, which abounds in the drift area of Southern Manitoba and Minnesota, has been attributed to the waste and driftage westward of the red clays and sandstones of the Kewenian formation of Lake Superior. It is not usually a Boulder-clay, but where it approaches rocky ridges, is seen to overlie or pass into clay with numerous local boulders. Boulders are often to be seen heaped in great numbers against the sides of steep rocky ridges. Not far from Rat Portage, a conspicuous instance is afforded by a steep escarpment of hornblendic rock, which is seen to be furrowed in a deep and fantastic manner by ice-action, while its base is piled with large masses of Laurentian rock. In many places also gravel beds and ridges containing boulders appear, as a more recent deposit than the red clay, in the same manner as we find in Eastern Canada and also westward on the plains.

An interesting feature of these clays in their extension into Minnesota is the presence in them of Foraminifera of several species to which attention has been directed by Mr. B. W. Thomas, of Chicago, who has kindly sent me mounted specimens of these organisms. They belong to the genera *Textularia, Rotalia,* and *Globigerina*; but are not properly fossils of the Boulder-clay itself, being in all likelihood derived from the Cretaceous marls of the west, which abound in such organisms. Indirectly, however, they constitute an evidence of the aqueous origin of the clays, as they imply much disintegration of the marls and the driftage of their materials to great distances.

At Stony Mountain and Selkirk, on the borders of the Red River plain, are cream-coloured Silurian limestones now extensively quarried, and affording a beautiful building-stone. They are rich in marine fossils, of which considerable collections have been made by a local geologist, Mr. J. H. Panton. From these it would appear that within a very moderate thickness of beds there occur fossils ranging from the Trenton to the Niagara age, thus presenting an instance of a long lapse of time marked by a very small amount of deposit, similar to that which occurs in some other western localities. The precise stratigraphical subdivisions of these fossils, if such exist, remain to be worked out. I may here remark that while the outcrops of these limestones are at present of comparatively small extent, the immense number of boulders scattered westward on the plains to the base of the Rocky Mountains, more than 800 miles distant, shows that they must, before the glacial period, have occupied a large area and probably overlapped large portions of the Huronian and Laurentian series.

In approaching the Red River at Winnipeg, we pass over the eastern half of the great lacustrine deposit of the Red-River valley, extending, with a width of about 40 miles along that river, from the north to the south of the province of Manitoba, and constituting with its extension southward into the United States, what some of the geologists of that country have somewhat fancifully named the basin of the extinct "Lake Agassiz." It presents a flat surface of the most typical prairie land, and consists of the finest possible silt with a covering of black vegetable soil. Very few boulders or stones appear on its surface, or in the cuttings made in it for drainage; and the former are of small size, and may be accounted for by lacustrine ice-drift under climatal conditions similar to those now existing.

West of the Red-River valley we enter on the higher prairie lands, extending westward about 700 miles to the foot of the Rocky Mountains. From the Red-River prairie, which is about 800 feet above the level of the sea, they rise by two principal steps or escarpments, and intervening gradual slopes, to the higher plains at the base of the mountains, which in some places are 4200 feet above the level of the sea. The physical features of this region have been fully described by Dr. G. M. Dawson, in his paper on the "Superficial Geology of the Central Region of North America," in the Journal of this Society for November 1875, where also will be found reference to the work of earlier explorers in this field. I may add that the facts stated in that paper afford, in my judgment, the best existing key to the solution of the difficult questions of glacial geology in North America; and that, when applied to the regions south and east of the districts described, they are sufficient to enable any geologist to perceive the fallacy of the theories of continental land-ice applied by extreme glacialists to explain the drift phenomena of the middle and western parts of the United States.

With the exception of a small area of Miocene Tertiary recently discovered*, the whole of this region is underlain by Cretaceous clays, sandstones and limestones, and by the shales and sandstones of Laramie or Lignitic Tertiary group, by some geologists regarded as late Cretaceous, by others as early Eocene (see Section, fig. 2, p. 382); but which the writer and other Canadian geologists have been disposed to regard as in great part a transition series, connecting the newer Cretaceous with the Eocene. Out of these formations the two prairie escarpments have been cut by water, the higher in a period of partial submergence before the glacial period, the lower at a later date by the waters of the extinct lake of the Red-River valley.

The latest results as to the stratigraphical arrangement and relations of these deposits are stated in the following table, abridged, and slightly modified from the Reports of Dr. G. M. Dawson in the

* At the Cypress Hills, Mr. R. G. McConnell, of the Canadian Survey, is stated to have found beds holding remains of *Brontotherium*, the first discovery of this kind hitherto recorded within the limits of Canada.

publications of the Geological Survey of Canada. In these, detailed descriptions of the structure and distribution of the different members of the series will be found. It is to be observed, however, that in consequence of the flatness and slight undulation of the beds, and the rarity of good exposures, as well as the probable recurrence of similar beds with somewhat similar fossils at different horizons, some doubts exist as to the detailed arrangement.

Formations in the Prairie country traversed by the Canadian Pacific. (Order descending.)	*European Equivalents.*
Laramie or *Lignitic Series*: sandstones, shales and clay, lignite, fossil plants, brackish and freshwater shells—1500 feet or more.	Paleocene or Latest Cretaceous.
Fox-Hill Group: yellowish sandstones and shales with marine shells—1500 feet or more.	Maestricht Beds (*Danien*).
Ft. Pierre Group: dark-coloured and grey shales with some sandstone, marine fossils and lignite—250 to 300 feet.	White Chalk (*Sénonien*).
Niobrara Group: limestone and marls with marine shells, and locally shales and sandstones with lignite and fossil plants—100 to 200 feet.	Chalk Marl.
Ft. Benton Group: light-coloured shales with shells and bones of Dinosaurs and lignite—200 to 400 feet.	Upper Greensand (*Cénomanien*).
Dakota Group: brown and grey shales and sandstones, with lignite and lignitic coal—200 to 300 feet. The Neocomian series does not seem to be represented east of the Rocky Mountains, but is found in British Columbia.	Gault.

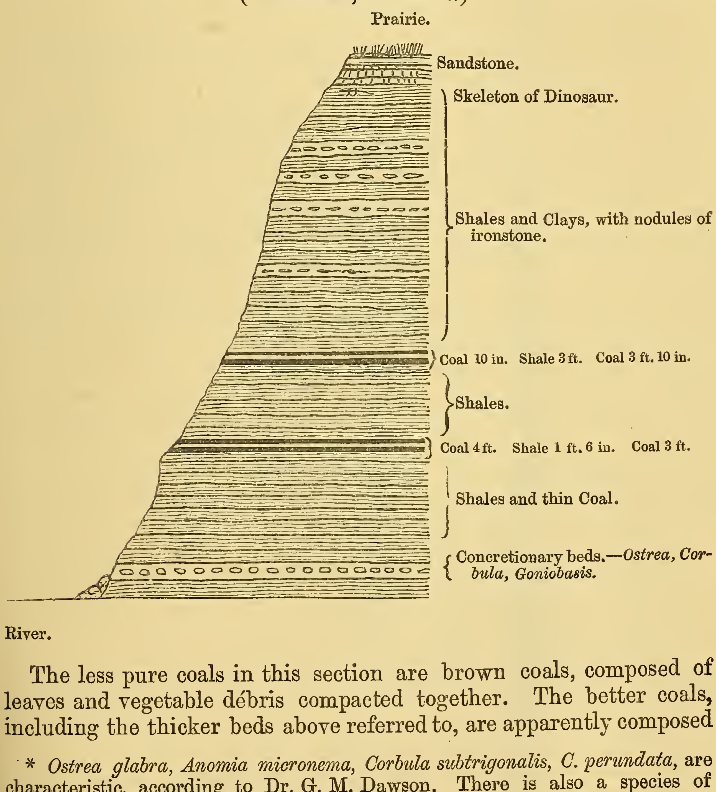
I may illustrate this section and also some of the difficulties incident to correlation of beds in this region, by reference to some exposures which I visited last summer.

One of these is in the vicinity of the town of Medicine Hat, where the railway crosses the South Saskatchewan river. Here the river runs through a deep cutting in the Cretaceous rocks, which in some places present high and broken cliffs seamed with coulées, and in others fall into grassy slopes or are encumbered with masses of burned shale of a bright red colour, produced by the spontaneous combustion of the lignites in the banks.

About ten miles above Medicine Hat, on the right bank of the river, at a point where one of the coal-beds was being opened, the cliff is about 300 feet in height, and consists of shale or indurated clay, of grey, dark, and purplish colours, with several beds of lignitic coal in the central portion; and near the top are irregular layers of grey and ferruginous sandstone, some beds of which hold pebbles and nodules of iron-ore.

At the base of the section (fig. 1), near the level of the river, the shales hold calcareous concretionary bands, with bivalve shells characteristic here of the Cretaceous beds *, which are the only marine fossils seen in the section. About 90 feet from the base of the section is a bed of coal 3 feet thick, and covered with a shale roof or parting of 2 feet 6 inches, above which is another coal, 4 feet thick, with a shale roof. For about 50 feet above this the cliff is occupied with shales, holding several thin coals; and on this rests another bed of coal 3 feet 10 inches thick with roof of shale 3 feet thick, and over this a small coal 10 inches thick. Above this shales again occur, and near the top a bed of ferruginous and pebbly sandstone very unequal in hardness and texture. In this Mr. Molyneux, an engineer in charge of the works, had found some large bones, and on further excavation we obtained considerable portions of the skeleton of a large Dinosaur believed to belong to the genus *Diclonius* of Cope, scattered teeth of which occur in the same bed.

Fig. 1.—*Section on South Saskatchewan river, near Medicine Hat.* (Thickness, 220 feet.)



The less pure coals in this section are brown coals, composed of leaves and vegetable débris compacted together. The better coals, including the thicker beds above referred to, are apparently composed

* *Ostrea glabra, Anomia micronema, Corbula subtrigonalis, C. perundata,* are characteristic, according to Dr. G. M. Dawson. There is also a species of *Goniobasis.*

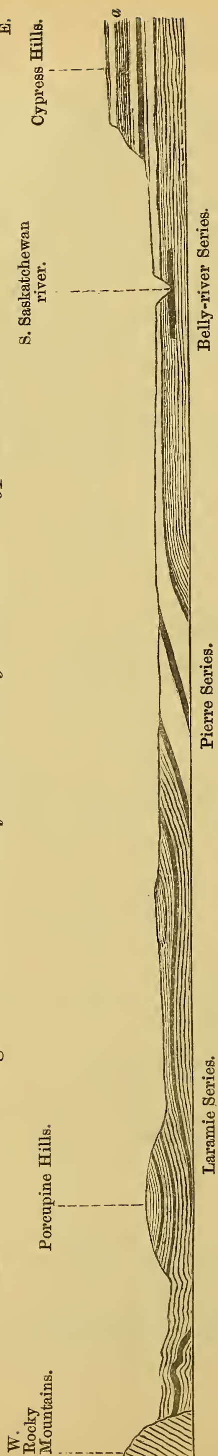


Fig. 2.—*General Section from the Rocky Mountains to Cypress Hills.*

a. Miocene.

The dark bands indicate the horizons of Coal and Lignite.

principally of coniferous wood, having the texture of a bright hard lignite approaching to the characters of true bituminous coal, and affording a valuable fuel. Beds of this character are very extensively distributed over the region*. The shales associated with the coals hold many vegetable fragments; but no well-characterized specimens were obtained, though there were abundant indications of forests of angiospermous and gymnospermous trees. Better-preserved remains of them, obtained from other sections, will be found referred to in a paper by the writer in the 'Transactions of the Royal Society of Canada' (vol. i. 1883).

These beds at Medicine Hat are believed, on stratigraphical evidence, by the officers of the Geological Survey to be below the Ft. Pierre group, and therefore probably of Cenomanian age; yet in lithological character they have a very close resemblance to the Laramie beds; and even their fossils, so far as known, are scarcely distinguishable from those of the upper series, both holding shells of the same genera. They would seem to occupy the top of a flat anticlinal, on both sides of which are seen beds a little higher in the series.

About twenty miles east of Medicine Hat, at Ross's Creek, some of the next beds in ascending order occur, and are believed to belong to the Pierre series. They are light-coloured marls and clays with *Ammonites, Cytherea*, and bones of fish and Dinosaurs; above these are gypseous clays; and, still higher, brownish shales holding a bed of lignite.

West of the localities above described, similar Cretaceous beds occupy the country nearly to the base of the mountains (fig. 2); and beds of coal, some

* See map by Dr. G. M. Dawson, and Report on Bow and Belly Coal Fields. Geological Survey of Canada, 1883.

of them supposed to overlie those seen at Medicine Hat, occur at Maple Island, Blackfoot Crossing, and elsewhere.

Near Calgary, however, on the Bow river, a formation occurs which differs from those previously seen, and probably belongs to the upper part of the Laramie group. Its most conspicuous feature is a bed of whitish sandstone, about 20 feet in thickness, and presenting all the appearance of a coal-formation sandstone. Some of its layers abound in well-preserved leaves of Dicotyledonous trees of numerous species and, so far as appears from a cursory examination, similar to those described by the writer from the sandstones of the Lignitic group near the Souris river *. In state of preservation and in some of their generic forms, these leaves much resemble those of the Swiss Molasse; and no doubt the Calgary sandstone is an Eocene Molasse, related in mode of deposition to the Rocky Mountains as the Molasse is to the old rocks of the Alps. This sandstone is underlain and overlain by beds of grey, ferruginous, and black shales, in which are calcareous bands holding fossil shells of the genera *Goniobasis* and *Corbula.*

West of Calgary, as the Cretaceous and Laramie beds enter the Rocky Mountains and approach the junction with the Palæozoic rocks, they become much folded and disturbed, and the coals contained in them become harder and drier in quality, in some places approaching to anthracites.

The development of the Cretaceous series in the region under consideration is, in the main, similar to that described by the United States geologists as occurring in the country south of the 49th parallel; and it shows the wide extent of plain and table land between the Laurentian and Palæozoic region on the east and the Rocky Mountains on the west to have alternated in that period between conditions of shallow water and of vast bogs and swamps. Such conditions were, however, more prevalent towards the south, where this ancient Cretaceous Mediterranean communicated with the ocean; and toward the north, in the vicinity of the Peace river, there seems to have been a barrier of land or shoals. With the exception of the folds impressed on their western edge by the elevation of the Rocky Mountains, these beds have remained entirely unchanged and undisturbed, and there seems to have been a continuity of deposition and an absence of unconformability from the Cretaceous into the Eocene and Miocene periods, though sandstones and conglomerates at several horizons indicate some considerable intensity of water-driftage. It would seem that over large parts of the area slight elevations and subsidences led to alternations of driftage of clay from the Arctic regions, or the accumulation of organic limestone and marl in warm waters sheltered from the north, with sand-drift in shallow water, or actual land and swamp surfaces holding lakes and lagoons.

With reference to the contrast between these undisturbed Cretaceous beds and those of some other countries, we need not go

* Reports Canadian Survey, Memoir on Cretaceous and Tertiary Plants, Trans. R. S. of Canada, 1883.

beyond America, since in the coast ranges of British Columbia the beds of this age are quite as violently disturbed and as much altered as in the mountain-districts of Europe and Asia. Throughout North America, however, there seems a far less development of great calcareous deposits than in the Cretaceous of the Old World, though in the Niobrara group we have Foraminiferal marls essentially of the nature of chalk, and toward the south abundance of marine organisms generically similar to those of the Chalk of Europe. In America, as in Europe, remains of Teleostean fishes become plentiful in the Cretaceous, and the Dinosaurian reptiles continue to the end without any indication of the placental Mammalia. In America as in Europe, angiospermous exogens of genera still existing appear in the middle Cretaceous, and Lesquereux has described in the United States, and the writer in Canada, a rich and abundant exogenous flora very similar to that still extant in America, from the Dakota, Benton, and Niobrara formations.

The distribution of the drift over these plains has been fully described in the paper above referred to. I shall therefore notice here only such new facts and inferences as presented themselves in connexion with the line of the railway.

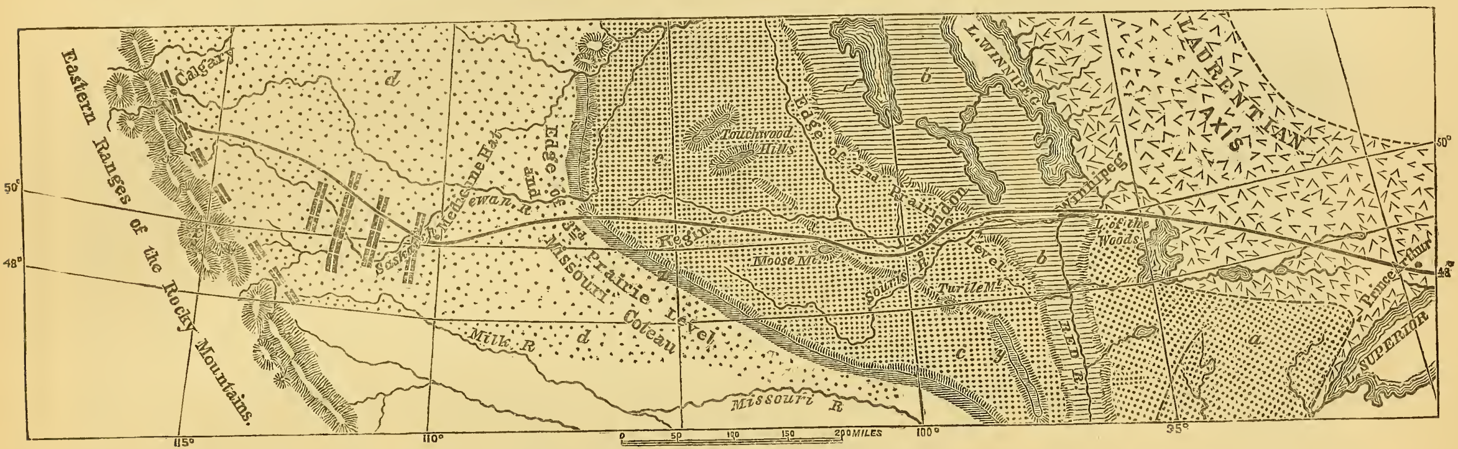
At the west side of the Red-River plain, where the railway ascends to the second plateau (see Map, fig. 3), are seen sandhills or dunes, obviously an old lake-margin, and, so far as seen, without large boulders or other evidences of heavy ice.

The second prairie plateau everywhere presents travelled boulders associated either with Boulder-clay or overlying sands and gravels. The percentage of Laurentian, Huronian, and Silurian rocks, and of stones from the Rocky Mountains among those visible on the surface, has been noted by Dr. G. M. Dawson, who has also mentioned the line of elevations made up of drift, perhaps based on outliers of Cretaceous beds, which extends from Turtle Mountain northward to the Touchwood hills along the middle of this plain. In the line of these eminences, where the railway crosses on the plain, there is evidence of a connecting belt of sand and gravel with boulders, and within this are Oak Lake and other lakes and ponds. Thus there is really a continuous margin of the glacial sea on this line, and the higher and more marked hills are merely its more elevated portions*.

The Great Missouri coteau to which Dr. G. M. Dawson first directed prominent attention as a glacial feature, and which fringes the margin of the third plateau, about 400 miles west of Winnipeg, is now known to be continuous with similar ridges extending southward into the United States and eastward towards the Atlantic, and which have been described as the terminal moraine of a great continental glacier. In the western plains, however, where it has its greatest development, it cannot be explained in

* The cuttings of the railway do not appear likely to modify the statements respecting the percentages of boulders; but they seem to show that, as in many other parts of America, boulders are more abundant near the surface than below.

Fig. 3.—*Sketch Map of the Country traversed by the Canadian Pacific Railway, between the Rocky Mountains and Prince Arthur.* (Slightly altered from a Map by Dr. G. M. Dawson, in Q. J. G. S. vol. xxxi. pl. xxxii.)



a. Boulder-drift area of Lake Superior. *b.* Red-river Prairie. *c.* Second Prairie level. *d.* Third Prairie level. *y.* First range of Coteau drift. *z.* Grand Coteau. **||**. Approximate outcrop of Cretaceous Coals.

this way, but must mark the margin of an ancient glacial sea, or at least of that deeper portion of such sea in which heavy ice could float, while in its upper portion it shows evidence of having been, in the later periods of its formation, an actual water-margin.

The railway, taking advantage of the oblique valley of Thunder Creek, crosses the coteau at one of its least-marked portions, but where it still presents very definite and striking characters. On entering it, the railway passes for nearly 30 miles through a rolling or broken country, consisting of successive ridges and mounds interspersed with swales and alkaline ponds without outlet. To this class belongs a somewhat extensive series of lakes known as the "Old Wives' Lakes." The highest point of the coteau on this section appears to be near Secretan Station.

As seen in the road-cuttings, the basis of the ridges appears to consist of thick beds of imperfectly stratified clay, derived from the disintegration of the local Cretaceous beds, but with many Laurentian boulders. In one place the clay was observed to be crumpled as if by lateral pressure. Above the clay are stratified gravels, also with large boulders, most abundant at top. The ridges are highest and most distinct at the eastern or lower side, and gradually diminish towards the upper or western margin, where they terminate on the broadly rolling surface of the upper prairie.

The history of the coteau would seem to have been as follows :—

1. The excavation in pre-glacial times of an edge or escarpment in the gently sloping surface of the Cretaceous and Laramie beds, and the cutting by subaerial causes of coulées and valleys of streams in this escarpment.

2. Submergence in the glacial period, in such a manner as to permit heavy ice loaded with Laurentian débris to ground on the edge of the escarpment and deposit its burden there, while at the period of greatest submergence deep water must have extended much further westward. These conditions must have continued for a long time and with somewhat variable depth of water.

3. Re-elevation, during which gravel ridges were formed, until at length the coteau became the coast-line of a shallow sea, which lingered at a later date along the line already referred to in advance of the coteau.

4. On the re-elevation of the country, the transverse ravines and valleys were so effectually dammed up by the glacial ridge, that the surface waters of the region, now comparatively arid, have to remain as alkaline lakes and ponds behind the coteau.

The upper prairie plateau, extending from the coteau to the Rocky Mountains, has, on its general surface, comparatively few boulders ; yet these are locally numerous, especially on the eastern and northern sides of some gentle elevations of the prairie. They consist, as before, of Laurentian gneiss, Huronian schists, and yellow Silurian limestone, all derived from the eastern side of the plains, some of the boulders of Laurentian gneiss being of great dimensions. Some of these have been used in modern times by the buffalo as rubbing-stones, and are surrounded by basin-shaped depressions formed by the feet of these animals *.

That strong currents of water have traversed this upper plain, is shown not only by the occasional ridges of gravel, but by the depressions known as "slues," which must have been excavated subaqueous currents.

Near Medicine Hat a terrace of boulders was seen at an elevation of about 200 feet above the river; and in sections of the drift observed in coulées, the boulders were seen to be arranged in layers; but whether these appearances had relation to fluviatile action, before the excavation of the deep valley of the Saskatchewan, or belonged to the original distribution of the drift, was not apparent.

Laurentian boulders were seen all the way to Calgary, but with an increasing proportion of quartzite boulders from the Rocky Mountains; and on the banks of the Bow river were large beds of rounded pebbles which must have been swept by water out of the valleys of the mountains, and are quite similar to those now observed in the bed of the Bow itself.

Beyond this, Dr. G. M. Dawson has recorded Laurentian boulders and fragments of limestone from the eastern Palæozoic beds, at elevations of from 4200 to 4660 feet, at the foot of the Rocky Mountains, evidencing a driftage of at least 800 miles, and an elevation considerably above that of the sources from which they came. He well observes that any thing which would explain the origin of the coteau must also explain the transport of these boulders so far above it and beyond its limits, as well as the contemporaneous distribution of boulders from the Rocky Mountains to the eastward. These phenomena are explicable on the hypothesis of a glacial sea of varying depth, but not on that of land glaciation, which would also be inapplicable in a region necessarily of so small precipitation of moisture and occupied by soft deposits so little suited to the movement of glaciers. There is nevertheless good evidence of the action of glaciers on a large scale in certain portions of the glacial period both on the Rocky Mountains and on the Laurentian hills and table-lands to the east.

My observations of 1883 were extended only as far as the railway-cuttings then in progress a few miles west of Calgary; but the road now extends 120 miles further through the disturbed and folded portions of the Laramie and Cretaceous, and the portions of the road to be opened this summer in the mountains may be expected to afford interesting exposures of these, as well as of the Palæozoic rocks which constitute the nucleus of the Rocky-Mountain chain.

* The buffalo is now extinct on these plains; but abundant traces of its former presence exist in the rubbing-stones, wallows, deeply-worn paths, and bleached skeletons, and at one place on the Bow river we saw a large deposit of bones covered with earth washed down from above, and apparently indicative of the destruction of a herd from some natural cause, perhaps unusual cold and heavy snow. The latter, when followed by thaw and frost, producing a hard icy crust, has sometimes proved destructive to cattle on the higher plains.

Discussion.

The President called attention to the numerous important subjects referred to in this paper, and expressed his conviction of the great gratification that was felt by the Fellows of the Society at having Principal Dawson among them in person.

Mr. Bauerman said he had no knowledge of the exact line of country described by Principal Dawson, but that he was pretty well acquainted with some neighbouring regions. The first point of importance to which he would advert was the occurrence of Upper Laurentian in the country west of Lake Superior. As that formation is represented on the Labrador by a form of gneissic rock almost entirely composed of labradorite, the discovery further west of a series stratigraphically equivalent, but lithologically different, was a matter of great interest. He next referred to the Laramie group, and remarked upon the great lignitic series which occurs similarly on other lines of railway crossing North America further to the south. All these rocks contain carbonaceous beds different from the usual Tertiary brown coals of Europe, some being bituminous, like those of certain parts of Austria. Near the head of the Colorado river, some 1000 miles south of the district described in the paper, there was good coking coal, and close by good anthracite also occurred in these same Cretaceous beds. He said that the Rocky Mountains, in this section, as seen by him, wanted the Laurentian axis which was met with further south. In conclusion he observed that the westerly carriage of glacial drifts, and the peculiar erosion of the surface of this flat country around the Great Lakes were very remarkable phenomena.

Mr. Topley inquired, with regard to the distribution of the anthracite, whether it was always found in connexion with disturbed beds.

Principal Dawson in reply thanked Mr. Bauerman for the additional illustrations which he had given from the country to the south of the Canadian boundary. In answer to Mr. Topley's question, he stated that in the undisturbed portions of the Cretaceous and Laramie, the coals are of various qualities, the difference depending partly on the material of which they are composed, whether wood of trees, or débris of foliage, &c., and partly on diversity of age; but the anthracitic coals are limited to the districts in which the beds are disturbed, and the same remark applies to the Cretaceous anthracite of the Queen Charlotte Islands on the west coast, as compared with the bituminous coal of Vancouver Island. He hoped that many Members of the Geological Society would be in Montreal in August, to take part in the British Association excursions over the western districts which he had described.

29. *On the* Dyas (Permian) *and* Trias *of* Central Europe, *and the true* Divisional Line *of these two* Systems. *By the* Rev. A. Irving, B.Sc., B.A., F.G.S. (Read April 23, 1884.)

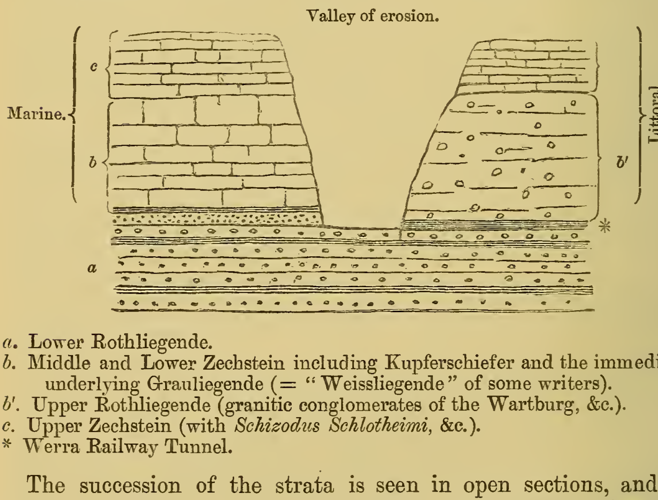
In bringing this subject before the Society, it is my intention merely to follow up and supplement that treatment of the questions involved which, through the courtesy of the Editor of the Geological Magazine, I was able to apply to them (more especially for the British rocks) during the year 1882. I shall assume that what I have written in that periodical is familiar, or at any rate accessible, to all Fellows of the Society who are interested in the question herein discussed. This paper was written, for the most part, last summer in Germany, and some of the facts were given briefly to Section C of the British Association at Southport. I must express my grateful acknowledgment of the aid which has been courteously given me by geologists of high standing on the Continent, in particular by Prof. Geinitz, Dr. Franz Ritter von Hauer, and Dr. Liebe. I am also greatly indebted to the Museums of Dresden and Freiberg, and to the Geologische Reichsanstalt in Vienna.

Without committing myself to a definite advocacy of a substitution of the name Dyas for the name Permian, I must be allowed briefly to point out that it is not a mere question of names. The Permian system of Murchison was essentially a tripartite one, and in applying it to the rocks of central Europe (and to those of the British area) he raised the question of the true position of certain thin-bedded sandstones and marls (Sand- and Mergel-schiefer of German writers), which he (following some German writers) named "Bunterschiefer." In so doing he necessarily raised the question of the true divisional line *between the Palæozoic and Mesozoic Series*. Whatever the relative values of the names "Dyas" and "Permian" may be, the facts connoted by those names respectively are of great importance in settling a vexed question of classification. It is beside the point to say that if the upper boundary of the Zechstein shows signs of denudation, there may have been, by a *quondam* upward extension of the Dyas, an original "Trias" of post-Carboniferous age: the question before us is, What is the true age of the "Bunterschiefer"? And it is impossible to discuss this without also considering the further question of the conformability or unconformability of the Dyas or Trias of Central Europe, and this of course involves us of necessity in the question of the true upper limit (if it can be drawn) of the Palæozoic Series.

This paper has originated simply in an attempt to answer the question as to the true age of the Bunterschiefer, and to do so as far as possible from direct evidence in the field.

The name Dyas (Δυάς), which was first proposed by M. Marcou in 1859, was adopted by Geinitz, in preference to the several geographical names which had been previously proposed, in his great work*, which appeared at Leipzig in 1862; and the name has been gradually coming into general use on the Continent since that time. It is not merely that the name links together in one post-Carboniferous system the two great formations of the Rothliegende and the Zechstein (the former a land- and shore-formation, the latter essentially a marine deposit), but it has reference also to the fact of a remarkable parallelism (much more general and more definitely marked than usual) between the middle and lower stages of the Zechstein and the conglomeratic series of the Upper Rothliegende, to which further reference will be made later on in this paper. Many sections might be given to illustrate this, but I shall content myself with a description of that represented in fig. 1, to which Prof. Geinitz was good enough to direct my attention last summer.

Fig. 1.—*Section near Eppignellen (N. Thuringia), showing the parallelism between the Upper Rothliegende and the Middle and Lower Zechstein.*



a. Lower Rothliegende.
b. Middle and Lower Zechstein including Kupferschiefer and the immediately underlying Grauliegende (= "Weissliegende" of some writers).
b′. Upper Rothliegende (granitic conglomerates of the Wartburg, &c.).
c. Upper Zechstein (with *Schizodus Schlotheimi*, &c.).
* Werra Railway Tunnel.

The succession of the strata is seen in open sections, and the character of the Upper Rothliegende conglomerate is altogether different from that of the well-stratified brecciated sandstones and marls of the Lower Rothliegende.

The main point with which we are at present concerned, however, is the true divisional line of the Dyas and Trias. So far from there being a natural passage from the one to the other (as Murchison supposed) there are clear and extensive signs of erosion of the Zechstein, upon which the lowest Triassic strata (the Bunterschiefer) are superimposed; and Prof. Geinitz has pointed out to me that the same break is observable in South Lancashire, where the Magnesian Limestone with *Schizodus Schlotheimi* (the equivalent of the Platten-

* 'Die Dyas oder die Zechsteinformation und das Rothliegende (Permische Formation zum Theil),' von H. B. Geinitz.

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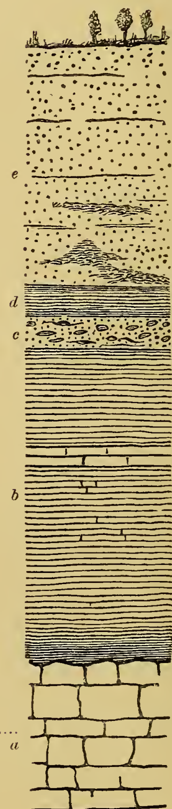
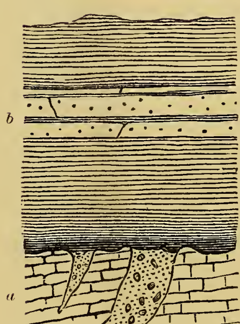
Figs. 2–8.—*Sections of Quarries*

Fig. 3.



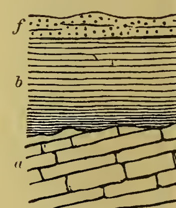
Quarry, No. 6.

Fig. 2.



Quarry, No. 7.

Fig. 4.



Quarry, No. 5.

f. Later drift, generally gravelly, in No. 1 c
e. Soft sandstone, with angular fragments o
d. Thin-bedded sandstone (4 feet).
c. Dolomite conglomerate (4 feet).
b. Dark red and mottled thin-bedded sands
a. Upper Zechstein (Plattendolomit) with *S*

dolomit of Central Germany) is overlain by the lowest Bunter strata. On this point it is only necessary to refer to the papers and correspondence which appeared in the 'Geological Magazine' during the year 1882 *.

We must now refer to actual sections for evidence of a considerable break in time between the deposition of the Zechstein and that of the Bunterschiefer.

1. The first section will be found described in the 'Sitzungsberichte' of the 'Isis' in Dresden for last year, by Hr. A. Dittmarsch. It is at Ostrau, in the eastern part of the kingdom of Saxony. With the aid of sectional drawings, Dittmarsch has given a very complete description of the sections at Ostrau, showing that the subjacent Zechstein (Plattendolomit) must have been eroded, fissured, and partly destroyed, and the widened fissures subsequently filled up with brecciated masses of angular fragments of dolomite (now bound together by a calcareous matrix), before the deposition of the Bunterschiefer.

"This section," says Dittmarsch, "furnishes a limit in time between the Plattendolomit of the upper Zechstein and the lower thin-bedded strata of the Buntersandstein, which one ought not any longer to attempt to explain away by artificially-constructed theories."

2. I have examined and made sections of the quarries near Meerane as given in figs. 2–8, Prof. Geinitz having directed my attention to them.

The sections (seven in number) on the fly-leaf form a continuous series, extending for about a mile along the face of the hills which lie to the right hand of the road from Meerane to the village of Haidchen, near the western boundary of the kingdom of Saxony. Nothing can be clearer than the relation of the Zechstein to the marly shales (Mergelschiefer) and the Lettensandstein (thin-bedded Buntersandstein) above. To make the full interpretation of the sections clearer, one or two remarks may be of some service, it being premised that the quarries are all open, and the sections fresh, so that these remarks record direct observations, and are not inferential.

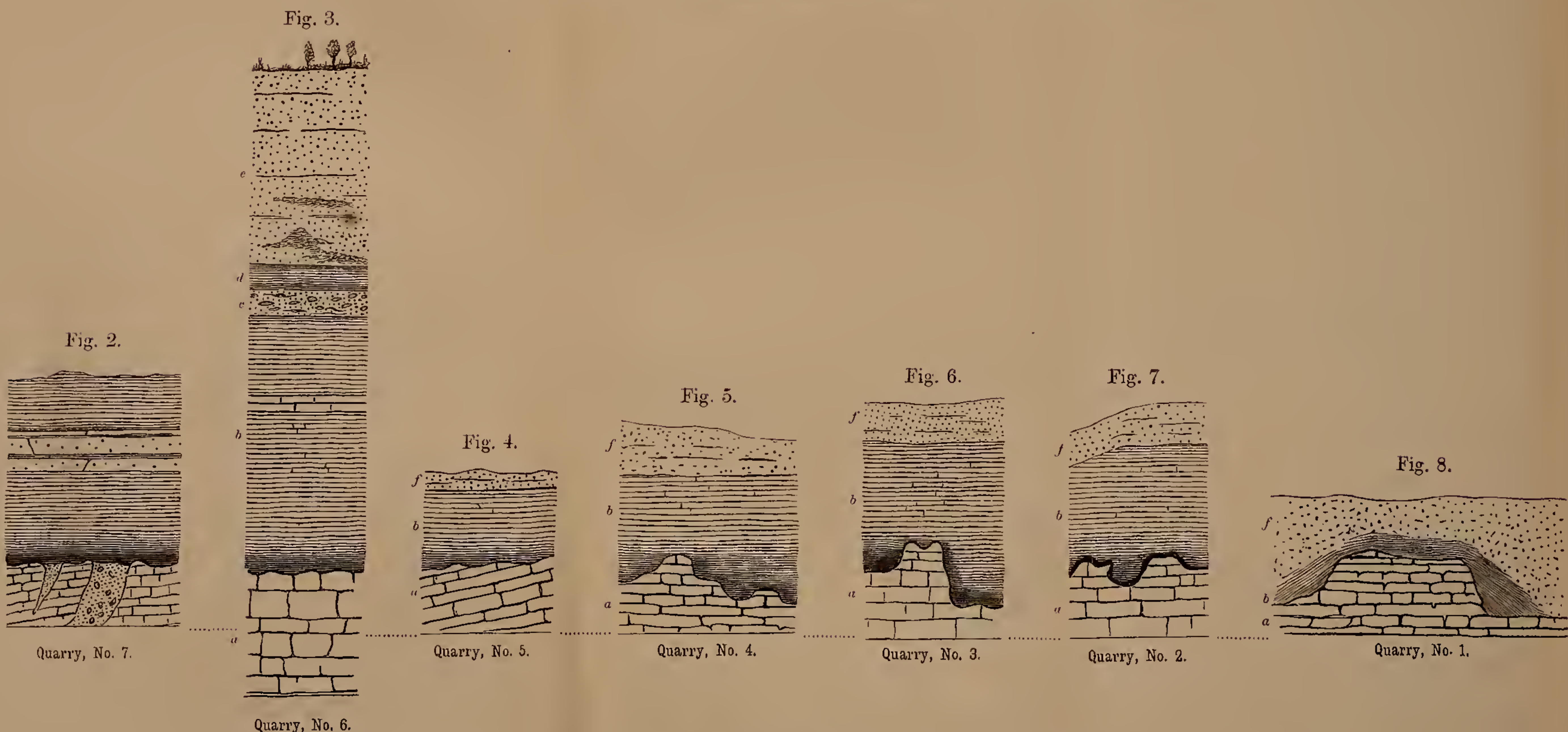
(1) The marly sandstones lie in all cases upon the highly eroded surface of the Plattendolomit (with *Schizodus Schlotheimi*) of the Upper Zechstein.

(2) The erosion of the Zechstein is most pronounced. Not only is it water-worn (as the upper surface of the Magnesian Limestone is in our northern counties), but the extent to which *subaerial* erosion has proceeded is very great. This is more evident in the sections than can be made clear from a drawing. These dolomite crags, on a small scale, remind one of the atmospheric erosion of the Dolomite Alps, though the sharpness of their angles has been subsequently rounded off a little by the scouring action of sand and water previous to the deposition of the Sand- and Mergelschiefer upon them.

(3) The upper series is most marly at the base, and becomes gradually more arenaceous as we pass upwards. Only occasionally

* Decade ii. vol. ix. pp. 158, 219, 272, 316, 491, 528, 559.

Figs. 2–8.—*Sections of Quarries near Meerane, in Saxony, showing the junction of the Zechstein and Bunterschiefer.*



f. Later drift, generally gravelly, in No. 1 consisting of broken and disturbed shaly marls.
e. Soft sandstone, with angular fragments of vein-quartz (occasional fragments of dolomite), deep red below, passing into buff-yellow above (30 feet).
d. Thin-bedded sandstone (4 feet).
c. Dolomite conglomerate (4 feet).
b. Dark red and mottled thin-bedded sandstones (occasionally as much as 1 foot thick), becoming more shaly near the base (40 feet).
a. Upper Zechstein (Plattendolomit) with *Schizodus Schlotheimi* (from 10 to 20 feet exposed).

and very slightly is the uniform horizontality of the Bunterschiefer, as shown in the drawings, departed from.

(4) In the quarry No. 7 (fig. 2), two great fissures have been formed in the dolomite, one of which is five feet wide, and its bottom is not exposed in the quarry. These are filled with a brecciated accumulation of débris, partly fragments of the Rothliegende, partly fragments of the dolomite itself; so that the latter was not only deposited, but even indurated, prior to the deposition of the superjacent Bunter.

(5) In some places the Bunter is as completely arenaceous and as mottled as the Lower Bunter Sandstone of the Nottingham country; and in a fresh section the mottled character prevails throughout the series more or less.

(6). Quarry No. 6 (fig. 3) gives by far the most complete example of the succession, as it includes a higher member of the Bunter series. The latter corresponds with the "Pebble-beds" of the Middle Bunter of England, except that it is redder, and the contained fragments are almost all angular and subangular fragments of vein-quartz (with an occasional angular fragment of dolomite), derived, along with the highly micaceous sands of the sandstones below, from the old gneiss which is exposed over such a large tract of country not far from here, and all the way to and beyond Freiberg.

The dolomitic conglomerate shows the enormous waste which the dolomites of the Zechstein were undergoing in early Triassic times. The dolomite occurs in it in the form of rounded transported boulders, for the most part imbedded in a red marly matrix, without any signs which I could perceive of concretionary growth; and this structure comes out in the clearest possible manner where the conglomerate has suffered weathering on the face of the quarry.

In Quarry No. 2 (fig. 7) the thick line represents a deposit of black bog-iron ore. The limestone is stained black, sometimes for several inches from the surface, and the smaller joints are filled with black ochreous matter. The erosion of the dolomite appears in this case to have gone on under a morass. The lowest Lettenschiefer are very marly here; colour varying through light grey, yellow, and light purple, to the bright red of the Sandschiefer above.

The evidence taken altogether in this district of the west of Saxony agrees with the observations of Herr A. Dittmarsch at Ostrau to the east, and points even in a more marked manner to a break in time between the Zechstein and Bunterschiefer.

Dr. Liebe of Gera informs me that the extensive erosion of the Zechstein dolomites, which I have described above, and which Herr A. Dittmarsch has described at Ostrau, is generally to be observed in the old Saxon country, wherever the upper limit of the Zechstein is to be seen.

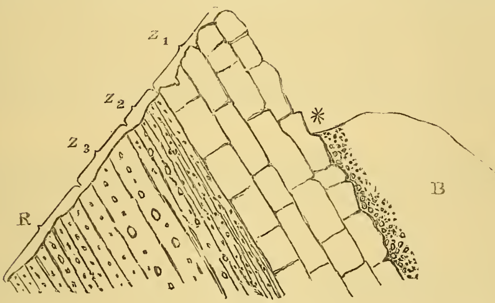
Space does not allow me to do more than suggest a reference here to the section given in Credner's Geology*, across the Triassic

* 3rd ed. Leipzig, 1876, fig. 244, p. 470. This seems to be regarded by Credner as a typical section.

district between Eisleben and Mansfeld, in which a relation between the Dyas and Trias at the eastern end of the Hartz region is shown, very similar to that which exists in Saxony, as I have shown above.

3. *North Thuringia.*—Having spent some time in this district last summer, with Eisenach as a centre, I have seen a good number of sections of both the Dyas and Trias around the margin of the Thüringerwald. One of the best is that furnished by the dolomite ridge known as Göpelskuppe, which extends in a N.W. to S.E. direction for about an English mile near the town of Eisenach and forms the end of the section given at p. 334 of 'Siluria.' The dolomite strata form the ridge of the hill from end to end, and there is no capping of the hill with Bunter strata. In the accompanying drawing (fig. 9) a transverse section of the hill is shown, the observations on which the section is based being made from three quarries and a road-cutting over the hill.

Fig. 9.—*Section across Göpelskuppe, near Eisenach.*



B. Buntersandstein, much contorted and dislocated, containing in some of its beds fragments of the strata Z_1 and Z_2. At the east end of the hill its junction with the Zechstein dolomites is seen.
Z_1. Dolomite, massively-bedded strata full of remains of Polyzoa.
Z_2. Finely-brecciated beds passing up into Z_1. } =Grauliegende.
Z_3. Coarse grey conglomerate passing down into R. }
R. Upper Rothliegende conglomerates of the Wartburg, &c.
* Breccia at base of B, lying upon the eroded surface of Z_1, containing (1) angular weathered fragments of Z_1, (2) smaller fragments of strata of the horizons Z_2, Z_3.

The conglomeratic series R, Z_3, Z_2 is only a local variation of the Upper Rothliegende, which is seen in such enormous proportions about the Wartburg and the Marienthal. The strata marked R are of the predominant reddish colour; but those marked Z_3 and Z_2 are finer and more stratified, and the matrix in which the fragments (porphyritic granite, quartz, schists, &c.) are included is of a grey ashy nature, largely derived no doubt from the tuffs associated with the quartz-porphyries and felsites of the neighbouring Palæozoic land. It is this local variation of the Upper Rothliegende to which the name "Grauliegende" is correctly applied. In a quarry further along the hill the massive limestones (Z_1) have been removed, and the strata of the horizons Z_2, Z_3 are of a finer and more calcareous nature; and here the original stratification would seem to have been obliterated by development of concretionary structure on a large scale, perhaps since the removal of the massive limestones. [Here it is worth while to note again the parallelism so frequently repeated between the conglomeratic Upper Rothliegende and the Rauchwacke of the Middle Zechstein.]

The actual junction of the Zechstein dolomites (Z_1) was seen clearly in one quarry; and there the lowest Bunter strata rest, with a breccia for their basement-bed, upon the eroded surface of the Upper Zechstein dolomites. The fragments included in the breccia are partly ragged weathered fragments of the limestone itself, partly derived from the strata of the horizons Z_2 and Z_3.

The Bunter strata yielded only small sections here and there, though enough to show that they are much contorted and dislocated, one or two actual faults being exposed to open day. In some of the beds of sandstone of this series fragments whose origin could without a doubt be traced to the strata of the horizons Z_2 and Z_3 (fig. 9) of the neighbouring hill, were found by me enclosed in the red sandstone. We thus have, in addition to the brecciated basement-bed shown in the figure, unequivocal evidence of the extensive erosion of the Zechstein strata in this region before the deposition of the lower Bunter strata.

At the south-east end of the hill the dip of the Zechstein and Bunter is observed to be the same, so that, if the junction of the two series were not seen, it might be inferred that there was a conformable sequence between them. At this particular spot the Bunterschiefer are less broken up by faults than towards the other end of the hill, and a country road happens to traverse the open country here in a direct line north and south. The strike of the thin sandy strata of the lower Bunter is seen for a considerable distance running due N. and S. along the line of this road; so that there is a discordancy of strike between the strata of the Bunter and those of the Zechstein of something like 45° of the compass. We are here near the end of the dolomite ridge of the Zechstein, and the map shows the Bunter passing beyond the end of this ridge and reposing against the Rothliegende, until finally it overlaps this and rests against the schists to the south. These facts, taken along with those mentioned in the description of the section, especially the discordancy of strike of the two series, suggest a marked unconformity, as a little consideration will show. If we could restore the Bunter strata here to their original position of deposition, and the Zechstein strata to the position in which they must have been placed relatively to the Bunterschiefer, when the latter were deposited upon them, we should necessarily have them in the position in which they existed in early Triassic times. The discordancy of strike now observed would then appear as an *unconformity of stratification.*

One or two remarks ought further to be made here on the general discordancy of deposition of the Bunter series upon the

Dyassic strata all round the northern end of the Thüringerwald. The Bunter strata not only lie, as I have just shown, unconformably against the Zechstein series on the side of Göpelskuppe, but they lie, as traced round the flanks of the mountains, against different members of the Dyassic Series.

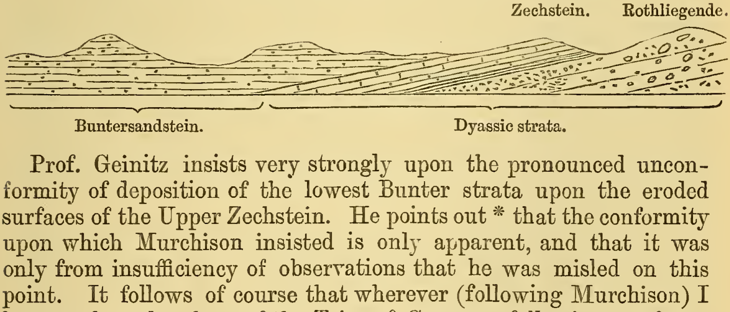
(1) Between Mosbach and Kittelsthal the Zechstein is overlain transgressively by the Bunter, so that the latter extends up an ancient bay of the old Thuringia land, and rests against the mica-schists on the one side and the Rothliegende on the other.

(2) At both ends of Göpelskuppe the Bunter overlaps the Zechstein and rests against the Rothliegende.

(3) For some miles along the Hörsel Valley the Bunter, which is visible at the foot of the Ramsberg, passes under the alluvium of the Hörsel (according to Prof. Senft) and reposes upon the Rothliegende of the hills which extend N. W. from the Wartburg.

(4) Lastly all round the western side of the northern end of the Thuringia Bergland the Zechstein series comes in again from the village of Brandenburg (at the junction of the Werra and Hörsel) and continues all down to and beyond Schweina. The dip (about 25°) of the Zechstein series is here plainly to the S. W., as is well seen about Eppignellen and Förtha; while in all the cuttings in which the Bunter sandstone is observed from the latter place to Salzungen, the strata appear to be horizontal, as in the sketch section here given.

Fig. 10.—*Section on western side of Thuringia combining sections on the Werra Railway, from Förtha to Burckhardsroda.*



Prof. Geinitz insists very strongly upon the pronounced unconformity of deposition of the lowest Bunter strata upon the eroded surfaces of the Upper Zechstein. He points out * that the conformity upon which Murchison insisted is only apparent, and that it was only from insufficiency of observations that he was misled on this point. It follows of course that wherever (following Murchison) I have spoken elsewhere of the Trias of Germany following conformably upon the Dyas, all that must now be considered as unsaid.

There is, it appears, no transition in Central Europe between the Dyas and the Trias; and if such a transition is to be found elsewhere, either in Russia or in the Alps †, the fact only seems to emphasize the more the break between the two systems in Germany.

The splendid collection of Zechstein fossils of Herr Robert Eisel of Gera, which their owner kindly allowed me to examine, impresses

* Sitzungsber. der Isis, *ad loc. cit.*

† *Vide* Geol. Mag. Nov. 1882, pp. 497, 498.

one strongly with the close relationship that subsists between the Zechstein and the Carboniferous *marine* faunas; and a similar closeness of relationship between the floras of the Coal-measures and the Rothliegende is proved by an examination of Von Hauer's collection in the Reichsanstalt at Vienna. The use of the term 'Post-Carboniferous,' as I have defined it elsewhere*, seems therefore to be fully justified.

General Relation of the Dyas Group to the Older Members of the Palæozoic Series.

When one studies the rocks of the Dyas Group in the field, as I have done during the past summer in Germany, an impression takes hold of the mind that in the conditions of their deposition the strata of the German Dyas are far removed from any close relation with the Trias Group. This impression becomes more and more confirmed as one goes on, and to a degree which no amount of reading about them will enable an English geologist to quite understand. Not only is there a stratigraphical break, but a very marked *petrological contrast* between the two groups, which can hardly be understood from mere diagrams and descriptions.

The Lower Rothliegende is for the most part a shore- and bay-deposit, filling in many cases the arms of the sea which washed the flanks of the more ancient Palæozoic land of Central Europe, lying very often unconformably upon the Coal-measures, in other cases upon the bituminous slates of the anthracite-bearing Culm, again in other localities lying upon the schists or porphyries of the still older land, and in Saxony against the syenite itself. In northern Thuringia, for example, it consists of fine micaceous sands and marls, with a more or less shaly structure, enclosing in some of its beds angular fragments of quartz to such an extent as to give it the character of a breccia, all its materials pointing to the waste of the adjacent land of Thuringia as their source. In this way materials were furnished and deposits formed, by which the productive coal-strata were covered up over many portions of what is now Central Europe.

The Lower Rothliegende in some districts, as in Thuringia, passes upward into the granitic conglomerate of the "Ober Rothliegende," which marks a further and distinct stage in the progress of the degradation of the more ancient land of Thuringia, a true "Gebirgs-insel" or mountain-island. In the vicinity of Eisenach, where I have examined it most in detail, I have found included fragments of granites, gneiss, quartz, mica-schist, diorite, quartzite, syenite, and even occasionally a lump of an older Palæozoic conglomerate; and to these Prof. Senft of Eisenach adds lydite, hornstone, and felsite. Every one of these can be traced, as to their origin, to the rocks now exposed in Thuringia. As a rule, the granite-fragments are much more rounded than the fragments of the other rocks, a fact which can be explained by the greater distance of transport

* Geol. Mag. Dec. ii. vol. ix. p. 494.

which they have undergone, the granitic conglomerate of the Upper Rothliegende lying, as a rule, contiguous to the schists and porphyrics, and more or less remote from the granite regions. The granite fragments are, some of them, of a porphyritic granite, others rather fine-grained normal granite. They are identical with the granites exposed over many miles of the higher parts of northern Thuringia, across the Rennstieg, for example, all the way from Ruhla to Altenstein and Liebenstein. In this district the coarse porphyritic granite predominates, but it assumes a more normal character towards Ruhla; and in one quarry about a mile from that village (famous in ancient legend), the one variety is seen passing into the other, and the two are commonly seen mingled together in the heaps of broken-up stone by the road-side. We may say, in fact, with Prof. Senft, that "the Rothliegende of the north-western Thüringerwald consists of the destruction-products of the Ruhla mountain-island" ('Gaea, Flora u. Fauna der Umgegend von Eisenach,' by Dr. Ferd. Senft, 1882, p. 29). In the neighbourhood of Gera the included fragments of the Rothliegende consist for the most part of quartz, clay-slate (with fucoidal markings), and culm-schists, furnished, along with the oxidized red marly matrix, by the older Palæozoic rocks of that district. Again in the Plauenscher Grund near Dresden, the syenite *massif* which extends over many miles of the kingdom of Saxony, has furnished the included fragments of the Rothliegende conglomerates for the most part. The uppermost strata of the Lower Rothliegende are generally bleached for several feet downwards, otherwise the character of the strata is the same as that of those below. In the Gera district, and especially in the Pfordener Berg, these are overlain normally by the Zechstein strata from the Kupferschiefer upwards. The change of colour is possibly due to the bleaching action of vegetable acids contained in the waters from the adjacent land, when the process of mechanical deposition of the materials became less rapid*.

The Lower Rothliegende strata are, as a rule, well-stratified aqueous deposits of a littoral character; but the same is scarcely true of the Upper Rothliegende as it is developed in North Thuringia. I have not seen the idea suggested anywhere; but the vast proportions of these deposits (*e. g.* about the Wartburg and Hohe Sonne), the angular nature of their included fragments (for the most part), and the feeble development of their stratification, as shown on their weathered surfaces, suggest, to my mind, a comparison with the mud-streams (Schlammströme) which one meets with in certain Alpine valleys; that is to say, instead of being true sedimentary aqueous deposits, they are, as I take it, but indurated accumulations of streams of mud and stones from the once higher mountains of Thuringia, and thus constitute a true Dyassic "diluvium".

This direct relation of the Rothliegende to the character of the adjacent land, which is so marked throughout that formation, and is generally wanting in the formations of the Trias, serves to establish

* See communication by the author to Section C of the Brit. Assoc. *Report*, 1883, pp. 504, 505.

a general broad physical distinction between the two groups of strata as they are developed in Central Europe.

This character applies also to some extent to the Zechstein. The Upper Rothliegende, it must be borne in mind, is never overlain by the lower and middle members of the Zechstein, though it is by the Plattendolomit, or uppermost member of that formation. Then again the horizontal variation of the strata of the Zechstein series is very marked and noteworthy. At one place the lower and middle members of this series consist of marls abounding in gypsum, which is extensively worked in many localities; at another, the Lower Rothliegende is succeeded in ascending order by the normal sequence of Kupferschiefer, Middle and Upper Zechstein strata; in others again the normal Kupferschiefer and Middle Zechstein are replaced by the conglomerates known as "Grauliegende," with an ashy grey-green matrix, derived for the most part from the tuffs associated with the quartz-porphyries and felsites of the adjacent primeval land. The importance of these facts can perhaps be only fully appreciated in the field; yet when one contrasts this horizontal irregularity of the upper members of the Dyas group with the uniform character of each of the three members of the overlying Trias, as they are exposed over hundreds of square miles in Middle and Southern Germany, and the regular and conformable succession of the Bunter, Muschelkalk, and Keuper, we find a striking contrast between the German Dyas and Trias, based on physical facts alone, the importance of which, when taken along with the palæontological evidence, can scarcely be denied or explained away.

General Relation of the Permian to the Trias.

Since Murchison wrote on the Permian Group the extension of our knowledge of this group and of the Triassic Group of strata has placed us in a position to form a more correct perception of their relation to one another in the European series of rocks; and this has mainly come about, thanks to the labours of our German and Austrian *confrères*, by the more accurate knowledge which we now possess of the *marine* conditions of the Triassic period, as they are recorded in the many thousands of feet of strata of Triassic age which cover extensive areas on both the northern and the southern sides of the Eastern Alps. I have attempted elsewhere * to give a succinct account of those strata, and need not therefore occupy space here with any details. Special reference, however, may be made to the writings of Credner, Von Hauer, and Gümbel, and to the splendid monograph of Mojsisovics on the Alpine Cephalopoda.

Taking a broad and general view, we may say of the Permian and Trias that they are inversely proportional: the former, so far as the European area is concerned, is essentially a *northerly* system, thinning out towards the south (a fact which Murchison recognized); the Trias, on the other hand, is essentially a *southerly* system, becoming more and more feeble in its development towards the north.

* *Vide* Geol. Mag. Nov. 1882, p. 494.

In the Russian area the Magnesian-limestone series constitutes an important formation of considerable dimensions as the representative of marine conditions. In North Germany it is palæontologically by far the most important member of the Dyas Group; but as we proceed southwards in the country about the Riesengebirge, in Bohemia and in Bavaria, the Zechstein member of the Dyas gradually disappears, so that there the Dyassic Group is represented only by rocks indicative of shallow-water conditions. The same holds good, as is well known from the ordinary text-books, for the Permian series of England, the Magnesian-limestone strata becoming gradually attenuated from north to south, so that they dwindle from a thickness of 600 feet in the county of Durham to a series of thin-bedded, unfossiliferous, and more or less gritty coarse limestones, until about the latitude of Nottingham they disappear altogether. Again, in addition to the vast areal extension of the Russian Permian series, it is worthy of remark that in Courland and Lithuania the Zechstein type is developed *, though not over a very large area; and Mr. Twelvetrees † has recently shown how complete is the development, in the Orenburg country on the west of the Urals, of the Zechstein formation, as distinct from the subordinated limestone strata which occur there interbedded with the lower series of sandstones, grits, and conglomerates, just as occasional limestone-bands occur in the Lower Rothliegende of Germany.

Upon the whole therefore we seem justified in saying that in Permian or post-Carboniferous times anything like deep-sea conditions prevailed chiefly towards the northern and north-eastern portions of the European area, in which the rocks of the period were deposited, and that as we proceed southwards we find signs of the gradual disappearance of conditions favourable to their typical development. This fact may help to explain the stunted and dwarfed condition of the Palæozoic types of life as they are presented in the fauna of the Magnesian-limestone or Zechstein series. It was not merely that the latitude of the marine area (or areas) in which these remnants of a Palæozoic fauna continued to exist, was rather high, but conditions as to temperature, more unfavourable to organic life (in its fuller development) than could be accounted for by latitude alone, would seem to have prevailed. Differences in the physical geography of this part of the surface of the globe, and a different relative distribution of land and oceanic waters, may have been, and probably were, such as to exclude the free oceanic circulation of warmer waters from the south, while free access was permitted to colder currents from high arctic regions. As the north-eastern area of Britain was shut off from the midland counties, and perhaps from what is now Lancashire and the vale of Eden, so on a much grander scale it would appear that there was an extensive region about the middle of Germany and Bohemia which shut off the area of the post-Carboniferous rocks of Europe from free communication with more southern

* Credner, 'Elemente der Geologie,' p. 484.

† Geol. Mag. Dec. ii. vol. ix. p. 409; also Quart. Journ. Geol. Soc. vol. xxxviii. p. 490.

waters. Extensive continental conditions must have prevailed*. The ancient rocks of the Bohemian region are probably the skeleton of such dry land as then existed. In travelling in that country and in the adjacent regions of Upper Austria one hardly fails to be struck with the resemblance of its mountain-regions to the mountains of Wales and Scotland. This resemblance is not a superficial one; in both cases we have the worn-down stumps of more ancient mountain-systems of much greater dimensions than those which exist to-day †. The elevation of Bohemia and Upper Austria, a region which is skirted on the south by the Danube from Passau to Krems, must have taken place in times long anterior to the upheaval of the Alps, and dates at least as far back as post-Carboniferous times. Since then, while many thousands of feet of Mesozoic strata were being deposited at the bottom of the sea, in what is now the region of the Alps, the Bohemian region has been suffering denudation. The Bohemian coal-field, which yields true seam-coal of Carboniferous Age, is a remnant of the deposits of that early period in Central Europe; and another remnant of the same once more extensive deposit is found in the coal-field of Saxony, where one seam of coal attains the enormous thickness of 24 feet. The Rothliegende of the kingdom of Saxony and of Bohemia, which is of huge proportions, represents nearly the whole of the post-Carboniferous deposits on the northern flank of the Bohemian region, which must be considered as extending so far north as to include the country about Dresden‡. In the shallow arms of the sea which washed the northern side of this ancient and now much-denuded remnant of an old continent, the coarse deposits of the Rothliegende were accumulated, deriving their materials mainly from the waste of the igneous, Cambrian, Silurian, and Carboniferous rocks of that region, as may be seen by an examination of their contents. This condition of things would seem to have continued through almost the whole post-Carboniferous period on the northern flanks of the ancient Bohemian region, while further to the west and north, in Thuringia and in the country about the Hartz, the major portion of the Zechstein strata were being deposited under conditions more or less truly marine. Towards the close of the Dyassic period things seem to have settled down and become more quiescent, a slight subsidence of the whole area occurring, since the upper member of the Zechstein (Plattendolomit) which elsewhere more generally overlies the middle and lower members of the Zechstein group, rests generally in the kingdom of Saxony upon the Rothliegende, the replacement of the

* Cf. Dr. H. Trautschold "On the periodical movements of continents," Geol. Mag. Nov. 1883. I am glad to find some of the ideas which I have ventured to put forward here, agreeing with some of those of Dr. Trautschold, whose paper I read after this was written.

† Cf. Q.J.G.S., Feb. 1883, p. 79; also Prof. Lapworth, Geol. Mag. Dec. ii. vol. x. p. 121.

‡ Dr. Trautschold (*ibid.*) notices that the absence of several systems of marine sediments speaks in favour of a long continental period in Russia, in the Government of Moscow, from the end of the Carboniferous period to the middle of the Oolitic period.

Middle and Lower Zechstein by the Upper Rothliegende being in that region, according to Geinitz, the usual order of things*. All through Triassic and Jurassic times, however, a large part of Central Europe, of which we may regard Bohemia as the centre, was elevated above the sea: and it is only when we come down to later Cretaceous times that we find evidence of the sea again spreading over the Bohemian main-land. An example of this sequence of things is seen in the neighbourhood of Dresden. In the Plauenscher Grund the Rothliegende is found overlying the productive Coal-measures, and both of these lie against the flank of the syenite *massif* of that district. Immediately upon the Rothliegende lie rocks of Cretaceous age, consisting of Greensand, Quader Sandstein, and Pläner Sandstein. From this sketch, which can be verified by a reference to Von Dechen's map of Germany, it would appear that it is more than a mere hypothesis upon which the present speculation rests; while in the Geologische Reichsanstalt at Vienna the same great break in the succession of the Bohemian strata is shown by the remains of the flora exhibited from the Coal-measures upwards to the Cretaceous rocks.

This ancient Bohemian district which may be considered *par excellence* the Cambria and Siluria of Central Europe, has probably never been wholly submerged since its elevation in post-Carboniferous times. In later Cretaceous times, however, a partial subsidence of the region permitted the intrusion of marine waters over great portions of the country which now are occupied by the basins of Vienna and Bohemia. What is especially important to note here is the prevalence during Triassic times of true *marine* conditions over the area now occupied by the Eastern Alps † with their various ramifications, and extending far away (how far it is impossible perhaps to say) to the south of this central European Cambrian and Silurian land-area; while continental conditions, as represented by the Bunter and Keuper formations, extended to the west and north of the same region, with an interlude represented by the Muschelkalk, when the marine conditions which prevailed to the south all through Triassic times were extended northward, though never so far as the British area. The feebler accentuation of the facies of the Muschelkalk as a distinct marine formation towards the north and west in the German area may be considered as a well-established fact of European geology‡.

The crystalline rocks of the Black Forest, against and around the eroded flanks of which the Triassic rocks lie, are probably another remnant of the great east-and-west barrier which has been described;

* See 'Führer durch das k. mineralogische Museum in Dresden,' p. 64.

† I do not mean to say there was then no land in the Eastern Alpine area. Our President, Prof. Bonney, has lately shown reason for believing in a considerable elevation of the crystalline rocks of the central chain prior to Triassic times ('Nature,' vol. xxx. p. 45); and there is enough difference between the Triassic strata and their included organic remains, on the north and south of the Alps, to show that they were not deposited in one and the same, although in connected, areas (Geol. Mag. Dec. ii vol. ix. pp. 499, 500).

‡ *Vide* Credner, *ibid.* p. 497, and the table, pp. 502–505.

and when we bear in mind the absence of the Zechstein (and therefore of Dyassic marine conditions) in the country intervening between the Black-Forest region and the Bohemian region, and the prevalence there of "continental" conditions through all the periods of the Dyas and Trias (except during Muschelkalk times), we can understand, I think, the marked difference which presents itself between the more northerly Dyassic marine fauna (Zechstein) and the more southerly fauna of the Alpine Trias. Even where dry land was wanting in the intervening area, the waters which existed must have been so shallow and turbid (as is shown by the nature of their deposits) that living forms would for the most part recede from them to the north and the south, leaving only such remnants of a fauna as are represented by *Palæoniscus vratislaviensis*, *Xenacanthus Decheni*, and *Acanthodes gracilis* of the red limestones, which are here and there intercalated with the mechanical sedimentary deposits of the Rothliegende*. The fauna which remained in the northern area became, perhaps for reasons already suggested, stunted and dwarfed, while the number of species diminished. On the other hand, the more favourable conditions prevalent in the marine area to the south of the great barrier would cause these forms to continue and even to flourish (with some modifications) long after animals of the same Palæozoic facies as themselves had disappeared altogether from the fauna of more northern seas. Migration of species caused by alterations in the relative levels of sea and land, with the accidental formation of barriers affecting oceanic circulation and therefore the temperature of the waters, together with such modifications of growth as would be induced by a somewhat altered set of conditions in their environment, can be accounted for on considerations based upon the indications which we can read to-day of the past physical geography of Central Europe; and such considerations seem to furnish the explanation of what has been hitherto looked upon as an anomaly in the phenomena presented by a comparison of the post-Carboniferous fauna with the fauna of the Alpine Trias.

Discussion.

The President pointed out that the name Permian was formed on a sound principle, and that the name Dyas was formed on a principle which was objectionable.

Prof. T. Rupert Jones, thanking the author for his collection of facts and opinions, protested against a continuance of M. Marcou's disrespectfully worded allusions to the late Sir R. I. Murchison's mistakes, whether supposed or proved. Sir Roderick thought he had reason to complete his "Permian System" symmetrically with the Bunterschiefer. If an unconformity really occurs between the Zechstein and this sandstone, it need not destroy the systematic succession, and certainly need not be made an occasion to reiterate irreverent remarks on one who advanced geology very much many years ago. As for the name "Permian," it was not to be thrown away because other strata also occur in the Government of Perm.

* Credner, *ibid.* p. 483.

As for the word "Dyas," if it meant (as asserted) the occurrence of two sets of strata, terrestrial and marine, it was applicable to many formations. Further, the asserted pre-Triassic denudation of the Zechstein may have removed strata enough to have constituted it once a Trias or even a Tesseras. The local absence of the uppermost portion of a formation allows the Lias, for instance, the Oolite, Chalk, Eocene, &c., to be found perfect only here and there; and the existence of any supra-Zechstein Permian sandstone anywhere negatives the general adaptability of the word "Dyas." The speaker criticized one of the illustrative diagrams, and pointed out that, with Mr. Irving's explanation of Prof. Geinitz's second aspect of Dyas, namely the duality or lateral parallelism of strata, we should have to regard nearly all limited, lenticular, intercalated beds as "Dyadic."

Mr. Topley did not think the evidence adduced was sufficient to prove the unconformities insisted upon. The facts shown in the sections exhibited could be explained by chemical erosion.

Mr. Blanford doubted whether several of the sections brought forward by the author had been rightly interpreted. He agreed with the last speaker that some of the sections adduced look like subterranean removal of a calcareous rock by water containing carbonic acid. He thought the name Permian, as being the older, ought to stand, but that Permian was merely Upper Carboniferous.

Prof. M'Kenny Hughes was in favour of retaining the old name "New Red" for both Permian and Trias of Britain. He considered that in this case the physical evidence was of more importance than the palæontological, especially as fossils were rare in both the lower and upper divisions. He criticized the fossil evidence, pointing out that new types came in with the Magnesian-limestone series: *Schizodus*, for instance, he looked upon as the forerunner of *Trigonia*. Though old forms, as *Producta*, lingered on, no one would draw the upper boundary of the Magnesian Limestone exactly where that fossil ceased to occur, while on the Continent Palæozoic types ran on into the Trias. If there were beds in other countries more closely allied, on both kinds of evidence, to the Carboniferous, by all means put them with the Carboniferous; but the Magnesian-limestone series of Britain could not on any evidence be bracketed with the Coal-measures.

Principal Dawson stated that in Nova Scotia and Prince Edward Island there was a gradual passage upward from the Upper Coal-formation to the Permian or Permo-Carboniferous, but that there seemed to be discordance between the latter and the Trias, though the two formations resembled each other in mineral character.

The Author disclaimed any idea of slighting the work or memory of Murchison. He did not regard the question as merely one of terms. Prof. Hull had admitted that Murchison's classification was indefensible. He insisted that geographical names are not the best for geological systems. He admitted that the Permian was an upward extension of the Carboniferous. He could not agree that subterranean erosion would account for the sections described. The facts brought forward indicated a considerable interval in time between the Dyas and Trias.

30. *The* Rocks *of* Guernsey. By Rev. E. Hill, M.A., F.G.S., Fellow and Tutor of St. John's College, Cambridge. *With an* Appendix *on the* Rocks *referred to, by* Prof. T. G. Bonney, D.Sc., F.R.S., Pres.G.S. (Read April 2, 1884.)

[Plate XX.]

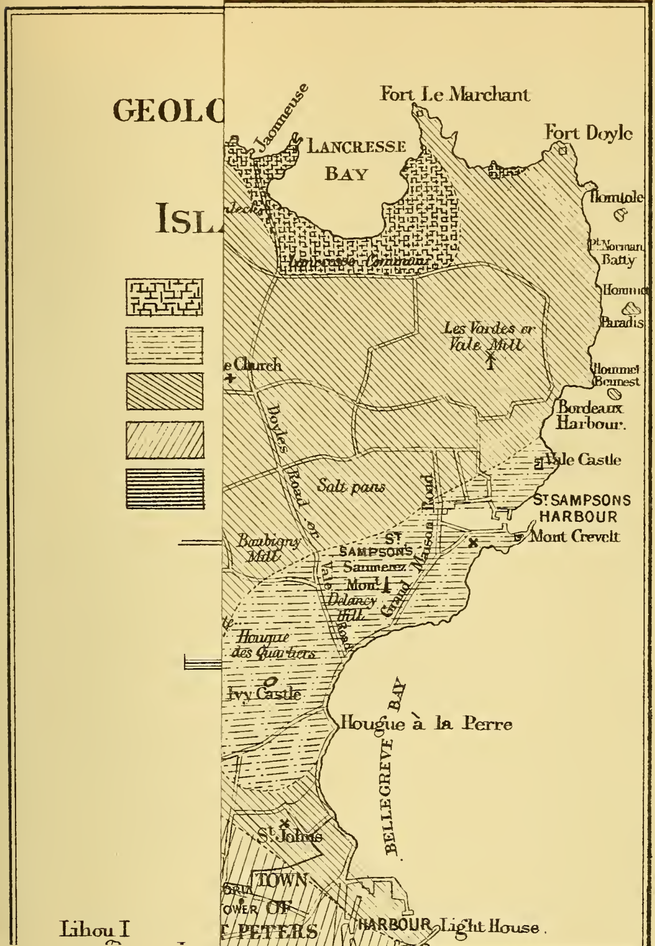
Contents.

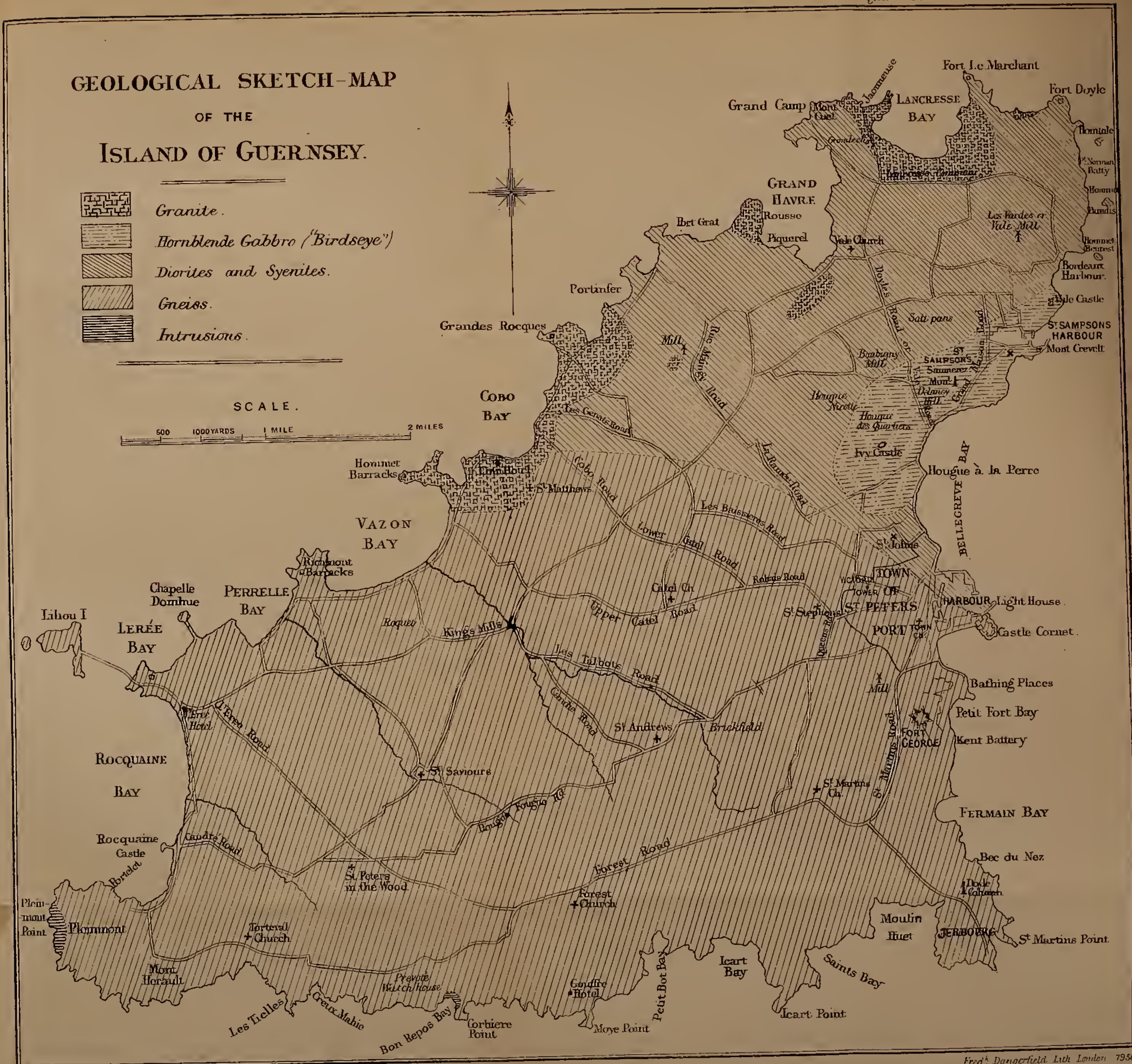
1. Introduction.

At the opening of this paper I desire to acknowledge my great obligations to Professor Bonney for his assistance throughout my investigations. I must also thank J. R. Cousins, Esq., of St. John's College, Cambridge, for valuable help.

Little has hitherto been written on the geology of Guernsey which would be of much use to a visitor. Macculloch contributed a brief account to one of the earliest publications of this Society. Ansted's book on the Channel Islands contains some remarks on its general features. There are two papers by Professor Liveing, with which in many respects I cannot agree, in the Cambr. Phil. Soc. Proc. vols. iii. and iv., and one by Mr. J. A. Birds in the Geol. Mag. for 1878, which contains some accurate observations. A few interesting but short papers on raised beaches and the like complete the literature of the subject. How scanty is the information furnished thereby may be imagined from the fact that not one of these publications contains a geological map; and the sketch map (Pl. XX.) which accompanies this paper is, so far as I know, the first which has ever been published.

Any map shows clearly enough the triangular shape of Guernsey, and with a glance at the scale of miles its dimensions can be easily estimated. But most maps do not even attempt to indicate the remarkable physical difference between the northern and southern parts. A spectator on the deck of a steamer approaching St. Peter's Port sees on the right a long low coast rising into a series of hummocks (each bearing the local name of Hougue), the highest crowned by an obelisk, the monument to Admiral Saumarez. On the left he sees a range of noble cliffs, with the Doyle column at one extremity and the ramparts of Fort George at the other; while in the centre of the picture the cliffs fall back into an amphitheatre lined by the quaint and striking town. Could the spectator hover above as a bird, or survey the island from a balloon, he would see that these cliffs are the edge of a table-land, whose northern face is a scarp which sweeps across from east to west. He would see the tableland a cultivated plateau, cut by a few deep valleys mostly running north-west. The low ground beyond the scarp he would see to be an alluvial centre surrounded along the coast by a horse-shoe ring of


GEOLC
ISLA
Fort Le Marchant
Fort Doyle
Jaonneuse
LANCRESSE
BAY
Lancresse Common
Les Vardes or
Vale Mill
Church
Bordeaux
Harbour.
Vale Castle
ST SAMPSONS
HARBOUR
Mont Crevelt
Doyles Road or Vale Road
Salt pans
Grand Maison Road
Baubigny
Mill
ST
SAMPSONS
Saumerez
Mont
Delancy
Hill
Hougue
des Quartiers
Ivy Castle
Hougue à la Perre
BELLEGREVE BAY
St Johns
TOWN
OF
PETERS
HARBOUR
Light House
Lihou I


GEOLOGICAL SKETCH-MAP
OF THE
ISLAND OF GUERNSEY.
Granite.
Hornblende Gabbro ("Birdseye")
Diorites and Syenites.
Gneiss.
Intrusions.
SCALE.
500
1000 YARDS
1 MILE
2 MILES
Fort Le Marchant
Fort Doyle
Grand Camp
LANCRESSE BAY
GRAND HAVRE
Rousse
Piquerel
Port Grat
Vale Church
Portinfer
Grandes Rocques
COBO BAY
Hommet Barracks
St Matthews
VAZON BAY
Richmont Barracks
Chapelle Dom Hue
PERRELLE BAY
Lihou I.
LERÉE BAY
Kings Mills
Les Talbots Road
Cobo Road
La Route Road
Les Bussieres Road
Lower Catel Road
Upper Catel Road
Catel Ch.
St Andrews
Brickfield
St Saviours
ROCQUAINE BAY
Rocquaine Castle
Pleinmont Point
Pleinmont
Torteval Church
Mont Herault
Les Tielles
Creux Mahie
Bon Repos Bay
Corbiere Point
Moye Point
Petit Bot Bay
Icart Bay
Icart Point
Saints Bay
Moulin Huet
JERBOURG
St Martins Point
Bec du Nez
FERMAIN BAY
Kent Battery
FORT GEORGE
Petit Fort Bay
Bathing Places
Castle Cornet
HARBOUR
Light House
ST PETERS PORT
TOWN
St Johns
Hougue à la Perre
BELLEGREVE BAY
Ivy Castle
Hougue des Quartiers
ST SAMPSONS
ST SAMPSONS HARBOUR
Mont Crevelt
Vale Castle
Bordeaux Harbour
Vale Mill
Doyle Road
Salt pans
Forest Road
Forest Church
St Peters in the Wood
Gouffre Hotel
Prevote Watch House
St Martins Ch.
Mill
Mont Cuet
Jaonneuse
Hommet Benest
Mont Delancey Hill

hummocks, which are pitted with quarries numerous almost beyond counting.

This restriction of quarries to the hummocks of the north is alone sufficient to prove a difference between them and the southern plateau. Should our aeronaut descend to the collection of specimens, he will obtain from the south scarcely anything but varieties of gneiss. The north, however, will furnish him with a curious medley of rocks: some seem to be syenites and diorites; some resemble gabbro in structure, but contain hornblende as their principal constituent; no small number are granites; some few may be taken for altered rocks. Into this chaos I have been endeavouring to introduce some order, with less success than I desired, but not altogether in vain. Previous writers have solved the difficulty by calling all of them metamorphic. They have not always, however, added evidence to assertion. I have tried in this paper to furnish materials as well as opinions.

2. The Gneiss.

The gneiss occupies all the island south of a line from Castle Cornet to Vazon Bay. Outcrops are seen beyond this line on La Ramée Road and Cobo Road; but as the centre of the island shows for the most part no rock above the soil, the boundary cannot be exactly traced. It forms, as described above, a table-land with cliffs on the south and east, and a well-marked slope on the north, but on the west it occupies low flats extending along the shores of Vazon, Perrelle, and Rocquaine Bays. And on the north too, judging from the outcrops above mentioned, it must extend some way into the central plain. Over the plateau it is shown in many road-cuttings and small quarries, but in these is generally very rotten and seldom can be studied well or at all. Our main dependence is on the magnificent sea-cliffs of the south coast. Even these for the most part plunge directly into the sea, and though their base can be reached in a few coves, and by occasional paths of more or less difficulty, it is rarely possible to examine more than a very few yards of their face.

Seen in these sections, the rock usually consists of quartz, felspar, and mica—usually white, rarely black—in widely varying proportions. Almost everywhere along the coast the quartz and felspar are aggregated into irregular masses two or even three inches long. There is a rude but generally well-marked structure which perhaps we may call a foliation, due to a parallelism of the longer axes of these masses. In some places there appear to be thin intercalated beds (usually consisting largely of mica), coinciding in direction with this foliation; and whenever the bedding can be made out with certainty, this is certainly its direction. But there is not often such marked difference in materials that the direction of the strata can be readily identified. There can, however, be no doubt of the metamorphic character of the rock as a whole; its irregularly aggregated constituents are entirely unlike the crystals of a granite. The coarsest varieties are found along the southern cliffs, from Moulin Huet to Torteval; along the east coast it is somewhat less coarse, occasionally containing granitoid beds, of finer material and often hard to distinguish from dykes; but even at its edge, round Castle Cornet, the aggregates are half an inch long. On the west coast also it maintains a similar character up to its boundary. But this coarseness is not universal. Along Perrelle Bay occurs a rock of very different character. It is bluish within, weathering white, and consisting of crystals which are seldom longer than one eighth of an inch. Its constituents are felspar and hornblende, rather well crystallized; it contains many dark oval nodes a foot or more in length*; and it has the massive appearance and jointing of an igneous rock. That it is not igneous is, however, shown both by a well-marked structure which it possesses, and by its gradual change as we trace it along the shores of Lerée Bay and the isthmus of Chapelle Domhue into the porphyritic gneiss of Lerée.

A rock almost undistinguishable from this occurs also in a quarry near the brickfield at the east end of Les Talbots Road. In another quarry, some three hundred yards to the south of this, the rock is as fine-grained as an ordinary sandstone—a dark micaceous rock with well-marked banding and little cleavage. This variety I have not discovered elsewhere.

One locality deserves especial notice. This is the little peninsula in Rocquaine Bay, on which stands a fort called on Grigg's map Rocquaine Castle, but on the Admiralty Chart, Fort Grey. Here, interstratified with the ordinary gneiss of the locality, are several beds of what seems to be slate, and slate by no means highly metamorphosed. This rock attracted the attention of the earliest observer, Macculloch, and is certainly that mentioned by Ansted as "a patch of clay-slate in Rocquaine Bay." It is difficult to believe that these beds have experienced the same agencies of alteration as the coarse crystalline gneiss of Moulin Huet and Petit Bot. They are obviously true intercalations; they cannot possibly be nipped-up pieces of an overlying formation. I doubted at one time whether the rock in which they occur was the normal rock of the neighbourhood; but subsequent examination seemed to render this certain. It is, however, variable in nature, and some which outwardly seems normal gneiss, within proves to be a similar slaty rock containing patches or pockets of coarser materials, and nodules $\frac{1}{4}$ or $\frac{1}{2}$ inch in long diameter of clear granular quartz. The finer beds are much crushed and nipped up; but the general strike and dip of all is N.—S. and vertical, agreeing in these with the other indications of the region.

What then is the history of these rocks, so exceptional in character? They cannot be, as at one time I conjectured, later beds, a sort of arkose of gneiss; for they seem to occur in conformable succession. It has been suggested to me that they may be dykes; and, slaty though they look, there are in Guernsey dykes as slaty.

* These nodes in a non-igneous rock are curious. Are they of material originally peculiar, or are they the result of some fragment of matter which has produced chemical change in the rock around it? Some similar phenomena in the upper gneiss of Sark rather suggest the former interpretation.

The finer and more contorted seams have so sharp a line of boundary that the suggestion may possibly be true so far as they are concerned. But others, those with the coarser pockets, pass so insensibly into the gneiss that I cannot accept this explanation for them. I believe these to be contemporary with the gneiss which surrounds them, and sedimentary like it. If so they have been subjected during the same ages to the same agencies of metamorphism. And if so, we have a strong argument in support of the opinion that the peculiar character of the coarser gneisses is due, not so much to the metamorphosing agencies they have experienced as to the peculiarity of their original constituents. It is rather strange, however, that I have not been able to find similar beds at any other point of their line of strike.

It is difficult to investigate the neighbourhood completely. The tide-swept Sound of Lihou, the storm-beaten precipices of Pleinmont, do not lend themselves readily to examination. I have not yet been able to establish any order of superposition for the beds of the Guernsey gneiss. I hope to resume the investigation in a future visit, or perhaps some resident will attack the problem.

3. The Diorites and Syenites.

The gneiss occupies, as we have seen, one half the length and fully three fourths of the area of Guernsey. The rocks I proceed to describe are found over the greater part of the remainder.

They have been described as metamorphic; I believe them to be igneous, upon the following grounds:—First, though largely quarried over all the area in all sorts of places, not one quarry of all the scores I have entered shows any clear bedded structure. One or two show a faint streaking of colour, neither conspicuous nor extensive. They disclose universally broad and deep masses of uniform rock varied only by an occasional dyke. There are no proofs of sedimentary origin. Secondly, these rocks are exposed in many outcrops on the shore. If any difference of texture existed, it would be certain to manifest itself on the coast. I have examined nearly every outcrop and many of them minutely. There generally is no indication of dip, no sign of stratification. When occasionally there is some appearance of banding, it is usually contradicted a few yards off by similar but entirely inconsistent phenomena. Two marked exceptions to this statement will be discussed a little further on. Thirdly, the distribution of the different varieties of the group bears no resemblance to a succession in members of a stratified series. If such a series were rendered crystalline by metamorphosis, though in any one quarry the material might be undistinguishable from an igneous rock, yet traced over a large area the differences in the original strata ought to disclose themselves as different varieties occupying bands of country or succeeding each other in some assignable order. I can detect nothing like this. There are several kinds of these syenites and diorites, but most irregularly arranged. Rocks very similar occur at widely distant points, as for instance at the quarry by St. John's Church, the quarries on Les Genats Road, and parts of the shore east of Fort Le Marchant. Again, at the same point, we may find the rock varying in a manner seemingly capricious, as may be seen a few yards south of Fort Doyle. Fourthly, there is the evidence of the contact between these rocks and the gneiss. On the west coast, though they are found extremely near it, about Cobo, yet I have seen no actual junction. Neither is it likely that any will be found in the centre of the island. But on the eastern side, though the harbour of St. Peter's Port occupies the general position of the junction, still in the rocks exposed at low tide on the north side of Castle Cornet breakwater, I believe an actual junction can be seen*. Even here to trace it is no easy task. The rocks are masked by quantities of sea-weed and shell-fish, intersected by a network of small infiltration veins, and torn by intrusive dykes in extraordinary variety and abundance. The gneiss, however, is tolerably easy to distinguish from the rest, and I certainly believe that the same rock that is found along the shore north of the harbour does occur here also, cutting sharply across the foliation of the gneiss and running into it with an irregular boundary, which can only belong to an igneous rock.

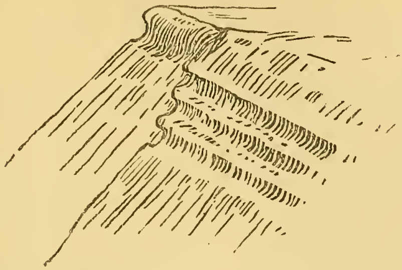
Lastly, Professor Bonney, from his independent microscopic examination, describes the whole of this series as igneous.

This mass of evidence is conclusive. Yet I long thought that Ansted might be right about the metamorphic character of these rocks. For though neither he nor any one else mentions any place where the bedding could be seen, I have myself discovered three spots where there are strong appearances of stratification and dip. These are all on the east shore of the north extremity of the island, and within a space of about half a mile. The southernmost, in some rocks near Pt. Norman Battery, consists of a lamination or banded structure dipping about 60° N.E. by N. There is a laminated slaty band and a sort of cleavage in the blue dioritic rock in which the slaty band occurs. The appearances here are not very striking, and are probably due to a dyke (the slaty band) and a platy jointing parallel to its walls. The next instance is a quarter of a mile further north, in a sort of bluff a few hundred yards south of Fort Doyle (fig. 1). Here a set of four or five deep grooves weathered in the rock belong to a series of parallel planes which dip at about 20° towards the west. These grooves correspond to some difference of structure, and there is a slight banding which appears to correspond to them in a quarry a few yards off. Very little difference is visible in unweathered fragments of the rock. They seem to me to resemble the banded structure developed by pressure in certain igneous rocks (as in gabbro at the Lizard, described in Quart. Journ. Geol. Soc. xxxiii. p. 903) rather than any truly stratified beds.

The last, and by far the most striking of these appearances, cuts right across the craggy headland on which stands the small fort called Fort Doyle. It consists of a well-marked set of slaty beds about 8

* These rocks are now being blasted away to improve the entrance to the harbour.

Fig. 1.—*Grooved Weathering in Dioritic Rock, a Quarter of a Mile south of Fort Doyle.*



or 10 feet thick, in the midst of coarsely crystalline rock, dipping about 50° or 60° to the N.E., visible on both sides of the headland and running into the sea. I thought at first that they passed continuously both above and below into the neighbouring crystalline rock, and that if they were sedimentary, so must it be also. But doubts expressed by Professor Bonney after examining slides from the rocks led me to make a more minute inspection than before. I had already noticed that the banded appearances were narrower and less conspicuous on the western side of the point. Investigating this, it appeared that some striping existed in the crystalline rock itself. I then saw that in places weathering developed this striping till it bore a close resemblance to bedded structure. Finally I was able, though with much difficulty, to trace an actual line of division between the slaty beds and the surrounding crystalline mass.

With hesitation, then, I venture to suggest the following explanation for this place. The igneous rock has caught up or surrounded a large slab of slaty beds, and structures have been set up in the igneous mass parallel to the surface of the slate. These structures weather into mock bedding, and cause the appearance of a continuous passage from normal igneous into normal stratified rock. It is not easy to be certain about the exact nature of these structures. They may perhaps be surfaces of crushing, where the rock has yielded along certain planes, such as Prof. Bonney has described in the 'Geological Magazine,' 1883, p. 436. Several yards to the south of the slaty beds is a thin streak not an inch wide, extending for many feet, which can scarcely be anything else (a section cut from it is described by Prof. Bonney). It seems to follow a joint, and has a horny texture, which runs in wavy lines through the crystalline syenite-like rock. Other similar streaks I have noticed along the northern shore.

It is obvious from the shattered condition of the rocks of this island that they have been subjected to enormous pressures. Where a rock under such pressures gives way along a plane, and one surface slides over the other, the powder which the rock will be ground into would probably resemble sedimentary material. Heat would be developed; would this not assist in recementing it?

If the explanations of these appearances here given can be established they remove the only objection to the igneous origin of these rocks. Some bedded structures at two localities on Bellegreve Bay belong to the group described in the following section. In a paper in the Cambr. Phil. Soc. Proc. (vol. iii. p. 76) these rocks are said to be visible underlying the gneiss below Fort George. However, an inspection of the whole shore, hasty but under favourable circumstances, showed no such appearance, and as above mentioned the rock seems to join the gneiss intrusively at Castle Cornet. When all these considerations are taken into account, I think that most observers will agree to abandon the metamorphic theory of these syenites and diorites.

In the group are included rocks of very various aspects, and perhaps of different ages. The most prevalent is perhaps a compact bluish rock as fine in grain as an ordinary sandstone. This is the variety at the junction with the gneiss: it is quarried in the town and by St. John's Church to some extent, and very largely north of St. Sampson's as well as in the neighbourhood of Cobo Bay. This furnishes the best kerbstones and "sets" for street-paving. A coarser rock of greyer colour with well-marked crystals of hornblende and felspar is also abundant. Occasionally it contains a good amount of black mica and sometimes a little quartz, so that some specimens approach rather closely to granite. The felspar when coarsely crystallized often shows plagioclase striping. A very beautiful rock, of well-shaped black hornblende and white felspar crystals about $\frac{1}{8}$ inch long, is quarried west of St. Sampson's near the "Saltpans" and near Vale. The Baubigny quarry also yields a rock resembling these, but with so much quartz that it must be ranked as a granite. Different varieties may, as I have said, occasionally be seen very close to each other. The rocks of Fort Doyle belong to the second variety above mentioned, and are mixed with rock belonging to the first. In the mass they look quite distinct, but it is difficult to find any decided separation.

West of Vale Church a true syenite occurs. To its east and north the rock quarried contains much mica. I have made no attempt to work out the limits of this variety, but I am much inclined to think it really a separate mass. A black hornblendic rock on the coast about half a mile south of Fort Doyle decomposes and exfoliates spheroidally. At one time I thought this a dyke, but no clear line of separation from the normal rock seemed to exist.

4. The Hornblende-Gabbro.

The curious rocks included in this section occupy an oval area extending from the outskirts of St. Peter's Port to Vale Castle beyond St. Sampson's, and from the shore to the hummock called Hougue des Quartiers. The quarry called Bouet is their southernmost extension, while they occupy the sea-shore from Hougue à la Perre Battery nearly to Bordeaux Harbour. Their boundary inland includes Delancy Hill, on which stands the Saumarez monument. They have hardly been noticed by previous writers; but the quarrymen have recognized their distinctness from the rocks of the previous section. Those they lump together as granite, distinguishing these by the odd name of "Birdseye."

These rocks are characterized by the predominance of hornblende. Sometimes the quantity is so great that hardly anything else can be seen. Sometimes it is segregated into large radiating prisms as much as an inch in length with interspaced felspar between. (This is in patches, called by the workmen "Sunburned," and appears to be connected with veins, or possibly with dykes.) More often it has formed itself into huge skeleton crystals crowded with felspar inclusions, but showing their unity by the lustre of their cleavage-faces. These reach an enormous size, one face sometimes occupying two square inches of a specimen. The felspar is generally in irregular grains, similar to saussurite, while in the diorites and syenites it is often in well-shaped crystals. At Mont Crevelt it has a pale greenish tint. Although the normal rock is so distinct from the diorites, yet it is by no means always easy to say whether an outcrop belongs to one group or another.

The north and south limits on the shore are well marked, the transition being very abrupt. At Hougue à la Perre Battery the hornblende aggregates give the boulders smoothed by the sea a peculiar spotted appearance, which is very striking and quite different from the uniform surface on the other outcrop a few yards to the south. This spotted appearance is seen at some other points, but nowhere more strikingly than here.

These rocks, like those of the previous section, present several varieties, which may possibly be of several ages. The very large skeleton hornblende crystals are seen at Hougue à la Perre, the quarry on the Grande Maison Road, and that on Baubigny Hill; the rock of the Bouet and of the Delancy Hill quarry has its hornblende in smaller crystals irregularly felted together, with a small proportion of felspar; the rock north of St. Sampson's Harbour has more felspar still, and does not very closely resemble the above, though it differs widely from the diorites which are close to it. All the rocks of Guernsey are cut by dykes, but these far beyond the rest, and as many of these dykes are hornblendic it occasionally becomes difficult to say what is normal rock, and what mere local intrusion. Thus a singular black rock on the north shore of Bellegreve Bay, with a strong jointing that approaches a cleavage, may possibly be a form of the intrusive rock which the quarrymen designate "Long grain." I believe, however, it is only a form of the normal "Birdseye." So again on the shore by Mont Crevelt, where the south pier of St. Sampson's Harbour runs out into the sea, there are appearances which may be due to a fault-breccia, but may also be due to a shattering by intrusions. I feel sure that among these numerous intrusive dykes many belong to the group of the previous section, so that these rocks must be older, although their position as an oval mass in the midst of those others would rather suggest a posterior date.

The question whether these rocks are metamorphic or igneous cannot be settled so decisively as for the diorites and syenites. The junction with the surrounding rocks affords evidence only in support of the igneous nature of those. As in the case of the last group, the quarries and the rocks of the shore do not in general show satisfactory signs of bedding. So too the distribution of the varieties over their area does not suggest a derivation from varying series of sedimentary beds. But they do in more than one place present appearances that very closely resemble remnants of stratification. On the shore at Hougue à la Perre, in the spotted rock described above, well-marked alternate layers of whiter and darker rock slope gently to the south-west. At the north end of Bellegreve Bay exactly similar appearances in the same peculiar variety of rock dip similarly in the same direction. In the quarry on the south side of Delancy Hill a similar banding may be noticed, but seems to dip steeply to the north. It cannot be examined, as the quarry floor is occupied by water*. However, I do not feel satisfied that any of these bands really represent beds. They are absent from the group in general, and even from other parts of the outcrops in which they occur. The rock does not at all resemble a metamorphic rock. Professor Bonney concludes from the microscopic examination that this group also is igneous. Though their boundary affords no evidence, there are rocks intrusive into the gneiss at Bon Repos Bay which consist mainly of hornblende and bear some resemblance to some of this group. I have caused analyses to be made of the Bon Repos rock and of a specimen of hornblende-gabbro from Hougue à la Perre. The results show considerable resemblance.

	Hougue à la Perre.	Bon Repos Bay.
Silica	45·82	45·28
Alumina	14·06	20·50
Ferric oxide	24·52	22·25
Lime	4·52	5·58
Magnesia	4·31	3·00
Loss by ignition	·97	1·00
	94·20	97·61

5. The Granites.

Granitic dykes occur at many points along the coast. These, however, will be mentioned in the next section. Here our concern is with such rocks as occupy considerable areas, areas that may claim recognition on a map.

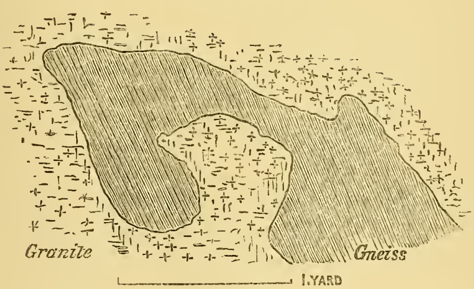
Foremost among these comes the granite of Cobo. This beautiful variety extends along the shore of Cobo Bay, and northward as far as the bay called Portinfer, while on the south it forms the whole of the peninsula on which stand the Hommet barracks. Its boundary inland is very irregular, but is seldom more than a quarter of a mile back from the shore. It is usually so decomposed that good specimens are hard to get. This is no doubt the reason why it is so little used for building. A quarry not far from the Cobo Hotel is

* I have shown, in Cambr. Phil. Soc. Proc. iv. p. 385, that the bed of stratified quartzite said to occur in this quarry is really a dyke.

the only place known to me where it is worked. For building-purposes granite is actually imported from Jersey. This Cobo rock is, however, very handsome and, if sound, would make a very fine material for the architect. It is pink, coarsely crystalline, with felspar crystals ranging from ·1 to ·4 inch long, and consists of flesh-coloured felspar with much granular quartz and a sprinkling of black mica.

Proof that this is truly igneous might seem needless, yet it has been described (Cambr. Phil. Soc. Proc. vol. iii. p. 78) as only an altered state of the red gneiss, so evidence must be given. A bank-cutting on the Cobo Road some quarter of a mile from the coast shows grey gneiss and granite in almost immediate contact; and, in the latter a caught-up fragment of the former. The granite is, however, greatly decomposed and so split in places by platy jointing that it much resembles gneiss; only colour and composition marked the fragment. If then this evidence be unconvincing, let the doubter

Fig. 2.—*Gneiss caught up in Cobo Granite. Shore south of Hommet Barracks.*



examine the shore south of Hommet barracks (fig. 2). Here among the rocks bared by a falling tide, the granite may be seen in actual contact with the gneiss that occupies the rest of Vazon Bay. The two is perfectly different; there is no difficulty in distinguishing them. The pink forms insulated masses in the grey, runs irregularly into it, flows round and includes portions of it, and presents all the regular appearances of igneous intrusion.

The relation of the Cobo granite to the rocks on its east and north is less easy to settle. In a quarry at the west end of Les Genats Road there appears to be a contact between the blue dioritic rock which is quarried, and granite. If so, the granite should be the later, as it seems to show a considerable alteration in character along the contact, while the blue rock remains unchanged. At the northern limit in Portinfer Bay it is intersected by a couple of bands of a dioritic rock (different from the common blue variety), but I see no evidence to show which is the later. In a quarry east of Vale church is a dyke of pink granite that resembles the Cobo rock. On the whole I have little doubt that the Cobo granite is later than the diorites.

Another important area occupied by granite is that which surrounds the bay called Lancresse. The sand hills which form Lancresse common make its inland boundary somewhat uncertain; but the road may probably without much error be taken as marking this. On the west the boundary on the shore lies about midway between the bays called Jaonneuse and Grand Camp, to the north of Mont Cuet; but I have not noticed any actual contact with the rock of Mont Cuet. On the west the boundary can be roughly traced across the heath by comparison of outcrops, and on the shore about 300 yards south of Fort Le Marchant the contact with the neighbouring rock is well seen. This is a blue diorite, weathering bluish-white, while the granite weathers into a pinkish white. This difference of colouring markedly distinguishes between the rocks. There can be no doubt that this granite is also igneous and intrusive into the rock which surrounds it.

This granite bears no resemblance to that of Cobo. It is a grey rock with a faint shade of pink that increases with weathering, and sometimes becomes the predominant colour. It is well crystallized, but the crystals are uniformly small, averaging, I think, about ·05 inch in length. The constituents are white felspar, quartz slightly stained, and black mica to the extent perhaps of one sixth of the whole. I noticed that there was very little quartz near the eastern boundary, and that there was a decided increase in the amount to the southward and westward, till it reached an equality with the felspar.

In the hollow of the bay between Forts Doyle and Le Marchant occurs a pink quartzose rock which was to me for long a perplexity. Not much can be seen above high-water mark, as it is covered by the turf, but a good deal is disclosed at low tide. It consists of much stained quartz, some felspar, and a good deal of black mica. It has a granulitic look, and a structure, caused by a tendency to a parallel arrangement of the constituents, that approaches a foliation. This is most noticeable on its eastern boundary. For some time I thought this an altered rock, probably belonging to the gneisses. But chancing one day to reverse my usual direction of survey along the shore, this rock suddenly reminded me of the granite I had just been traversing, the granite of Lancresse. Prof. Bonney independently sent the suggestion that this looked like a crushed granite. On a later visit I found a rock undistinguishable from this a little to its west, forming a clear dyke running up into the east side of the Fort-Le-Marchant peninsula, while on the west side similar dykes pass without break into the main Lancresse mass already described.

An oval area of granite, about half a mile long, lies south-west of Vale church, just south of the inmost extension of Grand Havre. I have preserved no specimen. Half a mile further to the south-west, by the mill on the Rue Maingy Road, is a small quarry in a rock very similar to that of Lancresse.

A granite entirely different from both that of Cobo and that of Lancresse is found on the promontory which forms the west side of

Grand Havre, on its east side in some of the quarries on Mont Cuet and Grand Camp, in a knoll by the road south of Lancresse Common, and, I think, in some of the quarries east of Vale. It is distinguished by the size of its crystals, which are usually about ·2 inch in diameter, by the size and perfect shape of its black mica, and by the presence of abundant and well-crystallized hornblende. My specimen from the knoll is rather decomposed, and shows less mica than the others, and little quartz. On Mont Cuet this is mixed up with a dark finely crystalline micaceous rock in a very curious way. The junctions seem scarcely sharp enough for intrusions; the absence of any trace of fissuring seems to exclude metamorphism along cracks or joints; the shape and arrangement of the patches show clearly that they are not included fragments or breccias. They remind me most of nodes or segregations, but I have never before seen these of such a size and degree of complication. Is it possible that the mass when just solidified or solidifying became subjected to stresses which did not actually rupture the rock, but only caused crystallization to go on differently in the parts where the strains came? A very similar relation between a white granite rock and a fine-grained dark mica-syenite occurs in two quarries west of Vale church, and is also thought by Prof. Bonney (see appendix, p. 422) to be the boundary of a node. Here, however, the white granite is that which veins the parent dark micaceous rock.

What would be the nature of the subsequent junctions if a superheated molten rock has forced its way through an igneous mass still nearly at the temperature of fusion? Will not this be again raised to the melting-point, and in parts be absorbed into the new comer, in others have a recrystallization along the contacts, and an interpenetration of constituents with the other? I suspect that this may be the cause of some of these phenomena.

A beautiful white crystalline rock consisting of quartz, felspar, mica, and hornblende, forms a large part of the great quarry west of the spot called on the map Baubigny Mill. This rock has a curious appearance of cleavage. The rest of the quarry is in a rock of the hornblende-gabbro group with huge secondary crystals of hornblende. Another rock of granitic affinities occurs at two or more spots on the west boundary of the above group, in the neighbourhood of Hougue Nicolle. The rare and imperfect exposures in this central part of the island offer little hope that the nature and relations of these rocks will ever be fully made out.

Besides the varieties here mentioned, several quarries afford rocks which contain quartz in larger or smaller quantity. Some of these may be true granites, while others seem rather quartz-diorites, and are probably only varieties of the dioritic group, with an unusual amount of silica. Sometimes a granitic material occurs veining an ordinary blue diorite, in the same manner as the mica-syenite of Vale, as in a quarry by a dark square tower above Les Genats Road. Very seldom is a rock actively quarried which contains any large amount of quartz. We find rock that may be classed with the granites in many abandoned excavations; but the windmill which marks a quarry worth clearing of water is usually a sure token of a diorite, syenite, or gabbro.

6. Dykes and Veins.

Guernsey furnishes a numerous assortment of minor igneous rocks. These vary in size from the smallest strings and threads up to the great masses at Bon Repos Bay and Pleinmont, which last covers several acres. They are so numerous that an observer has estimated them to occupy three per cent. of the cliff faces round the island *. Their diversity of constitution and character may be gathered from the following review.

Acid Rocks.—Granite dykes are numerous except along the southern cliffs. Many are grey or white, and though they contain hornblende, are probably offshoots from the Lancresse mass. As an instance may be taken one about 8 inches wide close to the bedded rock at Fort Doyle. There are many pink or red macro-crystalline dykes, extremely straight and uniform, which might be attributed to the Cobo mass, but that I fancy I have seen them cutting it. As they consist mainly of felspar and quartz they may be considered elvans. They are often rather decomposed, and in that state sometimes bear a good deal of resemblance to sandstones. To this group belongs the large dyke in quarry on the south-west of Delancy Hill, which, as mentioned in section 4, has been supposed to be a bed of quartzite. Felstones are rare. In the quarry on the Grande-Maison Road the hornblende-gabbro is cut by thin sheets of a crypto-crystalline felspathic rock, which meet and appear to be offshoots from a vertical dyke of grey granite. Round Castle Cornet are several intrusions of a beautiful pink felsite, so compact and glassy, and with so splintery a fracture, that perhaps it may be a rhyolite. One of these, on the north side of the breakwater near the timber bridge, contains very perfect double pyramids of quartz almost a quarter of an inch long. There are others of this class on the shore beneath Fort George.

Basic Rocks.—These are by far the most numerous and most various. Several types may be distinguished. One very pretty rock consists of well-shaped fresh-looking crystals, ·1 or ·2 inch long, of white felspar and hornblende. This occurs at Castle Cornet, near the boundary of the gneiss, at Portinfer, in the extreme outcrop of the Cobo granite, and abundantly at the north promontory of Fermain Bay, where a sudden change of strike probably indicates a dislocation of the gneiss. In this last area the intrusions are usually lenticular or irregular in boundary, but are sharply separated from the other rock, and cut its bedding or foliation obliquely. I think it very probable that the rocks of this group are simply offshoots from the diorites. Another type is grey, fine-grained, with grains, rarely exceeding ·05 inch, of somewhat greenish felspar. This occurs in large extremely regular dykes with straight walls, and is frequent over the whole island. A dyke of this kind quarried

* Quoted in Fisher's 'Physics of the Earth's Crust,' p. 186.

on Les Talbots Road was given the name of "Talvan" by the manager of the Bouet quarry, in conversation with me. To this group belong some dykes with pink blotches sometimes half an inch across, of which the best example occurs at the west point of Perrelle Bay; while I have other specimens from Leree, Jerbourg Point, and Castle Cornet. The pink blotches appear to be nodes of felspar surrounding a grain of quartz. The group, as a whole, appears to have been also originally diorite. The commonest type of rock among the dykes is compact crypto-crystalline and highly jointed, dark green or grey and slate-like. These dykes cut in sharply defined walls across all the principal rock-masses alike. They are perhaps diabases. The great intrusions, often 30 feet thick, which seam the southern cliffs are a characteristic feature of the scenery. The whole cliff of Pleinmont Point is formed by a mass of this kind, fully half a mile in length. Another group of large intrusions is conspicuous below high-water mark round the peninsula between Vazon and Perelle Bays. In the quarry south of Fermain Bay, and at other places, dykes occur in which a slaty cleavage has been developed. Along the cliffs of the south are various included schistose-looking masses which may in some cases be contorted beds, but in most cases, I think, are intrusive, as for instance in the cliffs about Torteval. On the shore west of Mont Crevelt a vertical band of rock is visible for a hundred yards or more, which can scarcely be distinguished in any way from a slate. But it is marked sharply off from the rock which it traverses; there is not the vestige of a transition, or of any bedding corresponding to it; and the boundaries are sinuous, so that the breadth varies irregularly. I am confident that this also is a dyke.

Dykes decomposed into an earthy state occur at Hougue à la Perre and Hommet Bennest.

Certain black stripes which traverse the 'Birdseye' (gabbro) at Hougue à la Perre and elsewhere are also no doubt intrusions. At the east entrance of the Delancy quarry can be seen an excellent instance. As it sends out strings and has a compact selvage, no one will question that it is an intruder. The microscope shows that it is hornblendic.

A singular type of rock is afforded by the great intrusion at Bon Repos Bay. This covers the whole floor of the bay, and extends half way up the cliff and apparently across Corbière Point. It consists of a closely felted mass of hornblende crystals, about $\frac{1}{4}$ inch long, often with no other visible essential constituent, though in parts there is some white felspar. I could not actually reach a junction, but have no doubt of its being intrusive in the gneiss, and I found a piece of what seemed to be gneiss imbedded in it. No doubt to be grouped with this, is a dyke at Leree, near high-water mark just north of the Lihou causeway, a mass of hornblende crystals of remarkably perfect external form. A rock occurring in the quarries of "Birdseye" and called by the workmen there "Long-grain" appears to be another variety. It has a platy cleavage which no doubt gives rise to the name. From the men's description I think it must occur as dykes; but an analogous rock on the north shore of Bellegreve Bay seemed to pass into the "Birdseye."

I have noticed no olivine and no unalterered augite in any rock of Guernsey.

Mica-Trap.—Two examples of this group have been discovered. One is a narrow dyke cutting the rocks on the shore at high-water mark, some way south of Bec du Nez, not far from the Doyle Column. Some strings of earthy matter in the cliffs near may belong to this, but are too decomposed to be certain about. The other, six or eight feet broad, crops out on the shore at Moulin Huet. Both are described by Prof. Bonney in the appendix (p. 426). As this group of rocks is rather rare, I may add that a dyke belonging to it runs up the cliff at the north-east corner of Port du Moulin in Sark; a very narrow and rotten one cuts a cliff on the east of Jethou; and large micaceous blocks, evidently fallen from the cliff, lie under the arch of the Creux de Vis in Jersey. These are all I know of. The rock decomposes deeply, so that it is easily overlooked.

Veins.—I would restrict this name to fissures filled with matter by segregration, sublimation, decomposition, or infiltration. I would withdraw it from all molten intrusions even of granite. Guernsey affords a fine field for study of the distinctions between these two classes. Can any infallible criterion of difference be laid down? The quartz in a vein is often milky, and almost always has some peculiarity of aspect; it is, I fancy, the best indication. A radiation of crystals from the bounding walls, a medial line of union between opposite growths to a common centre, are conclusive when they occur, which is seldom. Great and irregular variation in the size of component crystals is also more likely to happen in these cases than in the cooling of a molten magma. This last feature is well seen in a vein in the point next south of Fort Doyle (by the weathered-out bands mentioned before). This vein is about a foot thick, and contains quartz, large plates of mica, and masses of orthoclase felspar as much as two or three inches in length. An extremely large quartz vein cuts across the Jerbourg peninsula nearly under the Doyle Column. There are many others of inferior size, especially in the gneiss; and there are many networks of materials differing from the rocks they intersect, on whose origin it is difficult to be certain.

Direction of the Dykes.—I made some notes of the general lie of the great greenstone masses which stripe the cliffs from Jerbourg to Pleinmont. They seem to run in certain prevalent general directions. About Moulin Huet and Saints' Bay they usually strike N. and dip from 30° to 60° E.; thence onwards to the Gouffre they strike W.N.W. or W., and dip from 45° to 60° N.N.E. or N.; however, a very large one at Moye Point strikes N.E. and dips 70° N.W.; thence to the Creux Mahie the strike is W. and the dip N., and under Mont Herault the strike is N.W. and the dip about 45° N.E. There are, of course, exceptions, but even the exceptions sometimes bear evident relations to the rule. I made these observations in hope of finding some clue to the folding or rolling of the strata. There seems to be some tendency to a dip at right angles to the folds ; but the most marked feature is the general northerly and, therefore, inland dip. Possibly the character of the coast may have some connexion with this.

7. General Remarks.

Although I have no doubt as to the Archæan character of the Guernsey gneiss, yet absolute proof is wanting at present, and may perhaps never be obtained. It is possible that when Jersey shall have been satisfactorily worked out, some evidence may be forthcoming. There is a mass of diorite there on the shore at Greve d'Azette, east of St. Heliers, which closely resembles the dioritic intrusions into the gneiss at Fermain Bay. Again, the great crystalline masses which form three out of the four corners of Jersey remind me much of the Cobo granite. No gneiss, however, is known in any Channel Island except Guernsey and Sark*.

The relative ages of the rock-masses are fairly clear. The gneiss is no doubt the oldest. The "Birdseye" (hornblende-gabbro) is almost certainly next; indeed, unless we can identify the Bon Repos rock with it, we have no ocular evidence that it is later than the gneiss. The diorites certainly cut the gneiss, and almost certainly cut the "Birdseye" also. The granites are the latest of the more important groups; but I do not know their relations to each other. To arrange the dykes in chronological order would require much more time and attention than I have been able to give. Intersections are frequent enough, so that the materials exist; thus on the shore by Hougue à la Perre battery the "Birdseye" is cut by thin white dioritic dykes, while a broader black hornblendic band cuts right across them both. I fancy that the coarsest dioritic dykes are earliest, and contemporary with the diorite group; the less coarse greenstones next; the granitic dykes later still; and the compactest greenstones posterior to all. The mica-traps are, no doubt, late; their age may be the same as those known to exist on the mainland. The pink felsites of Castle Cornet resemble certain rocks of Jersey, and are probably also among the later intrusions.

The area occupied in north Guernsey exclusively by igneous rocks is, as may be seen from what has been said, very large, not less than six square miles; and whenever the outlying reefs are properly examined it will probably be found much larger.

Perhaps the most interesting feature of these rocks is the extent to which a structure tending towards that of schist has been developed in them by subsequent action. There can be little doubt that the agent has been pressure. Pressure, we know, can produce such effects, and the rolling and faulting of the gneiss show that pressure has been at work. Granite has had a gneissose aspect imparted to it; diorite has had slaty bands developed in it; greenstone dykes have been reduced to the condition of schist or slate. The like may therefore have happened in other localities. Two miles to the east

* Prof. Liveing has published geological sketch maps of Sark and Jersey in Cambr. Phil. Soc. Proc. vol. iv., and the account of Sark there is good.

lie the islands of Herm and Jethou. The rock of Herm has always been considered white granite. That of Jethou has a marked structure in vertical planes, but otherwise closely resembles this. These vertical planes run north and south, and therefore parallel to the most frequent strike of the foliation and folding in Guernsey. Shall we not here also find a case of a granite in which structure has been developed? Writers have talked of gneiss metamorphosed into granite. May not the process in some cases have been the very reverse, and some gneisses be mere alterations of granite? Most certainly, however, this island of Guernsey must not for the future be quoted as affording undoubted instances of syenites metamorphosed out of sedimentary rocks.

I am fully conscious of the deficiencies of this paper. Additional study would have removed some, but would certainly have suggested many more problems in their turn demanding solution. I have thought it best to publish the results already attained, and not to delay indefinitely. Besides, work such as would be necessary for the complete elucidation of the geology of Guernsey can hardly be done except by a resident; and perhaps this paper may be the means of inducing some resident to take up this most interesting inquiry.

APPENDIX.

NOTES *on the* MICROSCOPIC STRUCTURE *of some* ROCKS *from* GUERNSEY. By Prof. T. G. BONNEY, D.Sc., F.R.S., Pres. G.S.

GNEISS.

IN describing the specimens which Mr. Hill has selected and forwarded to me for microscopic examination, it will be convenient to group them lithologically rather than geographically. We will take first a series illustrating the gneiss, which occupies three fourths of the whole area of the island. These slides indicate that this region is occupied by a series of coarsely crystalline, rather granitoid gneisses, which have a general lithological resemblance to the more typical varieties of the Hebridean group of Scotland. It cannot, I think, be doubted that we have exposed here in the Channel Islands a fragment of the foundation stones of the earth, of rocks roughly corresponding in age with those that on the continent of America have been named Laurentian. A lengthy description is needless, as so many accounts have now been published of rocks of this character; enough to say of these, as a whole, that while indubitably not igneous, they do not generally exhibit a very marked foliation. Quartz and felspar are always present, and the third predominant mineral is usually a brown mica; the quartz, as seems to be commonly the case in these old gneissic rocks, is rather full of enclosures, many of which are certainly cavities. These vary much in form, some being very irregular, others rounded in outline.

Bubbles are not seldom present, but a good many cavities appear to be empty. The felspar is usually somewhat decomposed and occasionally so much so as to make it difficult to conjecture the species. Four specimens contain rather abundantly very characteristic microcline; there is always a considerable quantity of a closely twinned plagioclase, which generally, so far as one can infer from its extinction-angles, appears to be oligoclase; but it is very probable that albite is also present. Orthoclase is no doubt present, but the characteristic Carlsbad twinning does not appear to be frequent.

1 (*Fermain Bay*).—Contains a considerable quantity of microcline. The third mineral in this specimen is a brown mica, generally in aggregates of rather small crystals, though now and then larger occur, one being about 0·12 inch long. Occasionally a little of this is replaced by the pale green mineral which frequently appears as an alteration-product of the magnesian micas, but most of it is in excellent preservation. The slide contains a considerable number of crystals of apatite, generally associated with the mica. Near to the largest mica crystal is a group of three (besides some smaller ones) cut almost transversely to the principal axis, the largest of which is rather more than 0·01 inch in diameter. The rock appears to have been a little crushed and recemented.

.2 (*Bec du Nez*).—Consists chiefly of quartz and felspar (rather decomposed), with which are small films and clusters of a green mineral, associated with a little opacite and ferrite, and a few scales of a white mica, giving bright colours with polarized light. This is probably a hydrous soda or potash mica, but the green mineral is probably a hydrous magnesian mineral replacing biotite.

42 (*Petit Bot Bay*).—The felspar is rather decomposed, but a closely twinned plagioclase evidently predominates. There are aggregated patches of a scaly green mineral of the chlorite group, strongly dichroic and probably uniaxial, associated with apatite, opacite, and very little white mica, as in the last.

13 (*Petit Bot*; pink band, possibly a dyke (E. H.)).—Felspar rather decomposed, but plagioclase as above, with a little microcline and orthoclase recognizable. Some grains of iron peroxide, hæmatite, and perhaps a little magnetite; except one or two very minute scales of a brown mica, no other mineral present. The figure in Fouqué and Levy (plate vii. 2), granulite from Grape Creek, Colorado, will give an excellent idea of this rock. Many would unhesitatingly claim this rock as igneous, in which case it would best be called a pegmatite, but I feel doubtful on the point. It may be a vein granite, but I should not be surprised if field evidence showed it to be a metamorphic rock (*gneiss granulitique*). The difficulty has been enhanced by the rock having been crushed *in situ*.

11 (*Lerée*).—Rather akin to 42, but the replacement product of the mica is less abundant and characteristic. One crystal, about 0·07 inch long, resembling a mica in form, is almost wholly taken up by opacite. The rock appears to have been crushed.

9 (*Vazon Bay, Southend*).—Rather poor in quartz, rich in plagioclase. A fair amount of very characteristic hornblende, as well as

brown mica, the latter mostly in aggregated small scales. Apatite not conspicuous.

8 (*Vazon Bay, middle*).—Felspar, rather decomposed microcline and plagioclase recognizable, a fair amount of aggregated chlorite or some similar replacement-product of brown mica, with some scales, rather larger than usual, of a hydrous white mica, and a few microliths of apatite.

15 (*Castle Cornet*).—A considerable quantity of microcline among the felspar, several clusters of altered biotite, with a few scales of white mica and some granules of hæmatite and opacite.

48 (*Brickfield near Les Talbots Road*).—A gneiss with fairly marked foliation, consisting of quartz, felspar, and a dark brown mica. The quartz is rather clear, and occurs generally in rather small clotted granules; the felspar is in part orthoclase, but there is a considerable quantity of closely twinned plagioclase, extinguishing at small angles with the vibration-planes of the nicol, and probably albite or oligoclase. The mica occurs in small plates, generally aggregated; there is some opacite, and a little apatite.

Granite.

24, 26 (*Around Lancresse Bay, N.W. part of island*).—These specimens only differ in that one is rather more coarsely crystalline than the other. They consist of quartz, felspar, and black mica. The quartz contains a fair number of cavities, in many of which are small bubbles, often moving, but some are empty; others are rather dark, as if stained, and there are occasionally microlithic enclosures. Felspar is the most abundant mineral, usually in well-defined prismatic crystals, rather decomposed. Plagioclase predominates, frequently in closely twinned crystals, and sometimes with external zonal banding. By measurement of the extinction-angles I infer that much of it is oligoclase. I think, however, that some may be albite, and occasionally recognize orthoclase. The mica, not very abundant, is rather dark brown, containing evidently a considerable amount of iron. It is occasionally replaced by the usual green mineral. There is also a very little pyrite, apatite, &c. (38) does not materially differ, except that it has a little more apatite and a crystal of sphene. (27) contains much the same minerals, though it is rich in quartz; but it differs in structure, having a ground-mass which is almost microcrystalline, in which larger crystals of quartz and felspar, rather irregular in outline, are thickly scattered; it is, in fact, an example of the granite porphyry of some authors. The cavities in the quartz are smaller, and bubbles seem to be less frequent. (5) A granite of similar type to those named above, but seems to be a little crushed; fluid-cavities abundant. (25) Part of the slide exhibits a similar granite, the rest a rock consisting of hornblende, felspar, and a little quartz. At first sight one would suppose it an intrusive junction; but closer examination leads me to think it more probably a node of some kind. There appears to be a transition, though very rapid, rather than a break between the two rocks. There is no very marked difference between their felspars, and the cavities in the quartzes, as far as they can be compared, appear similar.

28 (*Cobo*).—This rock is a little abnormal in character, but I think I am right in classifying it as a granite. The mineral character does not materially differ from that above described. The felspar is a good deal decomposed, but a plagioclastic species is abundant; sometimes one of the latter is enclosed in a larger crystal of (?) orthoclase.

20 (*Dyke, Grande Maison Road Quarry*).—This rock consists of quartz and felspar intercrystallized, exhibiting, in parts, a micrographic structure, with occasional felspar grains rather larger than the rest. The outlines of these are irregular, and they appear to be frequently surrounded by an area exhibiting the micrographic structure. There is also a little brown mica, an iron peroxide, and possibly a small quantity of tourmaline. A considerable number of very small cavities; most of these seem to be empty, but in others I detected minute moving bubbles. The rock is a vein granite.

4 (*Between Forts Doyle and Le Marchant*).—This rock consists of quartz, felspar (orthoclase, plagioclase?, and a very little microcline), together with a little brown mica and iron-oxide. The rock has evidently been much crushed, some of its constituents, both of the quartz and of the mica, being of secondary formation. It is a little difficult to give the rock a name, as in more than one respect it is slightly abnormal; but perhaps it would be best to call it a granite*.

16 (*Dyke, Castle Cornet*).—It consists of quartz, felspar (decomposed, but apparently in great part orthoclase), and a little of a greenish mineral, probably replacing a black mica:—a vein-granite.

21, 22 (*Dyke, Delancy Quarry; thin seam, probably dyke, Grande Maison Road Quarry*).—These rocks have a general similarity, but the latter is the coarser and rather more definitely crystalline. The minerals are quartz, felspar, mainly orthoclase and microcline, and a very little brown mica and iron-peroxide. The rock from Grape Creek, already referred to, gives a fair idea of the structure, except that the felspars in the Guernsey rock are rather more rectilinear in outline. With some hesitation I refer it to vein-granite.

46 (*Castle Cornet*).—Is a quartz-felsite. The ground-mass is crypto-crystalline, in places imperfectly spherulitic, and in it are scattered numerous small scales of a filmy olive-brown mineral, probably a mica. Of the first order of consolidation are quartz, rather clear, showing crystalline angles, felspar, orthoclase with some plagioclase, and a little brown mica. The rock, though rather more micaceous than they, reminds me of the oldest quartz-felsites in Britain.

Hornblendic Rocks (Diorites &c.).

3 (*Near Vale Castle*).—This rock consists of a plagioclastic felspar, often rather decomposed, with hornblende, a rather fibrous greenish

* [I have convinced myself that this is a form of the Lancresse granite.—E. H.]

mineral resembling an alteration-product after biotite, grains of iron-oxide, and a fair amount of quartz. The felspar agrees best with oligoclase or albite. The rock has evidently been much crushed and recemented, and much of the quartz has the aspect of a secondary constituent. It is a quartz-diorite.

23 (*Dyke, near Fort Doyle*).—In all probability this rock has once been a basalt, but the felspar has been replaced by secondary microliths of more than one kind, until the original structure is practically obliterated; and the other constituent is a green, rather filmy, irregularly crystallized mineral, which is, in part at least, hornblende. There are some scattered granules of iron-oxide.

37 (*Between Forts Doyle and Le Marchant*), and 39 (*Houmets, near Cobo, ¾ mile east of Cobo Bay*).—It is a little difficult to say whether this rock should be called a quartz-syenite or a quartz-diorite, for the felspar is so much altered and replaced by secondary microliths. From the small portions which remain unaltered I should infer that plagioclase predominated, and class the rock with the latter. There is a considerable quantity of hornblende and biotite, both rather altered. The quartz, of which there is a moderate amount, contains numerous cavities, in which are generally small moving bubbles.

43 (*Portinfer*).—Has a general resemblance to the above, but is perhaps rather more distinct; a quartz-diorite.

30 (*Fermain Bay*).—Also a quartz-diorite with mica; some apatite is present, and probably a little sphene.

14 (*Castle Cornet, at boundary of Gneiss*).—A rather coarsely crystalline rock, consisting mainly of green hornblende, a very decomposed felspar, probably plagioclastic, with some altered biotite. There is also a fair quantity of apatite and sphene, with, of course, some iron-peroxide. The rock is a diorite.

7 (*Near Fort Le Marchant*).—The hornblende and felspar are yet more highly altered, but the rock is probably a true diorite; there is a fair amount of a white mica, probably hydrous.

41 (*Bon Repos Bay*).—Consists mainly of well-crystallized hornblende, some brown mica, iron-peroxide, a plagioclastic felspar (not abundant), probably oligoclase, and a little apatite. The slide is not a very good one for examination; but field-evidence, I am told, proves it to be a true diorite.

6 (*South of Fort Doyle*).—Consists mainly of hornblende, with probably a little altered biotite and some decomposed felspar. Some, at least, of the hornblende has the look of a secondary product. At present the rock may be regarded as an abnormal diorite or a hornblendic diabase; but I should think that very probably it was once a gabbro, rich in the pyroxenic constituent.

35 (*Fort Doyle*).—A diorite, with a little free quartz and apatite, somewhat crushed and decomposed.

36 (*Fort Doyle*).—The constituent minerals are quartz, felspar, very much decomposed, and a filmy, green, chloritic or micaceous mineral. I cannot give the rock a name, for it appears to me that the slide has been cut from a specimen which has been exposed to great local crushing, and subsequently recemented. (See 35 and 45 E. H.)

31 (*Quarry west of St. John's Church*).—A diorite, the felspar decomposed, the hornblende as in 6, looking in some cases like a secondary product, a little apatite, ilmenite, and (?) sphene.

Hornblendic Rocks (Gabbro-like).

The group of hornblendic rocks on the eastern side of the island, which are enclosed by the last-described dioritic group, agree with it in having hornblende as an abundant mineral, but present some marked differences.

17 (*Hougue à la Perre*).—Has, macroscopically, a considerable resemblance to a gabbro; microscopically, it consists of fairly well-preserved crystals of labrador felspar and hornblende, with some grains of iron-peroxide and a pyroxenic mineral presently to be described. The last two appear to have crystallized first. The felspar seems then to have commenced consolidation; for some small crystals of it are enveloped in the hornblende, which mineral also appears to have adapted itself to the outlines of the larger crystals. Thus the larger hornblende crystals are interrupted by small crystalline grains of felspar, as augite not seldom is by olivine; a few flakes of biotite are also included in the hornblende, which is very fresh-looking, strongly dichroic, with a characteristic cleavage. The pyroxenic mineral is difficult to identify with certainty; it is sometimes traversed by cracks containing a serpentinous mineral, and the smaller grains are almost wholly replaced by this. The cleavage and general appearance, as well as the optical properties, correspond fairly well with augite; so that we may, I think, refer it to this mineral. The rock must be classed with the labrador diorites, and is evidently closely related to the gabbros.

32 (*North end of Bellegreve Bay*).—Is a rock of the same family, but consisting only of labrador felspar (rather decomposed) and hornblende, with a fair amount of iron-oxide and a little apatite. The hornblende contains a considerable quantity of opacite, often belonitic, and arranged along the cleavage-planes; it is sometimes rendered quite opaque.

33 (*Mont Crevelt*).—Is a rock generally similar in character, but the felspar is greatly decomposed, and the hornblende looks rather altered.

19 (*Delancy Quarry*).—Has also a general resemblance, so far as the two dominant minerals are concerned, but it contains a considerable amount of brown mica, and is rather rich in apatite. It also exhibits a slightly banded arrangement of its minerals. The colourless mineral, interbanded with the mica, occurs exactly like the calcite figured by Zirkel (Micr. Petrogr. pl. v. fig. 1, cf. pl. ii. 4, iii. 3). It shows colours resembling those of a pyroxenic mineral with the crossed nicols, and appears to extinguish nearly or quite simultaneously with the mica, and with the only plane of cleavage (faintly marked).

34 (*Dyke? Shore, near Mont Crevelt*).—Is a much more minutely crystalline rock, containing micro-porphyritic felspar, in a groundmass of felspar and hornblende, greatly altered. I should imagine

that this was from a dyke, and that the hornblende was a secondary formation from augite, so that the rock had once been a basalt.

18 (*Dyke Junction, Delancy Quarry*).—Appears to be a junction specimen, a rock somewhat of the latter character cutting one of the former, both being a good deal altered. A vein of chalcedonic quartz cuts the finer rock. It is very possible that the coarse rock was once a gabbro and the other a basalt.

44 (*Quarry south of Baubigny Mill*).—This rock is coarsely crystalline, and consists of felspar, agreeing best with labradorite, hornblende, and a little brown mica, apparently rather altered, a little apatite and magnetite (?); the hornblende appears to have crystallized later than the felspar, and may perhaps have been produced by paramorphic or pseudomorphic action from a pyroxenic constituent.

Mica-trap.

The two specimens which may be included under this general designation come from the south-east of the island, one from Moulin Huet on the south, and the other from Bec du Nez on the east coast. The former (12) has a glassy-looking ground-mass of a very pale brown tint, which is thickly studded with crystals of brown mica, many of them not exceeding about 0·001″ in diameter, while others are as much as 0·03″, the latter including portions of the ground-mass, flakes of an almost opaque iron-mica, and microliths of apatite (?), together with a considerable amount of a mineral presently to be described. The ground-mass shows a rather indistinct trachytic structure, apparently consisting of a mass of elongated felspar microliths. The mineral mentioned above is at present evidently a secondary product. It is colourless, and occurs in prism-like flakes, not unlike one of the white micas which give moderately bright colours and have a silvery look with crossing nicols. Extinction takes place when the longer edges of the flakes are parallel with the vibration-planes of the crossed nicols, and, on the whole, I think that the mineral is probably talc. It occurs partly scattered in the slide, but also aggregated in more or less definite crystalline forms, which are outlined fairly continuously by granules of opacite. Within these it has a tufted habit, and is associated with a little ferrite. Exact parallels may be found in the excellent figures of rocks akin to mica-traps in the well-known work of Fouqué and Levy, or in Professor Barrois's recent volume *, where both augite and hornblende are figured as associated with mica, and these bear a general resemblance to our mineral. I may, however, note that in the former book, plate xxvi. (*Porphyrite andésitique micacée*, &c.) and plate xxvii. (*Porphyre syénitique micacée*, &c.) there is a mineral (replaced by serpentinous products) which in external form much resembles the above. The authors, with a little hesitation, ascribe it to bastite. That in the Moulin-Huet rock we have a magnesian bisilicate there can be little doubt. I should place it in the group for which I proposed the name of kersantite-porphyrite.

The specimen from Bec du Nez (29) has a more definitely crys-

* Recherches sur les Terrains Anciens des Asturies et de la Galice, pl. 1 & 2.

talline structure, consisting of elongated crystals (rather microlithic in habit) of oligoclase associated with a very brown mica, and a third mineral much altered and almost opaque; ferrite and opacite are scattered about the slide. This third mineral, more highly magnified, appears to consist of a mixture of minerals, chloritic and ferruginous. It is not impossibly a replacement of a pyroxenic mineral. Barrois notices the presence of gedrite in kersantite, a mineral whose chemical composition would be not unlikely to give rise to the appearances here described.

40 (*Rocquaine Castle*).—This rock consists of subangular fragments (generally less than ·01″ diameter), among which a clear quartz predominates, scattered in a ground-mass, which appears to be composed of quartz, felspar, and a green filmy mineral, possibly a chlorite, but more probably, I think, a variety of hornblende. This, I think, has certainly been formed *in situ*, and the ground-mass generally appears to have undergone some alteration. The rock has the aspect of a slightly altered sedimentary rock.

47 (*Rocquaine Castle, "pocket" of coarse rock in finer*).—In the greater part of the slide it has the appearance of a magnesia-mica gneiss (such as have been already described), which has evidently been considerably crushed, and here and there becomes quite pulverized, assuming an appearance which reminds us of No. 40.

45 (*Fort Doyle*).—A most perplexing rock: nearly half the slide, with a small portion of the exterior of the remainder, appears to be a diorite or a coarse hornblendic gneiss, poor in quartz (consisting mainly of a plagioclastic felspar and hornblende), indicating considerable crushing *in situ*; but between these there is a zone about $\frac{1}{4}$ inch wide presenting a singular resemblance to a schist or schistose rock not highly altered, consisting of minutely granular quartzose and felspathic materials, associated with filmy scales of a greenish micaceous mineral, in which are rarely scattered a few rather larger grains of quartz or felspar.

These three specimens are most perplexing. Taking 40 by itself, I came to the conclusion, though not without suspicion, that it was probably a slightly altered rock of sedimentary origin. As regards 47, had I taken it alone, I should have been of opinion that it was almost certainly one of the coarser gneisses crushed *in situ*. 45 looks like an interbanding of a minutely constituted not very highly metamorphosed schist in association with a coarse felspar-hornblende gneiss, which has been rather crushed. But is this association possible? It would be rash to give an absolute denial, with our present very limited knowledge of the metamorphic rocks and the effects of the agents of metamorphism, and I once collected specimens, near the top of the Bernina Pass, in Switzerland, where a coarse gneiss and a rather compact green schist appeared to occur in true association; but in every other case that I have seen where finer and coarser foliated rocks are associated, the constituents of the finer under the microscope exhibit a more complete crystallization than is seen in the Guernsey specimens, and even in the instance at the Bernina (which was rather imperfectly exposed) the green schist differs in some respect from that of Guernsey, so that without the very strongest evidence, from field examination, I hesitate to admit the possibility of such an association as this Guernsey specimen would require. We might have here a sedimentary rock of ancient date, which was in part an arkose of granitoid materials ; but so far as I have been able to study rocks of this kind, their evidence is not favourable to this identification. But examination of rocks from the Highlnads, and of some specimens from the Cheviots sent to me by Mr. Clough, has shown me that the results of local crushing are occasionally so singular, and, if I may use the phrase, rocks thus maltreated play such tricks that I incline to hold this to be the most probable explanation of these Guernsey specimens *.

EXPLANATION OF PLATE XX.

(Geological Sketch-Map of the Island of Guernsey.)

This map is reduced from Grigg's (Guerin's) map. It represents the outline at high water. At low tide a large additional area is laid bare ; many of the bays are then almost deserted by the sea, and Lihou becomes connected with the mainland. Only the most important roads are marked, either such as the visitor would naturally use, or such as are mentioned in the text. The boundaries can only be regarded as approximations to the truth ; in particular, the line between the gneiss and the diorites is, in the centre of the island, almost entirely conjectural.

Discussion.

Mr. Redman mentioned some facts illustrating the great hardness and durability of the Guernsey granite. These facts proved that the Guernsey granite was the most durable of the Channel-Island granites, and very much more so than the Aberdeen granites as laid down in the West India Dock tramway over forty years back.

Prof. Seeley inquired why the author, in his map of Guernsey, had grouped the syenites and diorites together ; and what were the felspars which they contained, or the circumstances which showed their relation to each other. He inquired what the author intended to imply when the gneiss in the south of the island was termed metamorphic, and the granites and other rocks in the north were termed igneous. It seemed to the speaker that, under the conditions of contortion in which the metamorphic rocks were admitted to be produced, it followed that the deeper-seated mass not only became more

* The above notes were written in ignorance, for the most part, of the results of Mr. Hill's work in the field. In a few cases I have struck out an expression of doubt, where it was removed by stratigraphical evidence ; but I leave these last paragraphs as they were written, because I think they afford a fair specimen of the " guesses after truth " which can be made with a microscope. He was, I believe, not quite satisfied at first as to the nature of the rock of which 45 is a specimen ; but after a reexamination of the locality, he tells me that he is convinced that this rock is only a case of peculiar local crushing in the mass, of which 35 is a more normal specimen. 36 is from a rock which is close by 45. This, however, consists mainly of quartz and felspar, and can hardly be a part of the same rock.

heated, but experienced pressure from more than one direction, which would cause the parallelism of the gneissose structure to be interfered with by throwing the crystals out of their schistose arrangement, so as to form the confused structure of a granitic rock. If this were possible, the gneiss and syenite might both be metamorphic. In Guernsey he would suggest that under the strain which the rocks had experienced in contortion, and while their materials were still in what might conveniently be termed a plastic state, the rock materials of the island had been faulted, with a downthrow to the south, so that the gneiss had been brought into juxtaposition with the syenite. The slip need not have been great in amount for subsequent denudation to have laid bare the rocks in the positions which the author had described. The speaker would ask whether the specimen exhibited, which appeared to include a junction between stratified and igneous rocks, might not rather be due to a minor fracture in a semiplastic rock, and be partly the consequence of foliated structure developed parallel to the fracture, and partly of the nature of a veinstone. He considered that the remarkable development of schistose structure in the rocks which the author termed igneous, and which, like all schistose structure, must be attributed to pressure, was strong evidence in favour of the gneiss and syenite being contemporaneous, and favoured his contention that in Guernsey they had consolidated under the same conditions.

Mr. Rutley considered that the term "Hornblende-gabbro" employed by the author was a very useful petrographical name. He did not think the difference of colour in some of the rocks was of much importance, especially as indicating bedding. He pointed out the interest attaching to the felstones of the Channel Islands, and remarked that spherulitic felstones somewhat similar to those of North Wales and the Lake Districts, which are of Silurian age, occur in Jersey. He suggested that some of the rocks in the Channel Islands might possibly be of the same age.

Mr. Topley was inclined to regard the parallel structure in the gneissic rocks as bedding, and not foliation; and the thickness of the strata is enormous. The rock sold as "granite" in Guernsey is really a syenite. There is no direct evidence that the beds are Archæan; but if such be their age, they may probably be correlated with the oldest rocks of Malvern.

Mr. Teall agreed with the author that parallel structure might be developed in igneous rocks by mechanical pressure. Diorite dykes in the Ardennes might be seen passing into amphibolite schists at their margins. Dr. Lehmann, in his recent work, called attention to the production not only of foliation, but also of structures simulative of bedding by the action of mechanical forces. The speaker did not think that a persistent dip for a considerable distance in regions of crystalline schist could be taken as indicating a regular succession of enormous thickness.

Mr. Marr asked if some of the igneous rocks might not be contemporaneous lava-flows. He remarked on the frequency of the inclusion of gneiss-fragments in granite, and suggested that this might be regarded as a crucial test as to the granitic nature of the rock.

Dr. Hicks thought with the last speaker that some of the rocks might be lava-flows. He said that included fragments, such as are common in some Scotch granites, were never found in the so-called granitoid rocks of Wales.

The President said that in the hornblende-gabbros the hornblende might not improbably be altered augite. The diorites and syenites pass into one another by the most insensible gradations.

The Author said that his paper was in part devoted to proving that the views expressed by Prof. Seeley were not applicable to these igneous rocks. The felstones of Guernsey were like those of Jersey, and it was not impossible that it might be practicable to fix the age of those rocks.

31. Studies *on some* Japanese Rocks. By Dr. Bundjiro Koto. (Read April 2, 1884.)

(Communicated by F. Rutley, Esq., F.G.S.)

The materials for this paper were kindly sent to me by Mr. T. Wada and Mr. Kato, Rector of the Tokio University, and were obtained partly from the petrographical collection of the Tokio University and partly from that of the Geological Survey of Japan. During the last few years those districts, in which our rock-specimens were collected, have been examined by O. Kuntze, E. Naumann, J. J. Rein, and other European geologists, but as yet no full descriptions of their researches have been published. Many specimens belonging to the Geological Survey were collected in the provinces Izu and Kai by Wada, and those from Kojuke during a two months' journey by myself. The rock-specimens belong mostly to grey porphyritic pyroxene-andesites, basalts, diabases, granites, diorites, and porphyrites.

The microscopic investigations have been prosecuted in the Mineralogical Institute of Leipzig under the direction of Geheimerath Prof. F. Zirkel, and the chemical analyses were made in the Laboratory of Agricultural Chemistry under Prof. W. Knop, to both of whom I here take the opportunity of expressing my hearty thanks.

Pyroxene-andesites.

The andesitic rocks were for the most part collected in the neighbourhood of Tokio and in the province of Izu, the latter a mountainous volcanic district in which the well-known Atami geyser and many other mineral springs of less note are situated. Most of the specimens belong to the coarse porphyritic type. They are grey or dark-brown in colour, somewhat porous and with a trachytic appearance. With the aid of a simple lens, or even with the naked eye, the component minerals may be clearly distinguished from one another. These rocks are not at all like the typical glassy augite-andesites from Santorin, Hungary, Java, and Australia, which are of a pitch-black colour, and have a resinous lustre and conchoidal fracture, but rather resemble typical hornblende-andesites. The ground-mass of these specimens is not, as is usually the case, a glassy paste containing felted microliths, but is mostly holocrystalline. Sometimes a few of the specimens show a glassy interstitial substance in small quantity. The rocks from the Kozuke province, however, approach in structure to the typical augite-andesites.

Porphyritic Constituents.

Plagioclase occurs in crystals ranging up to three millim. They are usually twinned on the albite type.

Besides the albite type, another system of twinning parallel to the macropinacoid is also developed, making an angle of from 86° to 87° with that parallel to the brachypinacoid*.

It is difficult to get mathematically accurate microscopic sections, and therefore optical researches are possible only in a few cases. In the basal section parallel to P, the maximum extinction of light takes place between 15° and 20° (in the sense of Schuster) with the edge P/M; but the exact point could not be fixed with any degree of certainty owing to the so-called undulatory extinction. The angular values are not constant, varying from 13° to 35°. In the brachypinacoidal sections parallel to M, the direction of maximum extinction makes an angle of from 5° to 6° with the edge P/M.

These measurements indicate that the felspar is labradorite, according to the observations made by Max Schuster †, while the following chemical analysis confirms this view.

The porphyritic felspar, by virtue of its difference in specific gravity from the other constituents, may be mechanically separated by Thoulet's solution (a mixture of potassium and mercuric iodide ‡). By repeated cautious treatment of coarsely pulverized samples of the rock from Ihama, Izu, I was able to obtain felspar grains, the purity of which was evident under the microscope.

The alkalies were determined by the new method of Prof. W. Knop §.

The analysis gives the following result:—

SiO_2	55·97
Al_2O_3	27·60
Fe_2O_3	1·68
CaO	11.88
MgO	0·66
Na_2O	3·83
K_2O	0·08
	101·70

Subtracting the quantities of Fe_2O_3, MgO, and K_2O from the sum, and calculating the remainder up to 100, the following numbers are obtained:—

* According to Stelzner, the angle made by two systems of lamellæ, one parallel to the macropinacoid $\infty \bar{P} \infty$, the other parallel to the brachypinacoid $\infty \breve{P} \infty$, amounts to 86° 40′ in labradorite. By comparing the angular measurements of the two felspars, our felspar is found to have a remarkable coincidence as regards optical behaviour with that of Stelzner. Berg- und Hüttenm. Zeit. xxix. p. 150.

† "Ueber die Orientirung der Plagioklase," in Tschermak's 'Mineralogische und petrographische Mittheilungen,' iii. p. 186.

‡ "Ueber die Verwendbarkeit einer Kaliumquecksilberjodlösung bei mineralogischen und petrographischen Untersuchungen," N. Jahrb. f. Mineralogie, &c. i. Beilage Band.

§ W. Knop, "Neue Methode für quantitative Trennung des Natrons und Kalis," Bericht der math-phys. Classe der k. sächs. Gesellschaft der Wissenschaften, 1882.

SiO_2	56·38	Oxygen quotient		30·69	
Al_2O_3	27·80	„	„	12·95	
CaO	11·96	„	„	3·42	} 4·42
Na_2O	3·86	„	„	1·00	
	100·00				

The oxygen ratios are 7·10 : 3 : 1·02, or approximately,
7 : 3 : 1.

The oxygen ratios would correspond to the following theoretical chemical composition :—

$$\tfrac{1}{2}Na_2O+\tfrac{3}{2}CaO+2Al_2O_3+7SiO_2=Na_2O+3CaO+4Al_2O_3+14SiO_2.$$

Calculating this in percentages, we have the following :—

SiO_2	56·83
Al_2O_3	27·61
CaO	11·36
Na_2O	4·20
	100·00

On comparing this analytically obtained result with Tschermak's theoretical composition of the plagioclase group, it is clear that our felspar approximates to a mixture of three molecules of albite with four molecules of anorthite, which gives the following percentages :—

SiO_2	53·6
Al_2O_3	29·8
CaO	11·7
Na_2O	4·9

The felspar in the Japanese augite-andesites is therefore labradorite. This labradorite is characterized by its large amount of silica and small quantity of alumina. The soda and lime approximately agree with the theoretical numbers.

Experiments in accordance with Bořický's method by treating thin sections with a few drops of hydrosilicofluoric acid, afford a large number of monoclinic or spindle-shaped crystals of calcium-silico-fluoride ($CaSiF_6+2H_2O$); but a comparatively small quantity of short hexagonal prisms of sodium-silico-fluoride (Na_3SiF_6) were likewise formed; so at all events this plagioclase belongs to the soda-lime felspars. It often exhibits the "progressive" zonal structure described by Höpfner *, and this is especially well marked in the brachypinacoid $\infty \check{P} \infty$. The optical behaviour of the inner and outer zones is not the same. In reference to the zonal structure the direction of extinction makes a greater angle by from 6° to 10°

* "Ueber das Gestein des Monte Tajumbina in Peru." N. Jahrb. 1881, ii. Band.

in the inner zones than in the periphery, indicating that the central portion is more basic than the external.

This optical peculiarity may be partly due to another cause. Usually the zonal layers strictly follow and run parallel to the contours of the crystals; but here and there the nuclear crystals are bounded by entirely different faces. It may possibly be that in this case the outer and the inner portion of a crystal are not parallel. If this be the case, then the crystal-nuclei must consequently show the extinction in another direction, and these differences ought not to be exclusively ascribed to chemical discrepancies.

Under the microscope these thin felspar-sections are usually seen to be stripped away in the centre; this is due partly to the decomposed state of the centre, the latter being easily obliterated in polishing and slicing, while the surrounding parts remain intact. These facts tend to show that the two respective zones are either different in chemical composition or in the molecular arrangement of the substance of the felspar.

The plagioclase is tolerably rich in microscopic interpositions, whose arrangements are diverse, viz. central, peripheric (very seldom), or in the intermediate zone between the exterior and the interior, or, lastly, without any order. They consist of granules of augite, fragments of felspar with twin lamellæ, magnetite grains and crystals, bluish crystallites (probably augite?), iron-glance, trichites, hyaline and semihyaline enclosures, and stone-cavities.

It is worth while here to remark that the more recent eruptive rocks are in general free from liquid-enclosures with spontaneously moving bubbles; but in the plagioclase of Japanese augite-andesites they are not rare, as for example in the andesites from Tšiogigahara, Ihama, Yawatano, &c. The same is the case in the augite of our andesites. The liquid in the enclosures appears to be water, the bubbles not being apparently affected by a slight application of heat.

The glass in the enclosures differs both in colour and in physical properties from that of the ground-mass; the enclosed glassy basis is sometimes devitrified and no longer isotropic. The felspars are often grouped in a confused manner; they are variously bent and cracked, owing to mechanical disturbances while flowing in a once semi-fluid magma.

Sanidine.—This occurs, in thin slices, mostly in square, rectangular, or broad irregularly shaped forms. The crystals are either simple or twinned. Sections of the orthodiagonal zone show the extinctions which coincide with the orthodiagonal axis and with the plane of symmetry. Sanidine occurs only in subordinate amounts, or is even entirely absent in many cases.

Augite is the second essential mineral component, and it claims our special attention on acccount of its many peculiarities. It occurs in these andesites as grains, as rounded fragments, or in the form of well-developed crystals with the combination of $\infty \bar{P} \infty$, $\infty \breve{P} \infty$, ∞P, P, in which the pinacoids are well developed at the expense of the prisms. The prismatic faces are, as a general rule, unequally developed, one pair being much broader than the other.

The augites in all hitherto-examined specimens are decidedly pleochroic:—

C=deep green; A=light green; B=brown; c : C=44°–48°.

A basal section always presents traces of the characteristic cleavages which intersect at about 87°. Simple as well as multiple twins are of common occurrence, and the polysynthetic twins display brilliantly banded polarization-colours similar to those of the twin lamellæ of plagioclase.

It is a very singular fact that the triclinic (?) nature of the so-called monoclinic normal augite entirely escaped the notice of observers until W. Cross lately called attention to this point. Basal sections of twins of the common type exhibit always an oblique extinction, in such a way that the deviation of direction in the two halves is nearly 30° from the plane of composition. If the normal augite be really monoclinic, then this should not take place; but in all observed cases, it indicates the triclinic (?) character rather than the monoclinic. Ought this fact to be simply ascribed to an *optical anomaly*?

Another mode of twinning is also observed in the augites of the augite-andesite from Tšiogigahara and in the basalt from Komura, both in the Izu province. In the microscopic sections, the twinning-plane makes an angle of 18°—13° with the traces of cleavage in the augite crystals, and consequently this twinning should not be identified with that of the common type. The composition-face of the twins may be perhaps ∞ P̄ 2 *. Cohen † and H. Sommerlad ‡ have described similar twins in hornblendes.

Since the publication of the admirable work of M. Fouqué §, lithologists have been led to distinguish the pleochroic and non-pleochroic augites in augite-andesites as two distinct species of pyroxene, the former hypersthene and the latter the normal augite. Rosenbusch ||, in his well-known work, discussed this subject very critically, and he was led to the conclusion that these (pleochroic and non-pleochroic) augites are one and the same species of monoclinic augite, although he did not absolutely deny the presence of hypersthene in augite-andesites, but only considered it "überaus wahrscheinlich." Lately a few lithologists ¶ have taken up this

* H. Sommerlad observed similar twins in the augite of the hornblende-basalt from Liebhard, Germany; but, following the example of Rosenbusch, he supposed that the plane of composition of these twins might be a clinodome. N. Jahrb. f. Mineralogie, &c. Beilage Band ii. p. 147.

† 'Geognostische Beschreibung der Umgegend von Heidelberg,' Heft i. p. 69.

‡ "Ueber Hornblendeführende Basaltgesteine." N. Jahrb. Beilage Band ii. p. 150.

§ 'Santorin et ses Eruptions,' Paris, 1879.

|| 'Massige Gesteine, p.' 411.

¶ W. Cross, Bulletin of the United States Geological Survey, no. i. 1883, and Hague and J. P. Iddings, American Journal of Science, vol. xxvi. September, 1883; J. J. Harris Teall, Notes on the Cheviot Andesites and Porphyrites, Geol. Mag. Dec. ii. vol. x. no. 225, 1883; No. 226, 1883; no. 228, 1883; and on Hypersthene Andesite, *ibid.* no. 230, 1883.

subject again in support of the views of MM. Fouqué; and W. Cross has stated that the chief subdivision of the augite-andesites may more properly be called hypersthene-andesite.

The augites in the Japanese andesites show analogous phenomena in thin slices. As already mentioned, some are pleochroic and some are not, or, at most, very feebly so, even if pleochroism be really present at all.

The pleochroic sections extinguish the light parallel to the axis *c*, and at right angles to it, while the non-pleochroic ones have the oblique direction of extinction. The question whether the pleochroic and non-pleochroic sections belong to two species of pyroxene, will be elucidated by the following explanations, which lead us to the logical conclusion that they are one and the same species.

If a monoclinic augite-crystal be cut parallel to ∞ P̶ ∞, then its optical properties are identical with those of rhombic pyroxenes, and the pleochroism is very strong, because C = deep green, and B = brown or sometimes reddish brown. In fact it is just like hypersthene. In the clinopinacoidal section the pleochroism is very weak or scarcely noticeable, because C = deep green and A = light green. These light and deep green colours appear in an approximately clinopinacoidal section as a mixed green; but the extinction-direction determines at once whether the mineral belongs to the monoclinic or the rhombic system.

For the sake of experiment, an augite crystal was picked out of a rock collected in Yawatano and immersed in soft balsam. The orthopinacoid showed an intense pleochroism and optically behaved just like the rhombic mineral hypersthene, for which it is often taken; but the clinopinacoid was non-pleochroic, the extinction-direction was oblique, c : C = 43°. Relying upon these facts, this mineral, seemingly belonging to two species, appears to be one and the same substance, *i. e.* normal augite. The property of pleochroism, which has been made of critical moment in distinguishing hypersthene from ordinary augite, is a very doubtful one, since the intensity depends upon the thickness of the section; and also because hypersthene, in a very thin section, no longer exhibits pleochroism, although a clinopinacoidal section of considerable thickness exhibits tolerably intense pleochroism. The intensity of pleochroism depends sometimes upon a certain stage of chemical change in augite. If hypersthene be really present, its basal section would probably show a trace of the brachypinacoidal cleavage, which I have never seen in my slices. The chemical analysis given in the sequel shows 10 per cent. of CaO, which is hard to reconcile with the assumption that this mineral is hypersthene.

The never-failing accompaniments are the glass-enclosures with or without fixed bubbles, which are arranged parallel to the longitudinal axis. In some augites the enclosed glass is brown, although no such glass-basis is present in the ground-mass. Augites, poor in longitudinal fissures, are rich in glass-enclosures, and *vice versâ*. This fact indicates that the presence of the one precludes the development of the other. Light reddish brown, grey or colourless apatite crystals also occur in the augites. Fragments of polysynthetic felspar, colourless microliths (augites?), and octahedra of magnetite occur as microscopic interpositions.

In rare cases, well-developed augite crystals are enclosed by a border of opacite aggregations. In the hornblendes of eruptive rocks such aggregations are by no means rare, and lithologists are in the habit of laying particular stress on this point as being characteristic of hornblende in contradistinction to augite when both minerals occur in the same rock. As yet only one such occurrence is known to me.

Pabst * was the first to mention this peculiarity, which he observed in augite-bearing hornblende-andesite from Kurokami Dàke, Kiu-Siu. Augite crystals are at times completely bordered by augite granules, forming a special zone, which zone, however, causes no departure from the original crystallographic outlines.

The granular wall is affected by the action of polarized light in a less degree than the central mass, but the optical orientation is just the same, both in the external wall and in the inner augite substance. Dölter and Hussak recently made the experiment of smelting dark green augite from a hornblende-andesite from Greenwood Furnace, North America. The smelted augite was changed into small light-brown grains, the optical characters of which remained unchanged. Our augites also seem to have undergone a partial smelting, and consequently the formation of granules is restricted to the periphery.

The individual crystals are, in general, strongly developed in the clinoaxial direction, a, and the glass-enclosures interposed in the plane parallel to that direction are flat. In the clinopinacoidal section the glass-enclosures appear rounded or oval, with air-bubbles; few, however, attain a moderately large size (0·03 millim.). When viewed from the orthopinacoidal face under low powers, the glass-enclosures appear as black rods. By employing high powers, and especially by moving the micrometer-screw, the black rods are seen to be really transparent, and they represent the side view of the flat glass-enclosures which are arranged parallel to the clinopinacoid. Lamellar structure, so common in the basaltic augite, appears to be absent in these crystals. The larger augite crystals are grouped together in the most varied manner, sometimes in stellate forms, at others two individuals form cross twins, which intersect at an angle of 79°. Perhaps this may be the twin whose composition-face is the hemidome $-P \infty$ (Naumann-Zirkel, 'Mineralogie,' 11te Auflage, p. 604). These twins can be best studied in the augite of the augite-andesite from the Miogi-San, Kozuke province.

An analysis of the pleochroic augite from Ihama in Izu, the material of which was isolated by Thoulet's solution, gave the following results :—

* 'Untersuchungen von chinesischen und japanischen zur Porzellanfabrikation verwandten Gesteinvorkommnissen.' Inaug. Dissert. Leipzig, 1880. Also in Zeitschr. d. d. geol. Ges. xxxiii. 1880, p. 258.

SiO_2	....	53·26
Al_2O_3	....	4·01
Fe_2O_3	....	3·42
FeO	....	14·07
MnO	....	trace
CaO	....	10·15
MgO	....	14·65
		99·56

From the above, we get the following numbers :—

Si	....	24·85
Al	....	2·12
Fe	....	2·39
Fe	....	10·94
Ca	....	7·25
Mg	....	8·79

from which it follows :—

$$R : Si = 1 : 1{\cdot}19$$

$$\bar{R} : R = 1 : 12{\cdot}40$$

$$R + \frac{\bar{R}}{3} : Si = 1 : 1{\cdot}18$$

$$Fe : Ca : Mg = 1{\cdot}02 : 1 : 2{\cdot}03$$

By the Thoulet solution, the augite and magnetite could not be separated from each other, the specific gravity of both being higher than that of the solution. The larger grains and crystals of magnetite were separated from the mixture by the magnet; but those which were enveloped in the augites and small granules attached to them could not be separated. The high amount of sesquioxide of iron in the analytical result should perhaps be attributed to this cause.

From a chemical point of view, this augite has the closest relation to diallage.

Magnetite, of primary as well as secondary origin, occurs in large quantity and constitutes one of the essential ingredients of the rock. It is found either in grains or in octahedra, and the augite is never free from its presence.

Magnetite is large in its dimensions in proportion as the other constituents are also large, but is inversely proportional in the perfection of its crystallographic form; that is to say, the coarser the other constituents the larger is the size of the magnetite, but the more imperfect it is in its crystallographic form.

Secondary magnetite (in contradistinction to the primary) originates from the decomposition of augite together with quartz and calcspar, and this magnetite, as well as that of primary origin, passes by decomposition into limonite.

Quartz occurs in the quartz-bearing augite-andesite in the form of grains and never in well-developed crystals. Glass-inclusions are tolerably abundant, and at times exhibit the hexagonal form of quartz. These glass-enclosures contain fixed bubbles, and also black rods which radiate from the centre to the periphery like the spokes of a wheel. The augite-andesite from Hošio contains quartz, which looks apparently homogeneous, but is really composed of many fragments of quartz crystals intimately united, each fragment in its optical behaviour being quite independent of the others, so that under polarized light the aggregate appears as a mosaic.

The quartz grains are free from liquid-enclosures, while in the felspars they are common. When both quartz and felspar occur together (as is usually the case), then the presence of liquid-enlco-sures in the one and their absence in the other make a striking contrast.

Quartz of secondary origin is by no means rare, and usually fills up the vacant spaces in the ground-mass. In this quartz numerous radially arranged air-bubbles occur. The general appearance is like that of fibrous chalcedonic concretions with vivid chromatic polarization. Secondary quartz arises from the decomposition of augite and partly from infiltration of silica.

Hornblende is very rare in these andesites. When it does occur its basal section is six-sided, being surrounded marginally by opacite. The latter is so arranged as to preserve the contours of the characteristic section of hornblende, the trace of prismatic faces making an angle of about 124°; and by these contours alone the original form is recognizable.

It is usually supposed that this opacite may have been produced by the caustic action of the rock-magma before its solidification, and that it is not due to subsequent decomposition. Zirkel * was the first who advanced this view, which has been partly confirmed by the experiments of A. Becker †; but nothing definite has been settled from his researches.

The opacite margins appear under low powers as heaps of grey grains mixed with some black granules. Where the accumulations are thin enough and magnetite grains are scarce, the microscope shows that the grey substance consists really of yellowish-brown granules. These yellowish-brown particles seem to me to be an augitic mineral, and by their colour and general habit they could not be distinguished from the augite-grains found in the ground-mass. In favourable cases these augite-granules can even be optically investigated, the columnar crystals in sections parallel to $\infty \mathrm{P} \infty$ extinguishing the light at 36° from the axis C., and they certainly belong to the pyroxene group.

As is well known, augite contains more lime than iron, while in amphibole the reverse is the case. During the act of transformation (probably induced by the caustic action of the once semi-fluid

* "Ueber d. kryst. Gesteine längs d. 40 Breitegrade in N. A." Ber. d. k. sächs. Ges. d. Wiss. 1877, p. 181.

† Neues Jahrb. f. Mineralogie, &c., 1883, ii. "Ueber die dunklen Umrandungen der Hornblenden und Biotite in den massigen Gesteinen."

magma and not by decomposition in the ordinary sense of the term used by Oebbeke) the iron in the hornblende becomes separated as magnetite or as some silicate of iron, and the residual substance will contain a higher percentage of lime in proportion to the decrease of iron, so that the resulting substance will have approximately the composition of augite. Oebbeke * says that when hornblende is for a long time strongly ignited, it becomes dark brownish-red, a change due perhaps to the oxidation of iron, while augite remains totally unaffected.

Mitscherlich, Berthier, and G. Rose † have shown that fused amphibole, in solidifying, crystallizes in the pyroxene-form, while pyroxene reassumes its original configuration. Höpfner ‡ and Oebbeke § share the same view. Therefore the transformation of hornblende into augite appears by no means surprising. The experiment made by Dölter and Hussak || corroborates this fact.

In addition to the augite-grains magnetite also occurs in the opacite margins, being sometimes sufficiently abundant to form pseudomorphs after hornblende. In other cases hornblende undergoes another mode of decomposition, and assumes a fibrous structure, in which condition it bears a great resemblance to enstatite. The fibrous hornblende is pleochroic. C = dark green. B = brownish green. A = light green. C > B > A. c : C = 17°.

Enstatite occurs only in a few andesites. It is found in rectangular sections, the colour being green or brown. It exhibits fine rectilinear striations and is distinctly pleochroic. C = sea-green. A or B = reddish brown. This rhombic pyroxene of course extinguishes the light parallel to the crystallographic axes. Besides the vertical striations, the enstatite is irregularly crossed by transverse veins. Very fine silky asbestiform fibres (chrysotile?) pass at right angles from these veins, along which decomposition has commenced.

This enstatite contains colourless needles and grey rounded crystals in great abundance.

Apatite.—Though not present in large quantity, apatite is, however, widely distributed, and may perhaps be ranked as an essential ingredient of andesitic rocks. In these it occurs in the form of crystals with rounded edges, and never shows a finished crystallographic form. Apatite is usually grey, brown, or almost black, these various tints being due to microscopic interpositions of cylindrical pores and opaque rods, which are mostly grouped in the centre of the crystals.

In one specimen the apatite contains an apatite microlith, showing the combination ∞ P, P, OP; and in another are liquid-enclosures with vibrating bubbles.

The imperfect form of the apatite individuals may be due to a

* Neues Jahrb. i. Beilage Band, p. 475. "Beiträge zur Petrographie der Philippinen und der Palau Inseln."

† Naumann-Zirkel, 'Mineralogie,' 11te Auflage, p. 597.

‡ Neues Jahrb. i. 1881, p. 172. § *Loc. cit.*

|| N. Jahrb. f. Mineralogie, &c., 1884, i. Band, p. 25.

partial reabsorption of original crystals by the solvent action of the once semifluid rock-magma. Apatite belongs, no doubt, to the early-developed crystallized minerals, for the felspar-fragments enclose apatite and in turn the felspar is enclosed in the augite.

Tridymite, or the triclinic modification of crystallized silica, occurs in various hand-specimens, being always of microscopic dimensions. It fills up the vacant spaces left in the ground-mass, and is consequently of a somewhat later origin, except in the case of the andesite from Hoŝio, in which tridymite is one of the normal constituents. It possesses the well-known hexagonal or rounded forms which lap one over the other, presenting the appearance of roofing-tiles. Tridymite is comparatively indifferent to the action of polarized light, and between crossed nicols it only transmits a faint blue light.

Scales of tridymite are always colourless, and the mineral possesses a vitreous lustre. Another morphological modification of it is found in the Japanese rocks, where the mineral is of a somewhat large size (0·4 mm.) and shows a fan-like twinning *. A horizontal view of the twinned crystals shows a deltoidal form with a line in the middle, bisecting the acute angle. This median line represents a trace of the joined faces of the twins upon one of the pyramidal faces, and the direction of maximum extinction lies at 17° on either side of this median line. The included angle measures 35°. Such twins are abundantly present in the rocks from the Izu-San.

Chalcedony occurs as a filling mass in various decomposed rocks, and is colourless or brown. It is made up of concentrically and radially arranged spherulites presenting faint cruciform figures between crossed nicols. By reciprocal compression, the spherulites assume polygonal outlines.

Other products of decomposition which deserve to be mentioned, are calcspar, epidote, and viridite. The first (*calcspar*) is found pseudomorphous after augite, and, partly, as a product of the decomposition of felspar. It occurs also in the clefts of fibrous enstatite, and in the veins of the rock-mass. Veins of calcspar are easily recognized by the rhombohedral cleavage of the mineral; also by its feeble chromatic polarization, and by the twinning striations which are caused by the entering and re-entering angles of $-\frac{1}{2}$ R. It sometimes contains fluid-enclosures with movable bubbles.

Epidote (secondary) is found in elongated grains in decomposed augites, forming tufts and irregular aggregates. It is of a deep lemon-yellow colour and is pleochroic. Its occurrence is always associated with that of viridite. Not only in augites, but also in decomposed felspars, yellow grains of epidote are met with, and these lead the observer to think that epidote may have been derived from felspars. Indeed, such an origin has frequently been assigned to it in petrographical literature. I think, however, that these epidote grains in the augite-andesite are derived from viridite, which often

* There is no doubt that these twins are the same which have been described and figured by Vom Rath (Poggendorff's Annalen, clii. tab. 1, fig. 1*a*). The twin-face is $\frac{1}{6}$ P, the mineral being taken as hexagonal.

fills up clefts in the felspars, and has been introduced as an alteration-product of the augite, and not of the felspars; that is to say, the epidote in decomposed felspars is of an authigeneous origin, but the viridite which generates the epidote is of an allothigeneous origin, in the sense of E. Kalkowsky.

The *viridite* to which I here refer is the chloritic or serpentinqous product of a decomposition of augite. It is sea-green or greenish brown, and consists of a very fine fibrous substance, the fibres being arranged parallel to the chief axis of the augite; at times the fibres form radial bunches from different centres, aggregations of which represent the pseudomorphs after augite. Viridite is very weakly pleochroic and displays aggregate polarization. It is partly soluble in HCl.

The ground-mass is mostly holocrystalline and microscopically phanerocrystalline. All the porphyritic ingredients recur in it, and this ground-mass is, indeed, a second and a different phase of the crystallization.

Hence the rock assumes a porphyritic structure. The felspar-microliths are lath-shaped simple crystals, or twins, possessing a hyaline lustre. The direction of the maximum extinction of the twinned microliths makes a smaller angle by 3°–4° with reference to the twin lamellæ, than that of the porphyritic specimens, and they are probably andesine or oligoclase. Optical verification is, however, very difficult on account of their minute size. These microlithic felspars of the ground-mass may differ in species from the porphyritic crystals, because the former (microliths) came into existence after the crystallization of the greater (porphyritic) felspar from a chemically different magma. Höpfner conjectures these to be a lime-soda felspar, and the porphyritic ones a soda-lime felspar.

Augite occurs in the ground-mass as grains or microliths.

Magnetite.—The primary magnetite is mostly found in well-developed crystals, while the secondary magnetite occurs in grains or as irregular masses. A glassy basis is rare; when present it is colourless or brown, sometimes devitrified, and contains trichites of all possible forms.

The ground-mass is of two kinds with reference to the genesis of the mineralogical components, the one of granitic, the other of diabasic structure; in the former the Mg-Fe-silicates crystallize out before the felspar component, in the latter the reverse is the case. In most cases, however, the structure of the ground-mass is of a granitic character.

Structural Variety and Individual Descriptions of Augite-andesites.

As I have already stated, the augite-andesites are obtained mostly from the Izu province, which lies south-east of the Fudji-San. This peninsula is a volcanic district, traversed from N.W. to S.E. by the Amagi range, the highest point being the Amagi itself (4700 metres above the level of the sea), a volcano with six plainly traceable craters, now dormant, the others having solfataras. The Omuroyama has a crater 200 metres in depth. All are well-shaped conical peaks. This district contains eleven thermal springs (41°–103°C.), one of which is the geyser of Atami.

The fundamental rock of this district is exposed only in one locality (Nasimoto), where beds of limestone are observed underlying the later eruptive rock, and these contain some remains of Foraminifera. These beds reappear at Simoda.

Volcanic tuffs of submarine origin fringe the coast and, occasionally, contain sharks' teeth, corals, and shells of Mollusca. This fossiliferous layer is found in the interior of the district at a considerable height (400 metres above the sea-level). The country has certainly undergone an upheaval at a comparatively recent date, as stated by Hahn in his work *.

The typical augite-andesite of the district is that from Ihama †. It is a dark grey and somewhat porous rock. Felspar (3 millim.) is the dominant porphyritic component. Augite ranks next to it and then magnetite. The composition is normal. The general properties of the mineral components have already been described; hence in the following pages only particular cases will be noted.

The felspar is fresh and hyaline (Tschermak's mikrotine), but variously bent and cracked, and the crystals are mostly rounded. It contains abundant glass-enclosures, steam-pores, colourless microliths, magnetite-grains, and trichites. Under high powers the oval or round glass-enclosures in the felspar are seen to contain very minute flat colourless bodies (K. v. Chrustschoff's discoliths) ‡. These are absent from the large felspar fragments enclosed in the augites, but abound in the liquid-enclosures with spontaneously moving bubbles. In a thin slice of the rock from the same locality I observed a felspar section which is twinned on the Baveno type. Its form is square and the trace of the twinning plane runs diagonally across that section. That this felspar is asymmetric, is evident, since the planes of the optic axis do not stand at right angles to one another in two halves of the resolved crystals, but make an included angle of 12°.

Augite is found in well-developed crystals in the combination ($\infty \bar{P} \infty$, $\bar{P} \infty$ $\breve{P} \infty$) with rudimentary faces of the prism and also pyramids. It is pleochroic and contains numerous glass-enclosures. Negative crystals with fixed bubbles occur, as well as liquid-en-clo sures. Biotite is present in small flakes of a brown colour, and displays strong absorption. This is the only one of these augite-andesites which contains biotite.

The augite is brown or grey.

The ground-mass consists of a mixture of the lath-shaped felspar, small augite prisms and needles, and also magnetite grains. A peculiar arrangement of these produces the microfluctuation-structure

* 'Untersuchung über das Aufsteigen und Sinken der Küster,' Leipzig, 1879.

† Unless otherwise mentioned, all the localities of augite-andesites are situated in the Izu province.

‡ Tschermak's 'Mineralogische und petrographische Mittheilungen,' Band iv. p. 481.

around the porphyritic constituents. Traces of the brown glass basis are present in patches here and there.

The augite-andesite from Yagisawa is essentially similar.

The felspar is rich in rectangular glass-enclosures, and a basal section extinguishes the light at from 17° to 19° with P/M. The discoliths are typically developed in this rock. Iron-glance and hydrated iron-oxides are found in the porphyritic crystals and in the ground-mass.

The augite possesses well-developed pinacoids. The porphyritic augite as well as that of the ground-mass crystallizes out after the felspar. Apatite is rare, and there is no glass-basis.

Closely allied to the preceding is the rock from Toda. It deserves our special attention on account of the presence of tridymite, which is found in vacant spaces in the ground-mass, and consists of small hexagonal or rounded scales lapping one over the other like roofing-tiles. Another modification (page 441) also occurs associated with the former. Grey or brown apatite occurs in the augite and in the ground-mass. Iron-glance is plentiful in the augite and in the felspar. No glass-basis. The microfluctuation-structure is very distinct.

Another tridymite-bearing andesite is from the Izu-San. The external appearance is light grey. It is somewhat porous, and it has a striking resemblance to the ground-mass of the trachyte of the Drachenfels, on the Rhine. O. Kuntze has mentioned the occurrence of a trachyte between Odawara and Atami. It is very likely identical with that of the Izu-San; and if so, Kuntze's* trachyte would prove to be a true augite-andesite, for the Izu-San rock is made up of augite and plagioclase. The felspar looks glassy, is well striated, and poor in microscopic enclosures, but contains large isolated steam-pores. Sanidine is also present. Large porphyritic augite crystals are scarce and show a weak pleochroism. The colour of the augite differs in different parts of the same crystal. The one portion may be yellowish brown, while the other is deep brown; the latter has a glassy appearance. Light bluish apatite is not rare. A few hornblende sections are occasionally found with the characteristic opacite margins filled internally with yellowish-brown augite grains, which result from the alteration of the hornblende †.

The peculiarity of this rock is the abundance of its tridymite, which is found everywhere in empty spaces in the ground-mass, presenting a peculiar form of twinning ‡. The well-known aggregation of hexagonal scales of tridymite suggestive of roofing-tiles, is here entirely absent. The tridymite is colourless, with a bluish tinge by reflected light. The augites crystallize after the felspars. Patches of brown globular granulated glass-basis are found in the interstices between the lath-shaped felspars. The ground-mass is mostly made up of felspar microliths, and a few augite grains and

* 'Mitth. d. d. Ges. für Natur- u. Völkerkunde Ostasiens,' 7tes Heft, Yokohama, 1875, p. 30.

† *Vide* page 440.

‡ *Vide* page 441.

needles and magnetite grains. This ground-mass presents another peculiar feature; the interstices between the microliths are filled up with a colourless anisotropic substance, which has a striking resemblance to tridymite, and I consider this to be a crystalline form of silica. The chemical analysis gives the following result:—

SiO_2	69·10
Al_2O_3	16·32
Fe_2O_3	3·70
FeO	1·37
CaO	5·10
MgO	1·12
Na_2O	2·91
K_2O	1·06
	100·68 { Specific gravity 2·4556.

The large amount of silica may be ascribed to the presence of tridymite. Another locality of the hornblende-bearing augite-andesite is Funabara. It is similar to that of the Izu-San. Here the alteration of the horblende into augite grains can be more favourably observed than in the Izu-San rock.

The augite-andesite from Yawatano belongs to the dark grey porphyritic type. It has a brown glass-basis with trichites and augite, the latter with liquid-lacunæ. Apatite is not rare and shows strongly developed prismatic faces. A clinopinacoidal section contains a large number of oval glass enclosures (0·016 mm.) with fixed bubbles, which, when observed from the orthopinacoidal face, appear as black rods running parallel to the axis C.

The rock from Kitayama is a dark grey porphyritic andesite, and contains augite with granular augite borders of a deep brown colour. This singular structure is not the result of a simple adherence of the augite grains around the larger individuals, but that of an actual decomposition caused by the caustic action of the once semi-fluid magma*. The reason (so, at least, I suppose) for this assumption is that the granular wall behaves optically just like the inner main mass, or what is the same thing, the wall is optically the continuation of the inner augite mass. On the contrary, if the external wall were the result of the simple aggregation of irregularly arranged augite grains, then it it is most likely that the individual grains would behave in a manner optically independent of each other, which in this instance is not the case. No doubt this action took place after the crystallization of the augites, but before the solidification of the ground-mass. Apatite and the glass-basis are wanting.

In the Amagi-San rock the augite is changed into a dark green fibrous substance with pleochroic undecomposed augite kernels in the centre. Different stages of the decomposition can be easily traced; it commences from the periphery and from the cracks; the

* *Vide* page 437.

resulting mass is green and fibrous. When decomposition is further advanced, the viridite dwindles away and becomes entirely replaced by calcite, which then forms pseudomorphs after the augite. As augite in becoming viridite increases in volume by taking up water, so the dirty green fibrous mass pushes itself into the ground-mass everywhere and fills up the clefts in the felspar. Some apatite is present. There is no glass-basis. The following is an incomplete analysis of this rock :—

SiO_2	59·14
Fe_2O_3	11·85
Al_2O_3	13·64
CaO	8·96
MgO	3·14

Specific gravity 2·5764.

In the rock from Kasiwada the augite is completely decomposed and represented by hydrous sesquioxide of iron. Porphyritic augite is scarce, but the ground-mass is exceedingly rich in augite grains and microliths. The felspar precedes the augite in crystallization. This augite-andesite possesses a diabasic character, that is to say, the crystallization of the Mg-Fe-silicate has generally taken place later than that of the components poor in iron, viz. felspar and its vicarious components. This holds good both for the porphyritic constituents and for the ground-mass. The interstitial spaces of the ground-mass of this rock are filled with a bottle-green devitrified substance which is but partially isotropic. The rock is traversed by veins and secretions of calcspar and chalcedony. The former is easily soluble in hydrochloric acid, leaving a skeleton of chalcedony behind in the veins.

The rocks from the Fusiwara pass * and also from Yawata † are exceedingly rich in specular iron. In the latter the plagioclase is irregularly broken and indented. Light reddish-brown or grey apatite is tolerably abundant.

The augite-andesite from the Miôgi-San in Kozuke has been concisely described by R. v. Drasche ‡. J. Rein §, in his work, called it a dolerite, and in another place a doleritic lava ||.

It is a brownish grey coarsely porphyritic rock consisting of augite, plagioclase, and magnetite, but no olivine; it is therefore not a dolerite, although its structure is doleritic. The augite crystals are strongly pleochroic and rich in specular iron. The augite forms the cross twins, whose composition-face will be most likely —P̄ ∞. The felspar shows few polysynthetic lamellations, but has a beautifully zoned structure. The ground-mass is holocrystalline, being a mixture of lath-shaped felspar crystals and augite microliths together with magnetite. The rock from the

* In the province Izu. † Kai.

‡ Neues Jahrb. 1879, ii. p. 41.

§ Petermann's 'Geographische Mittheilungen,' Ergänzungs-Heft 7. Der Nakasendo, p. 33.

|| 'Japan,' Band i. p. 47.

Usiú pass opposite to the Miôgi-San was analysed by O. Korschelt*, who obtained the following results :—

SiO_2	55·75
Al_2O_3	20·42
Fe_2O_3	6·44
CaO	8·33
MgO	3·79
Na_2O	5·74
K_2O	1·90
	102·37

The rock from Kanatake, in the province Kozuke, has a black glassy appearance and resembles that from Podhrad in Hungary. Under the microscope the ground-mass is seen to consist of glassy plagioclase in lath-shaped crystals, augite and grains of magnetite imbedded in a coffee-brown glass-basis very rich in augite belonites. The minute acicular bodies and spicular forms are gathered together in confused aggregations, and in some instances large augite microliths are bordered by incipient crystals forming plumose tufts like the feather of an arrow; the glass-basis around them is decolorized. In the rock from Kimimasu the components are of the normal type, except that the ground-mass has a spotted appearance caused by the irregular distribution of the glass leaving white spots in the mass. The spots are due to the aggregation of almost colourless, very minute augite microliths and a few felspar crystals. The remainder consists of the brown glass-basis with a few augite microliths.

Enstatite-andesites.

One of the enstatite-andesites occurs in Kokaze in Izu. It is a blackish-green rock and coarsely porphyritic. Enstatite, plagioclase, and augite are porphyritically imbedded in the ground-mass. The enstatite is not fresh, and consists of a green fibrous substance, the fibres lying parallel to *c*. It is dichroic; parallel to *c* it is sea-green; normal to *c*, reddish brown. Extinction is parallel to the crystallographic axis. Apatite with liquid-enclosures occurs in this rhombic pyroxene, and calcspar in the lenticular interspaces between the fibres of the enstatite. Pleochroic, fresh, monoclinic augite is present, and also plagioclase. The ground-mass consists of felspar and augite microliths with a little magnetite, which by their arrangement show the so-called microfluctuation-structure.

Another enstatite-andesite occurs in Nawatši. It is of a dark colour and contains the columnar enstatite; it is of the same character as that just described. When the enstatite is further decomposed, the fibrous substance is removed and is entirely replaced by calcspar. The latter is exceedingly rich in liquid-

* Transactions of the Asiatic Society of Japan, 1880. E. Kinch, "Contribution to the Agricultural Chemistry of Japan," p. 381.

enclosures with spontaneously moving bubbles. Augite and felspar, the latter with liquid-enclosures, are porphyritically imbedded in the ground-mass. Dark brown apatite is present.

The occurrence of rhombic pyroxene in augite-andesites seems to be rare. Hussak* found near Wiedena (east of Rohitsch) in southern Styria an andesite containing, besides monoclinic pyroxene, a mineral which is doubtless bastite. W. Cross † has mentioned the andesite from Buffalo Peak in Colorado as containing a rhombic augite which he considers to be hypersthene. A. Hague and J. P. Iddings ‡ have also found hypersthene-andesite at Lassen's Peak and Rainier, besides olivine-bearing hypersthene-andesites and hornblende-bearing hypersthene-andesite. Lagorio § found a rhombic pyroxene in certain andesites from the Caucasus. F. Becke ||, A. Wichmann ¶, and J. J. Harris Teall ** describe a few other occurrences.

Quartziferous Augite-andesites.

Quartz-augite-andesites are rare. Tschermak has mentioned one occurrence in Caucasia ††. Dölter ‡‡ has cited a few localities in Hungary, and Höpfner §§ in the rock from the Monte Tajumba in Peru. Tschermak is of opinion that here the quartz must have been formed before the solidification of the rock. The so-called quartziferous augite-andesite from the Andes |||| was afterwards proved to be false, although it contains 63–67 per cent. of silica, for no trace of quartz has been detected in thin slices of this rock. The high amount of silica must in this case be ascribed to its existence in the glass-basis in a latent state. I will here mention a few real occurrences of this rock.

The typical rock occurs in Hošio near the Arafune peak¶¶. It is pitch-black in colour and has a resinous lustre ; felspar (0·3 millim.) and augite are porphyritically imbedded in the ground-mass. Under the microscope the felspar and augite are generally seen to be rich in glass-enclosures and are irregularly bent and cracked. Quartz occurs in isolated patches in a rounded form and contains air-pores and glass-enclosures, the presence of which and their similarity to those in the felspar are strong arguments that the quartz is a primitive constituent of the rock. Tridymite occurs as usual in hexagonal scales, the aggregations of which form the lumps around which the felspar and augite-microliths assemble, showing at the same time a microfluctuation-structure. The tridymite appears to be a

* Neues Jahrb. f. Mineralogie (1880), i. 290.

† Bulletin of the United States Geological Survey, No. i. 1883.

‡ American Journal of Science, vol. xxvi. September 1883.

§ A. Lagorio, 'Die Andesite des Kaukasus,' Dorpat, 1878, pp. 18, 85.

|| Tschermak's 'Min. u. petr. Mittheilungen,' Band v. p. 526.

¶ *Ibid.* p. 38. ** *Loc. cit.*

†† 'Rosenbusch, 'Physiographie,' Band ii. p. 413.

‡‡ *Ibid.* p. 415.

§§ Neues Jahrb. f. Mineralogie &c. (1881), ii. p. 164.

|||| Zirkel, 'Die mikroskopische Beschaffenheit der Minineralien u. Gesteine,' p. 413.

¶¶ In the province of Kozuke.

primitive constituent of this rock. Hexagonal colourless apatite is pretty abundant, especially in the augite sections. The ground-mass consists wholly of a light-brown glass-basis with multitudes of microliths.

The rock from Sitaru contains quartz with hexagonal glass-enclosures, and glassy-looking plagioclase, both having abundant liquid-enclosures with movable bubbles. With a few exceptions, the augite is decomposed into viridite, and the felspar has also suffered a decomposition. Epidote grains and needles are plentiful in the decomposed augite. They have usually an intense yellow colour and are distinctly pleochroic. The ground-mass is holo-crystalline. Thirdly the rock from Kamifunabara also belongs to this group. Here the quartz grains are somewhat large (2 millim.) and rich in glass-enclosures. The latter show the hexagonal form of quartz and contain fixed bubbles and an amorphous opaque substance in the centre. The quartz is irregularly indented, forming bays and inlets; and the ground-mass is pressed into these spaces as in the quartz of quartz-porphyries and rhyolites. The rock-texture is coarsely porphyritic. The rock from Tsiogigahara is a dark grey porphyritic variety. The quartz occurs in grains and is rare. No glass-basis is present.

Hornblende-andesite.

Kamagawa, Kai province.

This is a dark-grey rock. The porphyritic ingredients are not so distinctly developed as in the augite-andesites. The microscope shows the mineral components to be hornblende, plagioclase, and magnetite, but neither augite nor apatite is present. The felspar is twinned and well developed, and contains liquid-enclosures. The pericline type of twinning also makes its appearance in this plagioclase. In the basal sections of the hornblende the characteristic cleavage is very distinct. The longitudinal columnar sections are seen to be made up entirely of fine fibres, which run parallel to the vertical axis, and black rods (or opacite) are interposed between them, causing the crystal to resemble enstatite; the oblique extinction on $\infty \mathfrak{P} \infty = 17°$. It is pleochroic, ranging from sea-green to reddish brown, or light brown. The hornblende is partly altered into epidote grains of a greenish-yellow colour. The ground-mass consists of lath-shaped felspar, hornblende needles, and magnetite octahedra, together with brown plates of hornblende showing a microfluctuation-structure. No glass-basis. Colourless apatite is plentiful.

Plagioclase Basalts.

Plagioclase basalts cannot be distinguished from augite-andesite except through the presence of olivine as an essential ingredient, and as these rocks occur closely connected with each other geologically, I was confronted with considerable difficulty in assigning a name to either, especially when the olivine is present in small quantity and in obscure forms. Taken as a whole, basalt is confined to the region near the crater of extinct volcanoes, and consequently appears younger than augite-andesite. These basalts may for the most part be regarded as dolerites, save a few glassy modifications—true basalt or basaltite.

Olivine is not found in great abundance in these rocks. It is always the first to decompose, passing into hydrous iron-oxide. Neither picotite nor chromite could be detected in these olivines.

Typical basalt occurs in Funabara. It is a uniformly crystalline, apparently homogeneous rock of a dark grey colour, in which the only macroscopically discernible ingredient is the olivine, in yellow patches. The microscope shows us a multiplicity of other ingredients. Plagioclase occurs in the small columnar form of simple crystals, and rarely in twins. In the twin crystals the direction of maximum extinction makes an angle of 15°–20° with the twin lamellæ. Broad tabular sections are rare. The felspar is partly soluble in HCl, the central portion being most easily attacked. Augite is most abundant and occurs in grains, possessing a yellowish brown colour, and showing no perceptible dichroism; it is free from enclosures except magnetite grains and felspar fragments. Its sections are usually six-sided, or it occurs in irregular grains, and all have suffered partial decomposition, being traversed by a brown rectilinear hair-like substance, which runs strictly parallel to the chief axis. The olivine contains many liquid-enclosures with movable bubbles. Magnetite octahedra are always enclosed in it, and when the olivine is fresh serve to distinguish it from augite. The magnetite occurs in well-developed crystals, which are larger than those usually found in augites. The globulitically-devitrified glass-basis fills up the interstitial spaces. The following is the analysis of this rock, the iron having been determined as Fe_2O_3:—

SiO_2	51·12
Al_2O_3	10·91
Fe_2O_3	21·89
CaO	10·32
MgO	2·41
Na_2O	3·74
K_2O	1·64
	102·03

Specific gravity 2·555.

The dark-grey dolerite from Amagi-San (Ômigutši) and from Išibe resembles those already described. The felspar is mostly decomposed in the central portion into a grey kaolin-like mass, while the surrounding portion remains quite intact. The augite presents no special characteristics. It shows a feeble indication of the variegated zonal structure. Olivine is found in crystals of various sizes, the largest being 3 millim; but these are rare. Small altered grains of it are widely distributed. Apatite is tolerably abundant as interpositions in felspar and augite. A colourless glass-basis occupies the wedge-shaped interstices in the ground-mass. The dolerite from Ihama also belongs to the preceding type; and that of the Asio Pass is characterized by containing olivine rich in glass-enclosures and trichites.

Basalt Lavas.

These are numerous, and are apparently homogeneous, black, slag-like masses, showing a striking contrast to the previously mentioned, dark-grey, porphyritic varieties, although the essential components are similar.

The typical one is the Ômuroyama lava. It is microporphyritic, containing plagioclase, olivine, and a few augite crystals in the ground-mass. The olivine is fresh but ill-defined; its periphery has a granulated appearance and a deep brown colour, due to the corrosive action of the once fluid magma. The crystals are free from glass- and liquid-enclosures. Magnetite is rare, being contained potentially in the brown glass-basis; the latter is full of globulites, and is partly devitrified into radially fibrous concentric bodies (felsosphærites), which transmit a faint light, like that in the anamesite from Steinheim in Germany*. The rock contains 56·31 per cent. of silica. In this lava, augite is the predominant constituent, and the interstitial spaces of the augite crystals are filled up with the brown globulitically devitrified glass-basis. The large augites are entirely composed of augite-microliths, which have been mechanically disturbed during the overflow of the lava from the volcanic funnel, so that these microlith aggregations assume fan-shaped or imperfectly radial forms. The felspar also contains large brown glass-enclosures with fixed bubbles. All of these conditions recur in every lava of the province of Izu, and serve to distinguish these rocks from dolerites. The olivine in the lavas is almost colourless, with a faint blue tinge, while in the dolerites it is greenish yellow. The specimens from Ômuroyama, Mimuroyama, and Itaru, are essentially the same as those before mentioned.

The pores in these lavas are round or oval, and walled by a deep brown glass-magma, which, in turn, is lined by a faintly coloured glass, which is not completely isotropic, owing to the strong tension to which it has been subjected at the moment of its solidification. By subsequent sudden bursting ("Spratzvorgang" of Reyer), during the cooling of lavas, these peculiar forms are disturbed. A perfect one is seldom seen in a microscopic section, being usually broken in the process of slicing. That the imprisoned gas-pores must have been suddenly burst open, is evident from the fact that the felspar-microliths have been broken at one end, where they come in contact with the margins of the burst bubbles.

The last of these rocks to be described is a glassy one from the Mount Amagi (Omigutŝi). It is an obsidian containing 74·327 per

* Zirkel, 'Basaltgesteine,' p. 145.

cent. of silica. The external appearance is black, homogeneous, translucent at the edge, and it possesses a conchoidal fracture. The microporphyritic ingredients are plagioclase, augite, and magnetite, the latter in octahedra. The asymmetric felspar contains abundant air-cavities and brown glass-enclosures. The augite occurs in well-developed crystals, and through the transparent glass-mass the crystallographic faces are distinctly visible. It occurs in the combination of $\infty P \infty$, $\infty P \infty + P \infty$, P, ∞P. The augite has a deep brown colour and is pleochroic and free from foreign interpositions. In the microscopic section many felsosphærites are present, bordered at their circumference by an anisotropic colourless substance. The glass-mass contains microliths with sharply pointed terminations (augite?), and these denote a microfluctuation-structure in the glassy paste.

APPENDIX.

Pre-Tertiary Rocks.

Granites.

The granite from Kinpozan, in the province of Kai, is a finely granular and uniformly crystalline rock, and is the matrix of the newly discovered tetragonal mineral, reinite ($FeWO_4$) of Fritsch. Under the microscope the felspar presents a fibrous or rather wrinkled appearance, although it is not so clear and distinct as in some granulites. The fibrous feature has been variously described by v. Lasaulx, Zirkel, Dathe, and Kalkowsky, and lately it has been very fully studied by Becke*. Under polarized light between crossed nicols the felspar mass is seen to contain an interposed substance, which in its optical behaviour differs from that of the enclosing felspar, and thus causes a peculiar aspect in the latter mineral. Looking more into details, this interposed felspar substance has the form of spindles which run parallel to each other. Under high powers, the lenticular bodies are seen to be traversed by many oblique fissures in the direction OP., and in these the maximum extinction is 18° with P/M, while in the enclosing felspar it is 6°. The extreme minuteness of the interposed substance does not allow an exact measurement, nevertheless the difference in the extinction-angles in the two felspars is beyond all doubt.

The basal section of the felspar mass presents, under polarized light, between crossed nicols, the so-called "eozoonal structure" caused by the difference in the index of refraction of the enclosing and interposed felspars. Where the basal sections of the chief mass could be examined, they were found to extinguish the light, as a rule, parallel to the edge P/M; but this is not always the case. Therefore whether the enclosing felspar be orthoclase or microcline yet remains to be solved.

Taking into consideration the optical properties † and general

* Tschermak's 'Mittheilungen,' iv. p. 107.

† Tschermak's 'Mittheilungen,' iii., M. Schuster, "Ueber die Orientirung der Plagioclase."

character above mentioned, it is very probable that the chief mass of the felspar may be orthoclase or microcline, and the imbedded spindle-shaped bodies a lime-soda-felspar; and the name microperthite* may fitly be applied to the interlaminated growth of these two sorts of felspars.

There are other sections of plagioclase in the thin slice, which do not contain these interpositions, and which frequently exhibit reticulated fissures parallel to $\infty \bar{P} \infty$, and $\infty \breve{P} \infty$. These are probably sections of microcline. Common orthoclase is also present, but requires no special mention. The quartz is the same as in common granites; it contains liquid-enclosures with spontaneously moving bubbles; and since the latter never disappear by slight warming the fluid is probably water.

The third essential ingredient is biotite. It is found in small laminæ, of a dark brownish-red colour, and possesses a peculiar nacreous lustre. The transverse section exhibits energetic pleochroism varying from pale yellowish brown, through brownish red, to black. Mica is not found in great abundance, consequently the rock has a light colour.

Tourmaline occurs in small prisms with indistinct terminations, and is intensely pleochroic, parallel to C, grass- or bluish green or black, at right angles to the latter deep brownish red. Another accessory ingredient is zircon. It occurs in grains or in long columnar forms in combinations of P, ∞ P, ∞ P ∞, and very frequently in ditetragonal pyramids. It is rare to find terminated crystals, the majority of them being imperfect or broken at one end. Often zircon individuals grow together one upon the other, the contact-face being P ∞, or P. Some of the columnar crystals are broken and faulted. The zircon is light wine-yellow or colourless, and possesses an adamantine lustre. Under polarized light between crossed nicols it exhibits yellow, violet, and green colours. It extinguishes the light parallel and at right angles to the chief axis. None of the zircon crystals are free from interpositions, the most common being transparent needles, which are arranged in a confused manner; but few of them are turbid or opaque. The nature of these microliths is unknown; some are found to be negative crystals of zircon with two or more bubbles contained in them.

Besides zircon, this granite contains another accessory ingredient, a peculiar kind of microliths. These occur in impellucid or, at the edge, slightly translucent or semitransparent pyramidal crystals, with sharply pointed extremities; the colour is deep brown. In order to isolate them, the granite powder was successively treated with HF and H_2SO_4, when the still undecomposed residue could be separated by Thoulet's solution. Eventually a minute quantity of these microliths together with zircon was obtained; but there was not sufficient material for a chemical analysis. The presence of zircon prevents even a qualitative test of these microliths. Viewed from above, the outline of these crystals is square, the side view is

* Becke, *loc. cit.*

an acute rhombic form which extinguishes light parallel to its diagonals. The square section becomes dark between crossed nicols, and remains so during rotation of the object-table. These minute crystals belong therefore to the tetragonal system. From the crystallographic form, the indifferent action of HF and other mineral acids, and the high specific gravity, they may be anatase. The crystal faces are not smooth, but possess a granulated appearance, and have a metallic adamantine lustre.

The plagioclase in the granite from Tamadare, Hitatši, is mostly decomposed, and is there in great part replaced by a pseudophitic decomposition-product. This secondary mineral occurs in undulating scales, which have a fibrous structure. The scales are, as a rule, so arranged that they make an inclined angle with the traces of the twin lamellæ of the plagioclase portions, which (traces) are still recognizable in some of the unaltered parts. The biotite is also not fresh, the margin from which the decomposition begins, becoming green in colour; and the final result is the production of colourless, non-pleochroic, wavy scales (sericite?). The latter could not be distinguished from the pseudophitic substance in the plagioclase. The extinction is parallel and at right angles to the folds of the scales. The altered biotite encloses tufts of yellow rutile needles, which show the sagenite arrangement.

The rock from Konaka, Hitatši, contains plagioclase of which the outer zone includes some quartz, which by its disposition gives rise to a micropegmatitic structure.

Besides zircon and rutile, titanite is also present; the latter has brownish-yellow sections with a rather rough surface, feeble pellucidity, and generally sharp cuneiform outlines. It shows fine striations in the shorter diagonal, in the direction parallel to the orthopinacoid or one of the orthodomes.

The quartz in the tourmaline-granite from Sai-Mura, Hitatši, contains enclosures of liquid carbonic acid. Some inclusions have a hexagonal form, and are of a tolerably large size (0·015 millim.). The bubbles disappear by a slight application of heat.

Quartz-mica Diorite.

The rock from Kamagawa, Kai, is coarse-grained, having a granitic appearance and consisting essentially of quartz, plagioclase, hornblende, and biotite, all equally well developed and visible without a lens. The plagioclase is found in coarse grains, extremely well striated and fresh, poor in microscopic interpositions, rich in liquid lacunæ. Besides the twin lamellæ of the albite type, twinning also occurs in the direction of the macropinacoid, making with the first an angle of 86°–87°. The maximum extinction makes 9°–13° with the twin lamellæ parallel to $\infty \bar{P} \infty$. The hornblende forms large plates, and its pleochroism is very distinct.

C = deep blackish-green. B = deep olive-green. A = oil-yellow. The hornblende and biotite have grown together in a peculiar manner, so that a section of the green hornblende shows layers of the intercalated brown biotite, and inversely, the brown-mica lamellæ contain hornblende individuals, indicating that they have crystallized at the same time.

Quartz is found in grains which are as well developed as those of the plagioclase. They are rich in foreign enclosures and full of liquid-lacunæ. The quartz also contains hornblende microliths, apatite needles, and numerous black "hairs," like the quartz in some tonalites of Southern Tyrol. These "hairs" in the quartz appear, under low powers, to be totally opaque; but high powers resolve them into light bluish-green pellucid thin plates. The extinction-direction of these plates is parallel to the longest side, and is 17°–20°. They probably belong to the amphibole group, and certainly cannot be identified with rutile, to which mineral these microliths have often been referred. Analogous interpositions are said to occur in the quartzite from Humboldt Mountain, Nevada *.

The biotite is found in large lobes having a peculiar pearly lustre. Apatite and the colourless microliths are found as interpositions in it. Zircon forms an accessory ingredient. It occurs in grains or in four-sided prisms with pyramids; the colour is yellow, the refraction is very strong. Sections display brilliant chromatic polarization. Tourmaline occurs in long needles, the pleochroism being very intense, ω dark green, ϵ deep brown.

Diorite-porphyrite.

Morisawa, Kozuke province.

This is a dirty-green rock. Viewed under the microscope, it bears a striking resemblance to that of Potschapel, near Dresden. Plagioclase and orthoclase are present in nearly equal quantity; the extinction-direction in the plagioclase makes an angle of 5°–8° with the twin lamellæ. Both of these felspars contain numerous empty cavities arranged in zones, in which the process of decomposition first begins. When the alteration is far advanced, the interior is entirely filled with colourless, somewhat fibrous scales, which, between crossed nicols, display intense aggregate polarization-colours. This substance is very like the pseudophite from Plaben, near Budweis, Bohemia †.

The hornblende is decomposed into viridite or, in other instances, filled with minerals of the carbonate group. The borders of the hornblende crystals consist of opacite together with epidote grains; and these are so arranged as to preserve the original contours of the hornblende crystals. The basal sections show the characteristic four- or six-sided figures. The longitudinal section is accompanied by linear aggregates of opacite. Large magnetite octahedra or grains are sporadically distributed in the rock. The rest of the rock mass is apparently a grey homogeneous ground-mass, which, between crossed nicols, transmits a feeble light and consists of

* Zirkel, 'Microscopical Petrography of the 40th Parallel,' p. 25.

† Described by R. v. Drasche, 'Min. Mittheilungen,' 1873, p. 25.

white grains or fibres which blend into one another, constituting a micro-felsitic matter.

Diabase.

Hinazuru pass, Kai province.

This typical diabase is a green finely granular crystalline rock, essentially consisting of clinotomous felspar (0·2 millim.), augite, ilmenite, and chloritic matter. Under the microscope the plagioclase, as is usual in diabase, is partially decomposed and is traversed by many oblique cracks, which are filled up with a green chloritic matter, while sometimes it is rich in pseudophitic decomposition-products. The extinction-direction of the felspar is 25°–35° with the twin lamellæ. Here and there unstriated sections are found, which may represent either a plagioclase-brachypinacoid or an orthoclase-clinopinacoid; but the presence of orthotomous felspar could not be made out with certainty.

Augite is found as an interstitial mass of grains or crystals between the felspar crystals. It may therefore have been crystallized out after the felspar. The rock consequently has the so-called *diabasic granular structure.* No well-developed augites are visible. The zigzag outlines of the augite are due to its occurrence between the felspar crystals. No trace of pleochroism is discernible.

Next in importance is the chloritic matter. It is green, yellow, brown, and always fibrous. In some portions the fibres are parallel, in others confused. Intermixed with the chloritic matter, we find many black grains with a grey decomposition-product (leucoxene); the black grains are most likely ilmenite. Apatite is wanting. The following is the analysis of this rock:—

SiO_2	50·22
Al_2O_3	19·41
Fe_2O_3	8·15
CaO	10·20
MgO	7·14
Na_2O	3·84
K_2O	1·20
loss on ignition	1·10
	101·26

Discussion.

The President, in speaking of the value of the paper, said that he had seen crystals of hornblende bordered by augite like those described by the author.

Mr. Teall remarked on the great value of the paper. The author's observations on the pleochroic pyroxene tended to confirm those made by Dr. Oebbeke on some rocks from the Philippine Islands. They did not, however, affect the existence of an important group of andesites in which a rhombic pyroxene occurred as the predominating bisilicate. Mr. Whitman Cross and others had not relied on pleochroism as a means of distinguishing the rhombic pyroxene, but on the fact that the majority of the longitudinal sections, irrespective of pleochroism, gave straight extinction. The mineral in question had also been isolated and examined, both chemically and optically, by MM. W. Cross, Iddings, Petersen, and himself, with results that clearly proved it to be a mineral of the hypersthene type. The existence of triclinic augite in association with this pyroxene had been practically given up by the author.

Mr. RUTLEY also commented on the value of the paper, and the interest attaching to the hornblende crystals partly converted into augite.

32. *On the* Serpentine *and associated Rocks of* Porthalla Cove.

By J. H. Collins, Esq., F.G.S. (Read January 23, 1884.)

Introduction.

These rocks were briefly described by me in a paper communicated to the Royal Geological Society of Cornwall, in the year 1879 *, as "much-contorted strata of slaty green and red serpentine and hornblende rocks in numerous alternations, all, however, having a strike to the N.N.E."

In the same paper I stated my belief that the whole series consisted of "highly altered Lower Silurian stratified rocks."

The Cove has been more recently visited by Prof. Bonney, and his remarks thereon were published in the Quarterly Journal of the Geological Society for February 1883. A brief reference is therein made to my paper, and the Professor considers that I have "completely mistaken the relations of the rocks to each other"†. I am glad therefore to be permitted to bring my views on this subject under the notice of the Society in sufficient detail to enable me to justify the opinions so distinctly controverted, so far at least as to show that the hornblende schist, serpentine, and other rocks described are distinctly interstratified, and that there is a real "passage" from one to the other. I am more especially glad of this opportunity, because the real question at issue is that of the origin of certain masses of serpentine rock, than which there are few more interesting or more important in the whole range of chemical geology. With much of what Prof. Bonney has written concerning the rocks of the Lizard district I very cordially agree, and I can from personal observation corroborate what he says as regards the present condition of the rocks; but when he goes on to say (*loc. cit.* p. 16), "There is *no appearance whatever* of a 'passage' (*i. e.* of the hornblende schist) into the serpentine," I think that he is entirely wrong, and that the rock specimens which accompany this paper will suffice to show that he is so‡. To me they seem veritable "passage" specimens, and similar ones may be collected by hundreds on the beach at low water.

Stratigraphy of the Porthalla Rocks.

The following distinct succession of different kinds of rock is observable within a space of little more than a hundred yards at the

* Trans. Roy. Geol. Soc. Cornw. vol. ix.

† The Professor continues "and not to add any thing to the work of De la Beche, *which he criticises.*" I hope it will never be thought improper for a local geologist well acquainted with a particular district to criticise the published statements of previous writers. In the particular case referred to, however, I have merely referred to the criticisms of other geologists on the views of Sir H. De la Beche, and intimated my concurrence with the very opposite ideas entertained by Prof. Sedgwick, Mr. W. J. Henwood, and Mr. Budge.

‡ These specimens are described in detail further on.

place referred to by the Professor and myself, a little to the east of the Cove :—

1. Crumpled shales and slates, sometimes containing veins and layers of quartz and flakes of mica.
2. Greenish slates of a talcose appearance.
3. Soft red shaly mudstones.
4. Red and green bands of serpentine, often passing into
5. Hornblende schist of the type characterizing the locality ("Pralla" or "Porthalla stone").
6. Pinkish or greyish granulite.

Of these rocks, No. 2 with No. 6 appear to represent Professor Bonney's "Micaceous group of the Archæan series," and No. 5 the hornblende group; No. 1 belongs to a different and much younger series; and No. 4, the serpentine, he regards as intrusive. I will now proceed to give my account of these rocks.

The slates and shales, as also the serpentine and hornblende schist, appear to me distinctly interstratified, the granulite as distinctly intrusive. The whole region seems to have been dislocated by numerous faults of at least two distinct periods, previous to which faulting it had been crumpled and contorted into numerous flexures, great and small.

The mutual relations of the rocks can only be seen by scrambling over the fallen masses at low water, or by struggling up over the broken cliffs, and even then only imperfectly. The coast is strewn for some distance with magnificent blocks of green serpentine, mostly of the kind represented by specimen C. These blocks are the purest in colour and the most solid of all the serpentines I have ever seen. They are mingled with great masses of the granulite which have fallen from above, and with numerous fragments of the hornblende schist. This rocky débris is present in such great quantity as to completely cover the foreshore in places, so as to hide the stratification to a considerable extent; but it is constantly being moved about by the waves, so that my repeated visits have afforded many opportunities of verifying the statements made above. These repeated visits have forced me to the conclusion that the whole of the rock series to the east of the fault mentioned by Prof. Bonney consists of stratified rocks altered *in situ* by a kind of selective metamorphism, as indicated by Sedgwick and insisted upon by Henwood and Budge (Trans. Roy. Geol. Soc. Cornw.), and not of stratified rocks traversed and disturbed by intrusive masses of serpentine, as supposed by Sir H. De la Beche, and now very strongly urged by Prof. Bonney.

I have represented upon the accompanying sketch map (fig. 1) what appear to me to be the main features of the coast geology from Nelly's Cove to Porthoustoe, including, of course, the special points in dispute. At Nelly's Cove (called Betsy's Cove by De la Beche), the rocks dip very steeply to the E.S.E.; they consist for the most part of dark shales, sometimes pyritous, and containing well-rounded pebbles of some still older fine-grained rock. There are a few bands of black

Fig. 1.—*Sketch-Map of the Porthalla District.*
(Scale 1½ inch to 1 mile.)

limestone exactly resembling those of Gernens Bay, and containing, in places, portions having an organic-like structure, the nature of which has not yet been determined; like the Gernens Bay limestones, they also contain minute fragments of Crinoids *.

These Nelly's Cove rocks are, in my opinion, certainly Lower Silurian, as are also the quartzites at the top of the hill (at Penare Farm a little to the N.W.) which were described by me in the paper already referred to as containing Lower Silurian fossils †.

Proceeding southwards from Nelly's Cove towards Porthalla, we soon reach some very siliceous conglomerates containing fragments of a rock which, both macroscopically and microscopically, resembles, and is in fact identical with, the "granulitic rock" of Porthalla. These beds seem to dip at low angles to the S.S.E., as shown in the map. They are succeeded by soft dark schists having nearly the same strike and dip, only a little more to the southward, which form low cliffs on both sides of Porthalla Cove. On the east side of the rivulet they extend up to the first fault, gradually, however,

* I believe that the specimen No. 733 collected by Dr. Boase "from Porthalla," which is now in the Museum of the Royal Geological Society of Cornwall, and which contains portions of an *Orthoceras* and other organisms, came from here (only half a mile from Porthalla), and not actually from the village or cove proper. I have searched there very narrowly without being able to find any limestone whatever.

† Trans. Roy. Geol. Soc. Cornw. vol. ix. (read Nov. 1879).

becoming more siliceous. All these beds I regard as newer than the rocks of Nelly's Cove and those immediately to be described, both the latter having a more considerable dip to the S.E. or E.S.E. They have probably been let down by a pair of faults.

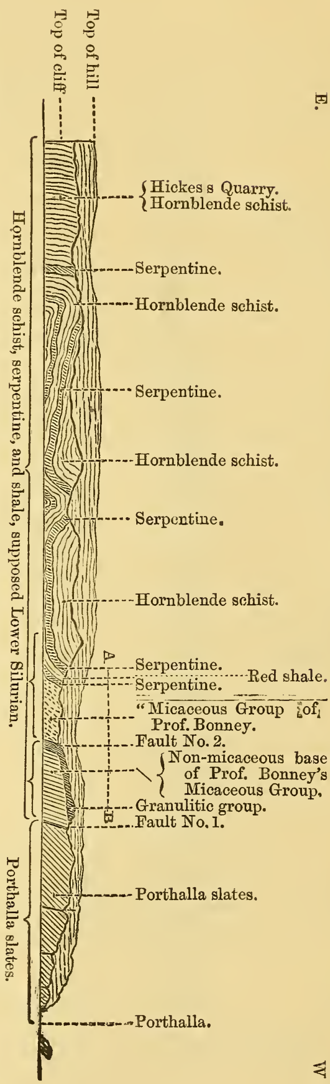
We now come to the tract which forms the main subject of this paper, extending eastward from "the fault" to Mr. Hickes's quarry, about ⅓ of a mile in all. This is illustrated in sections figs. 2 and 3. These rocks are considered by Prof. Bonney to represent the "Archæan" metamorphic series of the Lizard Head, which he divides into three groups, as under :—

The micaceous or lower group,
The hornblendic or middle group,
The granulitic or upper group.

He thinks he can identify here the "micaceous" group, containing in its upper part a stratum of granulite similar in character to the upper group, and also the middle or "hornblende" series, in which occurs the serpentine. This latter, he maintains, is decidedly intrusive.

Thus Prof. Bonney considers that two out of the three subdivisions of his Lizard Archæan series are represented here. To me the evidence seems all the other way. In the first place the rocks are very distinct, both chemically and mineralogically, as I shall show hereafter; of much greater importance, however, is the difference of strike.

Fig. 2.—Section of Cliffs near Porthalla, looking south. (Scale 16 inches=1 mile.)



The lower or "Micaceous Group" of the Archæan Series of Prof. Bonney is included within the region marked A........B, a distance of less than 200 yards.

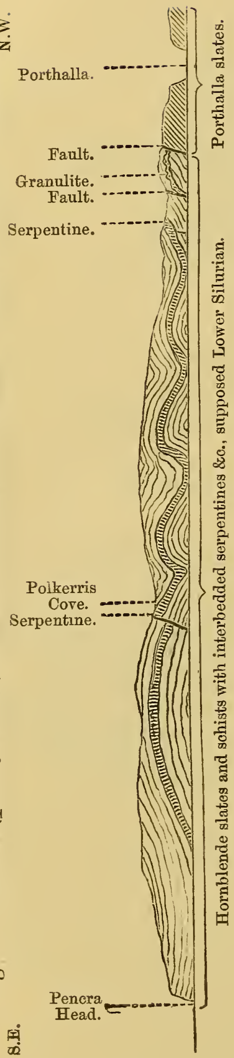


Fig. 3.—*Section (partly ideal) from Pencra Head to Porthalla.* (Scale 6 inches=1 mile.)

The general strike of the Lizard rocks referred to is a few degrees to the north of west, the prevailing dips being to the east of north. At Porthalla, on the contrary, the general strike is to the east of north, *i. e.* as nearly as possible at right angles to the direction of the Lizard rocks.

The band of granulite in the "micaceous group," which appears to Prof. Bonney to be a conformable bed of that series formed under similar conditions to the granulitic group of the Lizard, seems to me to be distinctly unconformable, and to have the character of an intrusive vein penetrating the "talcose" schists, as indicated in sections figs. 2 and 3. I believe, in short, that the Lizard rocks may be Archæan, but that those of Porthalla are of much later origin and most probably Lower Silurian.

The rocks beyond Hickes's quarry offer no special feature of interest. As already stated, they consist mainly of hornblende schist of the banded type interspersed with occasional bands of serpentine, the largest exposures of which latter are in the broken ground which succeeds the fault at Porthalla and in the little cove to the south of Polkerris. In the section fig. 3 I give an ideal representation of the country from Porthalla to Pencra Head, on a line which passes a little to the south of this cove. This section is given as the result of a careful examination of the country on several different occasions. It is, of course, partly hypothetical; but I believe it is in the main correct.

Veins of Gabbro.

These I have not yet seen in a perfectly satisfactory manner; but there are several bands of what I believe to be gabbro traversing the schist between the quarry and Dranna Point. I have examined the cliffs on several occasions, with the view of ascertaining the true nature of these veins; but the swell has always prevented me from taking the boat close up to the rocks. I have, however, repeatedly found on the shore, close to the quarry, loose masses of the schist, traversed by veins of undoubted gabbro. In appearance the gabbro does not seem to differ at all from the "Newer gabbro" of Coverack described by Prof. Bonney.

Detailed Description of the various Rocks.

I will now proceed to describe in somewhat more detail the more important of the various rocks as they succeed each other.

I have made analyses of nearly all the rocks referred to, and also prepared sections for microscopic examination. As regards their minute structure, I have little to add to the published descriptions of Prof. Bonney, except to remark that the serpentine differs extremely from that of Coverack and Cadgwith, and seems to me to be entirely destitute of any indication of the former existence of olivine.

The Slate.—This is the rock which forms both sides of the Cove, and through which the rivulet makes its way. On the north side it consists mainly of dark brown to black shales or mudstones, sometimes traversed by thin veins of calcite and others of oxide of iron. On the south or, rather, east side of the Cove, these rocks form low cliffs, generally pretty hard from the presence of innumerable veins or kernels of quartz, and occasionally spangled with minute shining plates of mica, especially near the faults to be referred to hereafter. As already stated, the dip of these beds is to the S.S.E., increasing from about 10° on the north side of the Cove to 50° or more on the east side near the fault. The strike differs but little from that of the "Ladock beds," which I consider to be Lower Devonian; and it is quite possible that these beds are of the same age. At any rate I agree with Professor Bonney in thinking them newer than the rocks on the east side of the fault.

The slates are traversed by a ferruginous fault or lode, which runs somewhat to the south of east, and dips to the west of south about 60°, as indicated on the accompanying map (fig. 1). This lode comes out on the shore in a little cove about 180 yards to the eastward of the Porthalla rivulet. It contains some concretionary masses of siliceous brown hæmatite, and has yielded a few minute crystals and grains of ilmenite *. In some places this lode-fissure has followed a "line of least resistance" between the "granulite" and the rock which it traverses. The lode may be followed along the shore near high-water mark for about 20 or 30 paces, the slate in its vicinity being very highly charged with siliceous matter, and very often exhibiting a brecciated appearance. It is then traversed "and heaved" by a fault running about N.E., and dipping very steeply to the south of east. At this point the lode contains very little oxide of iron; it is about 22 feet wide, as measured upon the beach, or perhaps a little more. The slates here are much contorted, that is, in the immediate neighbourhood of the fault.

Another fault, apparently parallel to that just referred to, and thus pretty nearly running in the strike of the rocks, exists a little further on. This may perhaps be assumed as the principal cause of the shattered condition of the rocks in the little cove immediately succeeding the "heave" above mentioned. It is no doubt "the

* The first and almost the only crystals of ilmenite which I have ever met with in Cornwall were sent me by Mr. Howard Fox, some twelve years ago, and came from this very lode at the point referred to above.

fault" referred to by Prof. Bonney as bringing up the rocks of the "Archæan Series" against the much newer slates, but which, as I think more probable, brings up the highly altered Lower Silurians against the equivalents of the "Ladock beds," which are, as stated, probably Lower Devonian.

"*Talcose*" *Slates* (Micaceous group of the Archæan series of Prof. Bonney).—In the immediate neighbourhood of the shattered rocks in the cove just referred to, may be seen a mass of greenish or brownish shales, very soft and apparently talcose, dipping steeply to the S.E. I say "apparently" talcose, because the greasy-feeling mineral is certainly not talc, the analyses showing that there is very little magnesia present. A little further on, as the serpentine is neared, these greenish and brownish shales pass into very soft red shales and mudstones, the change being evidently due to the peroxidation of the iron present. The following are analyses of the Porthalla rock, and of the Lizard rock which is supposed to be its equivalent. I have selected both specimens as being as far as possible typical in their respective localities:—

	Porthalla.		*Lizard.*	
Water lost in desiccator	0·15	2·80	0·10	0·85
„ at 100°C	0·00			
„ on ignition	2·65		0·75	
Silica		58·10		81·70
Alumina		21·33		10·40
Ferrous oxide	8·30			3·04
Ferric oxide	2·10			
Manganous oxide				trace.
Lime		0·72		0·40
Magnesia		1·15		0·70
Potash (with traces of soda)		4·60	Potash	1·33
			Soda	1·54
		99·10		99·96
Sp. gravity		2·77		2·612

It is obvious that these rocks are essentially different, whether they be of the same geological age or not.

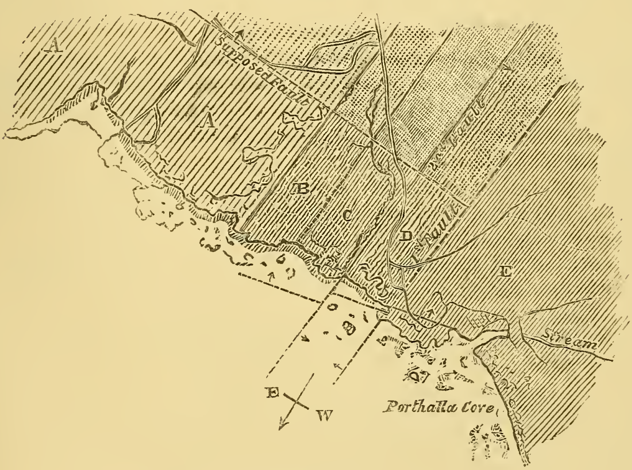
The Gneiss or Granulite.—In the upper part of the cliffs immediately to the east of the first fault, and extending as far as the broken ground which follows the second fault and somewhat obscures the first appearance of the serpentine, is a band or vein of granulitic rock (see specimen N). It consists essentially of nearly white quartz, pale pinkish soda-felspar, and a very little brown mica. Prof. Bonney regards this rock as a conformable bed of his micaceous series; but I must say it appeared to me much more like an intrusive vein, not coincident either in bedding or strike with either of the other rocks. It is not very easy to get up to this rock in the cliff face, but specimens are easily obtainable from the great blocks which strew the shore. I believe it is the same rock which occurs in large partially rounded masses in the conglomerate between Porthalla and Nelly's Cove; at any rate they are identical in appearance, both macroscopically and microscopically. They agree also in chemical composition, as will appear from the following analyses:—

	Rock near Fault.	Rock from Conglomerate to N. of Cove.
Water lost at 100° C. 0·06 } ,, on ignition 1·80 }	1·86	1·60
Silica	74·90	72·95
Alumina	10·20	11·50
Oxides of iron	4·94	5·15
Lime	1·12	1·62
Magnesia	0·72	0·31
Soda (with a trace of potash)	5·07	5·41
Loss	1·19	1·46
	100·00	100·00
Sp. gravity	2·681	2·69

The high percentage of soda (5 per cent.) in these rocks is somewhat remarkable, considering the very moderate proportions of alumina and lime. Nevertheless the "felspar" constituent, which is by much the more abundant, appears to be of the same kind that characterizes the hornblende schist of Porthalla. The rather high specific gravity and the almost total absence of "striping" in the microscopic sections of this rock, when viewed by polarized light, tell the same tale.

The Serpentine.—At a point about 60 or 70 yards to the east of the first fault, and succeeding the broken ground which marks the position of the second or great fault (fig. 4), is the first appearance

Fig. 4.—*Enlarged Plan of "Broken ground" near Porthalla Cove.* (Scale $\frac{1}{2000}$.)



A. Hornblende schist (No. 5).
B. Serpentine (No. 4).
C. Red and green shales and mudstones (No. 3).
D. Micaceous or "talcose" schists (No. 2).
E. Porthalla slates (No. 1).

of what appears to me to be a thin bed of *interstratified* serpentine. This lies between beds of the soft red decomposed shale just referred to, and after a few yards is succeeded by a much thicker bed. This second bed contains in its upper part thin bands of the hornblende schist, some of them exhibiting a perfect passage from one rock to the other. Succeeding this bed of serpentine, which is perhaps 40 feet thick, is a very thick mass of hornblende schist. All the beds at first dip sharply to the south of east, and afterwards they exhibit the great flexures shown in the sections, in addition to many minor curves. The whole series appears to me to be interbedded, each rock following closely the flexures of the other. The succession of the beds is best seen at and below high-water mark, as the cliffs hereabout are extremely ruinous, being traversed by numerous joints and minor faults. The joints are frequently lined with minute crystals of ilmenite or with crusts of calcite, and the little fissures are frequently filled with asbestos, calcite, or aragonite. Chemical action is still going on here to a considerable extent.

The great bed of serpentine is for the most part dark greyish-green, a few only of the bands being red. Many have a rich oil-green tint, others a granulated appearance, reticulated with thin bands of dark green.

Hornblende Schist.—The hornblende schist of Porthalla is a very peculiar rock indeed. It is very little fissile, the schistose structure being limited to a series of alternations of dark and light bands of its constituent minerals. These are as follows :—

(*a*) A dark green hornblendic substance of very indistinctly crystalline appearance, and which differs optically in a very marked degree from the ordinary hornblende of the Lizard rocks, especially in the absence of dichroism and of cleavage.

(*b*) A pale grey or cream-coloured uncleavable "felspar" of the kind known as saussurite, which has very little effect on polarized light, and which also exists in very undefined forms. In both these minerals there is a remarkable vagueness of outline, such as we might expect would result if the whole mass had been in a state of semi-fusion. The heat resulting from enormous local pressure such as these rocks have certainly been subjected to, would quite account for this indistinctness of outline in the constituent minerals.

The rock of course varies in composition as a whole according to the predominance of the dark green "hornblende" or the creamy white "felspar;" analyses showing the composition of the rock as a whole, and of each constituent separately, are given later on (p. 468).

At a distance of about a third of a mile from the Cove, the large quarry in massive hornblende schist known as Hickes's can be reached along the shore at low water. Beds of serpentine alternating with the hornblende schist can be traced nearly up to this point, and partaking of all the plications and contortions of this latter rock. On reaching the quarry, however, the strata seem to be nearly vertical; the serpentine plunges suddenly downward, and is seen no more for a considerable distance.

From here to Dranna Point the coast section can only be examined from a boat. There are several small coves or "zawns," excavated by the waves in the steeply inclined beds of serpentine for the most part, the projecting points and headlands being composed of the harder hornblende schist. In all there are, I think, five distinct bands of serpentine visible between the quarry and Dranna Point.

Analyses of the Serpentine.—The following Table shows the chief variations in composition of the serpentines of Porthalla. I add for comparison Mr. Hudleston's analysis of the black serpentine from Cadgwith (Q. J. G. S. vol. xxxiii. p. 925), from which it will be seen that there is no essential difference from a chemical point of view, whatever may be said as to their diversity of origin, and much as they differ microscopically*.

	a.	*b.*	*c.*	*d.*	*e.*
Water lost at 100°C............	12·82	0·46	0·55	1·85	12·35
,, on ignition.........		13·79	12·00	8·69	
Silica and insoluble	38·60	37·15	39·50	43·35	38·50
					1·37
Alumina............................	0·10	5·60	5·08	4·08	1·02
Ferrous oxide	11·55	8·80	8·12	10·74	4·66
Ferric oxide		1·10			3·31
Lime	trace	0·10	trace	1·51	1·97
Magnesia	33·62	32·80	34·65	28·43	36·40
Ferric sulphide	......	......	......	......	0·41
Nickel oxide	......	......	......	......	0·59
Alkalies and loss	3·31	0·29	0·10	1·35	......
	100·00	100·00	100·00	100·00	100·58
Sp. gravity........................	2·65	2·56	2·545	2·644	

There is nothing very remarkable about these results considered as analyses of rock-masses of serpentine. The first is somewhat more than usually charged with magnetic oxide of iron, of which many crystals are visible under the lens; while the second, third, and fourth contain unusually large amounts of alumina, traces, as I believe, of the original composition of the rock whose alteration has resulted in the production of the serpentine. The granular structure, I believe, tells the same tale.

Analyses of the Hornblende Schist.—Of course this rock varies greatly in composition according to the predominance of one or other of its chief constituents. Analyses are here given of a specimen of medium appearance (*a*), to which I have added for comparison analyses of the hornblende schist of the "Lizard" and of Pradanack, by myself and Mr. Hudleston respectively (*b*, *c*). Under *d* I give an analysis of the hornblendic constituent of the Porthalla rock, and under *e* of the felspathic constituent, each having been separated as carefully as possible before analysis. In *f* I have shown what would be the composition of a rock consisting of equal

* *a* is greyish-green and granular; *b* dark oil-green; *c* reddish-brown and granular; *d* dull dark red, all from Porthalla; *e* is from Cadgwith.

parts of *d* and *e*. It will be seen that this last column does not differ very widely from the composition given for the whole rock under *a*.

	a.	*b.*	*c.*	*d.*	*e.*	*f.*
Water lost at 100° C ...	0·48	1·30	1·50	0·51	0·10	2·69
„ by ignition...	3·40			3·20	1·50	
Silica	45·43	47·40	52·20	44·01	43·16	43·58
Alumina	19·93	19·30	12·10	11·95	28·50	20·22
Ferrous oxide	3·98	11·40	9·81	2·84	4·50	7·96
Ferric oxide...............	5·66		2·90	8·58		
Lime	11·98	11·80	12·20	10·51	17·08	13·79
Magnesia..................	9·34	7·75	7·17	16·15	2·84	9·50
Alkalies and loss.........	——	1·05	1·17	2·25	1·50	1·86
	100·20	100·00	99·05	100·00	99·18	99·60

The composition of the hornblendic constituent of this rock (*d*) is very nearly that of many pargasites, except that the proportion of peroxide of iron exceeds that of the protoxide. It has, however, none of the optical properties of pargasite, as it exhibits no distinct form or cleavage, either macroscopic or microscopic.

The felspathic constituent (*e*) is remarkably rich in lime, and also contains a good proportion of soda. Under the microscope it invariably shows the well-known clouded appearance indicative of incipient decomposition (kaolinization). To this very general incipient decomposition the low percentage of alkalies is probably due. The coloured bands regarded as characteristic of plagioclase are only visible in a very few places, and never very distinctly. Regarding the peroxide of iron present as replacing alumina, and the magnesia as taking the place of lime (except the minute proportion due to a slight admixture of the hornblendic constituent), the composition given in analysis (*e*) agrees pretty well with that required for anorthite according to the typical formula adopted by Dana, which requires—

Silica............	43·1
Alumina	36·9
Lime.............	20·0
	100·0

Even as it stands, the analysis is very near that of the anorthite from Neurode, analyzed by Streng and quoted by Dana under that mineral (no. 19) in his 'System.' It is the same "felspar" that was described by Prof. Bonney and analyzed by Mr. Hudleston (Q. J. G. S. vol. xxxiii. pp. 895–927). It appears to be characteristic of several of the rocks of the Lizard peninsula.

Description of the Rock specimens sent in illustration of the Paper.—An examination of the specimens exhibited in illustration of this paper will, I think, afford important information as to the manner in which these rocks have arrived at their present condition.

Specimen A.—A confusedly crystalline aggregate of dark green "hornblende" and light pinkish-grey and almost uncleavable "felspar" (saussurite), the latter forming, perhaps, 75 per cent. of the whole mass. The indistinctly formed crystals of hornblende are arranged in bands; but scarcely any tendency to split in the direction of these bands is noticeable generally, while across them the rock is extraordinarily tough. This may be taken as a typical example of the peculiar hornblende schist of the neighbourhood of Porthalla.

Specimen B.—This is like the former, but contains very much more of the hornblendic constituent. The foliation in this specimen would not be quite so distinct as in A were it not made more evident by the existence of a series of small contortions.

Specimen C.—A polished block of the rich oil-green serpentine characteristic of this locality. It exhibits a very distinct banded structure which Prof. Bonney regards as "flow-structure," but which I consider to be merely the traces of its former stratification. This view is, I think, confirmed by the fact that under the microscope the bands become less rather than more distinct.

Specimen D.—This is a partly unaltered hornblende schist of the kind resembling B, but traversed on one side by a succession of little veins and bands of true serpentine. The serpentine seems to have been developed on either side of numerous fissures or shrinkage-cracks, which are for the most part coincident with what I consider to be traces of the original bedding. At one place, four or five of these little stripes of serpentine have coalesced, so as to form a band nearly one inch wide, from which might be cut cubes of that size scarcely differing in appearance from the compact specimen marked C. Between the stripes of serpentine, however, the hornblendic and the felspathic materials remain almost unchanged, as is rendered evident to the eye by the want of polish of their surfaces as compared with the polish of the serpentinous portions in the same specimen. Even in these unchanged portions, however, if the slabs be viewed in certain positions, thin threads and specks of shining serpentinous substance are plainly visible throughout the mass. This specimen alone seems to me quite sufficient to prove that the serpentine here has been developed by molecular change from, rather than intruded into, the hornblende schist.

Specimen E.—Is much like D, but more largely hornblendic.

Specimens F, G, H.—Are similar, but mainly serpentine, the progress of the transformation being indicated by the reticulated bands and lines of darker colour.

None of the specimens D to H presenting an intermingling of hornblendic, felspathic, and serpentinous substance have been thought worthy of analysis, owing to their very heterogeneity; but it is certain that by careful selection of pieces a series of analyses could be obtained, giving every variation of composition between hornblende schist and pure serpentine.

Conclusion.

In concluding these brief notes, I would repeat, to prevent misapprehension, that while I do not deny that in some instances, even in the Lizard district, masses of highly basic and distinctly intrusive igneous rocks may have been altered into serpentine, yet, in this case, the evidence is altogether the other way. Careful examination of the cliff-sections affords evidence of stratification in the serpentine, both on the large and on the small scale, *i. e.* of the serpentinous change of stratified materials *in situ*; this conclusion is supported by the chemical analysis of hand-specimens, as well as by their macroscopical and microscopical appearance; it is paralleled by what Prof. Heddle has described of his observations in the Hebrides and Aberdeenshire *; while his theory, which is modified from that of Dr. Sterry Hunt, affords a full explanation of the manner of the change †. Furthermore, there does not appear to me to exist any reason for referring the numerous contortions which admittedly exist in the Porthalla rocks to the introduction of any intrusive mass whatever. It seems to me that it is begging the question to state that these contortions are due to the intrusion of the serpentine. Prof. Bonney does not, I believe, attribute the contortions to this cause, although Sir H. De la Beche clearly did; for he says "We find a mass of serpentine amid the hornblende slate between Dranna Point and Porthalla, on the north of the principal mass of serpentine, which has every appearance of having been thrust up among the hornblende slate, *twisting and contorting* the laminæ adjoining it in directions which we should consider consistent with the passage of the serpentine in a state of igneous fusion through them" ‡.

If it should be thought necessary to call in the aid of any such agent to produce the contortions in question, we have two intrusive rocks existing in the immediate neighbourhood, viz. the granulite and the gabbro. My own belief is, however, that the contortions were produced by an agency far more general, the same which has produced the axis of elevation of the south coast of Cornwall in the line of the Eddystone, and parallel to the general granitic axis of the Cornish peninsula.

My argument, that we have at Porthalla a "passage" from the one rock into the other is much strengthened by the fact that many such "apparent passages" are admitted to exist by all those who have examined the Lizard coast with any degree of detail—including Sir H. De la Beche and Prof. Bonney. De la Beche's description of that seen near the Lizard Town is as follows, and it would apply equally well to the others. "The hornblende slate," he says, "supports the great mass of the Lizard serpentine, with an apparent passage

* "Chapters on the Mineralogy of Scotland: iv. Augite, Hornblende, and Serpentinous change," Trans. Roy. Soc. Edinb. 1880.

† The discussion of this matter, originally contained in my paper, has been omitted by order of the Council.

‡ Report on Cornwall, &c., p. 30.

of the one into the other in many places—*an apparent passage somewhat embarrassing*," that is from his point of view; from mine, it is perfectly natural. He goes on to say, "Whatever the cause of this apparent passage may have been, it is very readily seen at Mullion Cove, at Pradanack Cove, at the coast west of the Lizard Town, and at several places on the east coast between Landewednack and Kennick Cove, more particularly under the Balk . . . . and at the remarkable cavern and open cavity named the Frying Pan, near Cadgwith." He goes on to say that at such places there is a good deal of calcareous matter, and a tendency to more red colour in the serpentine near its base than elsewhere*, and this is certainly the case at Porthalla also.

Finally, I cannot see any sufficient reason for referring these metamorphosed rocks to any Archæan series. I believe, indeed, that they are older than the rocks nearer the village (which there seems good reason, indeed, to regard as Post-Silurian); but, as I have said before, their strike and chief dip are the same as those of the Lower Silurians forming the greater part of the south coast of West Cornwall, and at present the evidence, such as it is, points to their being of the same age.

Discussion.

Professor Bonney said that it must be remembered that the rock in dispute was the one form of the many rocks bearing the name of serpentine, of which that at the Lizard was a typical example. Some general considerations Mr. Collins had failed to notice, which to him it seemed impossible to neglect in considering the question, viz. that there was abundant evidence that this kind of serpentine resulted from the metamorphism of olivine rock; that rocks of identical structure generally had but one origin; and that there was no well-authenticated instance of an olivine rock not igneous, for, even as a mineral, olivine was rare in sedimentary rocks. Further, it was idle to appeal to testimony which was not substantiated by the microscope. Coming, however, to Cornwall, we could not separate the Porthalla serpentine from that of the Lizard: what was the origin of the one must also have been the origin of the other. Now, if there were any signs which proved the intrusive character of a rock, these were exhibited by the serpentine of the Lizard. Further, it cut transversely across the ends not only of the hornblendic but also of the granulitic series. He asserted, however, that even at Porthalla the evidence was clear in several places. Mr. Collins had mistaken a serpentine in one case for a hornblende-schist, as might be seen by the specimen on the table. The streaky structure, if he would examine it microscopically, would be found to have nothing to do with bedding; and his asserted proofs were of the vaguest nature. As for the schists, the hornblende-schist of the Porthalla-Porthoustock district closely resembled that of the Lizard district; if the one were Archæan the other must be. The strikes over the two

* Ibid.

districts did not differ so much as Mr. Collins supposed. As a micaceous series in each case appeared below hornblende-schist, the speaker had supposed them identical. How the granite, which Mr. Collins supposed was intrusive in Lower Silurian, was to appear in a Lower Silurian conglomerate, he failed to see; also, why the absence of an overlying series need be explained; or why, if a bed showed just by a fault, it was therefore reduced in thickness. Mr. Collins's argument as to the non-identity of these micaceous schists at Polpeor and Porthoustock was misleading. He had selected a very exceptional rock from the one place, and compared it with one of a more normal type from the other. On such a method of arguing he would not comment in the author's absence.

Mr. Hudleston thought that Mr. Collins advocated something like the "transmutation" of the old alchemists. He asked how the alumina could be got rid of; it was most difficult to explain such a separation. The suggestion sometimes made that serpentine might have been formed by the alteration of gabbro, though highly improbable, was more likely than the idea of the change of hornblende schist into serpentine.

Prof. Seeley regretted the absence of the author, and cited certain cases of reputed changes of the same kind quoted by Gümbel in the Fichtelgebirge, by Zirkel in the Schwarzwald, and by other authors.

Mr. Teall stated that one of the best-authenticated cases of the formation of a substance having the composition of serpentine by the alteration of hornblende had been investigated by Weigand. It occurred in the Vosges. The serpentine, however, was associated with chlorite, in which the alumina, originally present in the hornblende, was doubtless contained. The microscopic structure of this serpentine was moreover very different from that of serpentine derived from peridotite. Other asserted cases of the formation of serpentine by the alteration of hornblende rocks had been recently investigated by Schultze, and always with the result that the true serpentines gave evidence under the microscope of having been originally olivine rocks. There were two questions involved:—one was the nature of the rock which by its alteration gave rise to serpentine, and the other was the relation which this rock bore to the associated hornblende-schists and gabbro. On the first point all recent observers were agreed that a serpentine showing under the microscope the net-like structure (Maschenstructur of the Germans) described by Prof. Bonney as characteristic of the Lizard serpentines had been produced by the alteration of olivine rocks. On the second point, however, there was by no means unanimity of opinion; and cases described by Kalkowsky in the Eulengebirge, in which olivine occurred as an accessory in the hornblende rocks and hornblende in the serpentines, appeared to show that sometimes the two rocks were very intimately connected.

Rev. E. Hill said that one of the serpentines of Porthalla is remarkably laminated; but he thought the lamination was due to the intrusion of the serpentine between the beds of hornblendic schist. Whatever doubt there may be about Porthalla Cove, where it is difficult to study the relation of the rocks, there are localities in the district in which the intrusion of the serpentine into the schists can be made out without the smallest possibility of doubt.

Mr. T. Davies regretted the absence of microscopic sections in illustration of Mr. Collins's paper. His own study of the question had led him to conclusions quite opposite to those of the author. He thought the Lizard serpentine showed under the microscope clear proof of its derivation from an igneous rock.

Mr. W. W. Smyth agreed with Prof. Bonney and Mr. Hill as to the clear evidence of the intrusion of the serpentine into the schist. At the same time there are undoubtedly points at which there appears to be an interlamination of the serpentine and the schists; but this is no proof whatever of transition from one rock to the other. He could not understand this transmutation taking place along narrow bands for hundreds of yards without the beds above and below being affected. He did not feel able to accept such disputable sections as those shown by the author as explaining the complicated relations of these two rocks in the Lizard district.

33. *On the* Recent Encroachment *of the* Sea *at* Westward Ho!, North Devon. By Herbert Green Spearing, Esq., M.A. (Read May 28, 1884.)

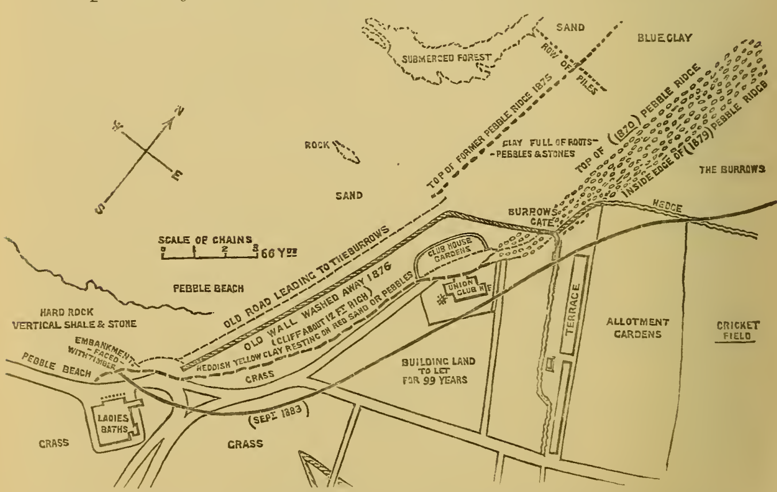
(Communicated by Prof. Prestwich, M.A., F.R.S., V.P.G.S.)

For the last nine years the sea has been encroaching on the land near Westward Ho! at the rate of about 30 feet a year. This encroachment only affects about a mile of the coast-line, but it is of special interest both on account of the formations which it exposes and the rapidity with which the sea has eaten into a district which had hitherto been apparently but little injured by it.

I have not been able to obtain any correct map of the district older than the parish map of Northam, and that does not give the actual limits of high tide with any accuracy, so that it is impossible to say how much further the land may have extended seaward when Westward Ho! was still unnamed and almost uninhabited. A very old inhabitant, however, told me that the grass used to extend for several yards beyond the old road leading from the ladies' baths to the Burrows, which was still in existence in 1875, when I first went to Westward Ho!

The accompanying map is reduced from one constructed from an

Map showing Recent Encroachments of the Sea at Westward Ho!



actual survey that I made in 1879, but the line of the top of the former ridge in 1875 was sketched in from memory, aided by the parish map.

The district which is principally affected by the encroachment is a large sandy common called the Northam Burrows. This common is the southern part of the delta of the united rivers Taw and

Torridge, and the inland part of it is rather below the level of the highest spring tides. All along the coast-line, however, there is a considerable area which is about 2 feet higher, and some of the sand hills near the mouth of the river are more than 30 feet above the general level. This coast-line is defended by a broad ridge of pebbles called locally "the Pebble Ridge." It is now about 50 yards wide, and the top is some 20 feet higher than the sandy beach, and about 7 feet higher than the level of the Burrows. It is said that its dimensions were formerly much greater and the pebbles also much larger *. The action of the waves seems to cause the pebbles to travel in a north-easterly direction along the ridge towards the mouth of the river, where they seem to be accumulating. Only a few rough experiments have been made on the subject, but the ridge is certainly much broader at the north-east corner of the Burrows, where there are three or four distinct banks of stones, forming altogether a bank about 150 yards wide and over a quarter of a mile long. The pebbles of the inland ridge are imbedded in the turf and covered with lichens.

It is equally certain that the ridge near Westward Ho ! is fast disappearing, and allowing the sea to encroach much more rapidly than it could formerly. It is not easy to account for this sudden weakening of a defence which has so long withstood the attacks of the immense Atlantic rollers and a tidal rise and fall of more than 30 feet. Various causes have been assigned, such as a gradual sinking of the land, a change of currents in the sea, and even the taking away of the pebbles by farmers and others to build their fences with. These may all have had some share in producing the change; but I am rather disposed to believe that it is chiefly due to a falling-short in the supply of pebbles from the west, where for a mile or more there are traces on the cliffs of one of the finest raised beaches in England. These "ready made" pebbles probably formed a pebble ridge on the adjacent sand soon after they were first attacked by the sea, and this ridge was gradually pushed backwards and sideways until it reached its present position.

There seems now to be quite a possibility that the sea may eat right through the lower part of the Burrows, and thus form a new mouth for the river, leaving the north-east part of the ridge as an island, or perhaps even washing it across on to the Braunton Burrows, which constitute the present northern half of the delta. The estuary has already made inroads in this direction at the Appledore or inland corner of the Northam Burrows; at one place a sand hill over 30 feet high, called the "grey-sand hill," has quite disappeared.

In Risdon's 'Survey of Devon' (published 1600–1630) it is said that a large heap of stones called the "Whibblestone," the burying-place of the Danish rover Hubba, had disappeared, owing to the encroachments of the sea. It is not quite certain exactly where this heap was; but at all events this seems to show that the

* Mr. Pengelly (Trans. Devon Assoc. for 1868) says of the pebble ridge—"It is also evident that its volume has been constantly diminishing, and is at present less than it has ever been before."

Appledore side of the estuary has for a long time been subject to erosion. If the river should thus form a new mouth, it would be of great importance to both Bideford and Barnstaple, as, although during the process the harbour entrance would be much injured, it would probably become much safer when all the accumulations at the mouth had drifted north-eastwards.

Of the formations that are exposed by the encroachment, one of the most interesting is a submerged forest which extends a distance of some 400 yards from the ridge to the extreme limits of low water, and probably further. It resembles ordinary English sunk forests in its composition; but in addition to the usual stumps, roots and branches of oak, birch, and hazel, it contains numerous animal remains, and in one place there are many flint chips and cores mixed with great quantities of the shells of oysters, limpets, periwinkles, &c. Some of the flints show that they have been exposed to the action of fire: a large piece of red oxide of iron was also found there.

The animal remains are chiefly ox, sheep, deer; but I have also found skulls of dog, pig, and goat. They were examined by the late Prof. Rolleston, and he considered the ox to be of an old type, similar to the Chillingham wild cattle.

The woody matter of the forest is, in places, some 18 or 20 inches thick; but generally only isolated roots are found. It rests on a layer of blue clay of varying thickness, but apparently thinning out seawards. Under the ridge this blue clay must be at least 4 feet through, and contains great quantities of estuarine shells. At low tide there are often several acres of it exposed, but it is getting very much worn away. The sea forms curious long deep furrows in it which are almost always at right angles to the waves.

This blue clay rests on a layer of unascertained thickness of rounded pebbles. This layer extends over a very large area; several hundred acres of it can also be seen at low tide near the mouth of the river, when it is covered with small patches of a shelly sandstone similar to the large stratified mass seen at the foot of the cliffs near Croyde, on the north side of the bay. It is so tightly packed that it is difficult to kick out a single pebble, and the larger stones are often split lengthwise.

But perhaps the most interesting deposits of all are those of which fresh sections are being continually made by the encroachments of the sea on the so-called building-land of Westward Ho! The frontage is not more than 200 yards, and in 1875 there was no vestige of a cliff to be seen, the pebble beach sloping gradually upwards from the sand to the fields. This thick bed of boulders has all disappeared, and now there is a steep clay cliff, which is about 12 feet high. Near the ladies' baths this clay rests immediately upon the hard rock (of the Carboniferous period) which crops out again in the hills above; but a few yards north, or nearer the burrows, a layer of sand of unknown thickness intervenes, and it is this layer of sand that has lately so much helped the sea in its work of destruction.

The long rolling waves have at high spring tides a tendency to scoop deep furrows in the pebble beach, of course at right angles to the shore-line; the layer of sand then becomes exposed at various points. The waves rapidly eat into this sandy layer; the clay is undermined and falls down in large masses, sometimes several tons in weight. This clay is then ground up by the ordinary tides, and thousands of tons have utterly disappeared in this way without forming visible deposits anywhere near. Curiously enough, this clay, when in suspension, seems to be carried just in the opposite direction to that taken by the pebbles, as on a rough day the discoloured water at ebb tide seems to drift westwards. The sand itself is rather large-grained, of a reddish-yellow colour, apparently containing no shells or other fossils, but with occasional concretions of black iron oxide, which are sometimes as big as a man's body.

Further east the bed of sand is mixed with clay and pebbles, and gradually merges into a thick and very uneven layer of water-worn pebbles, which sometimes extend within a foot of the surface of the field above. Still further east (where the Union Club House, built in 1875, used to stand) the sandy clay and rounded pebbles are mixed with many angular stones and penetrated with numerous roots of bracken and reeds, which seem to have grown in a thin layer of blue clay. This blue clay thickens rapidly towards the north and east, so apparently this is about the limit of the old estuary. The large pebbles lie generally with their longitudinal axis nearly due north and south; a great number of them are split lengthwise, and one half is then almost invariably pushed an inch or two beyond the other. I have never observed this in any other district, and am quite at a loss to account for it. Though the general appearance of this bed strongly suggests glacial action, I have not been able to find any scratched stones in it.

Just below the top soil, or below the blue clay in places, and resting on the sandy clay, are a quantity of nodules of oxide of iron, each about as big as a hazel nut; they extend apparently over a considerable area, sometimes forming lumps of several pounds' weight.

The thickness of all the layers varies very much at different points, but a typical section would show—

	ft.	in.	
Top soil	1	6	
Iron nodules	0	1	
Yellowish clay	4	0	
Ditto with occasional pebbles and stones	3	0	
Reddish yellow sand	2	0	and extending deeper.

Further east, where the blue clay begins, there would be—

	ft.	in.	
Top soil	1	6	
Bluish clay	1	0	
Iron nodules	0	2	
Yellowish clay	1	0	
Very red sandy clay with pebbles, angular stones, and roots.	2	0	and extending apparently much deeper.

I may mention that when the sea in 1876 washed away the old road leading to the Burrows, there were laid bare the foundations of some building, a rough stone pavement, and a round well with stone sides. I have never been able to ascertain anything about these buildings; there is no sign of them in the parish map, nor is there any tradition about them in the neighbourhood.

Discussion.

Prof. Prestwich expressed his regret at the absence of the author, who, he said, had special opportunities of observing the facts, as he had resided on the spot. The encroachment had evidently increased in amount within the last fifteen years, as indicated by the author. The ground washed away was not of a nature to be easily removed, the pebble-bed being derived from an old beach, not of mere shingle, such as that of Brighton, but containing rounded blocks of very large size. If the erosion continues, the lower ground will, in course of time, be washed entirely away. The idea of the clay underlying the locality being of glacial origin was confirmed by an observation of Mr. Maw on some clay near Bideford, in which he found large erratic boulders. The submerged forest was described by Mr. Pengelly as containing bones of recent species of animals and worked flints.

Mr. R. W. Mylne inquired if any indication was given in the paper of the amount of loss since the year 1600.

Mr. W. T. Blanford read a passage from the paper, stating that a book published between 1600 and 1630 mentions the fact of a cairn having been washed away, but gives no precise indication of its situation.

34. *On* Further Discoveries *of the* Footprints *of* Vertebrate Animals *in the* Lower New Red Sandstone *of* Penrith. By George Varty Smith, Esq., F.G.S. (Read May 28, 1884.)

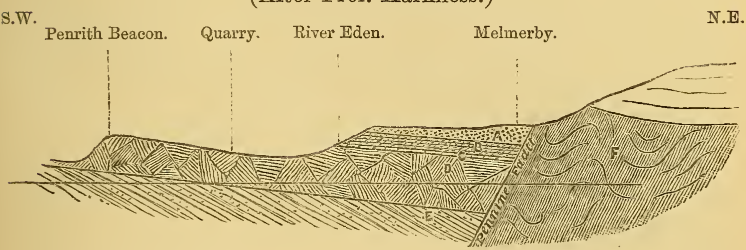
[Abridged.]

Hitherto not many footprints have been met with in the Penrith Sandstone. Impressions of the same nature as those found in the equivalent strata at Dumfries have been previously met with at Brownrigg in Plumpton, about five miles north-west of Penrith; and the late Mr. Binney and Prof. Harkness have noticed similar impressions in the flaggy beds near Penrith, but they were not so distinct as those found at Brownrigg. A notice of the discovery of a variety of impressions in the Lower New Red Sandstone of Penrith may therefore be interesting, and may serve to throw some light upon the general nature of the terrestrial vertebrate life of that period.

The footprints now referred to were met with in a quarry situate on the eastern slope of a hill, at a point about 200 yards north of the highway from Penrith to Alston, and about three and a half miles east of Penrith.

The geological position of the sandstone is shown approximately in the accompanying diagram section, which is based upon one by

Section of Hill from which the Footprints were obtained.
(After Prof. Harkness.)



A. St. Bees Sandstone.
B. Red Shales.
C. Magnesian Limestone, Gypsum, and Plant-beds.
D. Penrith Sandstone.
E. Carboniferous.
F. Pre-Carboniferous.

Prof. Harkness. This shows that the Penrith Sandstone rises from beneath the Magnesian Limestone, traces of the latter rock being found at a short distance to the north-east of the quarry, in the bank of the river Eden.

The tracks on cast No. 1 * appear to be those of an animal which evidently used its fore feet simply as supports, while throwing the weight of its body mainly on its hind feet. The impressions made by the hind feet are broader than they are long, and are nearly twice the size of those left by the fore feet, which occur almost immediately in front of the former.

* This paper was illustrated by facsimile casts of the footprints, which are now in the Museum of the Geological Society.

The tracks on cast No. 2 are clearly those of different animals, for the imprints marked "*a*" are, no doubt, those of a quadruped which used its fore feet as supports, much in the same way as that of cast No. 1. The impressions of the fore feet are only about half the size, and are situate between those of the hind feet. The imprints marked "*b*" on the cast, appear to be those of either an animal characterized by a bipedal mode of progression, whose feet presented the form of a pad and three digits, or else of a quadruped whose fore feet were much smaller than its hind feet, and fell into nearly the same place.

Cast No. 3 shows footprints which occur on the same stone as the impressions marked "*a*" and "*b*" of cast No. 2. The footprints in this case appear to be those of a much smaller or lighter animal, which placed its hind feet nearly in the prints left by the fore feet; these tracks are slight and of a circular form. The next cast, No. 4, was taken from a bed seven feet below that from which casts Nos. 2 and 3 were taken. The footprints here being of a more uniform depth, would also appear to have been made by a four-footed animal, and one which threw its weight pretty equally on all four feet. The bed from which these impressions were taken had an inclination of 25° towards the west, and from the blurred appearance of the lowest imprints, which, however, became more distinct as they ascended, it would appear that the bed at the time the impressions were made was probably inclined and partially covered with water. The prints are not of a uniform size, probably from the above cause.

Casts Nos. 5 and 6 were taken from a bed a foot and a half below that in which the last footprints occurred. It is doubtful whether each imprint on No. 5 is that of a single foot, or whether it is not rather that of both the fore and hind foot in coincidence.

The imprints on cast No. 6 are no doubt those of a quadruped, the impressions of whose feet appear nearly in coincidence.

All the foregoing footprints, except the first, were found *in situ*. The surfaces of the two last-mentioned beds were, in several places, so covered with footprints that it was impossible to get any additional sets of impressions, which in nearly every case took the same direction, namely, from west to east.

It seems doubtful whether each mark on cast No. 7 is that of a single foot, or whether it is not rather that of both the fore and hind feet nearly in coincidence; the appearance of a double row of toes and the abnormal number of six digits visible in some of the impressions, probably arises from the placing of the hind foot nearly in the impression of the fore foot. The imprints appear to be those of toes or claws, and take the form of a half-circle.

In cast No. 8 we have something similar to the latter, the impressions of the toes or claws being visible in a double row. It is difficult to say whether they represent the prints of a single foot, or are those of the fore and hind foot nearly together. They differ however from those on cast No. 7, in that the toes or claws take a slightly concave form, and turn alternately outwards. There are other marks on this cast than those described above, but they could not have been caused by the same animal; for on a close examination of the marks there appears to be a certain amount of uniformity about them, each alternate mark being reversed; the pace also is longer.

Cast No. 9 is, no doubt, the cast of the natural imprints of an animal entirely different from the others. The impressions are in groups of four, three turning in a straight line outwards, while the fourth turns inwards; and they appear to be those of a four-footed animal, each impression being that of the single foot; a hare when in motion makes a very similar track.

It may be thought that the markings seen on cast No. 10 are similar to those just described; but on a careful examination of them there appears to be a considerable difference between the two. In the first place the tracks occur in two lines of a uniform distance from each other, each line of tracks consisting of groups of four impressions each, the several groups occurring alternately. In each group in the right line the three first impressions form a line inclined outwards to the right, while the fourth impression inclines inwards to the left. The groups in the left line are just the reverse. It is very probable that these impressions were caused by a biped, the group of impressions in the right line being those of the right foot, and those in the left line of the left foot; this would appear from the groups in both lines occurring alternately and at a uniform distance from each other, and the fourth impression in each alternate group turning inwards.

All the foregoing footprints were found in the same quarry; and from the difference in the size and depth of some of them, as compared with the length of pace and form of others, it has been suggested that they represent the impressions of several different species, if not of different genera of extinct vertebrates.

There are several quarries in the immediate neighbourhood of this one; but I have never been able to find any footprints in them.

In a quarry of Penrith Sandstone in Whinfell Wood, situate on the top of a hill about three miles to the south-east of Penrith, I found a specimen of the cast of some footprints, but it was not nearly so distinct as those described above. On the same day I found, in another quarry about 100 yards from the last, a piece of stone showing five distinct and peculiar markings, which, although exactly alike, and taking the same direction, are not in any regular order. These markings or impressions are seen on cast No. 11.

Discussion.

Dr. Murie remarked that the question of footprints is a very difficult one. He had been in the habit in his youth of tracking animals, but had found that it was often difficult to recognize a dog's foot.

Prof. Prestwich said that in the Oxford Museum there were impressions very similar to those of Nos. 5 and 6 from the Trias of Storton Hill, near Liverpool.

Prof. Judd referred to the great interest of these fossils as coming from undoubtedly Lower Permian strata in which remains of vertebrate forms higher than fishes had so rarely occurred.

35. *The* Range *of the* Palæozoic Rocks *beneath* Northampton. By Henry John Eunson, Esq., F.G.S. (Read June 11, 1884.)

Contents.

I. Previous Knowledge of the Underground Geology.

1. The first investigation into the underground geology of Northamptonshire, or the strata lying immediately beneath the thick deposit of the Liassic series, consisting of limestones and clays, which covers the county to a large extent, was made in the year 1836. A company was then formed and a shaft sunk near the village of Kingsthorpe, about 2½ miles N.E. of the town of Northampton, for the purpose of reaching the Coal-measures, which, upon the advice of practical men, it was thought could be found at no great depth below the surface, "though competent scientific individuals, as Mr. Smith, the father of English geology, and Mr. Richardson, then of the British Museum, expressly denounced it as a mistaken enterprise"*.

An account of this shaft (fig. 4, p. 496) has been given by the late Mr. S. Sharp, F.G.S., in the 'Geological Magazine,' from which I extract the following passage †:—

"No accurate detailed section of the shaft was taken at the time; but at a depth of 210 feet from the surface, a water-yielding 'Limestone rock' in the Middle Lias (Marlstone) was pierced, which produced 36,000 gallons of water per hour. At a depth of 880 feet (as is stated in pencil-notes on a diagram in my possession, which notes are said to have been made by Dr. William Smith, F.R.S., F.G.S., &c.) the New Red Sandstone was reached, and a flow of brackish water of a like volume to the former occurred. The New Red Sandstone is stated to have consisted of 'sixty feet of Sandstone, twelve feet of Red Marl, and fifteen feet of Conglomerate.'

* Proc. of the South Wales Institute of Engineers, vol. ii. p. 198. "The Iron Ores of Northamptonshire." By W. Brown.

† "Note on a futile search for Coal near Northampton," Geol. Mag. vol. viii. p. 505.

At this point (a depth of 967 feet having been attained, and about £30,000 expended), the enterprise was abandoned."

The surface of the shaft is 374 feet above sea-level.

2. A boring was also carried out about the year 1846 by the London and North Western Railway Company at their Bridge-Street Station, to obtain water for their locomotives. The strata met with were as follows (fig. 2, p. 496)*:—

	feet
Superficial accumulation consisting of detrital gravels, dark tenacious clays with erratic boulders	46
Lias blue clay with bands of stone	550
Very hard pyritous rock	1
Variegated Sandstone, viz. red, green, and white with 15 feet of limestone	46
White sands	3
Magnesian limestone	4
Total...	650

No supply of water was met with until reaching 650 feet, when a spring of salt water rose to within 8 feet of the surface, containing in solution chloride of sodium, carbonate of soda, and sulphates of magnesia and lime.

The situation of this boring is in the valley of the Nene, and 191 feet above sea-level. From a well lately sunk in the immediate neighbourhood the alluvial gravels &c. may be taken at about 26 feet in thickness.

This was all the information then obtained regarding the underground geology. The Liassic series had been pierced, and below it beds of sandstone, marl, and conglomerate had been met with. There was then little doubt that these deposits were the upper beds of the Trias, which was thought to extend some distance eastwards under and beyond Northampton, attaining there some considerable thickness, about 500 feet, but not, however, reaching far beneath the Chalk of Cambridge or Bedfordshire†.

In the year 1878 the Northampton Water Company, when considering a further source of water supply, were advised by their Engineer, Mr. J. Eunson, F.G.S., Assoc. Mem. Inst. C.E., to bore through the Lias clays and the upper beds of the Trias, and to penetrate, if possible, the "Water-stones" which it was thought might extend as far eastwards as Northampton. The advice of Mr. R. Etheridge, F.R.S., and Prof. J. W. Judd, F.R.S., was obtained, who gave a favourable opinion upon such an undertaking, at the same time pointing out some of the reasons which might result in the non-success of the scheme. To these gentlemen I am greatly indebted for their kind assistance in preparing this paper.

It is from this boring and two subsequent ones, that we have the interesting discovery of the Palæozoic rocks so near the surface.

* A Report on the drainage of the Nene Valley by the Rev. C. H. Hartshorne, printed by Jas. Butterfield, Northampton, 1848.

† Hull, 'Coal-fields of Great Britain,' 4th edit. p. 530.

II. The Kettering-road Boring (fig. 3, p. 496)*.

The first boring undertaken by the Water Company was commenced in 1879 from the bottom of an existing well 203 feet in depth, situated on the Kettering road, and about one mile N.E. of the town. The surface of this well was 278 feet above sea-level.

After 18 feet of surface soil and Inferior Oolite the Liassic series commenced, and continued to a depth of 738 feet.

	ft.	in.
Surface soil	4	0
Inferior Oolite	14	0
Upper Lias Clay	153	0
Middle Lias (rock beds)	21	0
Lower Lias	546	0
	738	0

The last 20 feet of the Lias contained several bands of indurated clay and limestone, and rested unconformably upon an eroded surface of crystalline conglomerates and sandstones, in the following order:—

No. of bed.	ft.	in.	ft.	in.
			738	0
1. Conglomerate of sandstone with calc-spar, chert, and quartz	12	6		
2. Light-blue sandstone with limestone and chert	8	6		
3. Light-coloured sandy limestone with maguesian limestone	6	0		
4. Green sandstone, with hard and soft veins	8	0		
5. Dark-green sandstone	5	0		
6. Hard white sandstone	9	0		
7. Green sandy clay	0	6		
8. Hard white sandstone	1	0		
9. Green sandy clay	3	0		
10. Light-brown sandstone (fine-grained)	3	6		
11. Brown sandstone, coarser	3	0		
12. Green yellowish marl	3	0		
13. Variegated conglomerate, fine-grained, in calcareous matrix	2	6		
14. Brown marl, with blocks of dolomite	2	0		
	67	6	805	6

These beds were reported by Mr. Etheridge to have "no equivalents in Britain," "no series like them;" and it is difficult to say to what period they belong, no fossil of any kind having been found by which to fix their exact horizon. The Lias clays were unconformably upon them, the White Lias and Rhætic being altogether absent. The last bed (a marl) contained several blocks of a dolo-

* See paper by J. Eunson, C.E., F.G.S., in the 'Journal of the Northamptonshire Nat. Hist. Soc.' vol. ii. p. 29.

mitic rock, and rested upon an eroded surface of this Carboniferous dolomite 25 feet in thickness.

This rock yielded one perfect fossil (*Orthoceras oblatum*) and a few annelid-tracks, and was succeeded by Carboniferous Limestone crowded with characteristic fossils and containing bands of sandstone, passing at 844 feet into yellow shales containing plant-remains and numerous fossils, in which, at a depth of 851 feet, the boring was discontinued.

The Carboniferous strata were as follows:—

No. of bed.	ft.	in.	ft.	in.
			805	6
15. Red dolomite, fissured, with eroded surface, fissures filled with impure calcareous deposit	2	0		
16. Vein of white dolomite	1	0		
17. Dull red dolomite, jointed and very dense, containing a vein of quartzite towards the base, also *Orthoceras oblatum* and annelid-markings	22	0	830	6
18. Yellow sandstone containing *Lithostrotion junceum*, *Lithostrotion irregulare*, and *Lonsdaleia floriformis*	2	6		
19. Vein of red sandstone, fossils more numerous	1	0		
20. Yellow sandstone, similar fossils to those in beds 18 and 19	2	0	836	0
21. Dense orange-coloured limestone with calc-spar	0	6		
22. Yellow limestone, fossils numerous: *Chætetes*, *Cystiphyllum*, sp., *Lithostrotion irregulare*	7	6	844	0
23. Yellow sandy shales with plant-remains	1	0		
24. Band of black sandy shale &c.	0	6		
25. Yellow shales containing *Orthoceras*, *Productus scabriculus*, *Streptorhynchus crenistria*, scales of *Megalichthys*	5	6		
Total	45	6	851	0

Saline water was met with in this boring, coming, without doubt, from the beds above the dolomite. The yield, however, was only about 200,000 gallons per day. The water had a specific gravity of 1·013, and contained 1200 grains of mineral salts per gallon. The water appeared to have a level of about 150 feet above Ordnance datum.

III. The Gayton Boring (fig. 1, p. 496).

The second trial took place near the village of Gayton, five miles south-west of Northampton, not far from the Banbury-Lane crossing of the L. & N.W. Railway Co., about two miles north-west of Blisworth Station (see Ordnance map 52, S.W.). It was thought that under the known attenuation of the Trias westward, the Waterstones could be found, if only the site selected was at a sufficient distance beyond the Carboniferous rocks to have allowed the lower beds of the Triassic series to be deposited near Northampton.

This boring, 282 feet above sea-level, was commenced at the junction of the Upper with the Middle Lias, followed by the Lower Lias clays, the aggregate thickness of which was 581 feet.

The White Lias and Rhætic were here present in the following order:—

No. of bed.	ft.	in.	ft.	in.
			581	0
1. Hard white limestone with pyrites	1	0		
2. Sandy vein, with *Pecten*, *Ostrea*, reptilian bone	0	6		
3. Dense hard white limestone	0	9		
4. Sandstone, with limestone bands, *Pecten*, *Ostrea*	2	3		
5. White crystalline limestone	2	6		
6. White limestone with dark streaks	0	6		
7. Dense concretionary limestone	6	6	595	0
8. Green shale	7	0		
9. Grey shale	0	6		
10. Brown shale with green bands	4	6		
11. Soft green marly shale	4	0		
12. Hard green marl, false-bedding very strongly marked	2	6		
13. Black shales, with limestone bands and pyritous nodules	3	6	617	0

Among the fossils were Crustacea, *Terquemia arietis*, *Avicula contorta*, *Cardium rhæticum*, *Pecten valoniensis*, *Pleurophorus*, *Acrodus minimus*, *Gyrolepis tenuistriatus*, *Saurichthys acuminatus*, *S. apicalis*, *Pterodactylus* (bone).

The black shales rested upon the slightly eroded surface of a bed of grey marl with layers of coarse gritty sandstone, followed by the cream-coloured marls, variegated sandstones, and marls of the Trias.

No. of bed.	ft.	in.	ft.	in.
			617	0
14. Grey marl, with bands of gritty sandstone	3	0		
15. Cream-coloured conchoidal marl	3	0		
16. Red and green mottled marls	3	0		
17. Red marl	4	0		
18. Brown sandstone	4	0		
19. Red marl	3	0		
20. Brown marl	0	6		
21. Band of hard sandy limestone	1	0		
22. Red and green mottled sandstones	2	6		
23. Green and yellow sandstone	2	0	658	0
24. Hard white sandstone with pyrites	1	0		
25. Fine-grained green sandstone	0	6		
26. Green sandstone (strong odour of sulphuretted hydrogen when broken open)	0	6		
27. Green sandstone (large quantity of pyrites)	1	0		
28. Green sandstone (free from pyrites)	5	0	666	0
29. Yellow sandy marl	1	0		
30. Grey sandstone	1	0		
31. Light-coloured sandstone, with marly bands	4	0	672	0
32. Red marl	1	0		
33. Yellowish-green sandy marls	2	0		
34. Red marl	1	6	676	6

At $676\frac{1}{2}$ feet Carboniferous fossils were discovered in a bed of brown sandstone, followed by blocks of Carboniferous Limestone in a light-green sandy matrix, in no distinct order, and with no apparent regular bedding. These were succeeded by red, green, and dark-coloured marls, the last bed of dense dark shale resting upon an eroded surface of Carboniferous Limestone (unfossiliferous) at 699 feet. The beds, so far as it was possible to make out, were in the following order:—

No. of bed.		ft.	in.	ft.	in.
				676	6
35.	Brown sandstone, with Carboniferous fossils	0	6		
36.	Blocks of limestone in green sandy matrix	1	6		
37.	Limestone, with pyrites and fossils (much broken up)..	2	0		
38.	Hard brown limestone..	0	6		
39.	Green and brown limestone, and sandstone	1	6		
40.	Fragmentary limestone in sandy matrix (no regular bedding)	7	0		
41.	Green and brown marl (very much disturbed)......	3	0		
42.	Red, green, and black sandy marls	3	6		
43.	Black shale, on an eroded surface of Carboniferous Limestone..	3	0	699	0

The true Palæozoic rocks commence, without doubt, at 699 feet, the beds above representing a littoral deposit before an escarpment of Carboniferous Limestone, and over which the Trias seas encroached late in that period, which accounts for the absence of the "Waterstones" and the thin deposit of the Trias.

Among the fossils collected from these littoral beds the following were identified by Mr. R. Etheridge:—

Actinozoa..................	Cœnites.	
Echinodermata	Actinocrinus	ossicula of stems.
,, ...	Poteriocrinus	
,, ...	Rhodocrinus	
Annelida	Serpulæ.	
Bryozoa	Fenestella.	
,, ...	Ceriopora.	
,, ...	Ceramopora (?).	
Brachiopoda	Athyris Roissyi.	
,, ...	Chonetes.	
,, ...	Productus semireticulatus.	
,, ...	Rhynchonella pleurodon.	
,, ...	Spirifera glabra.	
,, ...	—— striata.	
,, ...	Streptorhynchus crenistria.	
,, ...	Strophalosia rhomboidalis.	
Lamellibranchiata	Aviculopecten.	
,, ...	Edmondia.	

Below the limestone, at 699 feet, a series of limestones and shales, the latter of a dark green and black colour, two beds of which were undoubtedly fireclay, extended to a depth of 778 feet in the following succession:—

No. of bed.	ft.	in.	ft.	in.
			699	0
44. Brown limestone, with eroded surface, and dipping 45–50°	1	0		
45. Hard dark shale	6	0		
46. Light-brown limestone	0	6		
47. Green sandy shale, with *Serpula, Syringopora* ...	5	6		
48. Hard indurated shale	1	0		
49. Green shale	6	0		
50. Whitish impure limestone, jointed, veins of calcite, and containing *Rhynchonella pleurodon* &c.	2	6		
51. Dark-brown shale (fireclay)	1	6		
52. Impure sandy limestone	7	6		
53. Hard green sandy shale	10	6		
54. Limestone (similar to bed 50)	0	6		
55. Green shale with fossils	1	6		
56. Impure greenish limestone	3	6		
57. Green sandy shale	2	6		
58. Limestone	1	0		
59. Dark-brown shale (fireclay)	2	6		
60. Impure limestone	1	0		
61. Hard black bituminous shale	3	0		
62. Sandy vein, annelid-tracks	0	6		
63. Dark shale	2	6		
64. Softer shale with fossils	3	0		
65. Limestone with bituminous veins	4	0		
66. Green shale	9	0		
67. Green shale with fossils	0	6		
68. Limestone	0	6		
69. Green shale	2	6	778	0

At 778 feet a decided change took place in the cores, the next 40 feet consisting of sandstones and coarse grits, some of the beds being fissured.

No. of bed.	ft.	in.	ft.	in.
			778	0
70. Hard white crystalline sandstone	2	0		
71. Green sandstone, *Terebratula sacculus*, &c.	1	0		
72. Fine gritty sandstone, a vein of brown sandstone near the base	2	6		
73. Hard white sandstone, with veins of calcite	0	9		
74. Coarse gritty sandstone, *Serpulæ*, and teeth of *Psammodus* and *Helodus*	0	6		
75. Coarser grit, well-rounded pebbles of quartz, ½ inch diameter and under	0	9		
76. Coarse grey sandstone	4	0	792	0
77. Grey micaceous sandstone, with plant-remains ...	6	6	806	0
78. Hard crystalline sandstone	1	0		
79. Dark-grey sandstone, Annelid-tracks, and *Serpulæ*	1	0		
80. Red and yellow sandstone	—		817	0
81. Red and green sandstone, fissured	1	0	818	0

Large quantities of these sandstones and grits were ground away in boring, so that it was impossible to give the thickness exactly of each successive bed.

The boring was continued to a depth of 994 feet, the beds, as far as 889 feet, consisting chiefly of marls, with a few bands of sandstone.

No. of bed.	ft.	in.	ft.	in.
			818	0
82. Chocolate marl	—			
83. Dark-green marl	—			
84. Red sandstone and marls, with *Modiola Macadami* at 840 feet	—		847	0
85. Red and green marl, with sandy bands	34	6	881	6
86. Blue sandy marl, with coniferous wood-remains	4	6	886	0
87. Grey-bluish sandstone, with plant-remains	3	0	889	0

The junction between beds 87 and 88 is distinct, the latter being a brown marl, and followed by thick beds of coarse red sandstone, containing some hard quartzose grits and a few layers of marl. Bed 95, at 942 feet, contained a fissure ½ inch in width, which also revealed a slight fault, the displacement, however, not being more than 2 inches.

No. of bed.	ft.	in.	ft.	in.
			889	0
88. Brown marl, with septarian veins replaced by sandy infiltration	11	0	900	0
89. Red marl with sandy layers	18	0	918	0
90. Fine-grained red and yellow sandstone	12	0	930	0
91. Coarse red sandstone	1	0		
92. Coarse purple quartzose rock	1	6		
93. Greenish quartzose grit	1	0	933	6
94. Red marl, with red and white sandstone bands	8	6	942	0
95. Very hard coarse grit (wide fissure filled with calcareous deposit)	4	0	946	
96. Red and white sandstone, with several layers of marl	12	0		
97. Pale-green calcareous grit	1	0	959	0
98. Red and grey sandstone, with marl and septaria	30	6		
99. Hard grey sandstone, fissured	1	6	991	0
100. Red marl	3	0	994	0

Specimens of these quartzose grits were submitted to Prof. T. G. Bonney, Pres. G.S., who has kindly favoured me with the following notes upon them :—

Bed 91, *at* 930 *feet.*—" A moderately compact, dull, light-red sandstone, becoming coarser in the lower part (see bed 92), and giving indications of stratification at an angle of 80° with the axis of the core. In the finer parts the grains are about ·01 inch, but in the coarser are three or four times that size, with occasional fragments exceeding ·1 inch. There is one fragment 1 inch long, but possibly that may be a vein. Many of the grains are quartz, and some are apparently felspar. The red colour is due to an external pellicle of oxide of iron."

Bed 92, *at* 931 *feet.*—" A rock resembling in texture the coarser of the above specimens, slightly more purple in colour, and decidedly harder. The quartz-grains constitute about ⅕ of the whole mass ; they are subangular to tolerably well rounded in form ; some contain abundant minute cavities, but others are rather clear. Bubbles appear to be very rare, but I have noticed a few. Some grains consist of a granular quartz, probably from a vein. The other grains are more difficult to identify; some are felspar, many probably decomposed felspar, others may be rock-fragments, but the structure is not definite enough, or the grains sufficiently well preserved, to enable me to speak positively. The grains appear to be set in a fine granular matrix."

Bed 93, *at* 932 *feet.*—"This rock is rather lighter in colour and looser in texture; it contains numerous granules and galls of a pale green muddy-looking material, which give a distinct character to the hand-specimens. On the whole, cavities are more numerous and slightly larger in the quartz-grains; bubbles are only occasionally present, but perhaps are relatively a little larger."

Bed 95, *at* 942 *feet.*—"A moderately coarse grit, containing fairly rounded granules of quartz, whitish to purple in colour, and a yellowish earthy-looking material, probably decomposed felspar, set in a hard light-coloured matrix. There is now and then a small quartz pebble, about as large as a pea. As regards the microscopic structure, there is little to add to the remarks already made, except that the cavities are very abundant in the quartz, and moving bubbles not very unfrequent. One quartz-grain contains a crystal of a greenish mica. The cement exhibits cleavage-planes, and is an impure calcite."

Bed 97, *at* 958 *feet.*—"This rock approaches in general appearance to bed 93, but has less of the green constituent. The cement is calcareous."

Whether this series of coarse sandstones, grits, and marls represents the Old Red Sandstone, or whether they must be classed as Lower Carboniferous, is a matter of some doubt.

In examining these rocks Professor Bonney remarked their similarity to some of the pebbles in the Bunter beds of Staffordshire, and even to the Torridon Sandstone of Scotland, which he had suggested* as the source of some hard quartz felspar grits in the former. He has, however, pointed out to me that although bed 95 bears a considerable resemblance at first sight to the pebbles in Staffordshire, the resemblance is not so close under the microscope. In it the calcareous cement is a very marked feature; but in six different specimens collected in the neighbourhood of Rugeley which he has examined it is not seen; and the cementing material in some cases is certainly quartz. Both have undoubtedly derived their materials from a common source, viz. granitoid rocks of Archæan age. Again, the peculiar hard quartzites of the Bunter pebbles have not been struck in this boring. Still the Bunter has evidently been derived from many sources, and this ridge beneath Northampton may have furnished its quota.

As in the other boring, saline water was met with. It contained about 1500 grains of mineral salts per gallon, and had a specific gravity of 1·015. The yield, however, did not amount to 100,000 gals.

* Geol. Mag. vol. vii. p. 404, and vol. x. p. 199.

per day, as tested by pumps. The water stood at 170 feet above sea-level, or 20 feet higher than at the Kettering-road boring.

Though in both instances the borings failed to provide the pure water, for which object they were carried out, yet the results are of the highest interest, and prove the extension of the Palæozoic rocks in a new area in Britain.

The results obtained from these two borings are much strengthened by the fact that they were executed with the diamond drill *, by which means the solid cores which were extracted (at times as much as 24 feet in length) of the strata passed through showed distinctly the exact position of the several beds and the nature of the junction between them; the fossils could also be collected perfect and from each particular horizon. The largest cores extracted were from the Kettering-road boring, and measured $19\frac{1}{4}$ inches in diameter, the cores of the Carboniferous strata at a depth of 851 feet measuring $14\frac{1}{2}$ inches.

The Gayton boring was commenced with the 18-inch "crown," giving $14\frac{1}{2}$-inch cores, and during the progress through the 994 feet the size was reduced six times, the last core measuring 6 inches in diameter †. It was not found practicable to test the direction of the dip of any of the strata.

IV. A Trial-boring for Coal at Orton, North Northamptonshire (fig. 5, p. 496).

A boring has just been accomplished by the Diamond Rock-boring Company in Harrington Dale, near the village of Orton, 5 miles to the west of Kettering and 12 miles north-east of Northampton, to test the possibility of Coal occurring in that neighbourhood. Through the kindness of Mr. J. Fleming, of Newcastle-on-Tyne, the owner of the estate, for whom the boring was carried out, I was permitted to examine the cores during the progress of the operations, the results of which I am pleased to be able to lay before the Society.

The position of the boring was upon the outcrop of the Upper Lias and 374 feet above sea-level. The Lias clays were pierced at 666 feet, the lower portion differing from the beds at Gayton in the absence of fossils, and from those at Kettering road in that beds of indurated clay and limestone were not met with. The clays were followed conformably by a bed of White-Lias limestone, similar in lithological character to the same bed at Gayton, but containing no sandy veins or fossils. The green shale (beds 6 and 8) is identical in appearance with bed 8 at Gayton; it is impossible to see any difference in them when examined side by side. It is also curious to remark the general similarity between this boring

* Carried out by Messrs. Docwra and Gulland.

† Proc. Inst. C. E. vol. lxxiv. p. 270, "On a Deep Boring at Northampton," by H. J. Eunson, Stud. Inst. C.E.

and the one at Gayton. The base of the clay at Orton is 292 feet below sea-level, as compared with 299 feet at Gayton, a difference of only 7 feet, the distance between the two sites being 16 miles; the White-Lias limestone is present at both places, but we have no mention of it in either of the two earlier investigations, nor was it found at the Kettering-road boring*; the green shale is very similar, but absent in the three other borings. At Orton no trace of Trias is found; the black shales and bone-beds are also wanting.

The thick bed of white sandstone, probably a local deposit, was followed by a breccia. This breccia contained fragments of quartz-andesite and also of quartz-felsite, the rock found immediately below and upon the eroded surface of which it rested. The quartz-felsite was proved to a depth of 74 feet, and in it, at 789 feet, the boring was stopped.

This rock was examined by Prof. Bonney; he remarked:—"This rock is a quartz-felsite, specks of quartz and crystals of whitish felspar about 0·1 inch long appearing in a very compact greyish matrix. This is traversed by very numerous minute cracks, which appear to be filled by a paler mineral. A distinct cleavage is exhibited, the planes, whose surfaces are slightly irregular, making an angle of about 18° with the axis of the core. Under the microscope the rock exhibits a rather indistinct devitrified structure, which in many parts is marked by the above-mentioned cracks, and subsequently formed minerals. I do not see any distinct indication of perlitic, fluidal, or spherulitic structure, but I believe the rock has once been a glassy rhyolite, and has been subsequently devitrified and crushed, whether simultaneously or not I cannot say. The usual filmy, almost colourless mineral (which extinguishes at rather small angles, some 10°, with the vibration-planes of the crossed nicols, and shows a sort of golden tint most brightly at between 50° and 60°) occupies, or to some extent "solders up," the cracks. There are also numerous granules of ferrite and occasional dark lines of an iron-oxide, which, I think, have occupied cracks. There are several grains of rather clear quartz, and crystals of felspar, orthoclase, and plagioclase, both rather decomposed. The quartz is cracked, the felspar still more broken. There are many microliths which I cannot certainly identify, but some, I think, are apatite, and perhaps there is a little mica."

In the opinion of Prof. Bonney this rock is very similar to that found at High Sharpley, in Lincolnshire, which he has described† as either "an altered rhyolitic tuff or a true rhyolite much crushed;" and he has little doubt that it is a member of the same series as the volcanic group of Charnwood Forest.

It is interesting to note the extension of this group so far southward as Northamptonshire, some 25 miles to the south-east of the Charnwood area, and which most probably, during the later Car-

* These three borings are situated between Orton and Gayton.

† Quart. Journ. Geol. Soc. vol. xxxvi. p. 342.

boniferous period, was an exposed land-surface, over which the much-desired Coal-measures were not deposited. This boring is another proof that it is improbable that the Coal-beds occur in North Northamptonshire.

The succession of the beds below the Lias was as follows :—

No. of bed.		ft. in.	ft. in.
	Surface soil	10 0	
	Liassic series. Upper, Middle, and Lower	656 0	666 0
1.	Junction bed between clay and limestone below	6	
2.	White-Lias limestone, with fissures containing large crystals of calc-spar and pyrites, $\frac{1}{4}$ inch cube	3 6	670 0
3.	Conglomerate	3	
4.	White sandy limestone	6 9	
5.	At the base of bed 4 a conglomerate of small rounded fragments of quartz-andesite ?, thicker on the lower part, more scattered towards the top	1 3	
6.	Green shale	6	
7.	Band of greyish sandy marl	1 9	
8.	Green shale, with light and dark shaded bands	7 6	688 0
9.	Coarse grey sandstone	24 0	712 0
10.	Breccia of quartz-felsite	3 0	715 0
11.	Quartz-felsite, with eroded surface, proved to	74 0	789 0

The largest cores in this boring measured $7\frac{1}{2}$ inches in diameter; the size was reduced four times, the last core measuring $2\frac{3}{4}$ inches.

The boring was commenced in October 1883 and completed in March 1884.

V. General Conclusions.

These borings furnish us with additional evidence for determining the extension eastwards of the Palæozoic rocks beneath the Mesozoic formations, and verify to some extent the conclusions drawn from the borings in the London and Oxford areas. If the beds met with at Gayton are taken as the Old Red, that locality is now the northern boundary of that series, which it was predicted * would probably be found to strike across England, and the most easterly extension of which has been determined at the borings in the London area.

The Carboniferous Limestone at Northampton may now be considered its most easterly underground extension known in England † if we disregard the reported discovery of that series at Harwich, and is in all probability an extension of the Penine chain, the axis of which is continuous as far as Nottingham, where it dips beneath the Secondary formations, and though not yet discovered in the London area, it may yet be found to the west.

The Trias was only revealed in the Gayton boring of the North-

* R. Godwin-Austen, Quart. Journ. Geol. Soc. vol. xii.

† Etheridge, Quart. Journ. Geol. Soc. vol. xxxvii. p. 231.

ampton area, and only 60 feet in thickness, which, compared with the thick deposits found on the borders of Northamptonshire and Warwickshire *, and again at Burford †, in Oxfordshire, shows that the Trias thinned out against the exposed plateau in the Northampton area, some parts of which were not entirely submerged till late in that age; and then it is doubtful whether the Trias reached beneath the town of Northampton, for the deposits between the Lias and the Carboniferous at the Kettering-road boring are not true Trias, but may be littoral or lacustrine beds. Again, this latter boring is situated midway between the Kingsthorpe Shaft and the Station boring, which are only 3 miles distant from each other, and I think that we may safely conclude that the sandstones, conglomerates, and marls discovered in these two earlier investigations are not New Red Sandstone, as then stated, but are identical with the abnormal series at the Kettering-road boring. No mention is made of the discovery of the White Lias and Rhætic in the earlier borings, nor was it found at the Kettering road.

In examining the thickness of the several beds and the comparative depths of the five borings, which are almost in one straight line ranging north-east and south-west, it will be noticed that the old land-surface at Orton is considerably higher than the others; the surface at Gayton is also high; but the Kettering-road boring shows a great depression. This may partly account for the absence of the White Lias and Rhætic, and the sandy appearance and uneven bedding which the lower parts of the Lias Clay presented in this boring, and which was not noticed at either Orton or Gayton.

With the discovery of the Carboniferous series at Northampton the question naturally arises as to the probability of a concealed Coal-field in the neighbourhood. The abortive boring for Coal at Orton has proved the absence of any in the north part of the county; but with the Carboniferous rocks dipping rapidly at Gayton (in what direction it was not ascertained, but there can be little doubt that it is south or south-west) we have reason to believe that to the south-west, possibly extending to Burford, where the Coal-measures were discovered, the much-desired Coal-beds may yet be found, beneath South Northamptonshire, Buckinghamshire, and Oxfordshire, and at a workable depth. Also that between the exposed Coal-measures of Atherstone and Nuneaton and the Carboniferous Limestone at Northampton ‡ there may extend a Coal-tract beneath the overlying Triassic series, which thins out towards the east.

* Hull, 'Coal-fields of Great Britain,' 4th edit. p. 529.
† Etheridge, 'Pop. Sci. Review,' July 1879, p. 290.
‡ Etheridge, Quart. Journ. Geol. Soc. vol. xxxvii. p. 231.

VI. Tabular Summary of the Borings.

Strata.	Gayton.	L. & N. W. R. Station.	Kettering road.	Kingsthorpe.	Orton.
	ft.	ft.	ft.	ft.	ft.
Surface-soil &c.	7	26	4	......	10
Oolite	......	......	14	120	
Upper-Lias clay	1	......	153	} 760	
Middle Lias (rock-beds)	20	20	21		656
Lower-Lias clay	553	550	546		
White Lias	14	......	......	......	12¼
Rhætic	22	......	......	......	9¾
Trias	59½				
Sandstones, Marls, &c.	......	54	67½	87	24
Carboniferous dolomite	......	......	25		
Carboniferous limestone and shale (littoral at Gayton)	22½	......	20½		
Lower Carboniferous limestones and shales	79	......	......	......	Breccia. 3
Lower Carboniferous sandstones	40	......	......	......	
Lower Carboniferous marls	71	......	......	......	{ Quartz-felsite. 74
Coarse red sandstones, with grits and marls	105	......	.... .	......	
Total depth	994	650	851	967	789
Height of boring above sea-level	282	191	278	374	374
Lowest depth attained below sea-level	712	459	573	593	415
Depth of old land-surface below sea-level	417	......	527½	......	341

Discussion.

The President expressed his sense of the great value of this communication.

Mr. Etheridge spoke of the care and skill displayed by the author in following and preserving the results of these interesting borings. He believed the red beds at the bottom of the Gayton boring to belong to the Old Red Sandstone. He regarded the paper as throwing much light on the character of the great Palæozoic floor of central England. He had identified about twenty-five species of fossils from the Carboniferous rocks.

Prof. Boyd Dawkins expressed his thanks to the author of the paper for the facts described, though he could not accept the generalization of Mr. Etheridge. He thought there was no proof of the non-existence of Carboniferous basins in the central area. The absence of coal in the district was not proved. He praised the author for his caution in expressing doubt as to the age of the red rocks met with at Gayton.

Prof. Judd pointed out that while only one deep boring was known before in the Northampton area, the author had added records of *four* others, *three* of them from his personal observations. He thought that as normal Trias had occurred in three of the four borings near Northampton, the abnormal beds in the same position at Kettering road were probably of the same age, though perhaps in an altered condition. He was inclined to refer the red beds at the bottom of the Gayton boring to the Carboniferous rather than to the Old Red Sandstone, seeing that these red strata alternate with ordinary Carboniferous sandstones full of plant-remains. He compared these Carboniferous strata with the Calciferous Sandstone series of Scotland.

Dr. Hicks asked if the breccia at a depth of 712 feet in the Orton boring had been carefully examined. He thought it contained fragments of a crystalline limestone and of the underlying quartz-felsite, and was worthy of the most careful examination.

Mr. Collins asked if the amount, as well as the direction, of the dip of the rocks was unknown.

The President stated that the breccia at Orton had not been among the specimens forwarded to and examined by him. He thought the quartz-felsite of Orton resembled the rock of High Sharpley in Charnwood in its general characteristics; and it further agreed with it in presenting a strong cleavage at a high angle. It had also some resemblance to the Pre-Cambrian quartz-felsites of North Wales. He thought the quartz-felspar grits, which, unlike the Torridon Sandstone, had a calcite matrix, proved the proximity of a granitoid axis.

The Author said the older rocks had a dip of from 45° to 50°, but the direction could not be made out. He had admitted in the paper the possibility of concealed coal-basins existing in the country to the southward.

[To face page 496.

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Fig. 5.
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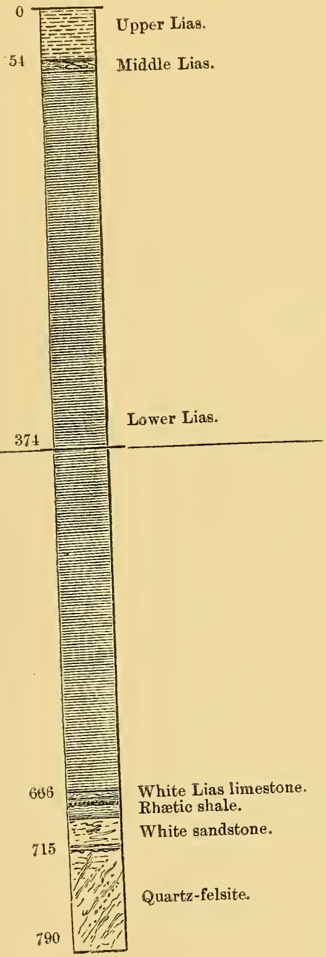

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Lias.
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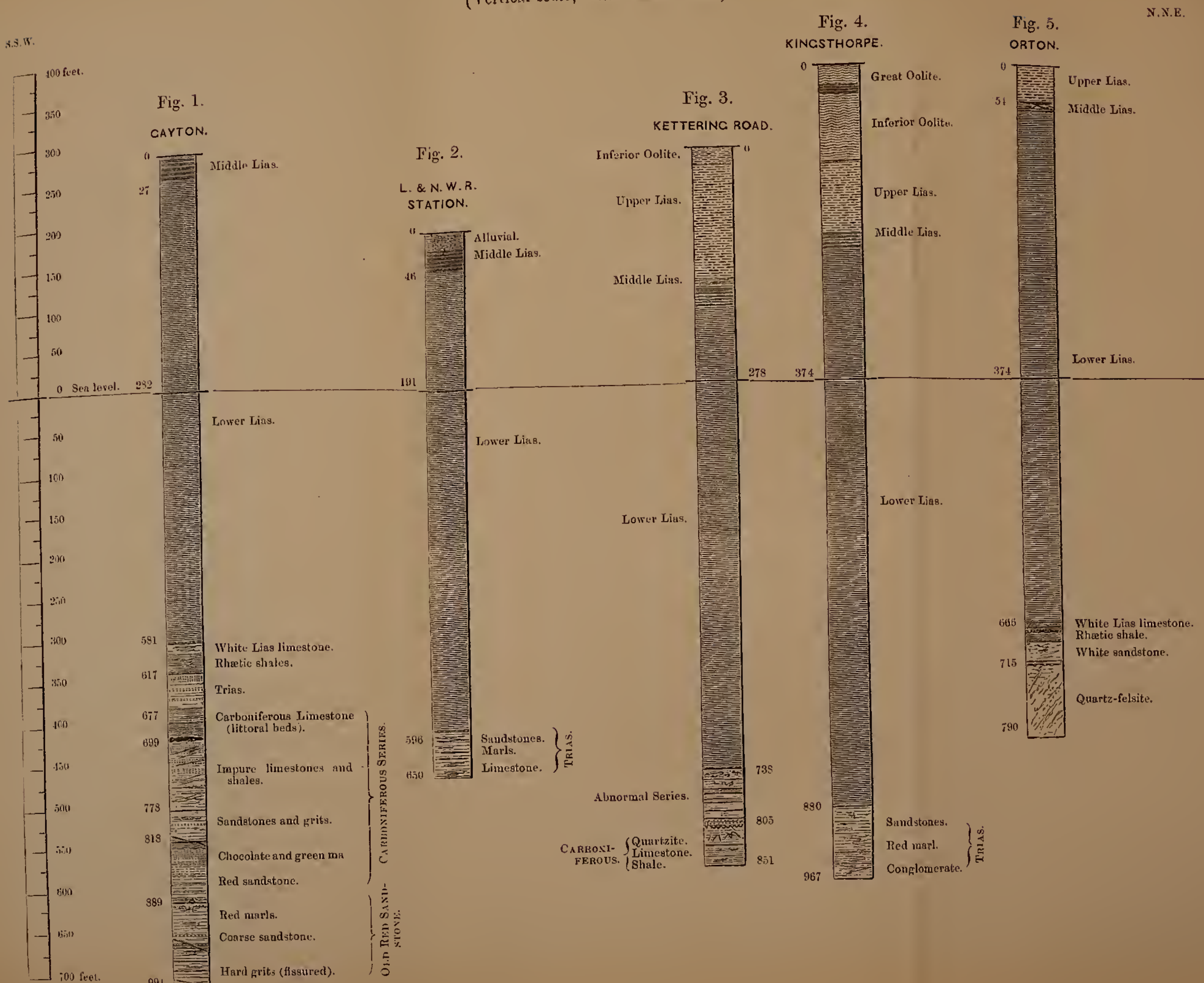
TRIAS.

Figs. 1–5.—*Sections of Borings, illustrating the Range of the Palæozoic Rocks beneath Northampton.*

(Vertical scale, 1 inch = 155 feet.)



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36. *On some* Zaphrentoid Corals *from* British Devonian Beds. By A. Champernowne, Esq., M.A., F.G.S. (Read June 11, 1884.)

[Plates XXI.–XXIII.]

The authors of the monograph of "The Devonian Fossil Corals," in the Palæontographical Society's volume for 1853, described and figured two species only of Devonian corals included in their subfamily Zaphrentinæ, namely *Hallia Pengellii* of those authors, and *Amplexus tortuosus*, Phillips. Since the publication of that work fresh material has been accumulating, and this will eventually necessitate a complete revision of the Devonian corals, involving, it may be, the admission of some new genera and the fusion of others.

To this end the way has been already paved to some extent by several palæontologists. For example, the genus *Battersbyia*, E. and H., has (metaphorically) had its corallites *extricated* from the so-called "cœnenchyma," and been classed by Dr. Duncan as a precursor of the aporose corals of the Mesozoic and later ages, under the family Palæastræidæ; whilst the "cœnenchyma" itself is manifestly, in various *Battersbyiæ*, *Stromatopora* of different kinds. Hence the name, though retained, has come to bear a very different meaning from that attached to it by its authors*.

In treating therefore of a particular branch of the subject, I have confined myself to noticing, and having figured, the best specimens which are at present available to me; but it must not be supposed that even this branch is brought up to date, as, with two exceptions only, the fossils I shall attempt to describe are all in my own collection, and I have scarcely ventured to go further than that.

With such very disconnected material at hand one can scarcely do more than show, as I shall hope to do, that in common with the American Devonians (in which many species of *Zaphrentis* are known and have been described by Rominger and others), these corals are somewhat better represented in European (British) Devonians than has hitherto been supposed. This paucity of European species is referred to by Dr. Ferdinand Römer †.

In the following I avoid as much as possible burdening scientific nomenclature: in two or three instances only, and with considerable diffidence, specific names are suggested; but on the whole I would prefer that the figures should speak for themselves.

Zaphrentis calceoloides, sp. nov.? (Plate XXI. figs. 1*a*, 1*b*.)

Somewhat calceoloid in shape, short in proportion to the width. Length 2 inches. Not distinctly curved, but the side corresponding

* Besides this, the works of Dr. Nicholson, Prof. Moseley, and others have helped to clear the ground in different ways.

† 'Lethæa geognostica,' Textband, 2nd part, p. 362.

to that of greatest curvature evident from its greater length and convexity. Calice elliptical in outline, measuring $1\frac{3}{4}$ inch by 1 inch, the minor axis being the plane of bilateral symmetry and containing the fossula. Septa about 40 primary, with traces of an intermediate series. Septal fossula deep, arising from the more convex side and extending a little beyond the bottom of the calice.

Obs. The coral here described is in an imperfect condition and has lost all trace of wall or epitheca, the outer surface being vertically marked by the edges of the actual septa and endothecal structures. The contour of the calice does not appear to be due to crushing, although a slight distortion is perceptible. The general form, on the contrary, suggests comparison with *Z. ungula*, Rominger, from the Corniferous Limestone of the Falls of the Ohio; but from this it is distinguished by its greater size and smaller septal number (*Z. ungula*, Rom., has 90–100 septa).

I venture to suggest the specific name of *Z. calceoloides* for the present fossil.

Loc. Mudstone Bay, in passage beds at the base of the limestone of Berry Head (Middle Devonian).

CAMPOPHYLLUM, sp.? (Plate XXI. fig. 2.)

This is a polished section of a coral, taken just below the general floor of the calice, but cutting through a well-marked septal fossula, which is seen filled with the surrounding matrix. It measures 2 inches by 1 inch 7 lines, but is somewhat oblique. The direction of vision is upwards or towards the calice, which is seen in a worn condition on the reverse side of the section. Septa about 92, of two orders. The primaries extend to near the centre; the secondaries are barely half as long. There are some tabulæ to be seen in the space below the fossula, and an outer zone of vesicular endotheca. These are omitted in the drawing, being in the original rather faintly indicated compared with the septa.

Obs. The endeavour to decide to what genus this specimen should be referred has caused me much perplexity. Perhaps it may be that my sole justification for introducing it under the title of this paper is its possession of a well-defined septal fossula. Dr. Rominger* has argued that Messrs. Milne-Edwards and Haime have set an undue value upon the presence of a septal fossula (or "fovea"), and that many of their so-called *Zaphrentes* have the essential characters of *Cyathophyllum*. Mr. James Thomson † has also shown that a septal fossula is a common feature even in groups of corals that are in all other respects widely separated.

At any rate the present specimen has far too complex an endotheca and perhaps too limited a "tabulate" portion thereof, besides the considerable development of the secondary septa, to be classed as a true *Zaphrentis*. It approaches *Campophyllum*, but it would be advisable

* 'Corals of Michigan,' p. 141.

† "On the development and generic relations of the Corals of the Carboniferous System of Scotland," *passim.*

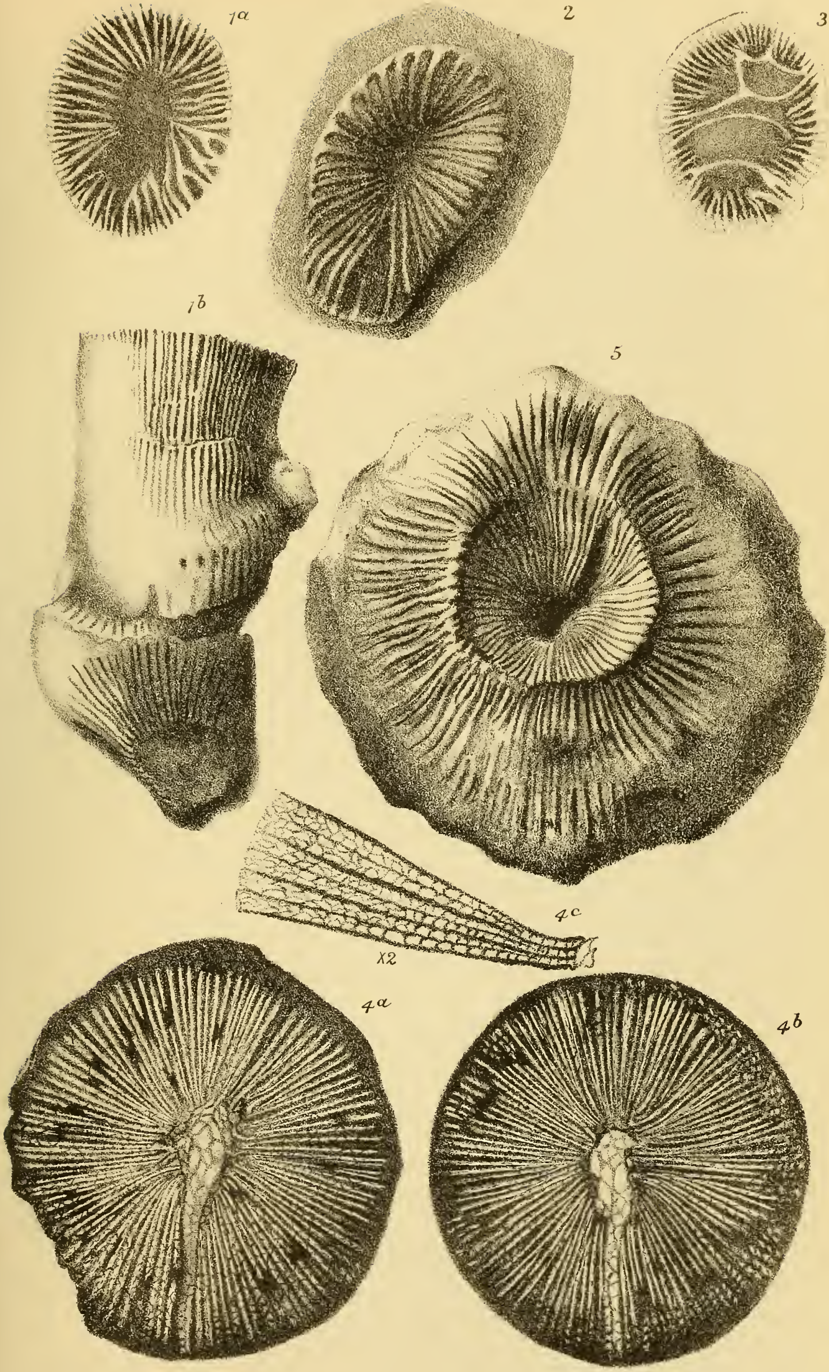
M. Sutt del et lith. Hanhart imp.

ZAPHRENTOID CORALS FROM SOUTH DEVON.

M. Suft del. et lith.

Hanhart imp

ZAPHRENTOID CORALS FROM SOUTH DEVON.



M. Suft del. et lith.

Hanhart imp.

ZAPHRENTOID CORALS FROM SOUTH DEVON.

to leave its place an open question, pending the discovery of more perfect material.

Loc. Mudstone Bay, the same as the preceding.

Lophophyllum, sp.? (Plate XXI. figs. 3 *a*, 3 *b*.)

This pretty little coral is seen as a polished section, the diameter of which is $\frac{3}{5}$ inch. It has 64 septa, of two orders. They are thick externally, appearing granulated (or striated?) laterally, but more slender near the centre; those of the second order reach half way. A large primary septum extends slightly beyond the axis, and is clavate at its inner extremity. The septa on each side of the latter form a fasciculate group, and are irregularly soldered at their edges, the same tendency to coalesce being observable in the septa opposite the primary. The endothecal dissepiments are fairly numerous, and a delicate epitheca can be recognized.

Obs. It is with much hesitation that I refer this specimen to the genus *Lophophyllum*. The septum in the fossula of a true *Zaphrentis* is always less developed than the remainder. The fossil has not the aspect of a *Hallia*, but the clubbed end of the primary septum appears to play the part of an essential columella.

Loc. From Triassic conglomerate, Hole Head, near Teignmouth, a spot which has produced a very large number of the Devonian corals of Devonshire.

Zaphrentis, sp. nov.? (Plate XXI. figs. 4 *a*, 4 *b*, 4 *c*.)

This is the lower portion only of a tall and, so far as one can see, straight *Zaphrentis*, that measures $5\frac{1}{2}$ inches in length*, both ends being rather imperfect. On the floor, exposed by fracture, there are 76 septa, of two orders. The principal ones are rather flexuous and nearly reach the centre as low crests on the tabulæ. The secondaries, as in all the true congeners, are minute, in this case under a millimetre. The septal fossula is well characterized, placed on the side of least curvature, and is produced as a shallow groove beyond the central axis. The epitheca is rather thin.

Obs. It may appear somewhat paradoxical to speak of "the side of least curvature" in a coral described as being straight. Nevertheless, reasoning from all analogy, we may probably be safe in assuming that, where the planes of the tabulæ are inclined to the longitudinal axis, the side *towards* which they dip does correspond morphologically to the side of least curvature.

Loc. Hill-Park quarry, Dartington, in Middle Devonian limestone.

Zaphrentis, sp. nov.? (Plate XXI. figs. 5 *a*, 5 *b*.)

This coral has the walls of its calice much broken down, and its base imperfect. When complete, it may have measured nearly 3 inches in height, and is covered by a strong epitheca. The calice, which is circular, is $1\frac{1}{4}$ inch in diameter. There are 50 principal septa, which extend irregularly to the centre; minute secondary

* Only the lower part of the coral is figured.

septa can be recognized between them. The surface of the tabulæ is very uneven, and appears to have small blisters and a pitted aspect between the ends of the septa. The fossula is very deep, formed chiefly by an inflexion of the tabulæ, and some of the adjoining septa bend towards and partly enclose it. There is no marked curvature in any direction.

Obs. We have here characters which appear to come very near to the genus *Streptelasma*, Hall. They consist in the confused nature of the central area above mentioned; but there is no distinct twisting of the septa such as the name implies. Rominger, however, regards *Streptelasma* as only a subgenus of *Zaphrentis*, and so far as the twisting of the septa is concerned, his figures of *Z. Stokesii*, M.-Edwards, certainly have it no less than *Strept. corniculum*, Hall, on the same plate *. Consequently, on the principle that the greater includes the less, I leave the specimen provisionally in *Zaphrentis* †.

Loc. Pit-Park quarry, Dartington, in dolomitic beds of Middle Devonian limestone.

[*Note.*—I refrain from suggesting specific names for the last two specimens, although they seem quite distinct; but my knowledge of the American forms being very limited, it might only lead to confusion were I to attempt it.]

Amplexus or Zaphrentis? (Plate XXI. fig. 6.)

Casts in dolomitic limestone similar to the one here drawn are common in the Dartington limestone at certain spots. The surface of the tabulæ is generally smooth, but faint lines from some of the principal septa extend nearly to the centre. The latter number about 40, a rudimentary series existing between them connected by sparse dissepiments. No septal fossula is visible, but probably such existed, at least on the upper floors.

Loc. Dartington, in dolomitic beds of Middle Devonian limestone.

Zaphrentis, sp. (Plate XXI. fig. 7, and Plate XXIII. figs. 1 *a*, 1 *b*.)

Epitheca strong; septa 66 and 78, of two orders, of which the principal ones extend some way towards the centre, whilst the secondaries are scarcely more than rudimentary. The position of the fossula can be noted in both specimens; but a deceptive appearance of it has been given to the specimen Pl. XXI. fig. 7. The lenticular dark spot at the bottom of the figure is accidental, and is not the fossula. That feature can be observed in the original (in the British Museum) nearly opposite to the dark spot, but the artist has failed to represent it. The figure, unfortunately, does not give the details well, being too diagrammatic.

Loc. Pl. XXI. fig. 7 (Brit. Mus.), Woolborough quarry, near

* *L. c.* pl. li.

† It is well to be on one's guard against being unduly swayed by stratigraphical considerations in estimating the value of two closely allied genera or species.

Newton Abbot. Pl. XXIII. fig. 1, Lummaton quarry, near Torquay, both in Middle Devonian limestone.

ZAPHRENTIS (or AMPLEXUS ?).

General form cylindro-conical, curved. Height 4 inches, diameter of the calice about $1\frac{3}{4}$ inch. Epitheca strong. Principal septa 64, with a secondary series which are very minute. The former are thick: they extend horizontally $\frac{1}{4}$ to $\frac{1}{2}$ inch from the epitheca; vertically they extend down the sides of the calice, which, in part of the periphery, is complete. The upper tabula is quite smooth for a space measuring an inch in diameter, the septa terminating at its margin. The fossula is well defined, but restricted to the septal area, and appears scarcely, if at all, to depress the tabula. It is many degrees out of the median plane of curvature, but is nearest the greatest curve.

Obs. This coral, from its large smooth tabulæ, approximates, in some respects, to *Amplexus*; but the most characteristic forms of that group (*e. g. A. coralloides*, Sby.) are totally devoid of secondary septa. This is a more reliable point for their generic diagnosis than the greater or less extent of the septa across the tabulæ *.

Loc. Orchard quarry, Dartington, in Middle Devonian limestone.

ZAPHRENTIS SUBGIGANTEA, sp. nov. (? var. of *Z. gigantea*, Lesueur). (Plate XXII. figs. 2, 3, 4, 5.)

Little or nothing is known as to the length and degree of curvature of these large corals. In transverse section they are circular, measuring about 2 inches in diameter. Epitheca strong. Septa from 110 to 124, of two orders. The principal ones can be traced almost to the centre as crests on the tabulæ. The secondaries scarcely attain 4 millimetres, including the epitheca. They often bend towards the primaries, and are united by a few dissepiments (or rather the subdivided margins of the tabulæ). These latter are large, and virtually extend across the entire visceral chamber. The fossula (well seen in fig. 4) is formed by a deep inflexion of the tabulæ, the septa bending round with the margin of the depression. In that example four principal septa can be seen within the circumscribed area, but these minor appearances would not be constant in all transverse sections.

Obs. There can be little doubt that these three specimens belong to the same species. Fig 3 has an illusory aspect of great stoutness of the septa and other parts of the sclerenchyma. This is due to crystallization perpendicular to their surfaces, as the line representing the actual plate can be clearly observed in the midst.

In the local (Devonshire) museums, almost invariably, the Zaphrentoids with wide tabulæ have been indiscriminately referred to *Amplexus tortuosus*, Phillips; and this fact has been somewhat pre-

* For opinions touching the relations of these genera, consult Rominger, *l. c.* p. 153, F. Römer, *l. c.* p. 362, J. Thomson, *l. c.*, Zittel, &c. As a whole, they are regarded as broadly separable.

judicial to their correct generic diagnosis. With regard to Phillips's species let me quote Messrs. M.-Edwards and Haime *. They say:—"Professor M[c]Coy justly remarks that the specimens described by Mr. Phillips were young individuals, and mentions a gigantic specimen, the diameter of which was 1 inch 9 lines." Hence it is clear that they rival in size the corals now before us. I may add that a portion of *A. tortuosus* (now on the table) considerably exceeds the size given by Mr. M[c]Coy; but I notice this difference between them and the present subject: all the septa are much more rudimentary, and they appear sunk in the substance of the epitheca (or theca?), from which they differ by having a more opaque, and consequently denser, tissue. They consist *of one order only*, and are about 62 in number. A fossula is rarely to be seen, and when present it is quite marginal and siphunculoid.

After consulting several works and the British Museum collections, I can find no species at all approaching these sections except *Z. gigantea,* Lesueur, from the Corniferous Limestone of North America †. With this, however, if we make allowance for the short pieces available from the Devonshire rocks, they agree in essential particulars. Rominger gives 150–160 septa for the American coral, whilst the highest number in my Pl. XXII. is 124. If we provisionally adopt the name *Z. subgigantea,* the qualifying prefix can be dropped if a closer approximation should be proved.

Horizon and localities.—In Middle Devonian limestone; figs. 2 and 3 (Brit. Mus.), Woolborough quarry, near Newton Abbot; fig. 4, Lummaton quarry, near Torquay; fig. 5, in black-marble quarry near Wolfsgrove farm, Bishopsteignton.

ZAPHRENTIS MUDSTONENSIS, sp. nov. (Plate XXIII. fig. 2.)

Calice oval, measuring $1\frac{1}{2}$ inch by $\frac{3}{4}$ inch, moderately deep. Principal septa 31, strong and straight, extending to the bottom of the calice, where they unite on the margin of a smooth, well-defined, central portion of the uppermost tabula. The merest rudiments of a secondary series can be observed close to the periphery. Septal fossula well defined, situated on the longer side, extending to the margin of the central area, and containing a septum which is shorter than the remainder, but included in the number stated.

Obs. This coral cannot be confounded with any British Devonian species hitherto described. It is to be regretted that the figure does not do it justice, the original being in a finer state of preservation than one might suppose from the figure‡. I have observed portions of one or two more individuals that I took to be identical with this.

Horizon and Locality. The horizon is lower in the series than that of any other species described in this communication, being the light-grey mudstones which form the hollow of Mudstone Bay, beneath the limestone mass of Berry Head and Sharkham Point.

* *L. c.* p. 223.

† Rominger, *l. c.* p. 46, pl. lii.

‡ This is from no fault of the artist, as a small coral (previously drawn) had to be erased, after which the stone was not susceptible of fine work.

As a specific name, *Z. mudstonensis* would perhaps not be open to the usual objections to a local appellation, inasmuch as it would serve to recall its horizon in a well-known coast-section.

AMPLEXUS TORTUOSUS, Phillips. (Plate XXIII. fig. 3.)

My object in introducing this figure of a described species here is twofold: first, for the purpose of comparison with corals herein referred to *Zaphrentis*; and secondly because it shows distinctly the quite marginal siphunculoid fossula, and that the septa are of one order only. The figures in the 'British Fossil Corals' (Edwards and Haime) give no indication of the fossula. The septa number 62, and are very short. Those on the left of the figure above are drawn too long, having been confounded with some radiating crystallization.

Loc. Quarry near Wolfsgrove Farm, Bishopsteignton, in Middle Devonian limestone.

CYATHOPHYLLUM ? BILATERALE, sp. nov. (Plate XXIII. figs. 4 *a*, 4 *b*, 4 *c*, & 5.)

Figures 4 *a* and 4 *b* are views of two transverse sections of an individual coral of unknown length, and measuring $2\frac{1}{4}$ inches in diameter. Traces of the epitheca still remain, but it is clear that the surface is, on the whole, somewhat abraded. 112 septa of two orders, the primaries stopping a little short of the centre, the secondaries from two thirds to three fourths as long. The bilamellate character of the septa is very distinct. There is a large septal gap or fossula, filled with vesicular tissue, against the sides of which the principal septa abut, and partially affect a pinnate arrangement. The endotheca is very abundant; in the intermediate zone these structures unite the septa as ordinary vesicular dissepiments, and outwardly become confused with a multitude of plates which branch from and often return into the same septum, causing a generally vesicular condition, through which, nevertheless, the septa are never completely lost sight of.

Obs. The specimen in question is an extreme type of a great number that occur in South Devon. It was found by a lapidary of Paignton, to whom I had mentioned the locality, and before I had an opportunity of a veto, met with the usual fate of being cut into a number of transverse slices, two of which are in the British Museum. They at least show that the fossula is a continuous feature. If it be simply a variety of *Cyathophyllum damnoniense*, Lonsd. sp., I can only say that I have never before observed indications of bilateral symmetry in that species; the most perfect calice of *C. damnoniense* that has come under my notice is one I brought from the Eifel, and it shows nothing of the sort. It is further, in my opinion, equally or more entitled to a place in *Cystiphyllum* (in which genus Lonsdale originally placed it) than in *Cyathophyllum*; and in this respect I am quite in harmony with the views held by Mr. Etheridge, junior. I also believe the Eifel specimen to be distinct from the present coral.

There still remains *C. ceratites*, Goldf., to be consulted in relation to this subject. To that species Edwards & Haime * referred the large individuals given on plate xvi. of Goldfuss † as *C. turbinatum*; but no transverse or longitudinal sections were given. The same authors mention "one or two small septal fossulæ." My impression is, that more requires to be known of *C. ceratites*; it may be a common Devonshire coral, but of this I cannot speak with certainty.

My fig. 5 clearly belongs to the same species as fig. 4. It has had all the outer part of the calice worn down, but I have succeeded in developing the central part, which shows the large fossula. The species may provisionally be named *Cyathophyllum ? bilaterale*, but may ultimately be placed with a known form.

Loc. A quarry in Devonian limestone and shale on the south bank of Tuckenhay Creek, on the Dart.

Summary and Conclusion.

The above descriptions of the material I have had to work upon are but imperfect, and in their very nature tentative; to no one can this statement be truer than to myself. The Devonian corals are difficult; they present very different aspects according to the condition and mode of fossilization, even of well-known species, and the less the number of individuals forthcoming of any form the more should one pause before asserting its distinctness (whatever specific distinctness may mean).

But to sum up that which has been advanced, in the first place, with regard to the main proposition, viz. the occurrence of *Zaphrentis* in our Devonian rocks. As above hinted, there is probably much more material in collections than what is realized. Thus, since the plates were drawn, I have again looked through the collection of the Torquay Natural History Society, and have also had the advantage of seeing some Devonian corals lately presented by Mr. Luxmore to the British Museum, and in both cases have fully satisfied myself that genuine *Zaphrentes* are included. Whilst, however, affirming the fact, I do so with no intention of conveying the idea that it is any remarkable discovery. In fact, on *à priori* grounds, it is no more than might well have been anticipated, and perhaps the wonder is that it should have hitherto escaped recognition.

In the second place, there are certainly three out of the seventeen specimens figured which have been regarded as not strictly admissible, even as Zaphrentidæ, although exhibiting bilateral symmetry. From these being exceptions, and from my having arrived at the conclusion after mature consideration, the legend of the plates was not altered on their account.

This brings us to another point, viz.—What are those correlations of structure upon which we may best rely for a definition of the Zaphrentidæ? We have (1) the successive complete floors, the

* Brit. Foss. Cor. p. 224. † 'Petrefacta Germaniæ.'

leading character upon which the generic name was founded (ζά-φρεντις "strongly-floored"). Correlated with this, we have (2) well-defined septal characters, notably the fact that, except near the periphery, their continuity as vertical plates is arrested by the floors, on the upper surfaces of which they only rise as crests. But this is not all; (3) the rudimentary condition of the secondary septa, taken in conjunction with (4) the almost complete absence of vesicular endotheca, forms a signal instance of correlation of structures. The only approach to the latter condition is an occasional marginal subdivision of a tabula, usually with an outward dip*. Lastly, there are (5) the septal fossula and other signs both external and internal of bilateral and, more rarely, of quadripartite symmetry. Though so strikingly developed in *Zaphrentis*, these characters are very feeble in *Amplexus*, whilst, on the other hand, they are shared by many Cyathophyllinæ and Axophyllinæ, as well as the Diplocyathophyllidæ of Mr. Thomson.

So far within the theca: the external characters are well known from better examples than any I can produce from Devonshire; and for this reason the word "costæ" does not once appear in the descriptions. I can only describe what I see. The "apertural gap" of Rominger, with costæ pinnate on both sides of a parallel pair, the "lateral gaps" with pinnate costæ meeting parallel ones,—these and other characters are fully set forth by Rominger, Dr. Duncan, and others.

Whatever corals fail to satisfy the above conditions should, in my opinion, be excluded from the pale of the Zaphrentidæ, how long soever they may have kept their place on sufferance †.

The Zaphrentidæ perhaps exemplify the salient characters of the Rugosa more than any other family, except only Lindström's "operculate corals" with their strange angular forms. They stand far apart from those Cyathophyllidæ which, according to Dr. Duncan, pass by insensible gradations into the great class Aporosa of subsequent ages; but that they are the skeletons of Hydroid, and not Actinoid polyps, I cannot for a moment bring myself to believe, although this opinion is held by so high an authority as Agassiz.

In conclusion, my best thanks are due to Messrs. Etheridge, senior and junior, for the ample assistance and valuable hints they have afforded me, and the free use of any British-Museum specimens bearing on the subject.

* Contrast with this the multitude of vesicles filling the interseptal loculi in corals whose secondaries attain, say, half or more of the length of the primaries, as in the Cyathophyllidæ, Axophyllinæ, &c. This, again, is correlated with a proportionate restriction of the tabulæ to the central area, a restriction that sometimes approaches the vanishing point.

† I have just for the first time studied Zittel's beautiful 'Handbuch der Paläontologie,' and observe that the above opinion as to the partial dismembering of the Zaphrentidæ has been forestalled. The genus *Hallia*, which was especially before my mind, has been placed under the head Pleonophora (the second subfamily of Diaphragmatophora, Dyb.); and the discoid genera of which *Hadrophyllum* forms a type, have been placed under the family Palæocyclinæ.

EXPLANATION OF PLATES XXI.–XXIII.

Plate XXI.

Fig. 1 (*a*, *b*). *Zaphrentis calceoloides*, mihi. Mudstone Bay.
2. *Campophyllum?* Mudstone Bay.
3 (*a*, *b*). *Lophophyllum?* Hole Head, near Teignmouth; 3 *b*, enlarged 2 diam.
4 (*a*, *b*, *c*). *Zaphrentis*, sp. nov.? (lower part). Dartington.
5 (*a*, *b*). *Zaphrentis*, sp. nov.? Dartington.
6. *Amplexus* (or *Zaphrentis*). Dartington.
7. *Zaphrentis*, sp. Woolborough (Brit. Museum). See also Plate XXIII. fig. 1 (*a*, *b*).

Plate XXII.

Fig. 1 (*a*, *b*). *Zaphrentis* (or *Amplexus*). Dartington.
2?, 3, 4, 5. *Zaphrentis subgigantea*, mihi (or var. of *gigantea*, Lesueur).

Plate XXIII.

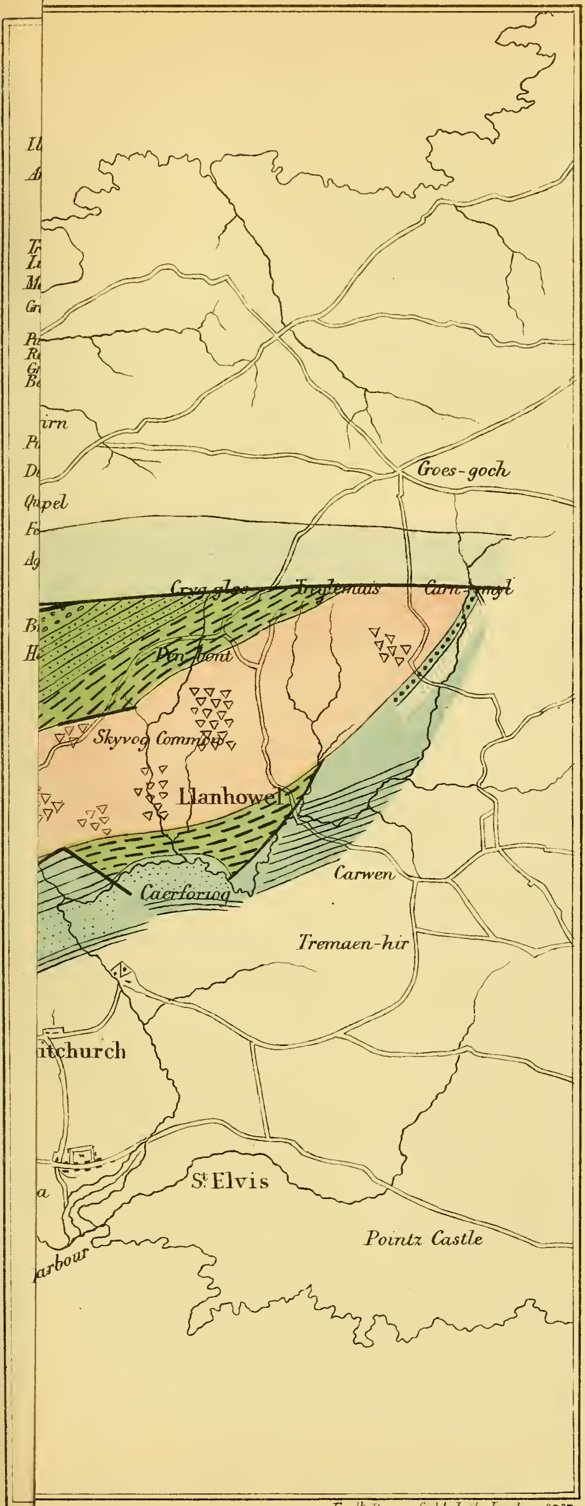
Fig. 1 (*a*, *b*), *Zaphrentis*, sp., see Plate XXI. fig. 7. Lummaton, near Torquay.
2. *Zaphrentis mudstonensis*, mihi, in shale or mudstone.
3. *Amplexus tortuosus*, Phillips. Bishopsteignton.
4 (*a*, *b*, *c*) & 5. *Cyathophyllum? bilaterale*, mihi, Tuckenhay Creek, on the Dart; 4*c*, enlarged 2 diam.

Discussion.

Prof. Duncan said that a more accurate definition of the Rugosa was very desirable. The author had wisely abstained from establishing new genera, or giving new generic diagnoses, while, at the same time, he furnished many details of character which would prove most useful in a generic revision of the group. He inquired whether the costal characters of the species could be ascertained. In his opinion the Mesozoic Corals or Aporosa were not the descendants of the Rugosa; and, in fact, it might be regarded as doubtful whether the latter are corals at all. From the great difficulty of understanding their nature, all precise details of structure, such as those described in the present paper, were of much importance.

Mr. Etheridge remarked that the author had worked most industriously upon the specimens contained in the British Museum collections, to which, indeed, he had very liberally contributed. The results given in the present paper were drawn from the investigation of a large number of specimens, and add much to the knowledge of the Zaphrentidæ.

The Author in reply thanked the meeting for the reception given to his paper. Few localities in Devonshire furnish specimens showing the external characters well.



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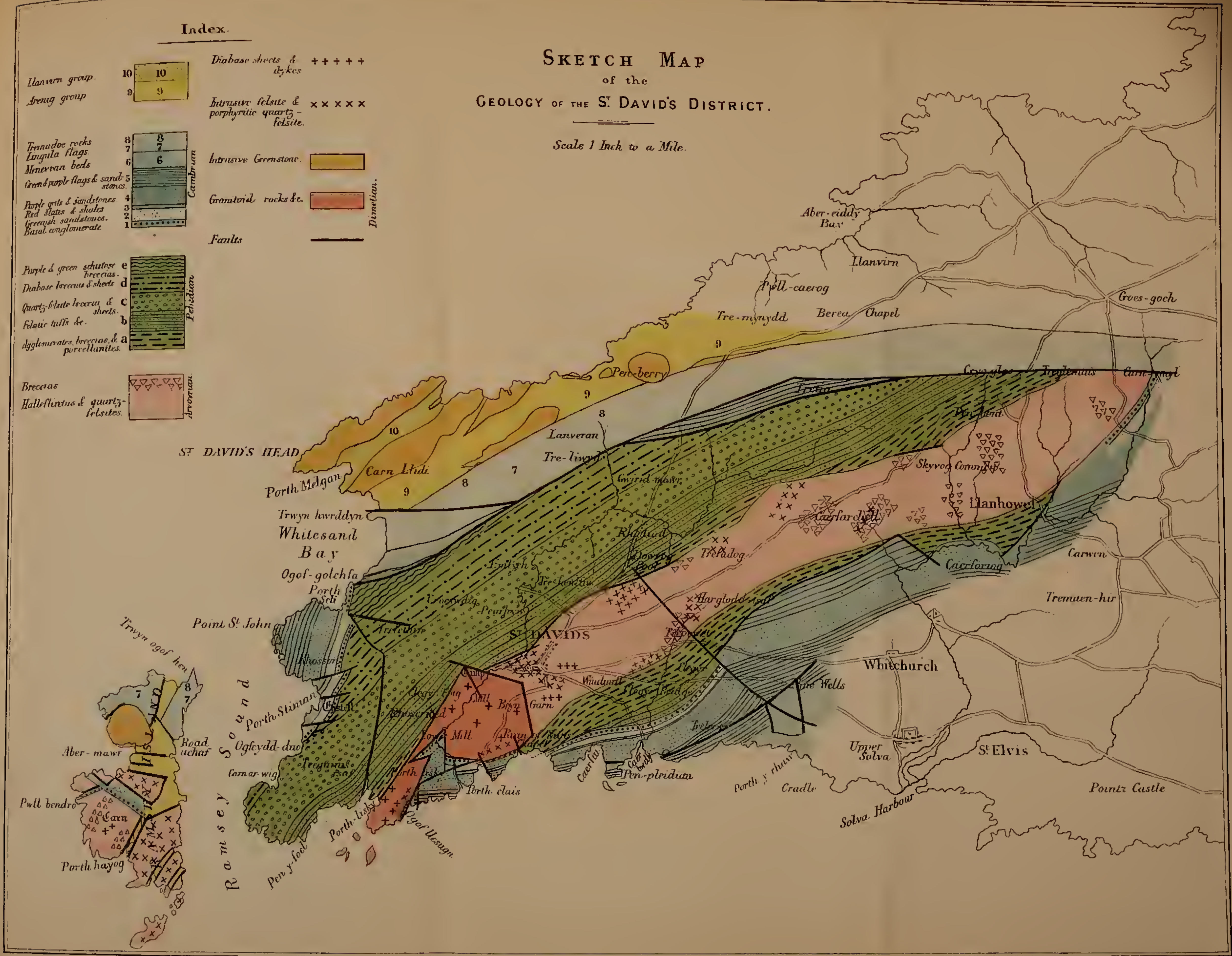

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37. *On the* Pre-Cambrian Rocks *of* Pembrokeshire, *with especial reference to the* St. David's District. By Henry Hicks, M.D., F.G.S. *With an* Appendix by Thomas Davies, Esq., F.G.S., of the British Museum. (Read May 14, 1884.)

[Plate XXIV.]

Contents.

I. Introduction.

The papers on the Pre-Cambrian Rocks of St. David's which I communicated to the Geological Society in the years 1876, 1878, and 1879, gave the facts concerning those rocks so far as they were then known. Since then I have revisited that district on several occasions, and have been able to obtain very much additional information in regard to them. Most of this has proved highly confirmatory of my previous conclusions, and it has shown that all the main points insisted upon in those papers are correct. Some of the evidence has tended, however, to cause me to adopt minor modifications of the views expressed; but this is only what I was quite prepared to expect, as further researches were being prosecuted in this and other areas. The growth of the question, so fraught with difficulties at first from its novelty and from the want of that special knowledge which time and experience alone can give, has been, I readily confess, "a process of development during a course of years." Of this I am not in the slightest degree ashamed; for as my sole object has been to arrive at the truth concerning these rocks, I have always been anxious to correct errors when made clear, as the result of fuller information, and also when they have been pointed out at any time by those whose special experience enabled them to do so.

The additional information now submitted has been gradually accumulated since my last paper was read in 1879; and it was reserved only that it might be placed in as complete a manner as possible before the Society.

The paper on the Rocks of St. David's, communicated to the Society by the Director-General of the Geological Survey, in March and April of last year, has compelled me to re-examine and therefore to refer again to many points which otherwise I should not have thought it necessary to trouble the Society with, believing that they had been sufficiently dealt with and satisfactorily proved, either in my previous papers or in communications dealing with similar questions, by such experienced observers as Prof. Bonney, Prof. Hughes, and others. The Director-General in his paper says that he entered upon this controversy with extreme reluctance, "but it was from a sense of duty that he came forward and defended the views of his predecessors." * It seems reasonable to suppose, however, that before claiming the work of his predecessors as correct, which had been done so very many years before, when these questions had not arisen, he would have seriously analyzed any apparently conflicting evidence brought forward since then, and also that, in the face of recent knowledge obtained by new methods of investigation, he would have endeavoured to make himself thoroughly acquainted with the nature and behaviour of these rocks in all the Welsh areas, and have visited all places of importance where information could have been obtained. Had he done this it would, it may be presumed, have prevented him from making very many of the statements contained in his paper, and of committing the serious errors which I am compelled now, in self-defence, to point out.

As the controversy now stands, it must necessarily appear that the views of the Survey, as expounded by its chief, are entirely at variance with those held outside the Survey, by those who have, of recent years, devoted all their time to the examination of the Pre-Cambrian questions in Britain. This is, to say the least of it, an unfortunate circumstance, since necessarily any alterations in the Geological maps can only be done through the Survey, and unless such corrections are made from time to time as new information is forthcoming, the maps soon become almost valueless.

* Quart. Journ. Geol. Soc. vol. xxxix. p. 333.

II. Corrections in the Maps suggested in the previous Papers.

The points mainly insisted upon in my previous papers as requiring correction are the following:—

1. The patch coloured in the Geological Survey map as intrusive syenite and felstone, extending from the coast to the S.W. of St. David's, under that city and to the N.E., in all about 7 miles in length, consists of granitoid rocks, of porphyritic quartz-felsites, of fine-grained quartz-felsites (old rhyolites), of hälleflintas, porcellanites, and of breccias, and these are of Pre-Cambrian age, and therefore cannot possibly be intrusive in the Cambrian rocks as indicated on the maps. Moreover, the terms syenite and intrusive felstone, I maintained, were petrologically either incorrect or utterly inadequate to indicate such diverse rocks, some of which could be clearly proved to be of sedimentary origin, and others volcanic ashes and breccias, &c.

2. To the N.E. of this area, near Llanreithan, another patch about a mile and a quarter long, also coloured as intrusive in Cambrian strata, was shown to consist of old rhyolites and breccias of Pre-Cambrian age.

3. The so-called granite on the shore to the south of Pointz Castle was stated to be made up of quartz-felsites of Pre-Cambrian age; and the great granite patch shown on the map as extending in a N.E. direction from near the rocks last referred to, for about five miles, was claimed to be composed of granitoid rocks like those to the S.W. of St. David's, and also, like the latter, to be of Pre-Cambrian age.

4. The patches coloured as porphyries and felstones intrusive in Cambrian and Silurian strata to the south and east of the so-called granite patch, and forming the elevated areas of Roch, Trefgarn, and Ambleston, with broken lengths extending altogether for from 8 to 10 miles, were also stated to consist mainly of quartz-felsites (old rhyolites), breccias, and hälleflintas of Pre-Cambrian age.

5. Returning to the immediate neighbourhood of St. David's, it will be observed that the differences between my views and those indicated on the Survey maps are very marked. The extensive area coloured there as altered Cambrian, to the W. and N.W. of St. David's, was stated by me to contain rocks totally unlike those which had been in this district and elsewhere classed as Cambrian; and evidence was given to show that the latter rested unconformably on the rocks called altered Cambrian, hence proving that it was necessary to class the latter as of Pre-Cambrian age.

6. I pointed out also that the long patch of so-called intrusive greenstone in the Survey map, extending in a N.E. direction from Ramsey Sound, consisted mainly of acid breccias, but with a few basic dykes, sheets, and ashes; and that other patches of so-called intrusive greenstone in the southern portion and making up nearly two thirds of Ramsey Island, instead of being basic rocks at all, were composed of acid types of rocks, mainly porphyritic quartz-felsites, old rhyolites, breccias, &c.

The above views, if correct, would necessarily change nearly the whole interpretation of the Survey map in the immediate neighbourhood of St. David's; therefore it was but natural that the Director-General should, as stated in his paper, before "admitting corrections of the views expressed upon the maps and sections of the Geological Survey," only do so after an "actual inspection of the ground" *.

III. Dr. Geikie's Conclusions.

The object of his paper communicated to the Society is stated by Dr. Geikie at p. 266, to be "twofold—first, to discuss the evidence for the assertion that Pre-Cambrian rocks exist at St. David's, and secondly, to lay before the Society an outline of what appears" to him "to be the true structure and geological history of that district."

In his conclusions at p. 291, he gives the main results of his resurvey in the following words:—"As the result of my resurvey, I find that the true meaning of the volcanic group at the bottom of the Cambrian strata there exposed, though partly recognized in the first edition of the map and section, had been subsequently lost sight of, these rocks having been erroneously renamed by the Survey 'Altered Cambrian,' with intrusive sheets of 'greenstone.' I have freely admitted this to be an important error." "Again, were the area to be resurveyed now we should not colour as one continuous belt of intrusive rock the long strip of country from the coast near St. David's north-eastward to beyond Llanhowell. We should endeavour, as far as possible, to represent only those portions of eruptive rock which are actually visible or unquestionably exist underneath the surface, leaving the intervening spaces on the map to be coloured with the tint used for the general stratified formation of each area. We should prefer to indicate in this way that there are detached dykes and bosses along a certain area of extravasation, rather than to map the whole as one continuous belt. But this would be, after all, a question of detail or style of mapping. The officers of the Survey were certainly correct in regarding the crystalline rocks, which they named syenite and felstone, as intrusive through the Cambrian strata; and this is the main question in the present discussion. In concluding this part of my paper I am bound emphatically to declare that the map of the St. David's district, as surveyed by De la Beche, Ramsay, and Aveline, is in its essential features correct."

IV. Some of the Main Differences between our Views.

I wish especially to call attention to the last two paragraphs quoted above, for they certainly touch the very essence of the disagreement between my own views and those of the officers of the Survey. In those paragraphs it is maintained that the granitoid rocks, their former syenite (our Dimetian), are intrusive in the Cambrian rocks. I hold, on the other hand, that they are the oldest

* *Ibid.* p. 261.

rocks in the district, and that the Cambrian rocks were largely built up of materials derived from them by denudation. They maintain that the felstones are intrusive rocks of later date than the sedimentary rocks. I hold that they also, for the most part, are of Pre-Cambrian age, but newer than the granitoid rocks, that the majority are old rhyolites or breccias, and that Dr. Geikie's so-called apophyses actually in places cut through the Dimetian rocks. Fragments of some of these are found abundantly in the Cambrian conglomerates.

The next point of importance is that relating to the connexion of the volcanic series with the Cambrian. The Director-General maintains that they are merely the lowest beds of the Cambrian. I hold that there is an abundance of evidence to show that they are truly of Pre-Cambrian age, that the Cambrian rocks are very largely indeed made up of fragments and finer materials derived from them by denudation, and, moreover, that the basal Cambrian conglomerates constantly overlap different members of the volcanic series.

The differences between the views of the Survey and my own remain therefore almost equally great after the resurvey by the present Director-General as they were before. As some points of importance in regard to the nature and distribution of many of the rocks have been made out since my paper in 1879 was published, it will be necessary for me to add some special remarks on each of the three groups into which they have been divided by me at St. David's, before referring in detail to the various points at issue between the Director-General and myself.

V. The Dimetian Rocks.

a. Evidence of Age.—That the Dimetian rocks are older than the Cambrian rocks has been proved, as I shall show, beyond the possibility of dispute, by the finding of an abundance of well-rolled fragments of typical Dimetian in the Cambrian conglomerates, and by the fact, proved by examination with the microscope, that the matrix of the conglomerate and also some of the grits and sandstones flanking the Dimetian at various points, are almost entirely made up either of minute fragments, or of the characteristic felspar and quartz, of the Dimetian.

The importance of these finds will be readily recognized by those who have taken part in or watched the discussions on these questions; for it has been constantly assumed by those opposed to my views, that these fragments could not be found. Moreover, the Director-General in his paper (at p. 288) makes the following statement:—" As the result of a most careful examination of the conglomerate belt along both sides of the fold I feel myself warranted in stating confidently that it contains not a single pebble of the characteristic granite of the St. David's ridge." The making of such a definite assertion, founded on negative evidence alone, seemed to me at the time rash in the extreme, especially as I had on several occasions, even without looking with any particular minuteness, found ample proof to show that the Dimetian, his so-called granite, as well as rocks of Arvonian and Pebidian types, had yielded very much of the material for the Cambrian sediments. My frequently repeated statements of these facts ought also, I am fain to think, have tended somewhat to modify conclusions arrived at by so hasty and imperfect an examination. From the paragraphs already quoted from the Director-General's paper (and many others, with equally strong assertions of the same kind, might be quoted from it), it is abundantly clear that the finding of these fragments in the Cambrian conglomerates at St. David's, as in the case of those in North Wales, already placed before the Society, destroys the very pith of his argument.

Indeed, this evidence alone is a sufficient reply to his paper; still I think it is due to myself and to the Society that all other evidence of a confirmatory character should be fully stated. This will be given more in detail further on, when all points where a contact between the Dimetian and the other rocks can be clearly seen will be specially referred to, and indicated, where possible, by diagrams, sections, or sketches.

b. New Areas in Pembrokeshire.—The general distribution of the Dimetian rocks in the immediate neighbourhood of St. David's was fairly indicated in my paper communicated to the Society in 1879; but since then I have examined an area on the opposite shore of St. Bride's Bay where rocks of similar types occur, which will probably prove to be of Dimetian age. Some of these rocks are coloured as greenstones and others as syenites, intrusive in Upper Silurian if not in Carboniferous beds. So far as I have yet been able to examine these I could not find any evidence to show that the main masses are intrusive in Palæozoic sediments, but my examination tended to prove that the grits of the surrounding Llandovery series had been mainly derived from them or from similar rocks. One point, however, is abundantly clear,—that the terms greenstones and syenites, applied generally to these on the maps, are as utterly inappropriate as in the cases at St. David's. The only rocks which could possibly come under this term are some dykes of diorite and diabase; but these form only a very small part of the area. The so-called syenite exposed at Johnston, in the railway-cutting and elsewhere in the neighbourhood, is a granitoid rock very similar to the Dimetian rock of St. David's, and is, as there, traversed by diabase dykes. The so-called greenstone, well exposed on the shore of St. Bride's Bay at Goultrop, Talbenny, &c., about 10 miles across the Bay from St. David's, is in reality for the most part not a basic massive rock at all, but consists mainly of rocks with a good schistose foliation, and similar in many respects to some of the oldest gneisses, though unlike any hitherto found in the St. David's district. These are described by Mr. Davies in his notes 82 and 83, and they are peculiarly interesting in consequence of being found in such intimate relationship with rocks of the Dimetian type. The further examination of these rocks may possibly lead to something definite in regard to the origin of the Dimetian, though of course it must be admitted that their age is doubtful.

c. As to the Origin of the Dimetian Rocks.—At present the evidence is not completely satisfactory, nor, indeed, can it be said that it is so with reference to the origin of the majority of the massive gneisses in Scotland and elsewhere. Whatever it may have been in the case of those gneisses, it was, in my opinion, of like nature in the case of the Dimetian. Whether we adopt a neptunian or a volcanic origin, or, what is more probable, a combination of both, for these rocks, one important fact constantly presents itself to our minds—that is that these rocks show peculiarities, wherever exposed, which lead us to suspect their age even where the stratigraphical evidence is not conclusive. The peculiar mode of fracture I mentioned as characteristic of the Dimetian at St. David's, is equally evident in the Johnston rocks, and in the so-called granite (Dimetian) of Brawdy, Hayscastle, and Brimaston. It is also equally marked in the granitoid rocks of North Wales, which have been classed with the Dimetian. This peculiar condition was also developed at a very early period, undoubtedly before the Cambrian conglomerates were deposited, as it is present in the fragments contained in those sediments. The diabase dykes in the Dimetian have been called in my papers by different names such as melaphyre, dolerite, &c. Dr. Geikie uses the general term diabase for these; and as it is on the whole perhaps the best term, I shall also use it throughout this paper, and it will prevent confusion. In early papers, before the microscope was so generally used to differentiate the various rocks, some of these diabase dykes, from their frequent parallelism with one another, and from a peculiar cleaved structure developed in them, were included in the Dimetian as interstratified bands. In my paper in 1878 I clearly pointed out, as the result of a microscopic examination of these made for me by Prof. Judd and Mr. T. Davies, that they were igneous rocks, and therefore of no value in regard to the question of the origin of the Dimetian. The dolomitic bands found by me in the cliff at Porthlisky may also, as suggested by the late Mr. Tawney, who examined them subsequently with me, be merely of secondary origin as the result of infiltration, "due to the decomposition caused by water filtering down joints, removing alkaline silicates, and depositing carbonates of lime and magnesia" *. Hence they also may be of no value in any question of the origin of these rocks. Mr. Tawney, however, even though he supposed that this evidence could not be relied upon, still strongly believed in the metamorphic origin of the Dimetian, and emphasized this in one of the latest papers † published by him, in which he gives the results of a prolonged examination of these rocks in the field both in North and South Wales, and by careful microscopical examination.

d. The Brecciated Portions.—The brecciated bands found at several places in the Allan Valley have been carefully described by Prof. Hughes, and there seems to be tolerably clear evidence to show

* Proceedings of the Bristol Naturalists' Soc. vol. ii. part 2, p. 116.

† Geol. Mag., dec. 2, vol. x. p. 67.

that they are the result of crushings and of subsequent infiltrations of secondary minerals along joints.

Evidences of similar conditions are present, as has been frequently mentioned by Prof. Bonney, in like rocks in North Wales; and I have also specially referred to these brecciated bands in my recent paper before the Society in describing the Dimetian rocks of Anglesey *. I know of no place, however, where they are so marked as in the Allan Valley at St. David's, particularly immediately behind the small farm called Halfesh, about midway between St. David's and Porth-clais, and in the face of the hill some few hundred yards to the south of that farm. To all who are interested in the study of the extraordinary changes which have taken place in these rocks as the result of crushing and subsequent infiltration, those places will well repay a visit. It is interesting to note that all these brecciated portions of the Dimetian which I had referred to were entirely missed by the Director-General and his assistants in their examination, and that they were compelled therefore, as stated at p. 274, to arrive at the conclusion that I had included in my Dimetian "portions of the undoubted bedded rocks (quartz-schists, quartzites, shales, &c.) which flank the massive rock of the ridge." Whether or not the evidences fail, which we have thought might tend to confirm our views that these rocks are of a metamorphic character, it seems perfectly clear that the arguments and deductions in the Director-General's paper can have no weight in solving the question; for they are all made subservient to one purpose, that is, to prove that the Dimetian is an eruptive granite of later date than the Cambrian rocks, to show, as stated in Dr. Geikie's own words at p. 274,—"that this rock is not only a granite, but one which has been erupted through the Cambrian strata, and must therefore be younger than they."

e. Petrological Characters.—With regard to the petrological characters of the Dimetian I have not much to add to that which I have written in former papers, or which is contained in papers by Prof. Bonney, Prof. Hughes, Mr. Tawney, &c. Mr. Davies will, however, refer to some fresh slides which have been prepared, and will explain the reasons why, when these rocks were first examined by him, he thought the term quartz-schist seemed to be the most appropriate for the peculiar conditions exhibited by them under the microscope. The term granitoidite suggested by Prof. Bonney seems perhaps on the whole best applicable to these rocks as exhibited at St. David's and in some parts of North Wales. On the other hand in parts of the same group in Anglesey the rocks are sufficiently schistose to be called true schists; and the rocks already referred to in South Pembrokeshire, if proved to be of the same age, as they appear to be, so far as the evidence at present goes, are also highly schistose. In the latter area the proportion of basic silicates is greater than at St. David's, and this is necessary to give the characteristic banding of the true gneisses. The accidental absence, as I

* Quart. Journ. Geol. Soc. vol. xl. p. 187.

am inclined to put it, of a due proportion of the basic silicates from the Dimetian at St. David's is the main cause why it is not a true gneiss instead of a massive granitoid rock. The various changes to which the Dimetian rocks have been subjected would undoubtedly have produced a schistose structure, were more of the basic silicates present. All, however, may even have had an igneous origin; but if so, the evidence that such was the case is now entirely wanting. One thing, however, is certain beyond doubt, that is that the Dimetian at St. David's is not, as asserted by the Director-General at p. 313, —"a central boss of eruptive granite with associated peripheral dykes, elvans, or amorphous intrusions of quartz-porphyry," which "has been protruded through the Cambrian strata," and this is the main point which we have to contest.

VI. The Arvonian Rocks.

a. Evidence of Age.—That these rocks, like the Dimetian already referred to, are older than the Cambrian conglomerates is a fact which cannot now be disputed, as the Cambrian conglomerates contain rolled fragments in abundance which cannot be differentiated from these rocks. Moreover in some places, notably in Ramsey Island (and in areas in North Wales, as described in a former paper *), the conglomerates repose unconformably upon them, and are almost entirely built up of materials which could only have come from such rocks. As in the case of the Dimetian, so with these, it has been maintained by the Director-General that they, or at least the majority of them, are properly indicated on the Survey maps as eruptive masses in Cambrian and Silurian strata.

I have referred above to the fact that fragments of these so-called Post-Cambrian eruptive masses are to be found in abundance in the basal Cambrian conglomerates, but we have still more important evidence which shows that the rocks I claim under the name Arvonian are not only Pre-Cambrian, but more than probably also of Pre-Pebidian date. In the lowest Pebidian breccias, more properly in some places to be called agglomerates, fragments of the peculiar quartz-felsites (old rhyolites), of the hälleflintas, and of the indurated argillites and breccias which together mainly make up the Arvonian group in Pembrokeshire, occur in such abundance, that no doubt can arise that they must have been derived from pre-existing rocks identical in their grouping and character with those we now class as Arvonian. The Pebidian agglomerates at Clegyr Hill, St. David's, are very largely made up of fragments of old rhyolites (spherulitic) like those found *in situ* in the ridge at St. David's and to the north-east; and curiously some of the so-called "adinole nodules or concretions varying from the size of a pin's head to that of a man's head or larger," described by the Director-General in his paper at p. 320 as occurring in the Porcellanite series near Nun's Chapel, are nothing more than fragments of these old rocks included in the associated breccias. These are described by Mr.

* *Loc. cit.*

Davies in notes 17 and 18, and I shall have occasion again further on to refer to them.

In the Pebidian breccias on the west side of the ridge, fragments of these old rhyolites, of the hälleflintas, and of the indurated argillites are constantly found; but probably the most important series to prove that the rocks I call Arvonian are older than those named Pebidian are the great agglomerates to the north and south of the Llanhowel ridge. At Llanhowel and reaching northwards to Carnymyl old rhyolites with flow-structure and sometimes spherulitic, alternating with bands of hälleflintas and fine acid breccias, are constantly met with. These are flanked at Treglemais (as is especially well seen in a field at a point in the Ordnance map indicated by the letter *t* of Penbont) by agglomerates containing fragments of all those found in the axis, many in a rounded or rolled condition. On the south side of the ridge in the Caerforiog Valley, as shown in the map, similar agglomerates are found containing large fragments of like character to those above described. The evidence at these points that the rocks forming the central part of the ridge must be of older date than the agglomerates is in my opinion most conclusive, and the latter are, as far as can be made out, the oldest Pebidian rocks in the district. The beds which immediately succeed the latter are porcellanites like those on both sides of the ridge at St. David's. The peculiar grouping of the rocks found in each of the Arvonian areas is an interesting point, and will be further referred to in speaking of their probable origin and special petrological characters.

b. New Areas in Pembrokeshire.—Since my paper in 1879 was read, I have examined an area in South Pembrokeshire not far from Milford Haven, and to the east of a place called Rosemarket, where rocks of a type in many respects resembling those in the Arvonian group occur. It is only a mile or so to the south of the Johnston ridge, where, as I have already pointed out, rocks of the Dimetian type occur; between these also another short ridge of granitoid rocks is found. It therefore appears tolerably clear that by the combined influence of denudation and faulting a considerable portion of the old Pre-Cambrian floor has become exposed in South Pembrokeshire, and that wherever it occurs in these areas the types of rocks forming it are similar. Three well-marked areas of elevation are thus indicated in Pembrokeshire—viz. (1) the district of St. David's proper; (2) that of Brawdy, Hayscastle, Roch, and Trefgarn towards the east; and (3) that of Talbenny, Johnston, and Rosemarket in the south. The Palæozoic rocks are troughed, folded, and faulted-in between these; and wherever the basal rocks of the Palæozoic sediments are exposed in these areas it is found that they contain materials which could only have been derived from rocks similar to those we claim to be in these areas of Pre-Cambrian age. I was particularly struck with the undoubted arkose character of the grit of Llandovery age in the Johnston and Rosemarket area, and small fragments of the granitoid rocks and of those of the Arvonian type occurred also in it in considerable abundance. The age therefore of the granitoid rocks, the hälleflintas, and the old rhyolites of the South Pembrokeshire areas is proved beyond doubt to be Pre-Silurian (Upper Silurian of Survey), and by every reasonable probability to be Pre-Cambrian.

c. Probable Origin and Petrological Characters.—That many of the rocks included in the Arvonian group must have had a volcanic origin is certain. Acid lavas and ashes prevail in it in all the Pembrokeshire areas; but associated with these occur some indurated argillites and quartz rocks. The doubtful rocks called hälleflintas *, so far as the microscopical and field-evidence can at present decide the question, appear to be mainly made up of fine volcanic ashes or muds. Sometimes fragments, chiefly of quartz, are recognizable in considerable abundance in parts of a slide, while the other portions are homogeneous. The rock appears as if it had been in a colloidal condition, but with fragments still remaining in parts unchanged.

Of course another very natural view concerning them would be that they were originally rhyolites which had subsequently undergone great change. As the old rhyolites, however, which are found in association with these rocks still retain marked evidences of their original character, it seems a fair presumption to think that the hälleflintas had some other origin. These hälleflintas were first recognized by Mr. T. Davies, when examining some slides for me for the paper communicated to the Society in 1879, as being of the peculiar nature characteristic of the rocks so well known under that name in Sweden. There, I believe, they are classed as sedimentary rocks. In Pembrokeshire they are mainly limited to the Arvonian group, and are found in each of the areas where rocks of that age are exposed. They are particularly well shown in the gorge of the Cleddau, between Haverfordwest and Fishguard, about Trefgarn, and also at and to the east of Roch Castle. But in the areas between the latter points, named Dudwell and Plumstone Mountains, true breccias, beds of quartzo-felspathic ash, and old rhyolites are the prevailing rocks (Notes 80 & 81). The hälleflintas will be fully referred to by Mr. Davies in Notes 73 to 79, and also those parts of them containing the peculiar replacements of felspar crystals by quartz, noticed by Prof. Blake in a slide from Roch Castle, and referred to by him in his paper read before the Society in January last †. Mr. Davies supposes these replacements to have taken place mainly in the brecciated portions; and as these rocks have been greatly fissured and completely permeated by secondary quartz, such a change could there readily take place. A fine quartzo-felspathic ash, showing distinct lines of lamination, makes up a considerable proportion of this group in Ramsey Island, in association with breccias and old rhyolites (Notes 12–14). The descriptions given in my previous papers as to the special characters

* The term hälleflinta is used generally for a compact rather flinty-looking rock, which in chemical composition does not differ much from one of the more acid varieties of rhyolites, and may be either one of these considerably changed, or an altered sedimentary rock.

† Quart. Journ. Geol. Soc. vol. xl. p. 308.

exhibited by the rocks of this group remain sufficiently accurate; but in addition to the quartz-felsites (old rhyolites), breccias, and hälleflintas mentioned, I have noticed also in some of the areas, as in South Pembrokeshire and in the area to the N.E. of St. David's, rocks which appear to be indurated argillites.

The latter show clear evidences of aqueous deposition during the period; and the fragments which occur in the basal Pebidian agglomerates point out that induration had taken place, to some extent at least, in these argillites before the agglomerates of the Pebidian were accumulated. It is highly important that the peculiar characters exhibited by the Arvonian rocks should be clearly understood, and that the fragments in the lower Pebidian breccias should be identified with rocks now exposed in the area. The evidence obtained in this way is perfectly conclusive in showing that there are acid lava-flows in the area which must be of older date than the Pebidian rocks. And yet the Director-General says at p. 300:—"All the siliceous eruptive rocks, so far as I have been able to discover, are intrusive, and belong, I believe, to a much later period than that of the volcanic group; in no single instance did they appear to me to be true superficial lava-flows." Dr. Persifor Frazer, of Philadelphia, who visited the St. David's sections under Dr. Geikie's guidance, says, however, on the other hand, in a paper published by him last year *, that the Pebidian breccia immediately to the west of Clegyr Foig rock "seems to be a remade rock, including within itself fragments of ortho-felsite, which would fix its origin as later than the latter."

Though this group consists so largely of volcanic materials, it seems to me, from all the evidence I have been able to collect, to belong to a period anterior to that during which the Pebidian rocks were accumulated or deposited; hence some such a name as Arvonian is necessary to indicate the geological position of the group.

VII. The Pebidian Rocks.

a. Evidence as to Age.—In my previous papers much evidence was given to show that the Pebidian rocks were older than the Cambrian rocks; also that the latter were very largely indeed built up of materials derived from the former, and that the basal Cambrian conglomerates not only overlapped the Pebidian rocks unconformably, but were found to be almost at every point in contact with different members of the Pebidian series. I was therefore much surprised to read the statements made over and over again by the Director-General in his paper, that the Pebidian is only a part of the Cambrian, and, as at p. 291, that it "passes regularly upwards into the fossiliferous Cambrian formations, from which it cannot be dissevered, and with which it must be classed."

Ample evidence will be given, in speaking of special areas, to prove that the Pebidian rocks must undoubtedly be of much older

* "A Comparison of the Eozoic and Lower Palæozoic in South Wales with their Appalachian Analogues in the United States," 1883, p. 10 (Trans. American Inst. Mining Engineers).

date than the Cambrian; that they had been uplifted to form shore-lines, and very much in their present mineral conditions, before any of the Cambrian sediments were deposited.

Their age as compared with the Dimetian and Arvonian groups is almost equally clear; for materials from each of those groups appear to be present in considerable abundance in the lowest beds of the Pebidian, according to the evidence furnished by microscopical examination. The quartz and felspar fragments, as will be mentioned by Mr. Davies in Notes 20, 22, &c., have all the characters which we consider peculiar to the Dimetian; and fragments of the hälleflintas, of the compact quartzo-felspathic ash-beds, of the indurated argillites, and of the old rhyolites of Arvonian type occur in them in abundance. The section at Porth-lisky is also very clear in showing some of the lower beds of the Pebidian overlying the Dimetian.

b. Origin and Petrological Characters.—The special characters exhibited by this group have been very fully referred to in my previous papers, and Dr. Geikie, in his paper, says that he accepts "generally the lithological descriptions" given in my papers. A very large proportion of the rocks in this group are of volcanic origin, but along with these there are some which offer ample evidence to show that ordinary marine sediments were also deposited during the period. On the Geological Survey maps the Pebidian rocks are coloured either as altered Cambrian or as intrusive greenstones. The Director-General, in his paper, p. 284, says that his predecessor, Sir A. C. Ramsay, in his original map and section, and in his early MS. report on the St. David's area, recognized the volcanic nature of these rocks, but that he "afterwards allowed this view to be set aside in favour of the opinion that the peculiar bedded rocks on the west side of the granite ridge are altered Cambrian strata through which intrusive 'greenstones' have been injected." He further states that it is the latter view which is expressed upon the second and latest edition of the Survey map and section, and acknowledges "that in this respect the present map and section are seriously in error, and that Dr. Hicks deserves the thanks of geologists for having, as it were, rediscovered probably the oldest group of Palæozoic volcanic masses yet known in this country." The only maps and sections of the Survey available to me were those referred to above by the Director-General as seriously in error, and I had no means of knowing Sir A. Ramsay's previous interpretation. It is, however, satisfactory to think that they are now likely to be corrected on that point, though I consider that this is but a trifling matter as compared with the other corrections necessary to make the maps intelligible, or to give in any way a fair interpretation of the knowledge which has been gathered together concerning the rocks of this area during many years past.

c. Thickness of the Group.—The thickness assigned by me to this group has been contested by the Director-General, and in his paper he has endeavoured to show that the same beds are repeated by an anticlinal fold, the centre of which is indicated along a line almost midway between the Dimetian ridge and Ramsey Sound. I fail to recognize that any evidence whatever has been given by him to prove this, and a full acquaintance with the rocks in this area tends certainly to show that the idea is devoid of foundation. The evidence that the sequence is a continuous one from the Dimetian axis to the coast on the west will be fully given when treating further on of the special areas. Yet it may be stated here that I have paid very much attention to this question throughout the district, and that in my papers of 1871 and 1875, before the Pebidian rocks had been clearly differentiated, a section with an isoclinal condition of the beds was given curiously like that shown in the recent sections by the Director-General, and along the same line of country. This question, therefore, is in no respect a novel one, but merely the revival of a discarded one—originally suggested by myself, but found to fail on further examination *.

VIII. Detailed Descriptions of Areas near St. David's.

Having, in the foregoing remarks, referred generally to the Pre-Cambrian groups in Pembrokeshire, and to some of the various points at issue between the officers of the Geological Survey and myself, it will now be necessary for me to describe in detail the several areas in the more immediate neighbourhood of St. David's to which the Director-General in his paper calls special attention. Others will also be added which seem to furnish any important evidence.

1. *Caerbwdy Valley and Area S.E. of St. David's.*

a. Cambrian Conglomerates.—The basal Cambrian conglomerates which everywhere in the district, when not dropped by faults, mark the boundary line between the Cambrian and the Pre-Cambrian rocks, stand out very conspicuously in the face of the hill on the west side of the valley immediately to the north of the mill, and are exposed also on the opposite side. The thickness of the more conglomeratic portion of the basal beds at this place is about 60 ft. The pebbles vary in size up to some quite a foot in diameter. The majority are well rolled, especially those of a compact or quartzose character. The schistose and ashy fragments are more angular, in accordance with their peculiar tendencies. The matrix is usually a mixture of particles of ashy materials, and of an arkose in which much of the felspar has become so decomposed that it is now only recognizable under the microscope. Sometimes the ashy material predominates, as in the case of the bands supposed by Prof. Geikie and his assistants to be contemporaneous tuffs; in other parts of the same series the matrix is a nearly pure admixture of quartz and decomposed felspar—a true arkose. Of course the more general condition is an admixture of all these with some other materials; but the

* See Quart. Journ. Geol. Soc. vol. xxvii. p. 388, and vol. xxxi. pl. viii. fig. 2.

special bands referred to are important as showing the main sources of derivation. The ashy particles are minute fragments derived by denudation from the Pebidian series; and the arkose material can with equal certainty, as will be pointed out by Mr. Davies in his notes, be shown to have been derived from the denudation of the Dimetian. Foreign fragments are found here, as in all conglomerates; but the matrix, like the succeeding grits and sandstones, points unmistakably to the true source of derivation of the sediments. It is very remarkable that the matrix of the conglomerates, and the succeeding grits and sandstones, should have been so completely neglected in the Director-General's inquiries. Supposing it possible that his view of a natural succession of the Cambrian on the Pebidian beds could be the true one, whence, under the circumstances, could the materials which build up the many hundreds of feet of the immediately succeeding sandstones and grits, which he admits are true sediments and not volcanic deposits, have been derived?

In this conglomerate many fragments of the underlying porcellanites, much in the condition in which they are now found, occur. Many years ago Prof. Hughes's keen and experienced eye detected in it one fragment of the porcellanite which could not be less than 9 inches across. Smaller fragments are abundant, and some have been cut for examination with the microscope (Note 61). Pebbles of quartz-felsites from the Arvonian and of volcanic rocks from the Pebidian, are also to be readily found. Quartzites and vein-quartz are also abundant as large pebbles. Whether the quartzites and the fragments of true quartz-schists which are occasionally found were derived from some Pre-Cambrian rocks in the neighbourhood, now covered up by the newer sediments or under the sea to the south and west, is a question which has not as yet been solved.

b. General Description of the Cambrian Succession, and of the Mineral Composition of the Beds.—The Cambrian succession, as it is exhibited towards the S.E. from this point, is the most complete in the neighbourhood, and as the different members in it will have to be referred to further on as they are brought by faults into contact with the Dimetian, it will be well now to describe them briefly. The rocks which immediately succeed the conglomerates are the greenish flaggy sandstones (2 on map, Pl. XXIV.). On microscopical examination these are found to be made up mainly of quartz—the dirty quartz of the Dimetian, and quartz such as may be derived from quartz-felsites or veins—and of broken bits of decomposed felspar. A dull green mineral similar to that found so abundantly in the Dimetian is also present in a broken condition, and there are also frequently present bits of mica, magnetite, &c. Secondary quartz and some chloritic and micaceous minerals are also developed in fissures and along the lines of lamination. This may be taken as the condition of these rocks throughout the district. Where crushed, however, in the immediate neighbourhood of faults, the fissured conditions become of course much more marked, and consequently there is a greater proportion of the secondary minerals present. The actual rock itself, however, remains much the same, and there is no metamorphism, in the sense in which that term is generally used, of the individual fragments which build up the rocks.

The rocks No. 3 on the map (Pl. XXIV.), which succeed the last mentioned, are red slates and shales, not of great thickness, but interesting as containing the earliest fauna found in this neighbourhood (probably the earliest of the types as yet found anywhere), and they form also a well-defined horizon throughout the district. These are succeeded by the thick beds of grits and sandstones (No. 4), usually purplish or greenish in colour, found on the shores on each side of Caerbwdy Creek. They are the rocks which have been quarried for the restoration of the cathedral. Microscopically they do not differ much from the green sandstones (No. 2), but they more frequently contain large fragments, and well-rolled bits of typical Dimetian may be readily discovered in some of these beds. The best spots, however, for collecting the typical fragments will be referred to in speaking of the Nun's Chapel area; but I have found numerous fragments in the grits of this area also, especially immediately to the south of the village called Trelerwr, which is on the strike of these beds. The next series (No. 5) is a thick one, and consists of alternations of flaggy sandstones, grey and greenish flags, and purple and red flags, slates, and grits. The lower beds contain a tolerably rich fauna, with the genera *Plutonia*, *Paradoxides*, *Conocoryphe*, &c. A part of this series, and also of the underlying one, has been dropped by a fault which cuts across the beds, as seen on the map (Pl. XXIV.), in a direction from N.E. to S.W. Continuing along the section further to the S.E., the Menevian beds (No. 6) are found resting conformably upon the upper beds of the last-mentioned series; and the Menevian beds are succeeded still further to the S.E., beyond the well-known creek of Porth-y-rhaw (where the Menevian beds were first explored, and most of the fossils obtained), by the Lingula Flags. In consequence of the repetitions of these last beds by frequent foldings, no higher beds than those belonging to the Lingula-Flag group are found along the coast between this point and the ridge of Pre-Cambrian rocks below Pointz Castle on the west shore near Newgale Sands. More inland, higher beds are found in the centre of the trough, which is bounded on the one side by the St. David's Pre-Cambrian ridge and on the other by the Brawdy and Hayscastle ridge.

c. Faults and their Effects.—These areas are at many points greatly traversed by faults, and any one who has a difficulty in believing that the faults indicated on the map (Pl. XXIV.) are not exaggerated in their number and extent, would do well to examine some parts of these districts where fossiliferous beds occur. For instance, the valley of Porth-y-rhaw, from Nine Wells to the coast, a distance only of about half a mile, would, I believe, more than convince any one who examined it that instead of faults being indicated on the map in too great a number, there are far fewer shown than can be actually traced. The same beds are repeated several times by faults in this valley, as proved by the rocks and fossils, and the Lingula Flags of the coast to the S.E. are actually thrown back about midway between Nine Wells and the coast, so as to dip under the lowest Menevian beds.

d. Pre-Cambrian Rocks in this Area.—Immediately under the Cambrian conglomerates in the Caerbwdy Valley are some reddish felsitic tuffs and breccias belonging to the Pebidian series, marked *b* on the map. The conglomerates clearly overlie the latter unconformably, as may be seen from the way they creep over different beds in the Pebidian series. The junctions are not very well seen here, but the evidence of unconformity becomes perfectly clear by following the line of strike of the Cambrian conglomerates. Below the series *b* are found the highly siliceous thin-bedded rocks which we have here called porcellanites. The microscopical characters of these rocks are not very satisfactory, but their sedimentary origin becomes thereby clear (Note 19). Associated with them are some fine breccias, consisting of fragments of quartz-felsites, of broken bits of quartz and felspar, and of basic lavas, all cemented together by a fine-grained material, probably derived mainly from decomposed felspar. Below the last-mentioned series the great agglomerates and breccias of Clegyr Hill are found. These were described in a former paper*, and their microscopical characters are given fully in the Notes to that paper by Mr. Davies (p. 166). The presence in these of numerous fragments of spherulitic quartz-felsites, like those classed as Arvonian, and found *in situ* in the ridge under St. David's and elsewhere, is a fact of importance; for many of these fragments show indications of having been rolled by water-action; and the finding of basic fragments and of indurated argillites occasionally in the same beds proves that they were derived, partially at least, by denudation from pre-existing series. As very many of the fragments, however, are angular, it is probable that the main portions may have been cast out by volcanoes, and but partially rearranged afterwards by water-action. These volcanoes seem to have broken through the quartz-felsites of the Arvonian, and thereby to have caused the admixture of the materials found. When my former paper, in which these agglomerates were described, was published, the Arvonian rocks were included in the Dimetian, the other name not having been at that time suggested. It is necessary to state this, as though it is clear that minute fragments of the true Dimetian do occur in these agglomerates, the larger masses mentioned were such as I should now class with the Arvonian. These agglomerates are exceedingly well exhibited in the hills on both sides of the valley near Clegyr Bridge, and in some rocky prominences in the fields towards Clegyr Farm. Beyond these points, towards the N.E., they are hidden for the most part in moors, &c. They are diminished also in thickness by faults which drop them along with some of the Cambrian beds. In the valley to the north of Clegyr Bridge, at Trefynard and Trepewet, some few exposures of rocks occur, which show that at these places there are intrusive porphyritic quartz-felsites, in some quartz-felsite breccias. These

* Quart. Journ. Geol. Soc. vol. xxxiv. p. 157.

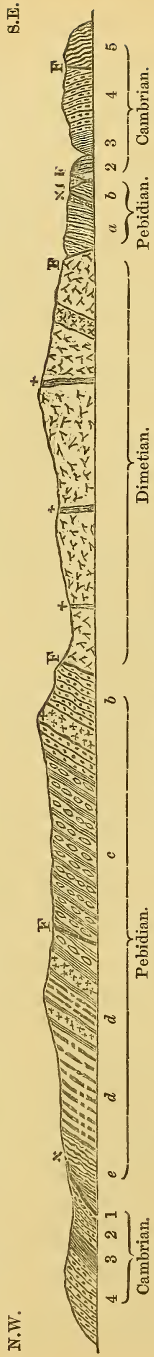


Fig. 1.—*Diagrammatic Section from South side of Porth Seli, Whitesand Bay, to Pen-y-Cyfrwy, S.E. of Nun's Chapel.*

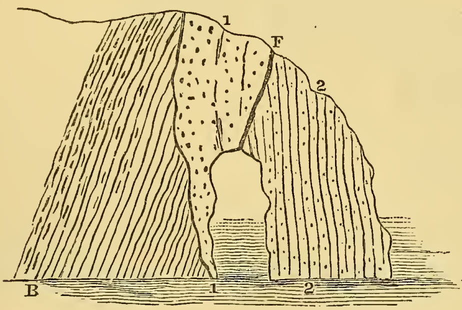
For explanation, see Index to Map, Pl. XXIV.

breccias are undoubtedly older than the agglomerates, and are therefore placed in the map (Pl. XXIV.) in the Arvonian series. In the district to the west of the valley towards St. David's there are no exposures of the rocks beyond the agglomerates which form the west hill. The only evidences we have as to the characters of the rocks in this area are those which have been obtained from the few wells that have been sunk. At the wells sunk at the Windmill, and at Glas-fryn, to the north, the only rocks found were fine-grained quartz-felsites like those found near the Church School, and some dykes of porphyritic quartz-felsites and diabase. I took pains to watch these wells carefully when they were dug. Last year, from another well opened in this area, a few hundred yards to the south of the Windmill, at a new house which is being built on the side of the road leading to Caerfai, it has been shown that quartz-felsite breccias traversed by porphyritic quartz-felsites occur at that point. These breccias are of so compact a character that were it not for the occasional presence of foreign fragments in them, they could almost be classed with flows which had been much crushed (Note 16). These breccias I am inclined to consider as of Arvonian age, as they are undoubtedly below the agglomerates which seem to me to mark the base of the Pebidian on both sides of the ridge. The large proportion of a dirty quartz like that characteristic of the Dimetian, in many of these Arvonian breccias, seems to indicate that the Dimetian was nearly in its present condition before the Arvonian breccias were accumulated.

2. *Nun's-Chapel District and Area S. of St. David's.*

The Cambrian rocks are well exposed along the coast between Caerbwdy Valley and Nun's Chapel; and the succession described to the S.E. of Caerbwdy is equally clear on the west shore of that creek up to the Menevian beds, which are the highest found on this coast. The latter, however, occur only at Pen-pleidiau Point, between Caerbwdy and Caerfai, where they are tolerably fossiliferous. In a cliff-section immediately to the S.E. of Nun's Chapel, the Cambrian conglomerates may be seen resting unconformably on the edges of the Pebidian rocks, as is shown in figs. 1 and 2. This section was

Fig. 2.—*Section showing Cambrian Conglomerate resting on edge of Pebidian beds in Cliff S.E. of Nun's Chapel.*



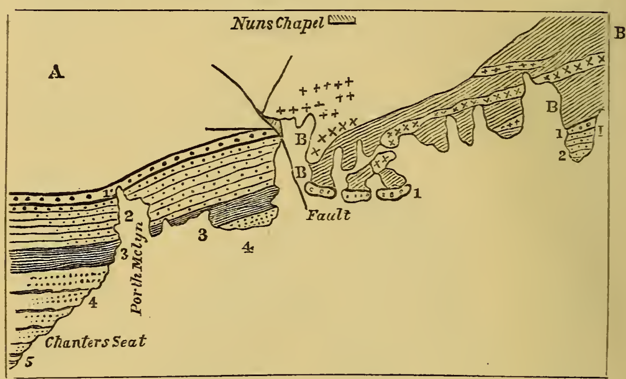
Cambrian { 2. Greenish sandstones. 1. Basal conglomerate. B. Pebidian. F. Fault.

referred to by me in a previous paper as proving marked unconformity in this area between Cambrian and Pebidian. Dr. Geikie, however, has endeavoured to explain away this appearance by calling it a case of "contemporaneous erosion accompanying Cambrian conglomerates"*. Evidently, on his theory of conformable succession, this was a very awkward case to deal with, and the only alternative was to call it one of contemporaneous erosion. This section and some adjoining ones, when examined with care, clearly show, however, that it is utterly impossible to explain away the facts on any such hypothesis. It is a curious fact also that this section is stated in the explanatory text of his paper, and in that accompanying the figure itself, to be in Caerfai, whilst it is in reality more than half a mile west of that creek, and in Nun's Chapel Bay. The section, as given in his paper at p. 287, also is clearly an imperfect representation of the conditions exhibited, though the unconformity can be recognized even there. Though some of the conglomerates have been dropped by a fault in this section, it is fortunate that it has only taken the upper beds, and has left the lower ones, where they rest on the Pebidian beds, undisturbed. The thickness lost by the fault has not been great, as the majority of the green sandstones forming the next series are present in the section in a nearly vertical position.

* Quart. Journ. Geol. Soc. vol. xxxix. p. 287.

In the plan of the coast to the south of Nun's Chapel (fig. 3) the

Fig. 3.—*Plan of Coast south of Nun's Chapel.*



Cambrian.
- 5. Green and purple flags &c. (*Plutonia* &c.).
- 4. Purple grits and sandstones.
- 3. Red shales (*Lingulella primæva*).
- 2. Greenish sandstones.
- 1. Basal conglomerate.

B. Pebidian.
A. Dimetian.
+ Diabase dykes and sheets.
× Intrusive Felstone.
F. Faults.

manner in which the Cambrian conglomerates overlap different beds of the Pebidian is shown. The conglomerates in the cliff-section (fig. 2) can only be properly examined by boat; but on the top of the cliff, and in the first field to the east, they are well exposed, and may be readily explored. In a westerly direction they occur in well-marked detached masses, forming the seaward fringe to the bathing-place directly below Nun's Chapel. Many of the pebbles are of large size, and the basal beds can be seen here again creeping over the edges of the Pebidian beds. In the little creek to the S.S.W. of Nun's Chapel the conglomerates are thrown back for a considerable distance, as shown on the plan, by a fault; but this fault, again, does not prevent the unconformable position of the conglomerates on the underlying beds being readily made out at the point to which both have been thrown back together. The Pebidian rocks have been very freely penetrated by dykes of porphyritic quartz-felsites and of diabase in this creek, as also between this point and the creek in which the section, fig. 2, occurs. These porphyries were described in my former papers, and are also fully referred to by Dr. Geikie. The Pebidian beds in this area are mainly porcellanites and breccias, chiefly acid breccias, though in the S.S.W. creek referred to above, and in the adjoining one to the east, basic breccias also are found. The "milk-white flint-like" masses, "adinole," described by Dr. Geikie at p. 310, and found so plentifully in the breccias, are not, in our opinion, concretions or aggregations, the result of metamorphism, as claimed by him, but actual fragments of older rocks. These are described by Mr. Davies in Notes 17 & 18.

This area is particularly referred to by the Director-General to prove, according to his views, the Post-Cambrian metamorphism of the rocks of the district that "attended the intrusion of the granite and porphyries," pp. 317–329 of his paper. In his section (fig. 2, p. 268) he shows the so-called granite (our Dimetian) as sending out from the main mass an arm (dyke) across the beds near Nun's Chapel, which reaches to the Cambrian conglomerates. This dyke is described as one of the peripheral dykes, intimately connected with the granite. Even if we had not the ample evidence we now have to show that this conclusion is based on highly erroneous observations, the very circumstance that not a single fact was brought forward by the Director-General to prove the so-called connexion between the Dimetian and the porphyries, ought to cause any thoughtful person to pause before accepting such a statement, made upon purely theoretical grounds. When taken to exhibit in a limited sense the influence of dykes on sedimentary rocks, the sections at Nun's Chapel are not of much value; as, from what has already been stated, the porcellanitic rocks undoubtedly owe most of their peculiar conditions to influences exerted at a much earlier period than that during which the dykes were intruded among them, as may be shown by abundant evidence from all parts of the district where they exhibit the same characters. Moreover, that these dykes have no connexion whatever with the Dimetian rocks is abundantly proved, as I shall explain further on, by our finding them cutting through the Dimetian at several different points.

In connexion with the supposed nature of the so-called "adinole" it is interesting to compare the analyses given by Prof. Persifor Frazer (at p. 18 of his paper already referred to) of the Dimetian at St. David's with that given in Dr. Geikie's paper (p. 320) of one of the "Concretions," as having been made by M. Renard. They are as follows:—

"Analysis of Concretion (Adinole) Nun's Chapel, St. David's. By M. Renard."

SiO_2	78·62
Al_2O_3	13·67
Fe_2O_3	1·22
MnO	trace
MgO	trace
CaO	0·30
K_2O	0·26
Na_2O	5·80
Loss	0·63
	100·50

Analyses of two specimens of Dimetian collected by Dr. Persifor Frazer at St. David's, in 1882, and made in his laboratory at Philadelphia gave:—

	I.	II.
Ignition	0·82	1·38
SiO_2	76·90	75·48
Al_2O_3	11·60	9·60
Fe_2O_3	0·71	1·73
FeO	2·56	4·26
CaO	0·85	0·98
MgO	0·59	1·32
K_2O	0·73	0·56
Na_2O	5·62	5·09
	100·38	100·40

An analysis of a fragment of the Dimetian from St. David's, made by Dr. Blyth, of Queen's College, Cork, was published in the paper by Prof. Harkness and myself in the Journal of the Geological Society in 1871, p. 387. The chemical composition proved to be as follows, and it may be said to be still nearer in some respects to that given of the so-called "adinole" concretion, by M. Renard :—

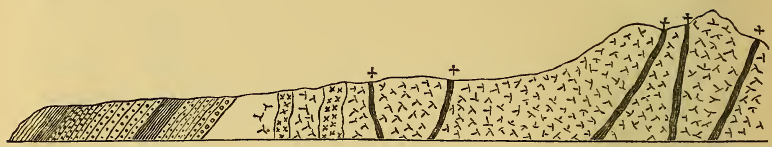
Silica	78
Alumina	16·5
Lime, Soda, and Iron	5·5
	100·0

I maintain that there is ample evidence to show that much of the material in the Pebidian breccias must have come from the denudation, or the breaking-up by volcanic forces, of some such rocks as the Dimetian, and of those I class under the name Arvonian; therefore it is probable that the Pebidian breccias and porcellanites at Nun's Chapel and elsewhere owe their origin in great part to such sources. Still these so-called concretions do not now show on microscopical examination that this was actually the case with them. This may be due in part to subsequent change. The fact that their chemical constitution, however, is so nearly the same as that of the Dimetian is a highly interesting one, but not conclusive on the point. That they are true fragments, however, of some pre-existing rocks, and not concretions, is clear beyond dispute, from microscopical (Notes 17 & 18) and chemical evidence *. Notes nos. 43–48 relate to specimens of the finer conglomerates of the Cambrian from the West Creek, Nun's Chapel. They show that the matrix is largely made up of a dirty quartz like that of the Dimetian, and of fragments of rocks like the underlying porcellanites (41), of felsites, of quartz-schists, and of quartzites, &c.

* Prof. Frazer calls attention also to the close chemical relationship between the so-called "Ash and tuffs" and the Dimetian. Further examinations in this direction may lead to important results bearing on the origin of the Dimetian.

In the next creek in this area, called Porth-melyn, to the south-west of Nun's Chapel, the Cambrian conglomerates contain more of a true arkose material than perhaps in any other part of the district. The yellowish decomposing substance, mainly felspar, so abundant in the conglomerates here, and in the immediately overlying sandstones, has given the name of melyn (yellow) to the creek. A slide made from some of this is described by Mr. Davies, Note 49. This is the only point in the district where I supposed, as shown in my previous maps, that the Cambrian conglomerate was in contact with the Dimetian without the intervention of a fault. The actual junction was not seen, but the matrix of the conglomerate and the material forming the sandstone, seemed to point to such a conclusion. Now that more attention has been given to the Cambrian series in this creek, it is abundantly clear that the Dimetian was the main source from which the finer sediments here were derived. Small pebbles also of typical Dimetian in any number may be found in the grit, and an arkose so identical in general appearance with the Dimetian itself is found on the west side of the creek, at a point called Chanter's Seat, that it would be impossible, I think, for any one to doubt about its origin. The nearest point to the conglomerates at which I have been able to detect the Dimetian, and that only because of a deep drain made in the field above Porth-melyn about three years ago, would be at a distance of about thirty yards. This drain was particularly important and interesting, in that it exposed two well-marked dykes of a porphyritic quartz-felsite (Note 10) identical in character with the one found in the cliffs to the south and south-east of Nun's Chapel, which is indicated in Dr. Geikie's section as an arm sent out from the Dimetian, here actually cutting through the Dimetian, with as sharp lines of demarcation as are usually observed where dykes cut through any of the newer beds. I took pains to notice these carefully at the time, and to secure specimens. The drain reached the whole length of the second field to the north of Porth-melyn, with an average depth of from 4 to 6 feet, therefore deep enough to expose good sections. A small part of this drain is still open at the upper end of the field, where a portion of the quartz-felsite dyke is exposed, as also a dyke of diabase. The Dimetian was of the ordinary type, quite in its natural condition, between these dykes and the Cambrian conglomerates. The Cambrian rocks exposed on the west side of Porth-melyn are identical with those found in each of the headlands on this part of the coast, but the highest beds (No. 5) in the section (fig. 4), map, and plan (fig. 3), are specially interesting, as having yielded the richest fauna belonging to that series anywhere in the district. The species *Plutonia Sedgwickii*, *Conocoryphe Lyelli*, *Paradoxides Harknessii*, &c. were first found here. The fossiliferous beds are of a rather dark grey colour, and cross the point where the figure 5 is placed in the section, fig. 4. The beds below are mainly grits and sandstones, and it is in these that Dimetian pebbles occur so abundantly. The place marked Chanter's Seat (fig. 3) can be readily examined, and the beds at this point are very rough grits, almost

Fig. 4.—*Section from the Coast to Bryn-y-garn.*



For explanation see fig. 3.

conglomerates, with rolled fragments of Dimetian up to the size of a hazel-nut, or larger. Under the series No. 4 come the *Lingulella-primæva* beds, and good specimens of that fossil have been found here, especially in the bright red beds on the east side of the creek. The yellowish sandstones and conglomerates at the base (Nos. 2 & 1) have been already referred to. The section, fig. 4, as taken from the centre of the Dimetian ridge from the well-known point of Bryn-y-garn in a S.S.W. direction to the extreme end of the headland on the west side of Porth-melyn, contains such important and conclusive evidence in regard to the questions at issue between the Director-General and myself that I submit it with perfect confidence to the consideration of any one who is interested in them, and has an opportunity of visiting St. David's. The slides described by Mr. Davies in Notes 49–60 were prepared from grits and fine conglomerates found in the series of Cambrian rocks on the west side of Porth-melyn. They give abundant proof of what seems perfectly clear even on macroscopical evidence, that the material deposited in the very earliest Cambrian period in this area was derived from such rocks as we now claim to be of Pre-Cambrian age. Almost every peculiarity recognizable in the underlying Pre-Cambrian rocks, is equally visible in the fragments contained in the overlying Cambrian rocks. This, to my mind, is perfectly conclusive proof of the Pre-Cambrian age of the rocks I class under the names *Dimetian*, *Arvonian*, and *Pebidian* in the St. David's area. My reply to Dr. Geikie might, as stated before, have been confined to these facts alone; but as so many statements have been made which I cannot allow to pass unchallenged. I propose to deal with each of the sections at the points referred to by him; and I shall be able, I think, to show how utterly impossible it would be, even on purely geological evidence, for the interpretations given by him of the conditions shown to be the true ones. Moreover, it is but fair to ourselves to state that our conclusions were mainly arrived at by critical investigations of the general geological facts exhibited by these sections.

3. *Porth-clais and Allan Valley.*

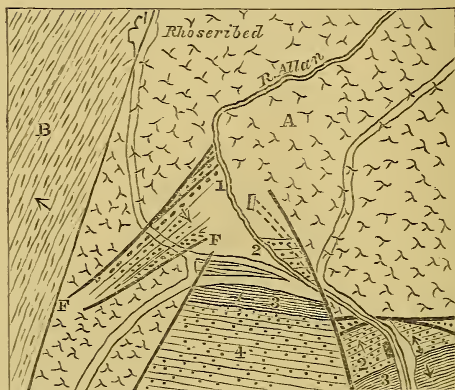
In Porth-clais farmyard, between the area last referred to and the Allan Valley, the Dimetian rocks, in their usual condition, are exposed, and they are seen here to be penetrated by dykes of porphyritic felsites. In the lane leading from the farmyard to the moor to the east I obtained specimens from the actual junction of one of the dykes* with typical Dimetian, containing parts of each. One of these is described in Note 8. The felsite is exposed also in the field to the north of this lane. This evidence, again, is conclusive in proving that the porphyries are not, as stated by Dr. Geikie, "grouped round the central boss of granite," our Dimetian, or, "intimately connected with it, like the elvans of granite districts" (p. 313).

In Porth-clais harbour, and in the Allan Valley immediately to the north, some of the most important sections referred to by the Director-General to prove that the Dimetian is intrusive occur. Of these he says it "is difficult to believe that they can have been actually seen by any one who could afterwards maintain the rock to be Pre-Cambrian in age" (p. 274). It is also stated on the same page that they "show the granite to be unmistakably eruptive; for the strata adjacent to it present examples of the induration and silicification so commonly, though not universally observable, along the borders of a granite boss;" also that he "searched in vain among the published papers for any account of these localities." In reference to these statements I need only say that all those who took part in the discussion, who had visited St. David's at any previous time, gave ample evidence to show that these sections were well known to, and had been examined by them, and that fortunately they had interpreted them in their true light. My papers also contain ample evidence to show that they had been carefully studied by me; and I need only say further that when the former Director-General, Sir A. Ramsay, accompanied by Mr. Etheridge, visited St. David's, their special attention was called by me to these sections. Fearing that further difficulties may arise as to the true interpretation of these sections, I have had some sketches prepared to show the exact spots where the facts are to be observed, so that they may be readily examined by those who visit the area in the future. The "tongue-like projection across the river at the ford" is indicated in fig. 6, and in the plan, fig. 5. Instead of being an intrusive tongue penetrating the Cambrian strata, as

* In Professor Blake's map (Quart. Journ. Geol. Soc. vol. xl. p. 295), these are indicated as fringing the Dimetian. The evidence is perfectly clear that they are intrusive in the Dimetian; hence conclusions based on this view are valueless. The want of knowing that these felsitic rocks here and about Nun's Chapel are intrusive dykes, and not old rhyolites like those I have included in the Arvonian, has caused him to suppose that the latter everywhere fringe the Dimetian, and therefore that the Pre-Cambrian Groups at St. David's belong all to one volcanic series. The evidence is clear, however, that this supposition, as stated above, is incorrect. The actual junctions here between the Dimetian rocks and the felsites are most sharply defined, and there is not a particle of evidence to show a gradual passage of the one into the other.

supposed by the Director-General, the evidence is perfectly clear that the Cambrian strata are here faulted against the Dimetian, as shown on the plan. Of this there are abundant proofs of various kinds. The line of junction is most clearly marked, and the con-

Fig. 5.—*Plan of Allan Valley at Porth-clais.*



For explanation see fig. 3.

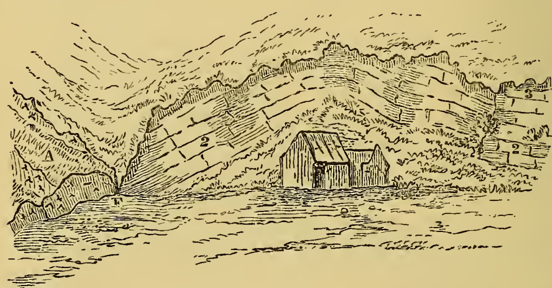
Fig. 6.—*Sketch in Allan Valley (south side) at Porth-clais, showing faulted contact of Cambrian Rocks with Dimetian.* (The place specially referred to by Dr. Geikie as showing intrusion of the latter into the former.)

2. Greenish sandstones. } Cambrian.
1. Basal conglomerate. }

A. Dimetian.
F. Fault.

glomerates can be removed without a particle of the true Dimetian being attached to them. There is no alteration set up in the materials at the junction, and no evidence of anything like a welding process having been set up. As a result of the faulting also, different beds of the Cambrian series are brought in contact with the Dimetian. On the west side the beds belong to a much higher horizon in the succession than those on the east side, from having been thrown back by a fault striking about N.N.W. These actually strike up to the west edge of the so-called tongue. On the east side the beds are made to dip towards and as if under that edge, a very usual condition in faulted junctions, as I shall be able to show in other sketches, and one well known to all stratigraphical geologists. There is another point to which special attention must be called in regard to this sketch, as it would appear from a sketch published in Prof. Frazer's paper already referred to (p. 14) that he, at least, when examining this section with Dr. Geikie, supposed that the Dimetian here cut into and enveloped a mass of the Cambrian rocks. The supposed evidence for this is clearly shown by his sketch to have been based on erroneously taking the Cambrian grits immediately to the north of the hut to be a part of the Dimetian. Better proof, perhaps, of the fact so often insisted upon by us that the matrix of the conglomerate has been derived from the Dimetian could scarcely be wished for than that so experienced an observer should make such a mistake under the guidance of the Director-General and of Mr. Peach. In his revised paper the sketch remains as before, but it is only fair to him to give the following quotation from that paper, issued after the abstracts of Prof. Geikie's paper and the reports of the discussions had been received by him :—"It would appear that neither Prof. Geikie nor Mr. Peach regarded the contact between the granite (containing some amphibole) and the sandstone (conglomerate ?) at that point in the river Allan figured in the sketch, as indicating an envelopment of the latter by the former, since no allusion is made to it. This relation seemed to the writer so clear that he sketched it, and had a woodcut made of it, in spite of the fact that it gave a rude shock to his gradually increasing conviction of the practical parallelism of the rocks of the South Mountain and those of South Wales, by seeming to prove that the granite was of later origin than the clastic rocks which it environed. The writer has probably made a mistake here, though of what nature he is yet ignorant, and it is only fair to say that while regretting that the error is his, he is gratified to know that this abnormal position of the respective rocks does not exist." The grit near the hut is described in Note 62, and the sandstone on the opposite side of the Dimetian in Note 63. Both show clear evidence of the presence of the dirty quartz, derived from the Dimetian, and of fragments of felspars, and there are no indications whatever of any alteration in the sediments such as would have been produced by the proximity of a great intrusive mass. In the sketch (fig. 6) it is necessary to state, that the beds marked 2, to the south of the hut, are really newer than the conglomerates and grits marked 1, though appearing in it to dip under the latter *. This is clearly due to the influence of a split fault, as shown in the plan. Behind the kilns on the opposite side of the river is the section mentioned by Dr. Geikie, where, according to his view, as stated in his paper (p. 276), "another junction of the granite with the Cambrian beds can be seen. The

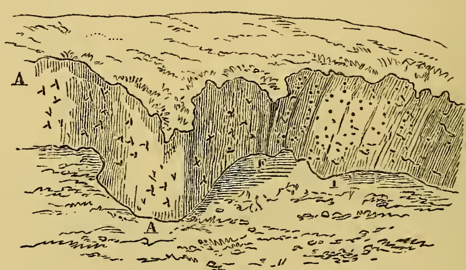
Fig. 7.—*Sketch of Quarry in the Allan Valley on north side of Porth-clais, showing faulted contact of Cambrian Rocks with Dimetian.*



3. Red shales (*Lingulella primæva*). } Cambrian.
2. Greenish sandstones.

A. Dimetian.
F. Fault.

Fig. 8.—*Quarry on roadside between Porth-clais and Rhoscribed, showing faulted contact of Cambrian with Dimetian.*



1. Cambrian basal conglomerate. A. Dimetian. F. Fault.

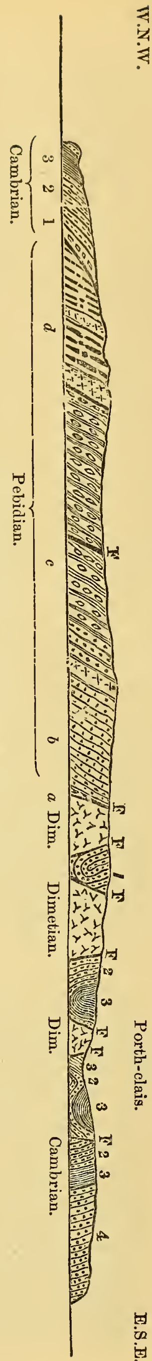
latter consist of greenish shales and sandstones dipping N. 20 W. at 55°, and are here again distinctly overlain by the granite, which cuts across the edges of the strata that dip beneath it." The interpretation of this apparent dipping under is the same as on the opposite side, and it is due entirely to the same fault.

* The place which Dr. Geikie exposed when at St. David's, as mentioned in his paper, is the flat surface marked with 1 near the centre of the sketch. It was further and more freely exposed during my visit with Prof. Hughes and party.

There is no evidence whatever of an intrusive junction; and I cannot make out how any one conversant with the usual conditions in districts where the old rocks are much broken could so mistake so clear a case of faulted junction as to believe that it was one of eating through the sediments, as shown in his section, by a great granite mass. The sketch, fig. 7, shows the actual conditions seen here, and the nature of the junction. Higher up the hill on this side Cambrian conglomerates are seen in contact with the Dimetian, so there is much crushing and confusion of the rocks on this as on the opposite site. Everything points unmistakably to results due here entirely to faults. The sketch itself is sufficiently clear on this point. Another quarry is referred to by Dr. Geikie as showing intrusive junction higher up the valley on the road to Rhoscribed. This is given in sketch fig. 8, which I think is almost sufficiently clear without description. It shows the Cambrian beds, as usual, thrown towards the older rocks, the Dimetian, by a fault. Here again there is not the slightest change produced in the material composing the Cambrian rocks, but much crushing is visible in those at the junction, with evidences of infiltration along joints.

In Dr. Geikie's map, at this point and towards Rhoscribed, a far wider space is shown between the dissevered Dimetian masses than really occurs, as the Dimetian can be clearly seen crossing the road at a distance only of about 35 yards from the other mass. Between these two masses the Cambrian rocks are dropped in, in a folded condition, dipping away from one and towards the other. The section, fig. 9, explains fully the manner in which the Cambrian beds have been dropped in among the Dimetian rocks to the west of Porth-clais. By failing to recognize the effects of faults in this area, the Director-General has been led into many serious errors, even in mapping the Cambrian rocks. To some series he has given an undue thickness, and others he has placed where they do not occur. At first sight a confusion of the beds might be made; but if one is at all acquainted with the order of succession of the rocks in this area and the peculiarities recognizable at various horizons, the whole matter becomes at once clear. As shown in the section at Porth-clais, the lower beds, 2 and 3, have been several

Fig. 9.—*Diagrammatic Section from near Castell, Ramsey Sound, to Porth-clais.*



For explanation see Index to Map, Pl. XXIV.

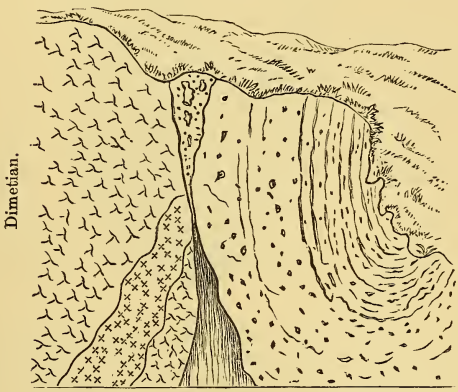
times repeated by folds and faults, with the result of apparently giving to them an abnormal thickness. The *Lingulella-primæva* beds, however, form such a clear and definite horizon that on examination the cause of this is at once evident. The series indicated by us as No. 4 extends to the extreme end of the east point of Porth-clais, and it is an entire mistake to show the beds marked by Dr. Geikie as his series No. 7 as occupying any part of that point. The only other matter which it is necessary to refer to in this area is the evidence supposed to be furnished by a quarry of the conglomerates nearly opposite the site of the old mill, to favour the view that contemporaneous volcanic tuffs occur in the Cambrian conglomerates. Whether the volcanic forces had completely expended themselves or not, before the conglomerates were deposited, may be an interesting point; but it is virtually of little or no importance in regard to the questions at issue. The evidence we have to deal with is as to the nature and position of the old floor which yielded the Cambrian deposits, which are acknowledged by all to have been true marine sediments. That this quarry, however, does not furnish the evidence supposed is perfectly clear, for the so-called volcanic materials alternating with the conglomerates here are, like those referred to in other sections, derivative materials from pre-existing volcanic rocks. The beds in this quarry dip away from the Dimetian, which occurs immediately behind. This area was very carefully surveyed by Prof. Hughes and myself, accompanied by a large party of well-trained observers from Cambridge in April of last year, and the conclusions as to the various points referred to given in the foregoing remarks are those which were arrived at during that time. Since then I have revisited the area twice, but mainly to complete the evidence.

I must here also express my great indebtedness to Prof. Hughes and to those gentlemen who accompanied him, for the great care and trouble with which the various points were examined into and worked out by them, and for the general assistance rendered to me by them in my reexamination of the district.

4. *Ogof-llesugn.*

The section to which such very special attention is directed in the paper of the Director-General, to prove that the Dimetian has been intruded into the Cambrian, occurs at or near the place indicated in the Ordnance map as Ogof-llesugn, on the coast to the west of Porth-clais. The evidence here, it is stated at p. 278, "completes the demonstration that the rock, which can be traced from St. David's to the coast south of Porth-lisky, is an eruptive mass that has been intruded into the Cambrian strata." Instead of the evidence here furnishing the complete demonstration of intrusion claimed in the above quotation, no more satisfactory evidence to the contrary could scarcely be desired or obtained anywhere. The want of recognizing the differences between igneous junctions and those produced by the influences of faults, foldings, and crushings among the older rocks, has caused the errors to be committed here as in the other areas referred to. Moreover, Dr. Geikie's statements tend to show that the examination here of the actual facts must have been imperfectly carried out; for the most important point of contact of the Cambrian with the Dimetian, shown in fig. 10, is not even referred to.

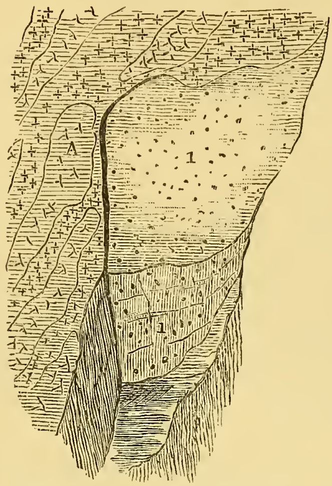
Fig. 10.—*Section showing contact of Cambrian with Dimetian in Cliff at Ogof-llesugn.*



When the Director-General read his paper, even minor faults were condemned by him. In a footnote, inserted after the discussion, it is stated, however (p. 277), that "possibly some slight displacement may have taken place at Ogof-llesugn; but the mass of conglomerates is imbedded in the granite." This does not very much improve the statement in the text on the same page that the "granite which extends continuously eastward from Porth-lisky, abruptly ends off and is succeeded at once by vertical sandstones and shales which are truncated by it nearly at a right angle." The point where the conglomerates and sandstones touch the Dimetian, and, according to the Director-General, are truncated by it, is shown in fig. 10, and I believe that those who have examined the spot, and they are now many, will admit that this sketch gives a fair representation of the conditions to be seen. It shows the Dimetian to be sharply defined, with some beds of the Cambrian conglomerate lying against it. The line of fault is clearly indicated by fault-breccia above and by a narrow cavern below, into which some of the younger members of Prof. Hughes's party were able to squeeze themselves for several yards. As much higher beds of the Cambrian series than these are found, directly to the north, to strike up against the Dimetian, it is clear that these beds are bounded at Ogof-llesugn by two faults, as shown on the map (Pl. XXIV.). These probably are some of the lowest Cambrian conglomerates, and they may have reposed almost directly on the Dimetian until disturbed by the faults. The presence of a great amount of arkose material in the conglomerates, and the fact that at this point a brecciated mass was found resting upon and sticking to the Dimetian, and consisting almost entirely of fragments of the Dimetian, lends some weight to this supposition. I do not feel quite justified, however, in claiming this breccia as a part of the true Cambrian conglomerates; but the examination of it with the microscope (Note 42) seems adverse to its being only brecciation of the Dimetian *in situ* as the result of the fault or crush. In any case, as there may be a possibility of doubt, I prefer to depend, for the evidence of Dimetian fragments occurring in the conglomerates, on those found in the beds already referred to, and in others which strike up against the Dimetian near here. The Dimetian between this point and the Allan Valley is defined by a sharp line, and the Cambrian beds all along strike up against it. According to the Director-General's view they have been actually cut or eaten through by the Dimetian. There is not a particle of evidence for this, but there are facts in abundance to show that the line of junction is a sharply-defined fault, and in the more gritty bands of these Cambrian beds fragments of Dimetian occur plentifully, even close to the point where the Dimetian is supposed to be eating through them.

Returning to the coast at and to the south of Ogof-llesugn we come to the place described by the Director-General as follows (p. 277):—"On the seaward face of the cliff the granite has torn off a mass of conglomerate and associated tuffs. These rocks have been so intensely indurated and silicified that the quartz pebbles are hardly traceable on a fresh fracture, though they project more evidently from a weathered surface. It is even difficult in places to say precisely where the line between granite and conglomerate should be drawn, so intimately are they welded together." I have endeavoured to show in the sketch, fig. 11, the real conditions exhibited here. The conglomerate is undoubtedly a part of the lower Cambrian conglomerate, and with it are some beds which belong to the next series, the green rocks. The mass appears to be surrounded on two sides, not by Dimetian, as stated by the Director-General, but by dykes of diabase containing lenticular fragments torn off from the Dimetian. The Cambrian conglomerate does not appear to have been much, if at all, altered by the dykes, and on the cliff side there is an open space at some points a few inches across, between the conglomerate and the dyke. Along the northern edge, especially where the conglomerate mass narrows, it seemed almost to stick on to the dyke; but there is no evidence here that it was actually penetrated by the dyke. The fine sandstone in association with the conglomerate is described by Mr. Davies in Note 64. As this seemed in the field to show some indications of having been altered by the dyke, I had it cut; but the microscopical examination does not support the view of any great amount of alteration. The idea that this mass of conglomerate is entangled by the Dimetian disappears instantly on examination, and the conditions exhibited are those due to crushings

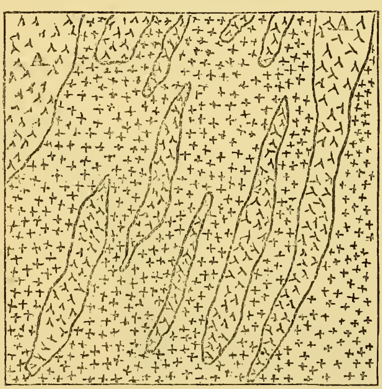
Fig. 11.—*Mass of Cambrian Conglomerate on shore, west side of Ogof-llesugn.*



1. Cambrian basal conglomerate. A. Dimetian. + Diabase dyke.

in the neighbourhood of the faults already referred to, and to dykes which here cut through the rocks in all directions. In fig. 12 an endeavour is made to show the actual facts observed on the flat

Fig. 12.—*Plan showing Dimetian broken up by Dyke on shore at Ogof-llesugn.*



A. Dimetian. + Diabase dyke.

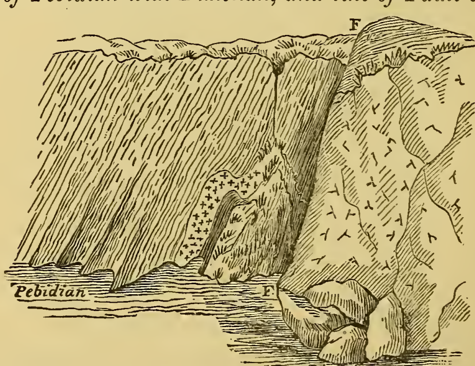
surface of the cliff as produced by the dyke to the west of the mass of conglomerate.

Evidence bearing on another important question already touched upon is furnished in the face of the cliffs here, as not only has the Dimetian been penetrated in all directions by diabase dykes, but also by dykes of porphyritic quartz-felsites, like those described in Porth-clais farmyard, in the fields near Porth-melyn, and as cutting across the Pebidian rocks near Nun's Chapel, furnishing additional proof against the view that the porphyritic felsites are in any way to be associated with the Dimetian rocks as peripheral masses. A slide from a specimen taken from one of these dykes in the Dimetian at Ogof-llesugn is described in Note 7. I have not found any of these porphyritic quartz-felsites cutting actually into the Cambrian rocks, but diabase dykes, differing somewhat, however, in appearance from the majority of those found in the Pre-Cambrian rocks, occur plentifully in them. The alteration produced by the diabase dykes in the beds they cut across, and the welding which takes place, may be studied with advantage in the cliffs along the coast between Ogof-llesugn and Porth-clais. One of these dykes is about 40 feet across, and the alteration produced by it in the rocks on either side is most marked.

5. *Porth-lisky and Ramsey-Sound Area.*

On the west side of the Dimetian the Pebidian beds lie at a high angle with a dip towards the N.W. Immediately at their point of contact with the Dimetian there are the usual indications of a fault, and doubtless a considerable thickness of the lowest beds has been dropped by it. That these are some of the lower beds of the Pebidian, not to be confounded with those under the conglomerate in Ramsey Sound, with which they are correlated by Dr. Geikie, is perfectly clear from the stratigraphical evidence here and at many other places in the area further north; the microscopical evidence also is most conclusive on this point. The sketch, fig. 13, shows

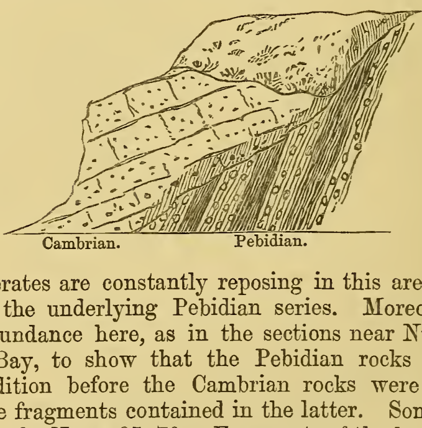
Fig. 13.—*Sketch of Cliffs in East Harbour, Porth-lisky, showing contact of Pebidian with Dimetian, and line of Fault between.*



F. Fault. + Diabase dyke.

that portion of the cliff at Porth-lisky harbour, where the Pebidian beds are in contact with the Dimetian. The line of demarcation is a perfectly clear one, but the beds are much crushed at the junction, and it seems almost incredible that any one could have supposed this boundary to indicate the outline of a mass of intrusive granite. The Pebidian beds here have a curiously arkose-like appearance; indeed some specimens, taken from the section a few yards higher in the succession than the position of the diabase dyke indicated, seemed by the aid of an ordinary lens to consist almost entirely of quartz grains and decomposed felspar. The microscopical evidence, however, does not quite bear out this view, though it shows unmistakably the same facts that have been so frequently referred to in reference to the Lower Pebidian beds on the other side of the Dimetian—that is, that rocks of the Dimetian type must have yielded a considerable amount of the detrital material found in the Pebidian beds, especially in the lower ones. Note 20 refers to the arkose-like rock mentioned above, 21 to a specimen from beds still higher up in the section, and 22 to one from the east side of the west harbour. These together give a fair representation of the rocks in the section between the stream and the Dimetian. West of the stream and forming the cliffs on the west side of the main harbour, the beds consist of acid breccias of various colours, with occasionally some bands of argillites and other detrital materials; Note 31 refers to a slide from a fragment tolerably typical of this series. At Ogof-henllys and behind the cottage on the top of the cliff near that place, some diabase sheets or dykes are found in the series; and they occur again further south, at Pen-y-foel, as mentioned by the Director-General (Note 34). The next series, *c* on the map, consists of the quartz-felsite breccias and schists of various shades of colour, which are so easily recognizable throughout the district, and have a well-marked horizon. They reach to the coast of Ramsey Sound at Ogfeydd-duon, and they are overlain unconformably by the Cambrian conglomerates as in fig. 14, in the first little creek to the north. These beds have had a schistose structure developed in them by crushing, and they appear to be, for the most part, old rhyolites, but with marked differences from those characteristic of the Arvonian group. Some of these beds are correlated by Dr. Geikie with the Porth-lisky beds, though they differ entirely from those. Moreover, he has failed to recognize the true direction of the strike in these beds, which is not in a line immediately below the Cambrian conglomerates, but inland and under, instead of over, the Trefaiddan and Rhosson series of basic ashes and sheets. Had the position of these beds and their true nature been recognized by the Director-General, he would have seen how fatal the facts are to his theory of an isocline in this area. The Note 33 refers to one of these schistose quartz-felsites from Carn-ar-wig to the south of Ogfeydd-duon, and Note 32 to another, from the same series inland, in the valley of St. David's, from a quarry in a field south of Emlych. The latter will be again referred to in describing that area. On the south shore of Carn-ar-wig and at Pen-maen-melyn, there are some beds belonging to series *d*, the basic tuffs, &c. These lie in true order of succession on the series *c* above described. These tuffs are largely made up of fragments of diabase, as may be seen from Note 36 from a specimen from Carn-ar-wig, and Note 37 from the same series east of Castell to the north. Note 35 refers to the dark green compact rock exposed at the old copper-mine at Pen-maen-melyn; a much altered felspathic diabase. To the east of Castell the basic rocks become exposed in several rugged knolls; other knolls to the S.E. are found to consist of the schistose rhyolites and breccias of series *c*. In the line of the section, fig. 9, which is taken from Castell, in Ramsey Sound, in an E.S.E. direction to Porth-clais, the Cambrian conglomerates are shown reposing unconformably on the basic series *d*. They can be seen in this position in the field to the east of Castell, having, between Ogfeydd-duon and this point, a distance less than a quarter of a mile, crept over the edges of a considerable thickness of the Pre-Cambrian beds. The unconformity shown in fig. 14 is most marked, and it is perfectly evident that

Fig. 14.—*Cliff-section between Castell and Ogfeydd-duon, showing unconformity of Cambrian on Pebidian.*

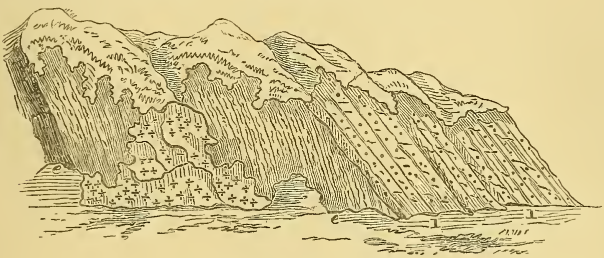


the conglomerates are constantly reposing in this area on different members of the underlying Pebidian series. Moreover, we have proofs in abundance here, as in the sections near Nun's Chapel in St. Bride's Bay, to show that the Pebidian rocks were in their present condition before the Cambrian rocks were deposited, as shown by the fragments contained in the latter. Some of these are mentioned in the Notes 65–70. Fragments of the basic tuffs *d*, and of the schistose rhyolites *c*, are plentiful in the Cambrian conglomerates in these areas, and many of the rolled pebbles of these rocks are of large size.

6. *Whitesand Bay, Rhosson, Clegyr Foig, &c.*

In this area the rocks for the most part are like those described in the section to the south, fig. 9, but higher beds of the Pebidian become exposed as the Cambrian conglomerates are followed to the north. By a strange error, the Cambrian conglomerates are shown, in the Director-General's map, to strike inland at a distance of more than a quarter of a mile to the east of Porth-seli, while in reality they are the rocks which form the cliffs for a considerable distance along the east shores of that harbour. This same strange mistake is evident also in his section, as a most abnormal thickness is given to the sandstones above the conglomerates, to enable the other beds to get into position. It certainly is a curious fact that the greatest exposure of Cambrian conglomerates in the neighbourhood of St. David's should be thus missed, as it evidently must have been, by the Director-General. This error of his furnishes the best proof that could be desired of the great unconformity between the Cambrian conglomerates and the Pebidian; for had the former continued to lie on the same beds of the latter as at Rhosson, less than a mile to the south, where they are well exposed, their position would be a quarter of a mile to the east of Porth-seli, as shown in Dr. Geikie's map. The facts, however, as stated above, prove that in this mile of country a quarter of a mile in thickness of nearly vertical Pebidian strata has been overlapped by the conglomerates. The sketch, fig. 15, shows the Cambrian conglomerates reposing upon the Pebidian

Fig. 15.—*Sketch of Cliffs on south side of Ogof-golchfa, Whitesand Bay, showing basal Cambrian Conglomerate* (1) *resting unconformably on Pebidian rocks* (*series e*).



Index as in Map, Pl. XXIV.

beds at Ogof-golchfa, Whitesand Bay. The conglomerates are of very great thickness here, the pebbles of large size, and many of the fragments are such as could only be derived from the Pebidian beds below. The large pebble exhibited by me at the meeting, when the second part of Prof. Geikie's paper was read, which was claimed by Mr. Peach to be a segregation, came from these beds; and Note 69 will show that it is a large pebble of a schistose quartz-felsite identical with the quartz-felsites of series *c* of the Pebidian. The conglomerates at Ogof-golchfa repose upon schistose felsitic tuffs and breccias, and some schistose argillites. Notes 39 and 40 refer to some of these rocks.

Section, fig. 1 (p. 524), runs in a S.E. direction from the south side of Porth-seli across the Pebidian rocks and the Dimetian axis to the shore of St. Bride's Bay below Nun's Chapel. It shows the usual series of Cambrian rocks in this area, and the Pebidian series as in the section to the south, but with a greater thickness of *d* and with the addition of a part of series *e*. Here again the evidence of a regularly ascending succession in the Pebidian, but broken by a few faults, is perfectly clear, and there is no indication of an isocline. The beds dip regularly in one direction at a high angle, and the alternations are well marked and easily traced. The crags of Croeswdig, Trelethin, Rhosson, and Trefaiddan, consist of basic tuffs, dykes, and sheets. No. 29 occurs west of Rhosson rock, almost under the conglomerate. Further evidence of this fact is furnished in several sections to the north. The only one to which I need refer, however, though I have collected evidence all over the district, is the one to the north of St. David's, in the Allan valley. Clegyr Foig rock has been frequently mentioned; it consists mainly of basic sheets or dykes like those at Pen-y-foel, which occur in the felsitic tuffs, series *b*.

7. *St. David's and to the North-east, and Allan Valley to the North.*

The ridge of St. David's and to the north-east of that city consists mainly, as already stated, of quartz-felsites (spherulitic) and of numerous dykes of porphyritic quartz-felsites and some breccias. These rocks are found at various points all along the area coloured as Arvonian to the N.E. of Llanhowel. In the quarries on the hillside to the N.E. of the Cathedral, and in the Church- and Board-Schools quarries, they are well known. There are many minor exposures also about the town. To the N.E. of St. David's I have collected specimens in exposures near Dowrog Pool (Note 11), at Harglodd-issaf, Hendre, Carfarchell, &c. I have also recently received some beautiful specimens of a porphyritic quartz-felsite from Trefadog, through the kindness of my friend Capt. Griffiths of St. David's. So far, therefore, as this portion of the area can be examined, the quartz-felsites form a very continuous belt in a N.E. direction from St. David's to the great fault above Bryn. The north edge of this belt is faulted probably at many points, and it is hidden greatly by the moors which extend along in that direction. The exposures of the Pebidian rocks along the area show them everywhere dipping away from this central belt. The Allan Valley to the north of the Cathedral gives a very fair section of the Pebidian rocks, dipping continuously to the N.W. Immediately north of the Board-School quarry the porcellanites, Note 23 (like those in Caerbwdy Valley to the S.W. of the central belt), are seen with a moderately high N.W. dip. Between these and the quartz-felsites there is, I believe, a fault which has dropped the lowest agglomerates as at Porth-lisky. The next beds in a N.W. direction are some greenish and purplish felsitic breccias (Note 23), and some argillites belonging to series *b*. These are succeeded by quartz-felsites in a schistose state, and some acid breccias. They may be examined in quarries opened lately on the west side of the river, in the fields belonging to the new vicarage-house at Penrhyw; also on the east side, in quarries in a field nearly opposite, through which the path leading towards Emlych passes (Note 32). Beyond this, at and about Emlych, there are other schistose felsitic rocks, and some rather dense-looking schistose beds (No. 41) *. To the N.E. at Maendewi, Rhodiad, and Gwrid, beds belonging to series *b* and *c* are exposed, and the rocks here are described in Notes 25–27. The series *d* and *e* found near Ramsey Sound and Porth-seli are not well exposed to the north of Croeswdig rocks. Indeed over the burrows and on the moors which occur to the N.E. there are scarcely any exposures at all, but the few that have been seen show that rocks belonging to series *d*, at least, occur here. North-east of Trelethydfawr Cambrian rocks are thrown down against lower members of the Pebidian by faults; and near Treliwyd some few beds of the Cambrian conglomerates are seen.

So far as it has been possible, the whole of the St. David's area has been explored. In the above remarks the general facts observed are given; and I do not think it is possible for other evidence to appear which can in any important degree vitiate the main conclusions arrived at.

8. *Ramsey Island.*

In my former paper I mentioned the occurrence in Ramsey Island of quartz-felsites, breccias, and hälleflintas belonging to the Arvonian series, and that these were covered at one point unconformably by Cambrian conglomerates, mainly built up from fragments derived from the former. In the spring of last year I revisited Ramsey Island with Prof. Hughes and party, and we were able not only to confirm our previous conclusions, but to add somewhat to the evidence. The interpretation is given generally on the Map, Pl. XXIV. We found that the mountainous area called Carn consists in part of old rhyolites, of beds of fine ash (hälleflintas), and of rough breccias (Notes 12–14). Note 15 refers to one of the detached masses whose age is not clear at present, but the probability is that they are Pre-Cambrian. The Cambrian conglomerates here are almost entirely made up of very well rolled fragments of the rocks found underlying them. They attain to a considerable thickness, especially towards the N.W., and appear to be succeeded by some of the greenish sandstones. The main part of the Cambrian, however, has been dropped by faults, as the Arenig rocks are exposed within a short distance of the conglomerates on the coast. That some, at least, of the intermediate beds must have been deposited in this area is clear from the fact that beds belonging to the Lingula Flags and to the Tremadoc series occur at the north end of the island, underlying the Arenig rocks †.

* Prof. Blake's map, Quart. Journ. Geol. Soc. vol. xl. p. 295, is incorrect in showing Cambrian rocks in this immediate area.

† In a recent letter Prof. Bonney, who has so frequently assisted me in these inquiries, writes to me as follows:—"As you are aware, I have examined some parts of the St. David's district pretty carefully, and feel bound to tell you that though I have had a rather large experience in studying the junctions of igneous and sedimentary rocks, I saw nothing at Porth-clais or at Ogof-llesugn which led me to suspect that the 'Dimetian' was intrusive in the

Conclusions.

The evidence submitted shows most clearly that the Survey map of the St. David's district and of other parts of Pembrokeshire is inaccurate in some of its most essential features, and in many of its petrographical and stratigraphical details. The present Director-General maintains that it "is in its essential features correct," and that the "officers of the Survey were certainly correct in regarding the crystalline rocks which they named syenite and felstone as intrusive through the Cambrian strata" (p. 291).

He also states that this point in regard to the intrusion or non-intrusion of these rocks in the Cambrian sediments "is the main question in the present discussion" (p. 291). In his conclusions (p. 324) he endeavours to indicate the manner in which, and at what period, this took place, in the following words:—"As volcanic activity died out, ordinary sedimentation was resumed, and the rest of the Harlech and succeeding groups of the Cambrian system were deposited.

"At a later period the whole of these rock-groups, which had been laid down continuously without discordance, were subjected to disturbance, the principal effect of which was to throw them into an arch, and to bend over this arch into an isocline with a general inclination towards the north-west. The strata likewise underwent a widespread foliation, which, in accordance with the structure and composition of the rocks affected, was chiefly developed in certain kinds of material.

Cambrian, but at the latter place much to induce me to consider the Dimetian far the older. The finer materials of the Cambrian frequently recalled to my mind grits which are known to be derived from granitoid rocks. There are none of the usual indications of secondary metamorphism, but some, as shown by Dr. Geikie's own slides, of faulting: the presence of secondary quartz proves nothing. I could not see any evidence in favour of the felsites being 'apophyses' of the Dimetian, and I considered them to have broken through it. In the present state of our knowledge it is very difficult to say whether the Dimetian is or is not a granite; but I cannot admit that there is any evidence whatever for its being a granite of later date than the Cambrian conglomerate, and believe it far more ancient. Further, it appears to me that there was good evidence in favour of a marked physical break at the base of the Cambrian series. There appears to be some unconformity (perhaps much), and there is certainly a marked change in the lithological character of the deposits above and below, the 'tuff' bands in the Cambrian being small in comparison with the great mass of ordinary sedimentary materials; and, so far as I have seen, there is nothing to prove that they are the results of contemporaneous eruptions. Besides, we do not efface the limits between Miocene and Pliocene because, in a country where there has been great volcanic activity in the former, some feeble sputterings have occurred in the latter. Lithologically your Pebidian and Cambrian at St. David's are about as different as they can be. I should also like to add that from time to time you have allowed me to examine the specimens used in preparing your present paper, and have lent me all the slides submitted to Mr. T. Davies, and I consider they establish your main conclusions, and I agree with his determinations in all important respects. I may add that the so-called 'fine foliation' which occurs both above and below the Cambrian conglomerate does not appear to me to have any bearing upon the question at issue. In the full sense of the words there are neither foliated nor metamorphic rocks at St. David's, if we exclude the Dimetian."

"Subsequent to these changes the south-eastern side of the fold was invaded by the rise of a mass of granite, with the usual peripheral quartz-porphyries. Accompanying and outlasting this intrusion a process of metamorphism went on, the effect of which has been to change fine felsitic tuffs or shales into hard, flinty, translucent masses, and to superinduce in them a finely crystalline structure, with the development of porphyritic-felspar crystals and veins and threads of crystalline quartz."

He further suggests that the granite and accompanying porphyries may possibly represent the roots of volcanoes belonging to the Lower Silurian period. He may indeed well say that the question of the intrusion or non-intrusion of the granitoid rocks (our Dimetian) into the Cambrian strata is the main point in the discussion; for the general deductions, and the theories of metamorphism so elaborately worked out in the foregoing quotations depend entirely for support on the, as I have shown, mistaken supposition that the Dimetian is an intrusive granite of later date than the whole of the Cambrian rocks. I have given abundant evidence to show that there is no foundation whatever for such a supposition, and have proved by every possible kind of evidence that the Dimetian rocks are of very much older date than any of the Cambrian rocks. I have shown also that the oldest of the Cambrian conglomerates received much of their materials from the denudation of the Dimetian rocks, and that the porcellanites, which the Director-General supposes were mere muds or other unchanged sediments until after the whole of the Cambrian rocks had been deposited, were in their present condition in Pre-Cambrian times, as shown by the fragments of them in the conglomerates; also that his so-called "adinole" concretions are mainly fragments of still older rocks enclosed in the porcellanite series, and not the result of metamorphism, with a development of porphyritic felspar crystals in ordinary sediments, as claimed by the Director-General. His theory as to the so-called apophysial nature of the felsites also necessarily falls through, on the grounds alluded to above.

Evidence has also been given which shows that the idea of the supposed fold in the Pebidian rocks must either have arisen from a process of theoretical deduction, or as the result of an exceedingly imperfect acquaintance with the natural sequence of the rocks and of the special petrological characters exhibited by the different members of the series. The assertions made, also, that the Cambrian conglomerates are conformable to the Pebidian rocks upon which they repose, and that "they do not contain the characteristic rocks of the St. David's district," are amply refuted by the evidence given of the manner in which they are seen to overlap different members of the Pebidian series, and by the abundant facts produced in the paper and in Mr. Davies's notes, to show that the characteristic rocks do occur in the conglomerates, as proved by macroscopical and microscopical examination.

Appendix.—Notes *on the* Microscopic Structure *of some* Rocks *from* Pembrokeshire. By Thomas Davies, Esq., F.G.S. (of the Mineralogical Department of the British Museum).

Nos. 1–5. These are textural varieties of the Dimetian, Nos. 1 and 2 being from Porth-lisky, Nos. 3 and 4 from Porth-clais, and No. 5 from a quarry south of the Camp. It is difficult to add to the descriptions already given of this rock. The quartz is of a peculiarly dirty aspect, being filled with enclosures, by far the larger portion of which are not fluid, but of a fine dusty nature, resembling much the dusty débris of felspars. It is often of a rounded character, like that of a typical quartz-felsite, and frequently in isolated crystals, surrounded by a mass of what may be immature or undeveloped rather than altered felspar. There is orthoclase and sometimes plagioclase and microcline. No mica is present, but in No. 4 there are evidences of the former presence either of hornblende or of biotite, probably the latter. The green chloritic mineral occupies interstices or fissures, or partly replaces the felspars, and it presents no indication of its having resulted from the decomposition of a micaceous constituent. A rhombohedral carbonate is present in No. 1, which is probably a dolomite. The peculiar dendrito-graphic structure existing between the quartz and the felspar is very striking in Nos. 2 and 3—a rock which, probably from crushing, presents a remarkably brecciated aspect. No. 5 is banded, the darker bands containing much of a fine-grained translucent grey mineral, which depolarizes light.

I may remark here that on a former occasion I thought this rock might be grouped with the quartz-schists (Q. J. G. S. vol. xxxiii. p. 232). At that time, however, but little microscopical work had been done upon the massive schists, and it was the unfamiliar crystalline relations of the constituents which led me to that view.

No. 6 is another specimen of Dimetian from the Brimaston Mountain. It is coarse-grained and, macroscopically, shows slight signs of foliation. Under the microscope the quartz exhibits the same dirty aspect as in the preceding, and also, as in those rocks, frequently appears in individual crystals resembling those of a quartz-felsite. There are traces of a mica, but it is much altered and obscured by opacite. The felspars are in large immature individuals, and, with the quartz, present sometimes a dendrito-graphic character. The rock seems to have been much crushed. Though from a different area, this belongs to the Dimetian type.

No. 7 is a purplish-grey compact rock, intrusive in Dimetian at Ogof-llesugn. It exhibits a fine micro-crystalline ground-mass, with a few crystals of orthoclase and plagioclase. The whole is pervaded by minute grains and crystals with square outline, of a black and opaque mineral. It is much fissured, the fissures being lined with secondary quartz. This is a felsite, slightly porphyritic.

No. 8 is from Porth-clais farmyard, and exhibits the junction of two rocks, which under the microscope present the characters of the

Dimetian and of a felsite respectively. The ground-mass of the latter is micro-crystalline, and shows small fragments of quartz torn from the Dimetian, which latter is scarcely, if at all, changed. There is no evidence of a passage from one rock to the other. Macroscopically the junction is well marked, though the edges are welded together.

No. 9 is a bluish-grey compact rock, with circular or ovoid patches resembling spherules. In thin section it resembles No. 7, but is still finer grained; the minute black mineral is present here also in abundance. The patches consist of a micro-crystalline ground-mass similar to the rest of the rock, and contain some diffused chlorite; they are surrounded by a belt of a slightly coarser texture than the remainder of the rock. This is also from Porth-clais farmyard.

No. 10, from a field north of Porth-melyn, is a compact grey rock, with numerous crystals of altered felspars and some quartz. Under the microscope the ground-mass is highly crystalline, with a tendency to a spherulitic structure in places, and encloses numerous crystals of orthoclase and plagioclase; the quartz is not so abundant. There is much of the green minerals distributed throughout, sometimes replacing the felspar crystals wholly or in part. This is a porphyritic quartz-felsite.

No. 11. East of Dowrog Pool. A dull dark-green rock, showing some enclosed small quartz crystals. Under the microscope it is seen to consist principally of fragments of quartz, much of which is of the dirty character of the Dimetian; some, however, are clear, and such as characterize the quartz-felsites. The small amount of felsitic ground-mass is micro-crystalline, and is pervaded by the bright-green mineral, which also fills fissures and cracks in the quartz crystals, and appears to have replaced most of the felspar. There is much iron-pyrites in small crystals, also magnetite and its decomposition-products. A few felspar crystals or fragments show traces of Carlsbad twinning. The whole appears to have been much crushed, for the rock, as well as the quartz fragments, is fissured and fractured in all directions, and the quartz much displaced. There is much secondary quartz.

No. 12. Carn, Ramsey Island. Macroscopically this is an excessively fine-grained rock, of a greenish-grey colour and hornstone-like fracture. Weathers white, the weathered surfaces presenting strong indications of bedding. It resembles an old rhyolite, but on examination of a thin section it appears as though it would group best with the hälleflintas, though it differs from the Roch-Castle-rock type in the larger size and character of the individual grains and in the absence of quartz nests. This is a very puzzling rock, which for the present I am inclined to regard as a quartzo-felspathic ash.

No. 13. Carn, Ramsey Island. This is a dark-grey rock, much marbled with yellowish white. In thin section it presents a micro-crystalline ground-mass, which is pervaded by a yellowish substance having no action on polarized light. Quartz and felspar crystals are present, the former being much fissured. This is a quartz-felsite.

No. 14, from Carn, Ramsey Island, is much like No. 12, but contains distinct quartz fragments. It may be regarded for the present, like No. 12, as a quartzo-felspathic ash.

No. 15. Aber Mawr, Ramsey Island. A greyish rock, with quartz and felspar crystals. The ground-mass is medium crystalline, with numerous small quartz and felspar crystals; this encloses larger crystals of the same minerals, though the two felspars are much altered or perhaps immature. Around some of the felspar crystals the dendrito-graphic structure is slightly developed: this structure also appears in parts of the ground-mass. Contains a little calcite in spaces, secondary quartz, and much epidote with chlorite, which appears in some cases to replace the felspar. This is a porphyritic quartz-felsite.

No. 16, from Well on the road to Caerfai. A bluish-grey rock, with many quartz and felspar crystals, and disseminated iron-pyrites. The micro-crystalline ground-mass of this rock varies very much in texture, and encloses abundance of quartz, which is frequently much fissured and fragmentary. This appears to me to be a quartz-felsite breccia.

Nos. 17 and 18, West Creek, Nun's Well, are fragments from a breccia. No. 17 contains two felspars, in a very fine-grained ground-mass; one crystal appears to be partly replaced or honeycombed by quartz. In No. 18 a dust-like substance, having no action on polarized light, pervades the whole ground-mass, though thicker in somewhat irregularly distributed patches. It is much fissured, and traversed by veins of secondary quartz. There are evidences of felspar crystals, around some of which appear traces of a former fluxion-structure. A mineral in slender prisms has been replaced by a black opaque substance. Epidotic and chloritic minerals are present, but much obscured by the decomposition-products of ferriferous minerals. These appear to be altered felsites.

No. 19. Caerbwdy Valley. A grey or greenish-grey compact banded rock, with hornstone-like fracture. Under the microscope, in ordinary light, it presents innumerable exceedingly minute grains of a very pale yellowish transparent mineral, in a clear ground-mass. Much of a greyish opaque substance is disseminated throughout. This is a porcellanite.

No. 20 is an arkose-like rock from Porth-lisky. It consists of fragments of felspar and quartz in a confused micro-crystalline ground-mass, which also contains much of a grey dust-like substance diffused throughout. This is probably a quartz-felsite breccia.

No. 21. West side of East Harbour, Porth-lisky. This is a fine schistose greyish rock with a white silky mineral. Under the microscope it exhibits fragments of quartz much resembling that of the Dimetian, separated by a filmy micaceous mineral which feebly depolarizes light. There are also occasional fragments of a rock resembling the porcellanites.

No. 22 is from the east side of West Harbour, Porth-lisky. It is a purple brecciated rock. Much of the quartz of this rock is of a dirty character. The large purple fragments present no definable structure and contain no minerals; they correspond very well in aspect with the porcellanites. It is a porcellanite breccia.

No. 23. Quarry north of Board School, St. David's. This is a porcellanite presenting the same structure as No. 19. It is much fissured, the fissures being occupied by a colourless foliated mineral which depolarizes light.

No. 24. By Quickwell Bridge, north of St. David's. A dull purple rock. This is a breccia containing a few fragments of a rock resembling the porcellanites, clear quartz, and fragments of two felspars and altered felsites. The cement is black and opaque. The rock consists principally of volcanic débris.

No. 25, from Maen-dewi. This is a porphyritic quartz-felsite very rich in quartz and felspar crystals, both of which frequently present a fragmentary or angular aspect. The ground-mass is also very confused, and between crossed nicols is microcrystalline and shows traces of an original fluxion structure. Contains chlorite in vermicular groups of crystals. Looks brecciated, but if so, it is probably *in situ*.

No. 26, from Rhodiad, is a pebble from a breccia. This somewhat resembles No. 25. The ground-mass varies in patches between a microcrystalline and a cryptocrystalline structure. It is pervaded by irregular grains of a mineral which sometimes depolarizes light. This is probably of secondary origin and appears to have frequently replaced part of the felspars.

No. 27. Another pebble from the breccia of Rhodiad. This is another quartz-felsite of a somewhat different character from the preceding. It has a clear ground-mass, which between crossed nicols is microcrystalline, and contains a smaller number of crystals of two felspars and of quartz.

No. 28, from Treglemais, is a breccia. Much of the rock is felsitic; but there are also fragments which, seen under the microscope, strongly resemble the hälleflintas, and also a rock with the minute indefinite structure of the porcellanite and having no action on polarized light. It also contains fragments of felspars and of quartz such as might have been derived from a quartz-felsite; also a fragment of a basic rock with columnar felspar. The whole is pervaded with a pale-grey mineral which is more abundant around the fragments. It depolarizes light strongly.

No. 29. Same rock as No. 28 and from same place, but contains more fragments of felspar and quartz, and also more of the basic rock. Contains the same depolarizing mineral, but here it is somewhat yellowish in colour.

No. 30. This is a greenish-grey compact rock from Treglemais, and is a fragment from the same breccia as No. 29. Ground-mass medium-grained crystalline carrying numerous, though isolated, spherulitic developments of the same. Felspar crystals are not numerous. Some of the secondary mineral characterizing Nos. 28 and 29 is here also, and some small diverging groups of crystals.

I think this rock should be grouped with the fine-grained spherulitic quartz-felsites of the St. David's Board Schools.

No. 31 is a breccia from Treginnis-Uchaf Field, S.W. of St. David's. This is similar to No. 28. Contains large fragments of a quartz-felsite in which the felspar crystals are only recognizable between crossed nicols; some of them possess the same cryptocrystalline structure as parts of the ground-mass. There are also fragments of a felspathic basic rock. The same granular depolarizing mineral pervades this breccia.

No. 32, from a quarry in field on the path to Emlych, N. of St. David's. A greenish rock with a somewhat schistose aspect. This is a quartz-felsite with much of a fine-grained black substance (opacite?), irregularly distributed, and sometimes closely aggregated in patches, giving the section a brecciated aspect. There is much chloritic and some epidotic mineral present.

No. 33, from Carn-ar-wig, Ramsey Sound, is macroscopically a schistose felsitic rock with a bright-green mineral. Under the microscope is seen to present a fluxion-structure, enclosing fragments of microcrystalline felsites with quartz and felspar crystals, which, however, do not, as a rule, lie with their longer axes parallel to the apparent foliation. The substance to which the schistosity is due is not arranged in continuous bands, but lies in small, wavy, lenticular groups. It is a schistose quartz-felsite (old rhyolite).

No. 34, from east of Pen-y-foel. This is a diabase, rich in olivine and felspar, and poor in augite. The felspar is in small columnar crystals much altered, and presenting, between crossed nicols, a microcrystalline structure.

No. 35 is from Pen-maen-melyn. This rock has apparently been much broken up and decomposed. Its fissures, which are very numerous and run in all directions, are filled with a fine crystalline carbonate of lime, which gives the whole a brecciated aspect. The destruction of the felspar has probably supplied the grey dust which pervades the whole. The augite has been broken up and in places partly replaced by a yellowish dichroic mineral. There are sufficient traces left, however, of both of these minerals to show that the rock was originally a felspathic diabase.

No. 36 is a dark-grey ashy-looking rock from Carn-ar-wig. It appears to be a brecciated ash. It contains fragments of a rock resembling a felspathic diabase mixed with crystals and fragments of felspars, which have been so altered as to present a fine-grained microcrystalline structure between crossed nicols. There are some fragments of felsites with a few quartz grains.

No. 37, from east of Castell, is a dull purplish ashy rock with some epidote. In thin section it presents similar characters to No. 36, but is of finer materials, and the felspar crystals are more abundant. It contains much opacite and the pale-green mineral.

No. 38. West of Rhosson Rock. This is a very compact greenish rock with minute brownish-red spots. In thin section with ordinary light there are seen abundance of columnar crystals, which are probably immature, or completely altered felspar; its habit is that of a plagioclase. Augite in minute irregular interstitial grains is present and also olivine. This is another diabase.

No. 39, from Ogof-golchfa, Whitesand Bay. A dull greenish and purplish schistose rock brecciated with fine materials. The mass of this rock is of exceedingly fine grain, showing between crossed nicols a very minutely granular mineral which depolarizes light. Here and there are ovoid fragments of microcrystalline structure (probably felsitic) and the débris of rocks like Nos. 36 and 37, but still more altered. An occasional quartz crystal is also present. Contains some magnetite and also opacite, which, besides being irregularly distributed, lies thick in places along the lines of foliation. This is a schistose tuff.

No. 40 is from the same locality. It is a similar rock to No. 39; but is more schistose and contains more of the microcrystalline felsites and quartz, with much distributed magnetite.

No. 41. A pale greenish compact rock resembling a hornstone, from Emlych. The constituent of this rock is so exceedingly minute and indefinite that its nature cannot be determined even by means of the microscope. Seen with a ¼-inch objective in ordinary light it appears to be schistose, and between crossed nicols is distinctly so. It is probably a fine tuff.

No. 42, from Ogof-llesugn, is a greenish breccia with large fragments of quartz, and quartz with felspar. In thin section shows much quartz, some clear and some dirty. Contains fragments and crystals of two felspars, also distinct fragments of a rock consisting of quartz, altered orthoclase, and plagioclase with an interstitial pale-green mineral. Some of the fragments exhibit the dendrito-graphic structure so frequently found in the rock of the Dimetian ridge. The whole appears to be cemented by a kaolin-like paste. There can be but very little doubt that we have here a breccia consisting almost entirely of the débris of the Dimetian, as the fragments above described are not to be differentiated from it. The fragments are not sufficiently angular to admit of the supposition that they are the result of a brecciation *in situ*.

Nos. 43–48. These are specimens of the Cambrian conglomerate from West Creek, Nun's Chapel. They consist very largely of quartz, but principally of the dirty kind. Some enclose fragments of a well-defined quartz-schist, the mica constituent of which is pale-coloured and slightly dichroic. There are also fragments of a felsite with outline indications of the former presence of crystals of felspar, and of a schistose rock like No. 41, quartzite, and traces of a mica much obscured by alteration.

No. 49 is from the Lower Cambrian conglomerate of Porthmelyn, near Nun's Chapel. It consists principally of the dirty quartz with traces of felspars, which in some instances have disappeared during the preparation of the section. This is an arkose and probably derived from the Dimetian.

No. 50. Cambrian grit or conglomerate from near Chanter's

Seat. Consists largely of small quartz pebbles, some of which are clear, others of the dirty Dimetian type. Encloses a small but distinct pebble of quartz and felspar.

No. 51 is a conglomerate from near Chanter's Seat, the pebbles of which are mostly small. Among numerous pebbles of more or less dirty quartz are several of plagioclase and microcline felspar, much altered, and several small pebbles of the dirty quartz with plagioclase. A small pebble of a much altered basic rock is present also. These pebbles are not closely aggregated, but are cemented together by a dark-grey cement.

No. 52. Cambrian from near Chanter's Seat. Contains quartz in small fragments with felspars much altered. The cementing material is here very dark and opaque, probably from the presence of much iron-oxide. Encloses a pebble with associated quartz and decomposed felspar.

No. 53. Grit from Chanter's Seat. Macroscopically an arkose-like rock consisting of rounded quartz and decomposed felspars. Microscopically it is found to consist of the same minerals, the plagioclase and orthoclase being more rounded than the quartz and much altered, in some instances almost entirely replaced by quartz and the greyish-green mineral so frequent in all the rocks of this area. Some small pebbles are present, the structure of which resembles that of a basic rock.

No. 54. Cambrian from near Chanter's Seat. This is similar to 52. Contains a pebble of dirty quartz and altered plagioclase, with some decomposed felspar.

Nos. 55–60. Cambrian grits &c. from Chanter's Seat and beds below. Prepared sections of these conglomerates or grits enclose small but well-defined pebbles of dirty quartz associated with altered felspars.

By far the larger portion of the quartz pebbles have also the characteristic cloudiness of that of the Dimetian. The clearer pebbles are suggestive of having been derived from quartz-felsites. Numerous rounded crystals and grains of altered felspar, some of which can be distinguished as plagioclase, are shown in all the sections, though varying in amount. Some of the sections enclose fragments which strongly resemble the more quartzose parts of the fine-grained Dimetian. Fragments of quartz-schists with mica, and traces of individual mica plates are present, but very sparsely.

No. 61. Cambrian conglomerate from Caerbwdy Valley. Contains some quartz, like the preceding, fragments of a felsite much altered, and also a fragment of a porcellanite. More of the felspathic cement is present in this section.

No. 62. Cambrian grit in contact with Dimetian, from Porth-clais. Consists almost entirely of dirty quartz, but with more of the felspathic cement, which also carries smaller quartz grains. There are some rounded fragments of a felsite.

No. 63. Cambrian sandstone in contact with Dimetian, from Porth-clais. This is a very fine siliceous grit, but it contains very numerous fragments of felsite and of felspar, some of which is plagioclase. A colourless mica is present.

No. 64. Cambrian sandstone from Ogof-llesugn. This is a much finer rock than 63, but with a $\frac{1}{4}$-inch objective is seen to consist of the same minerals; the felspars, however, with the exception of a little plagioclase, seem to have been much broken up. There is more of the micaceous mineral than in 63.

No. 65. Cambrian conglomerate, west of Rhosson Rock. Is composed of dirty quartz with fragments of quartzite and quartz-schist with mica.

No. 66. Cambrian conglomerate, west of Rhosson Rock. Encloses much quartz, but contains a fragment of a schistose felsite like 39, also fragments of quartz-schist with a nearly colourless mica. A yellowish foliated mineral occupies the interstices between the detrital fragments. The remains of felspar are too much altered to allow the recognition of its specific character.

No. 67. Cambrian conglomerate, west of Rhosson Rock. Much dirty quartz in a dark cement with fragments of a rock resembling 33.

No. 68. This is a pebble from the Cambrian conglomerate, west of Rhosson Rock. It is a fairly typical quartz-schist with some interstitial felspathic material, and much of a nearly colourless mica.

No. 69. This is a large pebble about 6 inches long by 5 inches wide, which has been brought from the Cambrian conglomerate of Whitesand Bay. It is a well waterworn pebble, and presents a well-marked schistosity. A thin section between crossed nicols presents a cryptocrystalline ground-mass enclosing a few crystal outlines of felspar. These are now almost entirely replaced by crystalline quartz, which also occupies fissures. An occasional quartz crystal such as are characteristic of quartz-felsites is present. It is a schistose quartz-felsite and has great resemblance to No. 33.

No. 70. A dark fragment from the Cambrian conglomerate near Castell. Shows in the section a very dark and dirty microcrystalline felsitic ground-mass with much quartz. It is a quartz-felsite.

No. 71. A pebble from the Cambrian conglomerate, Ramsey Island. Shows a microcrystalline ground-mass which, with ordinary light, presents a brecciated structure; between crossed nicols this is not visible. Quartz and felspar crystals are sparse, and the latter much altered. Secondary quartz in fissures.

The view that the Cambrian conglomerate of St. David's encloses much waterworn débris of the Dimetian is, I think, fully justified by the evidence now adduced from the examination of many slides of this rock, few of which have failed to afford evidence of the presence, not only of pebbles of a rock which under the microscope could not be distinguished from it, but also of its individual mineral constituents. The slides examined and described here are not selected ones, but have been taken as they were cut. The peculiar quartz of the Dimetian, thronged, as it is, with extremely minute enclosures other than fluid, causing its well-known dirty aspect, is abundant. The felspars of both rocks are of the same character and habit, although necessarily more fragmentary in the conglomerate. Though not abundant they are there, and can be mostly distinctly recognized. In some cases they are not more altered than in the Dimetian; but in others the structure has entirely disappeared, leaving a kaolin-like mass which feebly depolarizes light.

The contents of the Cambrian conglomerates of St. David's found in the sections examined are:—

Quartz, both dirty and clear.
Small pebbles consisting of dirty quartz with two felspars.
Individual felspars, both orthoclase and plagioclase.
Felsites.
Quartz-felsite.
Quartz-schists.
Quartzite.
Basic rocks.
Porcellanite.
Mica much altered.

These are all cemented by a magma which appears to be more or less of felspathic origin.

No. 72, from Treglemais, is a hälleflinta-like rock, apparently brecciated *in situ*. It is of exceedingly minute grain and encloses a few fragments of felspar and of quartz.

No. 73. Roch Castle. This section has already been described (Quart. Journ. Geol. Soc. vol. xxxv. (1879), p. 291, No. 2). I have but to reiterate that this rock contains undoubted sharp angular fragments of quartz.

No. 74. Roch Castle. A similar rock to No. 73, brecciated.

No. 75. Roch Castle. Macroscopically this is a dull siliceous rock containing small fragments of a dull white, and larger fragments of a bluish-grey hornstone-like rock. In thin section it presents a similar structure to Nos. 73 and 74, but contains angular pieces of a dense rock which has no action on polarized light except in minute points.

No. 76. Roch Castle. A similar rock, but of a reddish colour; the included fragments are not so large. In structure it is similar to the preceding, but somewhat more coarsely crystalline; it is much obscured by abundance of iron oxide.

No. 77. Roch Castle. A hornstone-like fragment similar to that enclosed in No. 75, but of a coarser texture and more quartzose in aspect, with some attached fragments of a yellowish compact rock. The section shows an exceedingly minutely crystalline ground-mass almost inert between crossed nicols, with much quartz in irregular grains distributed in patches and groups. The yellowish compact fragments which are associated with it are quite inert between crossed nicols, and present no definite structure.

No. 78. Roch Castle. A dull greyish-white rock. In structure almost identical with No. 73.

No. 79. Roch Castle. A grey compact rock with visible nests of quartz. A microcrystalline ground-mass with much felspathic dust distributed in patches. Contains very numerous ovoid nests of quartz, which in some brecciated portions appear in ordinary light to resemble crystals of felspar. Between crossed nicols this resemblance disappears. The hälleflintas from Roch Castle now examined vary but little from those previously described. They are brecciated; some contain undoubted angular fragments of quartz and of rocks with indefinite structure; one contains fragments of what may have been a felspathic rock, or of felspathic débris in which the crystals of felspars, if they were such, are now replaced by quartz. The whole of these rocks are traversed by numerous fissures of secondary quartz, and crystalline nests of the same. They are probably indurated and altered bedded ashes.

No. 80. Plumstone Mountain. This rock shows a very fine-grained felsitic ground-mass crowded with fragments of quartz, evidently detrital. A quartzo-felspathic ash.

No. 81. Plumstone Mountain. A yellowish-grey compact felspathic rock with numerous black spots. A thin section shows that it is entirely felspathic; it consists of large felspar crystals in a ground-mass of smaller columnar crystals of the same. They are both orthoclase and plagioclase; many of the porphyritic crystals are replaced, or partly so, by a dark-yellowish mineral which depolarizes light, and it is minutely dispersed throughout the ground-mass. A porphyritic felsite.

No. 82, from Goultrop, south side of St. Bride's Bay, is a rock which, macroscopically, appears to consist of felspar and quartz and to be distinctly foliated.

In thin section it presents distinct bands of crystalline quartz remarkably clear and free from inclusions, with an occasional large crystal of microcline or orthoclase, which are tolerably fresh. These alternate with bands of mingled felspars and quartz, the former of which sometimes appear as rounded or irregular grains. They seem to be much altered, between crossed nicols depolarizing light only in minute points and patches. A few small crystals or laminæ of a green dichroic mica are sparsely scattered, while a green structureless mineral with some opacite occupies fissures.

No. 83, also from Goultrop, is a similar rock, but of a greener colour and not so markedly of foliated aspect; a section shows that the constituents are not arranged in such distinct bands as in No. 82. The rounded and irregular felspar grains are more numerous, and some, as in the preceding, show traces of twin striation. A green dichroic mineral occurs in wavy bands and is tolerably abundant. It is traversed by veins of secondary quartz.

Both of these rocks (Nos. 82, 83) present a distinctly gneissic aspect, more marked in No. 82, which, especially, bears a remarkable resemblance to some old gneisses.

EXPLANATION OF PLATE XXIV.

Geological Sketch of the older rocks of the St. David's district.

Discussion.

The President, in inviting discussion on this important paper, expressed a hope that Fellows would limit their remarks to the points raised in connexion with the St. David's district and not attempt to consider the general theories of metamorphism. He also trusted that the question would be discussed in a calm and scientific spirit.

Mr. Topley said that the Director-General of the Geological Survey went to St. David's quite prepared in large part to accept Dr. Hicks's views. He stated that Sir Andrew Ramsay's earlier views were certainly much more correct than the later. He admitted that if the statements now made by Dr. Hicks as to the presence of undoubted Dimetian fragments in the conglomerate could be substantiated, the main question was settled. He adverted to the fact that this evidence had not been brought forward at the reading of Dr. Geikie's paper. He insisted that the specimens now exhibited were exceptional in character, and that the Cambrian conglomerate is mainly a quartzose conglomerate and not made up of Dimetian materials. He admitted that some small fragments in the conglomerate did resemble Dimetian. He accepted the *apparent* unconformity in some places between the Cambrian and Pebidian; but this was explained by Dr. Geikie as due to contemporaneous erosion. The sections could only be judged by those who visited the country and compared the interpretations of Dr. Hicks and Dr. Geikie. He remarked on the peculiar fact of Dr. Hicks finding everywhere in small areas no less than three unconformable divisions of the Archæan series. This point had been insisted on by Prof. Blake. He alluded to the views of MM. Renard, Wichmann, and Zirkel as confirming those of Dr. Geikie. With respect to the paper of Mr. P. Frazer, Dr. Geikie was not responsible for it, for that gentleman left the English surveyors before their work was concluded.

Prof. Hull had not visited the district, but he insisted that the field-work at St. David's had been done by such excellent geologists that he could not believe that it was to be set aside on such evidence as that brought forward by Dr. Hicks. He thought that the supposed inclusion of fragments of the older rocks might be accounted for by the breaking up of lavas as they flowed over the bottom of the sea, and the inclusion of the fragments in the still flowing mass.

Principal Dawson remarked that some Canadian geologists had objected to the use of the terms Pebidian and Dimetian for the Pre-Cambrian rocks described by Dr. Hicks, and thought they should have been named Huronian and Laurentian, since they resembled these rocks so much in mineral character. After hearing the paper and the discussion which followed, he thought Dr. Hicks might be excused for inventing new names rather than identifying the disturbed and much disputed rocks he had described with the widely distributed and indisputable Pre-Cambrian rocks of Canada. The questions involved as to these beds were both stratigraphical and lithological. The sections exhibited showed great disturbance and complexity, except two of them, which appeared to show distinct unconformable superposition of the Cambrian on the Pebidian. He would ask Dr. Hicks to explain if these cases were really as plain in nature as they appeared in the diagrams. With reference to lithological questions, the most important and, indeed, decisive fact was the occurrence of pebbles of Pebidian and Dimetian rocks in the Cambrian conglomerates. In the case of mere grits, quartz sand and fragments of felspar went no further than to indicate derivation from granitic rocks of some kind. The occurrence of actual pebbles was, however, a decisive point. With reference to the Pre-Cambrian rocks of Canada, which had been referred to, he would say that, though the great Laurentian and Huronian series were clear and undisputed, there were cases where rocks having many of the mineral characters of these series were so involved with folded and partially altered Palæozoic sediments that they presented as great complexity as any in Wales or Scotland, and had led to much controversy. As an old member of the Society, but one who could very seldom be present at its meetings, he desired to express his gratification in witnessing its continued life and activity, and its energetic discussions of matters of geological fact, and more especially its prosecution of the great questions involved in the lithology and stratigraphy of the old crystalline rocks.

Prof. T. McK. Hughes said the principal question at issue was whether the so-called Dimetian was older than or intrusive in the Pebidian and Cambrian. He thought that Dr. Hicks had somewhat unwisely accepted the challenge of the Director-General to allow the settlement of the question to depend upon the finding of fragments of Dimetian in the base of the Cambrian, as he did not believe that the little particles of felspathic rock in the grit would carry conviction. All the junctions between the Cambrian and the Dimetian are faulted ones. At the one point where the junction could be best studied, there was no proof of contact-metamorphism but only of crushing. He thought Dr. Hicks had gone far towards demonstrating the truth of his views concerning the principal question.

The President could not admit the validity of the rule which Mr. Topley sought to establish, that the reply to an attack should be given immediately. He had seen all the slides referred to by Dr. Hicks and Mr. Davies, and was bound to say that they bore out the views of the author as to the presence of fragments of Dimetian rock in the grit of the Cambrian. He fully agreed with all the more important conclusions at which Mr. Davies had arrived.

Dr. Hicks, in reply, said that when the Director-General read his second paper he had only the night before returned from St. David's, and it was therefore impossible to reply to the whole of the attack at the time. He was anxious also that the evidence which he had obtained should be thoroughly examined by the most competent authorities before it was submitted to the Society. Well-rolled pebbles of the Dimetian were so abundant in the Cambrian at one place (Chanter's Seat) that they formed nearly the whole material of some of the beds. The statement that the three unconformable divisions always occurred, even in *small* areas, was incorrect. He denied the repetition of the beds as asserted by the officers of the Survey. He thought the Pebidian in its characters and relations strikingly agreed with the Huronian of Canada, as admitted by Dr. Dawson. The unconformities were perfectly clear in coast-sections.

38. *On the* Internal Structures *and* Classificatory Position *of* Micrabacia coronula, *Goldfuss, sp.* By Prof. P. Martin Duncan, M.B. (Lond.), F.R.S., F.G.S., &c. (Read June 11 1884.)

Micrabacia coronula, Goldfuss, sp., called *Cyclolites* by William Smith (1816), is a characteristic fossil of the Upper Greensand, and has been found at Warminster and, according to W. Smith, at Chute Farm and Paddle Hill, near Dunstable, and in the beds at Essen and Le Mans; it is also found in the "Cambridge Greensand." Bolsche has described a *Micrabacia* from the Senonian.

The external characters of the species have been beautifully delineated by Milne-Edwards and Jules Haime, in their monograph of the British Fossil Corals *, and the description of the specimen used as a type is, as might be anticipated, careful and correct. Allowing for variation in some parts, the description permits any specimen to be recognized, specifically, from the appearance of the external structures. It does not appear that these authors made sections of this coral, and as their work was classificatory and not necessarily morphological, they probably did not think it necessary to investigate the internal structures specially.

The generic diagnosis of the type was also carefully given by Milne-Edwards and Jules Haime, and the genus *Micrabacia* was separated from the genus *Fungia*, Dana, by them.

They placed the genus in the family of Aporose Corals called Fungidæ by Dana, and in their own subfamily Funginæ, which includes Fungidæ with perforated walls. The generic and specific diagnoses and the synonymy are given in the 'Histoire Naturelle des Coralliaires,' vol. iii. p. 29.

After the careful descriptions of these authors had appeared, came the work of M. de Fromentel, entitled 'Introduction à l'Etude des Polypiers Fossiles,' 1858–1861. It does not add anything to the knowledge of the genus or species, and merely complicates the classificatory position by uniting the form with others which are morphologically distinct.

Many years since the late Dr. S. P. Woodward directed my attention to the species, and to its interesting resemblance to a discoid *Stephanophyllia*.

On working at the subject I was not so impressed as my teachers, MM. Milne-Edwards and Jules Haime, had been of the importance of the remarkable arrangement of the costæ in *Micrabacia coronula*, because some Australian corals, with which I was then familiar, indicated that the peculiarity could or could not exist in different species of a genus. Subsequently, thus influenced, I described *Micrabacia Fittoni*, a new form from the Gault of England †.

* Pal. Soc. 1880, 'British Fossil Corals,' pt. 1, Tab. x. figs. 4–4*a*, and p. 60.

† 'Monograph of the Secondary Corals of England,' Pal. Soc. pt. ii. no. 1, p. 37, 1866.

Lately, during a revision of the genera of the Corals, I have carefully re-examined the structure of *Micrabacia coronula*, and have compared its internal morphology with that of *Fungia* and *Anabacia*, and especially with that of a new recent species (*Diafungia granulata*, nobis *), which, although it cannot enter the genus *Micrabacia*, presents in many points very striking resemblances.

Micrabacia is one of those genera the comprehension of which is impossible without the study of the nearest allied recent genus. This modern type is the genus *Fungia* (*pars* Lamarck, consolidated by Dana). The nature of the synapticula of *Fungia* (the essential morphological element of the family in which the genus is placed), the character of the septa (some solid, some perforate), and the nature of the wall, hitherto quite misunderstood, were considered in a communication to the Linnean Society †.

On comparing *Micrabacia* with other members of the subfamily Funginæ, it is evident to me that MM. Milne-Edwards and Jules Haime were perfectly correct in their estimate of the classificatory position of the genus—that it is allied to the genus *Fungia*, and that it has been misplaced by M. de Fromentel.

The following is the generic diagnosis given by Milne-Edwards and Jules Haime in 'Hist. Nat. des Corall.' vol. iii. p. 29, 1860:—

"The corallum is simple, lenticular, plano-convex, and without trace of adherence. The wall is sensibly horizontal: it presents delicate non-echinulated and simply granular costæ, which alternate with the outer edge or margin of the septa, and the intercostal grooves have a regular series of little perforations. The septa are moderately numerous, straight, denticulated, and are free at their inner edge. The columella is rudimentary or does not exist."

Milne-Edwards and Jules Haime distinguish *Micrabacia* from *Fungia* because the first-named has non-echinulated costæ, and the last has its septa and costæ directly continuous. These authors do not describe the synapticula of *Micrabacia*, nor the method of formation of what they call the wall, which is regularly perforated.

These are important points, and it is necessary to study them, and also the condition of the septa, which are said by one author to be perforated.

This research is all the easier since the description of the genus *Fungia* ‡ explained the nature of the synapticula, their relation to a system of interseptal channels opening at the base of the coral, and communicating with the medium at the surface of the calice also, and the structure of the base itself, which has not a true theca or wall.

In manipulating *Micrabacia*, sections should not be cut vertically, but the coral should be fractured with bone nippers in that direction. The result is to show the synapticula well.

Taking the structural details given by MM. Milne-Edwards and Jules Haime, in the order followed by those authors, there is no doubt that the shape of the corallum is what they state it to be. But the

* Journ. Linn. Soc. Zool. vol. xvii. p. 417. † Ibid. p. 137. ‡ Ibid.

base, although circular in outline, is not horizontal in any of my specimens, for there is a slight but decided hollowing which permits the coral, not to rest upon the whole surface of the disk-like base, but only on its edge or circumference.

At first sight this is an unimportant peculiarity, yet it clearly relates to the nature of the synapticular structures, and to the more or less perfect canal-system within the coral. Were the base perfectly flat, there could be no ready communication between the outside medium and the interseptal spaces from below. Such a communication, although distinctly opposed to the idea of a Cœlenterate organism, is evident enough in many of the Funginæ, and especially in the genera *Fungia* and *Herpolitha*. In the *Fungiæ* especially the base is hollowed out and the corals rest on the edges of the disk, leaving a space for water between the supporting substance and the centre of the base.

The costæ are as described by MM. Milne-Edwards and Jules Haime; and it facilitates the comprehension of their relation to the septa by stating that each costa bifurcates at the circumference of the base of the coral, and that the right-hand bifurcate process of one costa unites with the left-hand bifurcate process of its neighbour, and that a septum is prolonged from this union (fig. 3).

This arrangement necessitates the septa being continuous in direction with the intercostal spaces, and not with the costæ.

The regular perforations of the intercostal grooves are very symmetrically placed, and add to the beauty of a well-preserved fossil. These openings lead up into the coral, between the septa into the interseptal loculi.

These spaces are bounded at the sides by costæ, and internally and externally by bars which are the lower ends of synapticula, and not portions of a theca or wall.

In order to comprehend this statement and to examine the synapticula at the base and higher up within the interseptal loculi, it is necessary to fracture a coral, so as to separate some septa from those next to them.

On examining the exposed sides of the septa it is found that these moderately close, unequal laminæ are solid. They are denticulate at the free edge, rather thin here and there near the serrated margins, and more or less ornamented with lines of granules which never unite across the interseptal spaces with their fellows of the opposed septa.

But there are fractured surfaces seen on the sides of the septa, situated on irregular eminences which vary in length, and have a decided trend from the base or lower part of the septa, radiating more or less, to about three-quarters of the distance from the lower part of the septa to their upper free edge (fig. 1). Sometimes the projections approach nearer the edge. The projections are synapticula broken across; and it is noticed that whilst some are long and extend uninterruptedly over much of the septal side, others are shorter, and that a few bifurcate. The synapticula are stout, moderately thick from within outwards, and tolerably close one to the other, the intervening space forming a canal when the septa are placed in normal apposition and the fractured surfaces of the synapticula are united. The synapticula are rarely continuous up an intermediate loculus, but are usually in continuous series, and the direction is well preserved (fig. 1). But this discontinuity interferes with the perfectness of the canals and permits them to communicate.

Figs. 1–3.—*Structure of* Micrabacia coronula.

1. 2. 3.

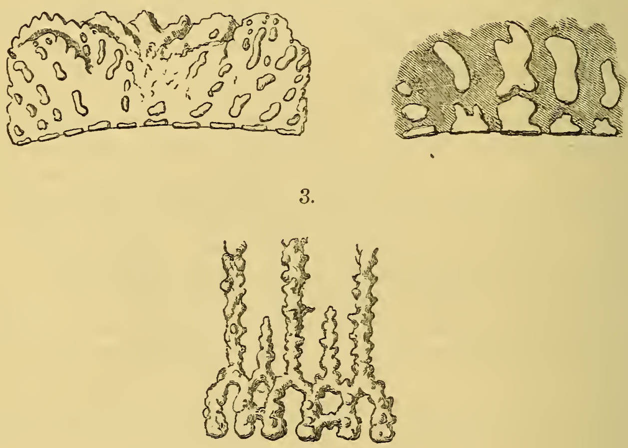


Fig. 1. A section of *Micrabacia coronula*, magnified, showing basal and septal synapticula.
Fig. 2. Synapticula ending close above the basal synapticula, much magnified.
Fig. 3. Side or marginal view, showing bifurcating costæ terminating above in septa, much magnified.

Sometimes the synapticula, when looked at from above, are slightly constricted ; but their length can never be appreciated from such a view, for only their tops are then seen.

On tracing the synapticula, in fractured specimens, downwards in the lower parts of the interseptal loculi, they will be found usually to cease above the base (fig. 2), and to be succeeded in order by others, which are short and variable in shape. Those at the base are the bars seen between the costæ at the base of the corallum. The spaces between these bars pass upwards into the more or less continuous canals just mentioned, and the bars are evidently synapticula.

The synapticula are often large, rather high up in the loculi, and they cover much of the surface of the septa, but there is much variation in their development in different individuals.

The costæ unite in series before reaching the centre of the base, and carry one line of granules, and this appears to be the rule.

On turning the corallum on its edge so as to see the junction of the septa and the costæ, the interesting bifurcation is occasionally very visible and sometimes is marked by the thickening of the ends of the costæ (fig. 3). Weathering or rubbing down, assists the demonstration.

The columella is small and rudimentary. From these considerations the generic characters of *Micrabacia* should be thus modified :—

Corallum simple, lenticular, convex above, slightly hollowed out below, resting on the edge of the basal disk. Costæ delicate, simply granular, bifurcating at the calicular margin. Intercostal spaces crossed by synapticula, and having a regular series of openings leading upwards into the interseptal loculi. Septa continuous with the intercostal spaces, and formed by the junction of a process from the two nearest costæ, arched, denticulate, solid, unequal.

Synapticula well developed in series, continuous or discontinuous, terminating moderately high up on the interseptal loculi, and ending below as intercostal bars having canal-like spaces between them. Columella rudimentary.

Remarks.—Were the synapticula invariably continuous as processes from the base to high up in the interseptal loculi in *Micrabacia*, this genus would present but slight distinctions from *Fungia*, Dana. There are other distinctions, however, of greater or less importance, such as the regularity of the spaces on the intercostal grooves in *Micrabacia* and their irregularity in *Fungia*, the regularity of the synapticulate bars in the one and their irregularity in the other, where they are often confused by a kind of thecal growth at the base.

In *Fungia* there is a curious overlap of large strata in relation to small ones, and the costæ are echinulated; these characters are not seen in *Micrabacia*. The young septa are often fenestrated in *Fungia*, but not in *Micrabacia*.

The genus *Halomitra* has synapticula resembling those of *Micrabacia* within the septal loculi, and the discontinuous synapticulum is a very Lophoserine character.

Now *Micrabacia* is older than *Fungia*, and the slight structural distinctions are therefore very suggestive of descent.

Finally, there is now great doubt about the generic position of the species, *Micrabacia Fittoni*, I described in the Monograph of the British Fossil Corals, Palæontological Society, from the Gault *. The type has unfortunately been mislaid by its possessor, so it is necessary to consider the excellent delineations given on plate xiv. figs. 6–9, by De Wilde.

One question is—Are the broad processes with blunt angular terminations costæ from the apices of which thin septa appear to arise? If they are costæ, the form is not a *Micrabacia*. The second inquiry

* 2nd series, 1870, pt. ii. no. 2.

must be, What are the thin light lines ending in thin septa at the margin and base of the coral (plate xiv. fig. 8)? If they are costæ, the probabilities are that the form is a *Micrabacia*. Again it is necessary to know whether the intercostal spaces of the figure (9), which are dark and black in colour, were not the positions of the small thin costæ which bifurcated further out, and to inquire what are the spaces visible on the base of the magnified figure of the base (7). I do not feel disposed to remove the species yet from *Micrabacia*, but would rather suspend my decision until the type is found. In the mean time *Micrabacia coronula*, Goldf., sp., is a true member of the group Funginæ of Milne-Edwards and Jules Haime.

Discussion.

The President inquired whether the fossil described occurred in the Cambridge Greensand.

The Author said that it did, but he thought it was as a derived fossil.

Mr. Champernowne remarked on the well-marked character of the synapticula, and the relation of the fossil to the Fungidæ.

Mr. Etheridge confirmed the statement that the structure of *Micrabacia* could not be seen in cut sections, but only by breaking the coral.

The Author pointed out the peculiarities in the structure of the costæ and septa, and thanked the President for the information regarding the discovery of the form in the Cambridge Greensand.

39. *The* Archæan *and* Lower Palæozoic Rocks *of* Anglesey. By C. Callaway, Esq., D.Sc., F.G.S. *With an* Appendix *on the* Petrology *of the* Rocks by Prof. Bonney, D.Sc., F.R.S., Pres. G.S. (Read May 28, 1884.)

In papers communicated to this Society * and the Geological Magazine † I have described in some detail the Archæan formations of Anglesey. I came to the conclusion that there was no satisfactory evidence of more than two of these systems, the Gneissic and the Slaty—the former metamorphic, the latter, on the whole, hypometamorphic, but passing here and there into true schists, hardly less altered than some of those which occur in the older series. This work was too laborious and absorbing to permit me to pay minute attention to the Palæozoic strata of the island; and this was the less necessary, since other workers were approaching the investigation from the side of the newer rocks. Their labours tended strongly to support my views, so far as they referred to the central part of the island; but much remained to be done in the north and west. I therefore determined to work round the margins of the Archæan areas on which Holyhead and Amlwch are respectively situated, and I have had the satisfaction of ascertaining that these masses are fringed on the east and south respectively by shore-deposits, which furnish evidence similar to that ‡ which has been for some years familiar to us in the conglomerates which overlie the central axis. I have also discovered most interesting proof of the relations between the two Archæan systems.

A. Relations between the Amlwch Archæan Mass and the Palæozoic Rocks to the South.

As the Palæozoic strata of Northern Anglesey dip in a northerly direction, in apparent conformity with the altered § rocks which lie to the north, the two groups might seem to be in true sequence. Sir A. C. Ramsay, however, held || that they were separated by a fault; and of the correctness of this view I have no doubt. Sections showing the actual contact are very rare. By far the most distinct junction is at Porth-y-corwg, on the east coast, where the rocks are exposed in a perpendicular cliff. Conglomerate and dark shale are brought against the hypometamorphic slates by a fault, which is nearly or quite vertical. A notch is formed in the coast at the contact of the soft Palæozoic rocks with the tough green

* Quart. Journ. Geol. Soc. vol. xxxvii. p. 210.

† Dec. 2, vol. vii. p. 117 (March 1880)

‡ Recently given in greater detail by Dr. Hicks and Prof. Bonney (Quart. Journ. Geol. Soc. vol. xl. pp. 187, 200).

§ Throughout this paper I use the term "altered" as inclusive of "metamorphic" and "hypometamorphic."

|| 'Geology of North Wales,' 2nd ed. p. 235.

slates. Even were no fault visible, a break might be inferred from the fact that the rocks to the north of the junction are crumpled into very sharp contortions, and have undergone partial metamorphism, while the shales immediately to the south of the line are apparently unchanged and have suffered no contortion.

I have traced the junction of the two groups from this point westward to Llanfflewin, three miles from the west coast, and nowhere have I found the slightest evidence of a passage, though the two kinds of rock are frequently seen within a few feet of each other. Some details on this point may be of interest.

A little north of Byttia, nearly two miles west of Porth-y-corwg, the two formations are exposed within a few yards of each other. The Pebidian is a pale-green altered slate, of the ordinary type. The Palæozoic is a conglomerate, dipping with the Pebidian; yet there are no signs of beds of passage. Moreover, I traced the conglomerate along to the east, and ascertained that it was the same bed which at Porth-y-corwg lies south of the fault, so that the dislocation must extend at least as far west as Byttia.

West of Byttia the line of contact curves round to the south-west, and the conglomerate is no more seen, a conjunction of circumstances more naturally explained by faulting than thinning-out. Black shales, standing vertical, or even dipping away from the Pebidian, are now in contact with the older group for nearly a mile to the south-west.

At Nantglyn, $2\frac{1}{4}$ miles W.S.W. of Byttia, we come to an excellent junction. The two types are seen almost in contact in the road, and the shales are well exposed in the quarry at the house. But there are no shale-beds in the contorted series or altered beds in the shales.

Black shales may be seen at several points between the last locality and Llanfflewin. They sometimes approach to within a few yards of the Archæan; but nowhere along this line have I been able to find the slightest evidence of a passage between the two formations.

On the west coast, south of Carmel's Point, I again observed Palæozoic shales and altered Pebidian rocks in cliff-sections, and the faults were perfectly clear. There is, then, no reason to doubt that the Porth-y-corwg fault extends right across the island, throwing down the Palæozoic strata against the Pebidian of the Amlwch area.

We are not, however, left to the negative evidence of a fault. The conglomerate which fringes the Pebidian from the east coast to Byttia furnishes us with positive proof of the superior antiquity of the contorted series. The included fragments are mainly of types such as are found in the Pebidian of the Amlwch area. Some of the pebbles are of ordinary Pebidian slate (No. 113, p. 584), such as occurs in central Anglesey, as well as in the north, so that their teaching is not decisive. Others are of quartzite, and their testimony is equally inconclusive. But the predominant fragments are of grey compact limestone, and many of them are of great size, indicating a neighbouring source of derivation. This rock (No. 119,

p. 586) is undistinguishable from the Cemmaes limestone *, which occupies so conspicuous a place amongst the Pebidian strata of the northern area. There are small exposures of a similar rock at Llanfaethlu, near the west coast, and at Cerrig Ceinwen, in the centre of the island, all in the Pebidian; but since the limestone at Cemmaes is by much the nearest to the Byttia conglomerate, and occurs in great force, it is unnecessary to seek a more distant source of derivation.

As the Palæozoic strata between Llanerchymedd and the northern area have a general dip to the north, they present the appearance of a regular ascending series. If this aspect is not delusive, the thickness must be very great. The following facts, however, throw doubt upon the ordinary interpretation.

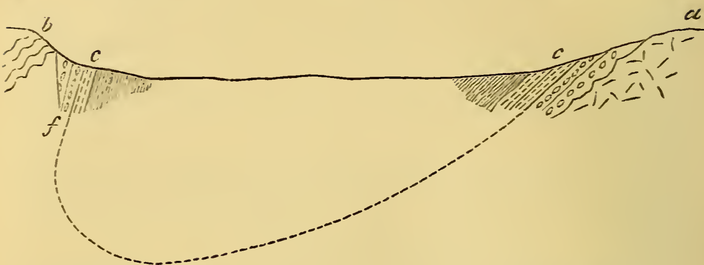
1. The conglomerate which is in contact with the boundary fault from Porth-y-corwg to Byttia is *underlain* by grits, and the grits are *underlain* by dark shales and slates. This succession is very well seen in a quarry near Porth-y-corwg farm and elsewhere in the vicinity in natural sections. I have not found the conglomerate west of Byttia; but $2\frac{3}{4}$ miles to the west-south-west, near Gwredog, the grit is seen in the road, again *overlying* dark shale, the Pebidian cropping out just beyond the grit to the north.

I venture to make the suggestion that the conglomerate and grit may be the ordinary basement beds of the Palæozoic in inverted order. I have shown the actual succession in fig. 1, the dotted curve below the base-line being hypothetical. The well-known ascending series, as seen round the margins of the Archæan masses of central and north-eastern Anglesey, is (1) conglomerate †, (2) grit, and (3) shale. The grit at Porth-y-corwg (No. 130, p. 587) and Gwredog (No. 133, p. 587) is undistinguishable from some varieties (Nos. 129, 132, p. 587) succeeding the conglomerates which underlie the black shales on the south and east. The conglomerate is unlike that which is admitted to be the base of the Anglesey Palæozoic; but this does not militate against their correlation; for it has been shown by other authors that the materials of the basement conglomerates vary with the nature of the Archæan rocks in their vicinity, and I have pointed out that the northern conglomerate is in all probability derived from the northern area. That no other beds ever come in between this conglomerate and the Archæan strengthens my suggestion. The fault between the two groups presents no difficulty; for the Palæozoic could hardly have been folded back by the thrust of the Pebidian without fracture. On theoretical grounds, I should suspect this dislocation to be reversed; but, as I have no direct proof of the hade, I have, in the section, made the fault vertical.

* See Quart. Journ. Geol. Soc. vol. xxxvii. p. 236, No. 52.

† I at first regarded this rock as a part of the Archæan, but a new reading of the Twt-Hill section required a reexamination of the question, and I frankly accept the Palæozoic age of the Nebo conglomerate and grit. The presence of pebbles of well-known Anglesey gneiss in the Twt-Hill conglomerate always appeared to me a suspicious circumstance.

Fig. 1.—*Generalized Section across the Palæozoic Rocks of Northern Anglesey.* (Scale, one inch to the mile.)

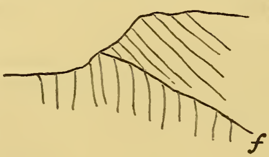


a. Granitoid Rocks.
b. Pebidian.
f. Fault.
c. Palæozoic { Conglomerate. Grit. Shale.

The blank space in the centre of the section is occupied by black shales, probably frequently repeated by folding and sometimes reflexed.

2. There is the clearest proof that the Palæozoic rocks have been thrust laterally by a powerful force from the north. On the north side of Porth-y-gwichiad (fig. 2) the shales have been fractured by a reversed fault with a very low hade to the north, and the beds of the upper mass lie with a low northerly dip upon almost vertical strata, which at the top are bent over towards the south. This appears to be a case of an overfold converted into an overfault by a continuance of the lateral pressure, according to the principle expounded by Prof. Heim *. At Llanbabo similar evidence is to be

Fig. 2.—*Overfault in Black Shale on Porth-y-gwichiad.* (Scale, about one inch to 50 feet.)



seen in a large quarry near the church. In another quarry to the east of the road, a little north of Fferam-gyd, the strata are repeatedly broken by small horizontal faults, the upper masses being pushed a few inches to the south. The presence of thin quartzose seams renders the dislocations very clear.

3. In the black-shale section between Porth-y-gwichiad and Porth-y-corwg, there are suggestions, though not actual proofs, of repetitions by folding. In high cliffs the beds are sometimes seen to form part of a sigmoid curve; and though, on the whole, the

* 'Mechanismus der Gebirgsbildung,' Band i. pp. 220–223. See also a paper by Prof. Lapworth, F.G.S., in the 'Geological Magazine,' August 1883.

rocks are homogeneous, we find, as we traverse the section, similar varieties of the shale reappearing again and again. If these are folded repetitions, there must be folding back towards the south, since the dip is almost uniformly to the north.

The facts here adduced appear to me most easily explicable on the supposition that the Palæozoic rocks of northern Anglesey originally formed a trough, which was fringed on both the north and south by conglomerates, and that, by thrust from the north, the strata on the northern side were folded back. Whether or not this hypothesis can be sustained, there is no doubt that the Porth-y-corwg conglomerate was derived, at least in part, from the altered rocks of the northern area, which are thus shown to be of greater antiquity than the strata which they apparently overlie. The close lithological resemblances between this older series and the Pebidian rocks of central Anglesey place their correlation beyond reasonable question.

B. Relations between the Holyhead Archæan Area and the Palæozoic Rocks to the East.

The Clymwr Fault.—A little south of Llanbabo, the strike of the Palæozoic rocks abruptly shifts from about east and west to south-south-west or north and south, and the deposits change from black shale, with basement bands of grit and breccia, to massive conglomerate. We must therefore place a fault immediately to the north of Clymwr. This dislocation coincides in direction, and may be actually continuous with, the Porth-y-defaid fault*, which brings the ashy Pebidian slates and shales of the north-west against the Holyhead schists. The Clymwr fault separates the Palæozoic area just described from the one about to be discussed.

Clymwr Conglomerate.—South of the Clymwr fault is a mass of conglomerate and grit, one mile and a half in length from north to south, by about one mile broad. Commencing on the north at Clymwr, it terminates on the south about 100 yards south of Bodnolwyn-hir. A small hollow intervenes between these rocks and the nearest outcrop of the Archæan. The dip is steadily to the east, that is, away from the Archæan, at moderate angles. The strata have weathered in several parallel escarpments, and, unless there is repetition, the thickness must be several hundred feet. The included fragments of the conglomerate are chiefly rounded pebbles of granitoidite and angular fragments of altered slate (Nos. 117, 118, p. 585) undistinguishable from the Pebidian (No. 112, p. 584) of the area to the west. Associated with the coarser strata, are beds of grit, apparently derived from granitoid rocks. There appears to be no definite order in this series, but I may observe that the bands with the largest fragments do not occur at the base.

Cwaen Shales.—Where the conglomerate disappears, south of Bodnolwyn-hir, black shales come in, and are well seen around Cwaen-wen, almost in contact with the Archæan. They are also exposed on the strike to the north, near Cwaen-goch, and are

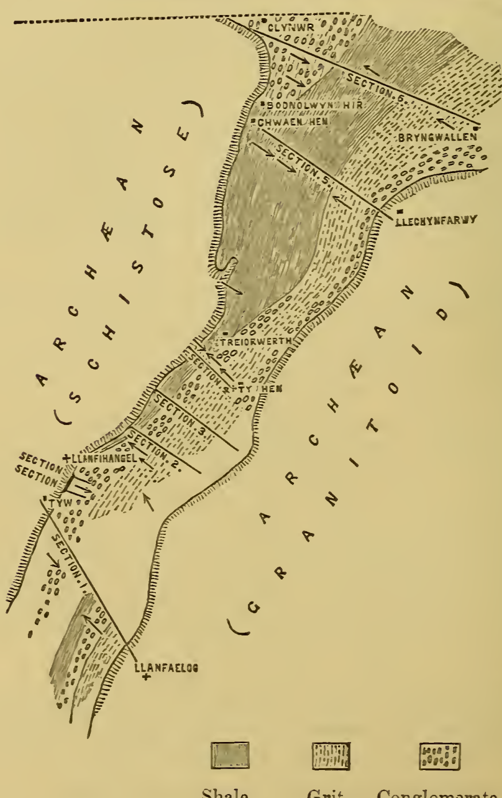
* Quart. Journ. Geol. Soc. vol. xxxvii. p. 224.

evidently continuous with the well-known black shales north-west of Llanerchymedd. These shales may be traced for over four miles to the south-south-west, disappearing a little north of Llyn Treffwll. They fringe the Archæan for the whole distance, usually dipping *away from* the older rocks. At their base, south of Bodnolwyn-hir, are some thin bands of grit.

Llanfihangel Conglomerate.—North-east of Llanfihangel the Cwaen shales pass down through some seams of grit into a conglomerate, similar to the rock at Clymwr. This conglomerate remains in contact with the Archæan for about a mile, disappearing near a cottage called "Harlech," under the sandy tract which margins Cymmeran Bay. The rock is well exposed in the craggy ridge east of the farm of Tywyn, where in one place it is seen to dip to the east.

The Clymwr and Llanfihangel conglomerates, with the intervening Cwaen shales, are thus seen to fringe the western Archæan area for

Fig. 3.—*Sketch-Map of the Treiorwerth Syncline.*

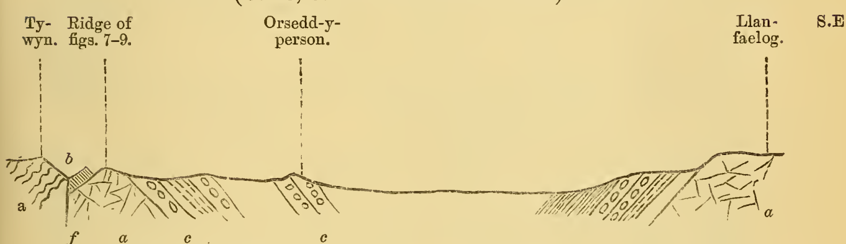


its entire distance from north to south, and where seen, they almost invariably dip away from it.

The Treiorwerth Syncline (see map, fig. 3).—The recognition of the three groups just described will help us to work out the stratigraphy of the band of Palæozoic rocks between the central axis and the western (Holyhead) area. A few sections will throw some light upon its structure. As the beds lie in a basin, and Treiorwerth is situated about midway between the two extremities of the zone, we may call it the Treiorwerth syncline.

Section (1) *from Llanfaelog to Tywyn** (fig. 4).—Leaving the granitoid axis, we first come to grit, which, a little higher up, near Ty-ceryg, yields *Orthis*, and, within 200 yards, passes gradually up into green conglomerate †, with pebbles of granitoidite and unrounded fragments of green shale, the pebbles and fragments being sometimes of great size. A little to the south, on the west side of Llanfaelog, this conglomerate is overlain by black shales, which are also well exposed along the shore of the bay to the south-west. All the dips hitherto seen are north-westerly. Rock is

Fig. 4.—*Section from Tywyn to Llanfaelog.*
(Scale, two inches to one mile.)



a. Holyhead schist.
a. Granitoid rock.
f. Fault.
b. Pebidian.
c. Palæozoic.

covered for some distance to the west, but reappears at the railway, near "Orsedd-y-person." South of the line, there is a clear dip to the south-east, so that we seem to have come to the west side of a syncline. The rocks, too, are very similar to the grits and conglomerates overlying the granitoid axis; and in a quarry to the north of the railway we find the same *Orthis* in a green grit overlain by conglomerate, the rocks dipping to the north-east. From here we soon come to the Llanfihangel conglomerate in the ridge at Tywyn. This rock, on the Survey map, is lettered as Carboniferous (*d*), with a query ‡. There is not, however, the

* The numbers (1) to (6) in this and the following sections correspond with the numbers on the map.

† This end of the section agrees with part of one by Dr. Hicks, Quart. Journ. Geol. Soc. vol. xl. p. 193.

‡ This may have been suggested by the apparent derivation of the conglomerate from the metamorphic rocks to the west, originally supposed to be Cambrian.

slightest reason for separating it from the *Orthis*-bearing grit and conglomerate which occurs within 200 or 300 yards, and with which it is connected by almost continuous outcrops. At its base, the Llanfihangel conglomerate rests upon a small inlier of granitoidite. The dip here also is towards the east. We may, then, safely conclude that the rocks in this line of section are arranged synclinally. On the western side of the basin, the conglomerate covers a much larger surface than in the eastern outcrops; but, owing to the obscurity of the bedding and the want of continuity in some parts of the section, I could not ascertain whether this was due to faulting or folding.

Section (2) *south of the Holyhead Road.*—About Llechylched and Bryn-gwyrain the rock is a grey felspathic grit (no. 132, p. 587). At the stream near "Factory," the green conglomerate comes in. It is of the same type as in the last section. The dip, as seen south-south-west of Cymunod, is clearly to the north-west at 60°. This rock is overlain at Tyn-lon by black shale with bands of greenish-grey grit, contorted, but striking west-south-west and south-west. At Allwyn-goch, the dip of these strata is north-north-west at 80°. They are here overlain by green conglomerate, whether a repetition by folding or a higher band, I could not ascertain; but the former seems the more probable. The main points to be noted in this section are that the green conglomerate is overlain by black shale with grit bands; that the dip rises nearly to the vertical towards the contact with the Archæan; and that the strike is rather more to the west than the direction of the Palæozoic zone, which, as stated, is south-south-west.

Section (3) *north of the Holyhead Road.*—This is similar to the last, save that the ground on the strike of the green conglomerate is covered, so that we can only infer the presence of that band. The strike of the black shales varies between west-south-west and south-west.

Section (4) *from Ty-hen to the Archæan west of Treiorwerth.*—This line runs obliquely across the zone from south-east to north-west. At the bottom of the slope east of Ty-hen, granitoidite is exposed, and a few yards to the west is a quarry of the *Orthis*-grit. In the road beyond we pass through a considerable thickness of grit, which, towards the north-west, approaches in its composition the grit of the green conglomerate series. Overlying this, though we must follow the strike to the north to find exposures, is the Treiorwerth or Llanfihangel conglomerate. Near a cottage on the main road, south-west of Treiorwerth, the grit bands of the black shale occur in place, striking to the south-west. A little further to the west, the shales, without grit, are vertical, and in the quarry the dip gradually falls to 80°, east-south-east. These beds may be followed on the strike to the Cwaen locality.

This section is similar to the last two; but higher beds come in, and the dip of these is reversed, as if we had reached the axis of a syncline.

Section (5) *from Llechyn-farwy to Cwaen-hen* (fig. 5).—Leaving the metamorphic axis, we pass over the *Orthis*-grit with a north-westerly dip, and, west-north-west of Bodsuran, come at once to black shales. The green conglomerate has therefore disappeared within a mile and a half of Treiorwerth. The shales are here a mile and a half broad, forming a syncline whose axis is nearer the western than the eastern margin. North of Cwaen-hen, the shale contains grit bands, and we appear to have reached its western base. About 200 yards to the north, the Clymwr conglomerate crops out.

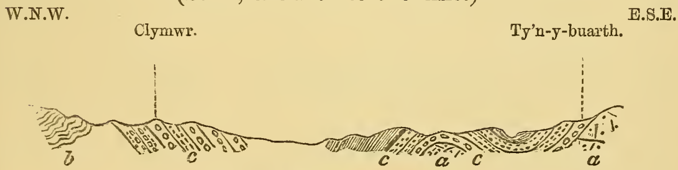
This section displays a synclinal structure. Taking in the ground a little to the north, we find the Clymwr series rising from under the western side of the fold; but I am not prepared to affirm that the succession is absolutely unbroken. Whether or not the Clymwr rock exactly represents the Llanfihangel conglomerate, there is no doubt that its position is below the black shales, so that the syncline is sufficiently complete for our purpose.

Fig. 5.—*Section from Llechyn-farwy to Cwaen-hen.*
(Scale, one inch to one mile.)

For explanation see Fig. 4.

Section (6) *from west of Bryn-gwallen to Clymwr* (fig. 6).—West of Llanerchymedd, the Archæan appears in several small islands surrounded by conglomerate and grit, which roll about in many low undulations apparently determined by the position of underlying masses of the old rock. The black shale also frequently

Fig. 6.—*Section from west of Bryn-gwallen to Clymwr.*
(Scale, one inch to one mile.)



For explanation see Fig. 4.

appears. The grit series is very thin, for, in a field at Ty'n-y-buarth, west of Bryn-gwallen, its basement conglomerate rests upon Archæan, while in the next field to the west it is conformably overlain by shales. A quarry in this field yields Trilobites and other fossils.

In the field still further to the west, near Bryn-terfyn, we are still on grit, horizontal or with low easterly dip. At Cereg-meingeia we appear to be in the same beds; but, a little to the west, the grit begins to dip at a high westerly angle, and is conformably succeeded by the black shales. The ground is then covered for some distance, and the next rock seen is the Clymwr conglomerate, well exposed at Caer-gwrie and in a knoll to the south.

In this section, the fossiliferous grits, conformably overlain by the shale, dip away from the central Archæan ridge, that is, to the west; while the Clymwr grit and conglomerate dips away from the western Archæan area, that is, to the east. The synclinal structure is therefore clear. The only break in the section is in the covered ground east of Caer-gwrie, where we should expect easterly-dipping black shale, but as this gap is precisely on the strike of the easterly-dipping shales at Cwaen-wen, we need not hesitate to complete the syncline. In fig. 6, however, I have preferred to represent only what was actually seen in the line of section.

From these sections, it is evident that the Palæozoic rocks lying between the central granitoid axis and the western Archæan area form a synclinal fold, more or less broken, and in some places complicated by repetitions*. On the eastern side, the facts are simple, as the same zone of grit and conglomerate fringes the Archæan from Llanfaelog to Llanerchymedd; but on the western margin the relations between the metamorphic and the unaltered rocks are more complex. The line of junction seems to be a fault, which cuts across the Palæozoic strata very obliquely.

It is hardly needful to state the inference from the above facts. The Palæozoic rocks fringing the western Archæan frequently dip away from it, and at their base contain numerous fragments of the hypometamorphic schists common in the north-west of the island. The altered rocks of Western Anglesey must therefore be older than the Llanfihangel and Clymwr conglomerates.

C. Relations between the two Archæan Groups.

In my previous papers, the superior antiquity of the gneissic series has been inferred from (1) its more advanced metamorphism, and (2) the analogy between the two groups and the known Archæan succession. The only evidence from included fragments was furnished by the Llanfechell grit, a band in the northern Pebidian. Under the microscope some of the small bits were seen to be of schist, which appeared, in Prof. Bonney's opinion, to be derived from the older Anglesey series. More decisive proof can now be adduced.

Sections at Tywyn (figs. 7–9).—In the autumn of 1879 I observed that the Llanfihangel conglomerate contained large fragments of contorted schist; but, as the former was lettered on the Survey map as "Carboniferous," and I had not then worked out the

* There is obviously great complexity south of Llanfihangel.

Palæozoic groups, I was unable to use the fact, though I more than suspected that the "Carboniferous" hypothesis could not be sustained. During visits made to Anglesey in subsequent years, I paid special attention to this locality, and procured additional information of peculiar interest. I found, within a quarter of an acre, the outcrops of three rock-systems—Gneissic, Pebidian, and

Fig. 7.—*Plan of Tywyn Ridge.*
(Scale, about one inch to fifty yards.)

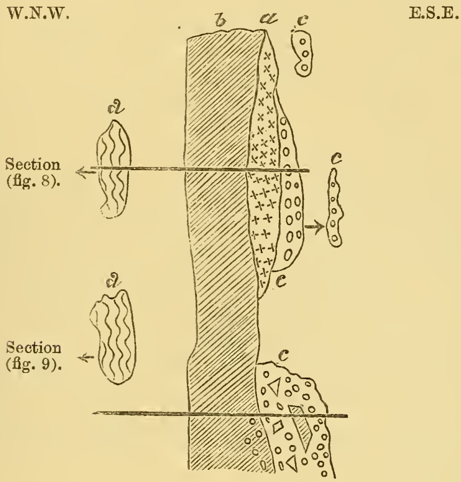


Fig. 8.—*Section at Tywyn. Northern Ridge.*
(Scale, double that of plan, fig. 7.)

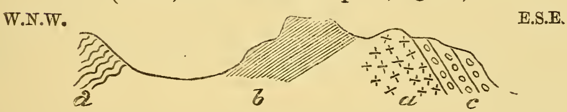
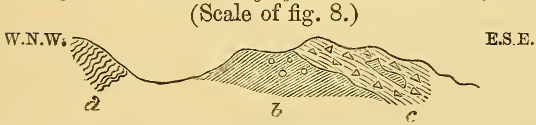


Fig. 9.—*Section at Tywyn. Southern Ridge.*
(Scale of fig. 8.)



For explanation see Fig. 4.

Palæozoic, with proof of succession in the order here given. See plan (fig. 7) and sections (figs. 8, 9).

In the middle of the northern section (fig. 8) projects a ridge (*a*) of granitoid rock (No. 110, p. 583), six feet wide and less than one hundred feet in length, striking nearly south-south-west.

On its western side, at the distance of a few feet, runs a parallel elevation of pale-green slate, with veins of a green mineral like epidote. The slaty rock is not clearly stratified, but planes which may represent bedding dip westerly. This band extends further to the south than the granitoidite, and, just where the older ridge would underlie if it were continued to the south, as is most probably the case, the slate contains pebbles (shown above *b* in fig. 9) of granitoid rock, of the same general type as that which forms the ridge (Nos. 114, 115, pp. 584, 585).

Resting on the granitoid axis on its eastern flank, and in actual contact with it, crops out the Llanfihangel conglomerate and grit, dipping easterly at 50°. At the base (Nos. 124, 125, p. 587) is grit which can hardly be distinguished in the field from a granitoid rock; but the presence of very small pebbles of a soft schist determines its derivative origin. Within a few yards (No. 126, p. 587), it becomes very distinctly fragmental, but is still largely composed of the constituents of granite. It then passes up into the ordinary green conglomerate and grit (No. 127, p. 587).

A few yards to the south of the granitoidite, the conglomerate reappears, resting immediately on the green slate with granitoid pebbles (fig. 9), the surface of the slate sloping easterly, in accordance with the dip of the grit in the northern ridge. The conglomerate does not display clear dip. It is very coarse, containing large pieces of the green slate (No. 116, p. 585), with smaller fragments of gneiss (Nos. 120–123, p. 586), a variety largely made up of hornblende being conspicuous. No. 120 is from the junction of the slate with the hornblendic conglomerate, and includes both.

A great deal of the conglomerate about here is composed of gneissic fragments; but, strange to say, though the green Holyhead schist occupies the area to the west, its outcrop appearing within fifty yards of the ridge, I have not been able to detect a single fragment of it in the conglomerate. There is plenty of a green altered rock: but, so far as I have observed, it is all of ordinary Pebidian types.

The Holyhead schist is separated from the ridge just described by a small hollow. As the dip of the schist is north-westerly, it might seem as if it overlay the granitoidite in regular sequence. But to this view there are the following objections:—

1. The green schist is, in central and eastern Anglesey, conformably underlain by thin-bedded grey gneiss, quite unlike the massive granitoid rock of the Tywyn ridge.

2. The granitoidite of our section is immediately succeeded on the west by the slaty rock, which is almost unaltered; and it is nearly incredible that it should directly underlie, without beds of passage, so highly metamorphosed a rock as the Holyhead schist.

3. If the green schist were in sequence above the granitoidite, it must have been above water when the Llanfihangel conglomerate was formed; and as it lies within a stone's throw of the conglomerate it would almost certainly have supplied it with fragments. But

none are found. Indeed, I have not been able to discover this schist in any Anglesey conglomerate, most of the contained fragments being either gneissic or slaty. This is a very singular result if the schist is intermediate in age between the granitoidite and the slaty veins; but is perfectly intelligible on the supposition that the Holyhead schist is older than the granitoid rock, and had not been exposed by denudation when the conglomerate was formed.

From the ground just described we have clearly ascertained the following facts:—

1. Both the granitoid and the slaty rock of Tywyn are older than the Llanfihangel conglomerate.

2. The granitoid is older than the slaty rock. The presence in Anglesey of two formations anterior in age to the Llanfihangel conglomerate is thus distinctly proved.

D. Age of the oldest Palæozoic Rocks.

The problem of the age of the altered rocks of Anglesey appeared to be simplified by the alleged discovery of Tremadoc fossils in the lower Palæozoic strata. The most prominent of these fossils is an *Orthis*, which has been identified as *O. Carausii.* It occurs in great numbers in the grit which overlies the basement conglomerate, and it may be traced from Llanfaelog, near Cymmeran Bay, to the northern Bryn-gwallen, north-west of Llanerchymedd. The last locality requires special notice.

About half a mile to the south, near another Bryn-gwallen, the *Orthis*-band lies a little above a quartzose conglomerate, about a hundred yards from an inlier of the granitoid Archæan, as noticed by Prof. Hughes and Dr. Roberts. At the northern locality the facts are similar. In a field near Ty'n-y-buarth, is another inlier of the gneiss, with conglomerate resting on it to the west; and at a short distance, just inside the next field, is a quarry of the grit, containing fragments of what appear to be *Illænus* * and *Asaphus* *. In a similar grit in the neighbouring walls we find the *Asaphus*, with *Ogygia* * and the *Orthis*. This band is certainly on the horizon of the *Orthis*-grit of the southern localities; for, in addition to the identity of the *Orthis*, the rock is at about the same distance above the gneiss as in the section at the southern Bryn-gwallen.

As the *Orthis* occurs in the same beds with what seem to be typical Ordovician genera, it may appear superfluous to discuss its affinities; but I venture to think that, without the Trilobites, the Brachiopod would not be decisive of the question. This species is supposed to be separated from *O. calligramma* by its smaller size, its fewer ribs, and the comparative flatness of its dorsal valve. But *O. calligramma* is a very variable form. I have collected, from undoubted Ordovician strata in North Wales and North America,

* These Trilobites have been named for me by Dr. H. Woodward, F.R.S., but he states that their fragmentary character renders their identification a matter of difficulty.

specimens which widely differ from Dalman's type, and closely approximate to the Anglesey form. It would be hazardous to found important conclusions upon slight differences in the case of such a plastic species as *O. calligramma.*

Neseuretus ramseyensis, a fragment, has also been referred to this horizon*; but its occurrence can at present decide nothing; for it is also said † to have been found by Professor Henslow at Treiorwerth, in association with *Asaphus Powisii* and other Bala fossils.

The Trilobitic fauna of Bryn-gwallen is not sufficiently distinct to enable us to fix an exact horizon. The evidence seems to point to a Llandeilo age. At least it is clear that it would be hazardous to place the Trilobite beds lower than Arenig.

I by no means contend that these rocks are not Cambrian. I simply maintain that the evidence adduced strengthens the position of those who doubt.

The rocks of Llanbabo may have some bearing upon the question, though perhaps not a decisive one. In a small quarry at the church, I found in black shales a *Diplograptus,* probably *D. foliaceus.* These shales, in a large quarry in the next field, pass down through thin-bedded sandstone into massive grit. This series seems to be the same as that which overlies the granitoid mass at Pen-lon, and the strike also coincides. There is, therefore, at least a probability that this grit is nearly at the base of the Palæozoic succession in Anglesey, and the *Diplograptus*-shale is not 50 feet above the grit. Half a mile to the south this Graptolite is found in association with other well-marked forms, so that the horizon can be fixed. These fossils have been determined for me by Prof. Lapworth as follows:—

Dicranograptus ramosus, Hall.
Climacograptus Sharenbergii, Lapw.
Dicellograptus Morrisii, Hopk.
Leptograptus, sp.

This fauna, in Prof. Lapworth's opinion, indicates a Bala age. If the underlying grit is the equivalent of the *Orthis*-grit, the Ordovician age of the latter is demonstrated.

Elsewhere in Anglesey, Prof. Hughes found a Graptolite fauna which Prof. Lapworth refers to the "highest Arenig or lowest Llandeilo"‡.

In the present state of our knowledge, I am obliged to admit that the presence of Cambrian rocks in Anglesey has not been proved. This concession may seem to justify the contention that the altered groups may have furnished pebbles to the basement conglomerates, and yet be no older than Lower Cambrian. To this I would reply:—

1. The Pre-Palæozoic rocks of Anglesey are utterly unlike the admitted Lower Cambrian of Harlech and Llanberis. To say nothing of the metamorphic schists and gneiss, we may ask—Where

* Hughes, Quart. Journ. Geol. Soc. vol. xxxvi. p. 238.
† Ramsay, Geol. N. Wales, 2nd ed. pp. 225, 226.
‡ Hughes, *ibid.*

on the mainland are the limestones, quartzites, hornstones, felspathic shales, and flinty slates, which are so prominent in the Anglesey Pebidian? Where, on the other hand, shall we find in Anglesey any thing corresponding to the cleaved slates of Llanberis? To say that they are present, but metamorphosed into something else, is a pure assumption. Besides, we are justified in demanding proof that argillaceous slates can be altered into felspathic shale, quartzite, and limestone.

2. While the Pre-Palæozoic rocks are quite unlike known Cambrian strata, they closely resemble formations which in other parts of Britain are known to underlie Lower Cambrian beds. Several years ago I called attention * to the affinities between the slaty series and the Pebidian strata of St. Davids, which certainly underlie Harlech rocks, as the most recent critics admit †. The resemblance to certain Salopian types is also well marked.

3. Those who hold that the schists of Anglesey are of Cambrian age can hardly, I think, have considered the difficulties which their hypothesis involves. These schists were in their present state of metamorphism before the deposition of the Ordovician rocks. We are therefore called upon to believe ‡ that, during the Upper Cambrian period, the Lower Cambrian rocks sank thousands of feet, were covered in by a great accumulation of strata, were metamorphosed into gneiss and schist, were raised above the sea-level, and were not only stripped of the Upper Cambrian masses, but were themselves deeply eroded by denuding agencies.

4. According to Sir A. C. Ramsay § there must have existed near the Caernarvonshire area, during Lower Cambrian times, "an older rocky land," "hilly or even mountainous," which supplied to the Cambrian deposits granitoid materials ‖, "purple and black slates, quartz-rock, felspathic traps, quartz porphyries and jaspers." But rock-masses still visible in Anglesey and on the adjoining mainland could have furnished all these varieties, except the black slates. Which, then, is the more probable supposition—that the altered rocks of Anglesey are the eroded fragments of a Pre-Cambrian region, or that Sir Andrew Ramsay's Pre-Cambrian masses have been entirely swept away, and a portion of the Lower Cambrian series has been subsequently metamorphosed into a wonderfully close mimicry of the vanished land?

But, whatever estimate we may form of the evidence here adduced for the Archæan age of the less-altered Pre-Ordovician rocks, it will be difficult to resist the proof which the Tywyn sections furnish with respect to the gneissic series. The green slaty rock, which on the old hypothesis is Lower Cambrian, contains numerous rounded fragments of the granitoid rock which abounds in Anglesey. Such evidence needs no further comment.

* See Quart. Journ. Geol. Soc. vol. xxxvii. p. 211.

† Dr. A. Geikie, *ibid.* vol. xxxix. p. 286; Prof. J. F. Blake, *ibid.* vol. xl. p. 294.

‡ This argument, of course, proceeds upon the popular hypothesis that regional metamorphism takes place only at great depths.

§ Geol. N. Wales, 2nd ed. p. 196. ‖ *Ibid.* p. 19.

E. Physical Geography of the Anglesey Region in Ordovician Times.

The principal Archæan masses must, I think, have occupied about their present position during the deposition of the Ordovician rocks.

That the northern area was dry land, is evident from the masses of Cemmaes limestone in the fringing conglomerates.

The central area was also above water; for the basement Palæozoic conglomerates contain not only boulders from the granitoidite, but also pieces of hälleflinta such as we find east of Llanfaelog, and numerous fragments of purple and green shale, very similar to types characteristic of the tract west of Malldraeth Marsh. The gneissic rocks were probably in part covered by the Pebidian, for some of the fragments of shale in the conglomerate west of Llanfaelog are of large size and unrounded, so that they can hardly have been derived from the present Pebidian masses, the nearest point of which is three miles distant.

The western area furnishes similar evidence. The large angular fragments in the Tywyn conglomerate cannot have travelled far, and the pieces of altered shale in the Clymwr conglomerate must have been derived from the neighbouring land to the west.

But Anglesey was probably but the margin of extensive land-masses lying to the west or south-west. The Llanfihangel conglomerate thins out rapidly towards the north-east, so that west of Llanerchymedd the *Orthis*-grits pass up into the black shales. Below this conglomerate is a considerable thickness of grit of similar composition, which must have been derived from similar rocks, but from a more distant source. This grit also grows thinner towards the north-east.

The vanished land which once occupied what is now St. George's Channel probably extended into what is now Ireland. The hill of Howth, north of Dublin Bay, is built up of a considerable thickness of Pebidian rock; and if we extend the strike of the Anglesey gneissic series to the south-west, it will coincide with the strike of similar metamorphic rocks south of Wexford*. There is then no great improbability in the suggestion that the space intervening between Wales and Ireland was in the Ordovician period a tract of Archæan land.

F. Summary of Results.

1. The hypometamorphic rocks of northern Anglesey are shown by the evidence of included fragments, of greater alteration, and of more intense contortion, to be older than the Palæozoic strata to the south.

2. The metamorphic and hypometamorphic rocks of western Anglesey are proved by similar evidence to be of greater antiquity than the Palæozoic groups to the east.

* See Geol. Mag. Dec. 2. vol. viii. pp. 494–498.

3. The Palæozoic rocks of northern Anglesey probably lie in a syncline folded back to the south, those of the central band forming an ordinary syncline bounded on the west by an oblique fault, which may not materially affect the relations of the rocks on each side of it.

4. There is at present no satisfactory proof that any of the fossiliferous rocks of Anglesey are older than the Ordovician epoch.

5. There is clear evidence that the gneissic rocks are of greater antiquity than the hypometamorphic group.

6. There is reasonable proof that the hypometamorphic series is of Archæan age.

I am much indebted to the President for the notes which, with his wonted kindness, he has furnished on the microlithology of my paper. The arkose at the base of the Palæozoic strata of Tywyn is very puzzling in the field; and, without the aid of the microscope, it might have been difficult to convince hostile critics that the rock is really fragmental. This is one of these cases in which the old school of geologists would probably have affirmed an actual passage between the metamorphic and the unaltered rocks. It will, I think, be considered a strong confirmation of the truth of my conclusions that the application of microscopic tests by an independent and skilled observer has not materially modified any opinion which I had formed in the field, but has, on the contrary, added strength and clearness to my original convictions.

Appendix.

Note *on some* Rock-Specimens *collected by* Dr. C. Callaway *in* Anglesey. By Professor T. G. Bonney, D.Sc., F.R.S., Pres. G.S.

The following specimens have been collected by Dr. Callaway during his more recent investigations into the geology of Anglesey, and placed in my hands, together with the slides prepared from them, for description. In this I have kept in view their bearing on the more important petrological and stratigraphical questions rather than the determination of minute points of only mineralogical interest.

110 (Tywyn ridge, p. 577).—A pinkish and greenish mottled crystalline rock, whose appearance suggests that it is metamorphic rather than igneous. In short, it is extremely like some of the less coarse granitoid members of the Hebridean series of N.W. Scotland. Examined with the microscope, it is seen to exhibit a marked fragmental structure: this, however, I have no doubt, is the result of crushing *in situ*. The finer interstitial material between the fragments appears to consist of dark dust, impure epidote, viridite, and here and there a little of a greenish micaceous mineral. The rock itself exhibits the structure of one of the coarse granitoid gneisses (such, for example, as the coarse gneiss already described

from the railway-cutting near Llanfaelog *, consisting of orthoclase, microcline, and oligoclase or albite, with quartz in rather irregular granules. The last, as is usual in these rocks, contains numerous very minute cavities, generally empty, but now and then showing a tiny moving bubble, together with other enclosures, apparently filmy microliths. The felspar also contains many of the latter. There are a few groups of vermiculites of a chloritic mineral.

111 ("School," west of Cwaen-hen).—A green schist, constituents very minute. Microscopically examined, this is seen to consist of extremely minute granules of quartz, giving to parts of the slide a chalcedonic aspect, and minute films of a very pale-green micaceous mineral, with a darkish dust, which may be provisionally called ferrite. The two principal minerals are arranged in bands in which the one or the other predominates, and these exhibit beautiful corrugations. I should conjecture, from their appearance, that they had been produced subsequently to the segregation of the minerals. The micaceous constituent may be of more than one species, some scales seeming to be more like a chlorite, others more resembling a true mica. With crossed nicols, and the flakes placed at an angle of about 45° with the vibration-planes, fairly bright colours are given. It is, in short, the mineral or mineral group so frequently found in these grey-green or olive-green schists of Anglesey and elsewhere; and though this rock is rather more minutely constituted than most of my own specimens, I should group it with the schists of Holyhead Island and the adjoining part of Anglesey, and with those of the Menai district.

112 (Brwynog, p. 571).—A greyish-green schistose rock, whether a satiny slate or a true schist it is not easy to say. The difficulty is not wholly removed by microscopic examination. The constituents are extremely minute, but appear, on examination with a high power, to be fairly well defined, and to differ from those last described only in size; though one or two parts of the slide do not look so highly altered. I therefore feel doubtful, as the rock has evidently been much compressed, whether to regard it as a member of the last group, which I think we may safely consider Pre-Cambrian, or as one of the older Palæozoic rocks exceptionally altered.

113 (N.W. of Byttia, Amlwch, p. 568).—A pale-green slaty or schistose fragment, in a gritty matrix. Under the microscope the rock appears to be less highly altered than the last: it consists of quartz, some probably in minute fragments, a brown argillaceous material, and a fair amount of a greenish chloritic mineral in films and also in streaks. I think, from the general aspect, that the fragment was nearly in its present condition when broken off from the parent rock, and that it is rather a schistose slate than a true schist.

114 (Tywyn ridge, p. 578).—A rounded pebble, about $\frac{3}{4}$ inch in longer diameter, in a greyish-green matrix, which exhibits a distinct cleavage. Under the microscope the pebble is seen to be one of the coarse granitoid gneisses, upon which, as I have so often described

* Quart. Journ. Geol. Soc. vol. xl. p. 201.

them, it is needless to dwell. It has been broken across after being imbedded in the matrix, which fills up the interspace (about ·02 inch wide). Gneiss or granite (and I believe it to be the former), it was substantially what it now is when it was imbedded in its present matrix. This exhibits the ordinary aspect of many of the clay-slates—an intimate mixture of brown dust, minute specks of quartz, and films of a greenish mineral, in which are scattered larger fragments (not generally exceeding about ·01 inch in diameter) of quartz, a green mineral (apparently hornblende), epidote, and, perhaps, decomposed felspar. Some of the larger constituents appear to be from a granitoid rock, others from an argillite or schistose rock.

115 (*ibid.* p. 578).—A mass of slaty conglomerate, the matrix rather darker than in the last case, with a pebble of coarse gneiss about $1\frac{1}{2}$ inch diameter. The matrix has a general resemblance to the last described, except that there is more opacite. The smaller fragments also are similar: one is from a crystalline rock consisting of felspar (decomposed) and hornblende; several are clearly from granitoid rocks; one, possibly, may be a rhyolite. A fragment about $\frac{1}{8}$ inch diameter exhibits a distinctly foliated structure. It consists of a decomposed felspar, an altered brown mica, and a very little quartz. Only a small portion of the larger pebble is included in the slide; but this is enough to indicate that it is one of the usual coarse granitoid rocks already mentioned.

116 (*ibid.* p. 578).—A green slaty rock like the matrix of 114, from which, under the microscope, it does not materially differ, having evidently derived some of its fragments from the same sources. Macroscopically and microscopically, the resemblance is as close as possible.

117 (Caer-gwrie, south of Clymwr, p. 571).—A fragment of a pale grey-green schistose rock, in a fairly coarse gritty matrix. Macroscopically, the fragment much resembles 112. Examined microscopically, the similarity is not less; and to describe it would be to repeat the words, including the expressions of uncertainty, there given. This specimen also exhibits evidence of compression in the zigzagging of its laminæ; but I may make one remark, which seems to me of importance—that from the relation of these to the boundaries of the fragment, I feel perfectly certain that this structure is not due to any pressure which the conglomerate has undergone, but existed anterior to the time when the fragment was detached from the parent rock. The matrix included in the slide is a typical "arkose," being wholly made up of fragments of quartz and of decomposed felspar, with a grain or two of iron peroxide and some ferrite, and a greenish chloritic mineral (probably a secondary product after biotite), materials obviously derived from a granitoid gneiss or granite.

118 (Ridge, south of Clymwr, p. 571).—A rather coarse grit, with well-rolled fragments of quartz, &c., up to the size of a small pea, and one angular piece about 2 inches in diameter, of a schistose rock like that in 117. Examined under the microscope, the grit is found to contain fragments of more than one variety of gneiss, the usual

coarse type occurring with one more finely foliated variety; a fragment of a coarse schist or gneiss, very poor in quartz, consisting almost wholly of felspar (decomposed) and altered biotite; also little bits of schist and schistose rocks, rolled fragments of decomposed felspar (one showing the remains of polysynthetic twinning), and grains of quartz, many exhibiting the agglutinated granules with irregular outlines so characteristic of portions of gneisses and highly altered schists, together with the fragments of quartzites, &c. The grit is evidently mainly composed of detritus from Archæan rocks. The schistose rock named above has not been included in the slide. A brownish-green mineral often occurs between the grains, which perhaps in the main is altered detrital material from a magnesia-iron mica.

119 (south of Porth-y-corwg, p. 568).—A lead-coloured grit, with some angular fragments, one a compact greyish rock, full 2 inches in diameter. The matrix, under the microscope, contains only a few grains certainly derived from the coarse gneisses, but has an indubitable fragment of mica-schist, resembling those of the Menai type, and several bits of schistose rocks and grits. The above-named fragment is an impure limestone; it has a very close resemblance to a specimen described for Dr. Callaway in a former paper (Quart. Journ. Geol. Soc. vol. xxxvii. p. 236, no. 52).

120 (Tywyn ridge, p. 578).—A slaty, somewhat gritty rock, of a grey-green colour, one side of the fragment changing suddenly to a very dark green. The slide includes both these varieties, with a small piece of what appears to be a fragment of a rather different rock. On examination, we find the paler part to present a general resemblance to 116, but to be rather more streaky in aspect. In it are scattered fragments of felspar, hornblende, and of a rather coarse felspar-hornblende rock. The fragment contains felspar, apparently crushed, and showing decomposition-products: between many of the apparent granules is a pale-green viridite; there is some altered biotite and well-crystallized hornblende. The dark-green part mentioned above is almost wholly composed of subangular fragments of well-crystallized hornblende, with some grains of magnetite; the adjoining part of the first-described matrix is generally blackened with opacite.

121 (*ibid.* p. 578).—From a fragment in a dark rock resembling the last, especially in its darker part. This fragment is rather coarsely crystalline, mottled pinkish and dull green. The microscope shows that its component minerals have a streaky arrangement, and by the aspect suggest that the rock is metamorphic rather than igneous. The minerals are felspar—too much replaced by secondary products for the species to be identifiable—green hornblende, and altered biotite, with some grains of ilmenite and, perhaps, magnetite: I think there is a little apatite. The hornblende in this rock, in colour and general appearance, corresponds with that occurring in fragments in 120.

122, 123 (*ibid.* p. 578).—Coarse fragmental rocks, both in matrix and fragments much resembling the last. A lengthy description is needless. The fragments, so far as they occur in the slides (it is possible a more quartziferous rock may also be present), correspond with the above-described, and the matrix consists of detrital hornblende and felspar, evidently derived from a similar source. Some of the felspar is certainly albite or oligoclase; and epidote, as might be expected, is present, especially in one of two fragments of more finely granular aspect. I think we may safely assert that the materials of 120–123 have not travelled far.

124, 125 (*ibid.* p. 578); 126 (10 yards east of ridge, p. 578).—Greenish grits, composed almost wholly of fragments of metamorphic rocks, some resembling those last described, others approaching nearer to normal gneisses and to schists, with one or two of a less highly altered aspect. 125 contains a fragment of a schisty epidosite; and 124 a fragment of a mineral consisting of a pale-green network with colourless interspaces; the latter dark with crossed nicols, the former almost so.

127 (30 yards east of Tywyn ridge, p. 578).—Greyish-green grit. Constituents more varied. The felspar-hornblende rock is wanting, but there is one fragment of a decomposed felspar rock with a little of a green mineral, probably metamorphic; there are, however, the usual fragments of gneissic rocks, with schistose fragments resembling that in 117.

129 (Llanbabo quarry, p. 569); 130 (farm west of Porth-y-corwg, p. 569).—Greenish-grey grits, consisting of fragments of quartz, felspar, a variety of schists and schistose rocks, argillites, "hälleflintas," &c. 129 contains more fragments of the less-altered kinds of rocks; 130 more quartz, felspar, and fragments resembling the more crystalline varieties described above.

132 (Llechylched, pp. 569, 574); 133 (east of Gwredog, Rhosgoch, p. 569).—Brownish grits; constituents minute. These, under the microscope, are seen to be rather angular in form. Quartz, decomposed felspar, mica, &c., with iron oxides, and the brownish-green mineral already described, are the principal constituents. 132 has more mica; 133 is more earthy and ferruginous, and has more of the greenish mineral.

It may be well to state briefly the conclusions to which I am led by the study of this interesting series of rocks:—

(1) The conglomerate from which specimens 120–127 have been collected has derived its materials from a very varied series of rocks. Some of these, when it was formed, were but little changed; while others were considerably metamorphosed. Others, again, were coarse granitoid gneisses, presenting a general resemblance to the most ancient rocks which have as yet been discovered, such as the Hebridean series of N.W. Scotland or the Laurentian rocks of North America. Moreover these rocks were substantially in the same stage of metamorphism when they were rolled into pebbles as they are at the present time. There must then have existed at no great distance a land surface undergoing denudation, in which a series of rocks in very different states of mineralization were exposed. This

can only have been the result of earth-movements on a great scale, at a time long anterior to the formation of the conglomerate, and of denudation continued through a period so long as to allow the very foundations of a mountain-chain or upland district to be exposed. This conglomerate, in fact, must have been formed from and on a floor composed of outcropping beds of gneisses, schists of various kinds, argillites, and grits.

(2) Volcanic materials, such as are so common in the conglomerates in Caernarvonshire and near Beaumaris, belonging either to the very base of the Cambrian or to a somewhat older series (as I believe), cannot be certainly identified in these Anglesey conglomerates, though a few fragments may belong to rhyolitic rocks. Hence we may conclude that volcanoes were few or absent in this district.

(3) Since these conglomerates were formed they have been subjected to great earth-movements, sufficient to produce in their finer constituents a rude cleavage, together with those minor mineral changes which are facilitated by compression.

(4) A comparison of 116 with 114, 115, the first occurring as a fragment in the beds mentioned above, seems to indicate the presence of a conglomerate composed of similar materials to that mentioned in (1), but decidedly more ancient than it; so that Dr. Callaway is justified in referring the two conglomerates to distinct geological formations.

These investigations, then, lead us to the same conclusion as the researches of my friend Dr. Hicks in the district about Llanfaelog, namely, that the granitoid rocks, whether some of these be true granites or not, and the schists of Anglesey are of Archæan age, and are the outcrops of a great floor of ancient rocks upon which the continuous series of the older Palæozoic rocks of North Wales was deposited. It is probable that these were to a very great extent, if not entirely, concealed from view comparatively early in the Cambrian period. Some of its coarser grits, as in the Harlech district, are evidently formed from the ruins of Archæan rocks, and obviously all its sediments must have been derived from existing land-masses, composed, of course, of earlier rocks; but, so far as I have at present studied the ordinary Cambrian slates and grits, I should say that they indicated a derivation from a comparatively distant source. The Cambrian period of Sedgwick, the Cambrian and Lower Silurian or Ordovician of later authors, appears to have been one of continuous depression and sedimentation over at least all the North-Wales area, and the land, I conjecture, lay to the north-west, where now "rolls the sea." At the end of this time began another epoch of "mountain-making," when the border-zone of the newer sedimentary deposits was subjected to great lateral pressure, the cleavage of North Wales was produced, and a new age of denudation and of transference of sediment was begun.

Discussion.

Dr. Hicks, while, in the main, agreeing with the author so far as the Archæan rocks go, was, as regards the Palæozoic beds, inclined to believe that Prof. Hughes was right. He thought the Trilobites referred to as of Ordovician age were referable to *Niobe* and *Neseuretus*—Cambrian forms. He thought *Orthis Carausii* was confined to the Cambrian, and that it is associated in Anglesey with another Cambrian *Orthis*. The stratigraphical as well as the fossil evidence seemed to support Prof. Hughes's view that the fossiliferous beds were of Tremadoc age.

Dr. Roberts thought that in Anglesey there are contorted rocks of different ages, some probably not Archæan.

Mr. Harker also thought that the author had failed to distinguish the fact that the altered rocks of Anglesey are not all of the same age. The author's supposed Pebidian beds were found, when traced to the northward, to be intercalated with conglomerates containing fossils. He agreed with Dr. Hicks in thinking that the fossils in the Palæozoic schists are Tremadoc and not Ordovician.

Mr. Hudleston asked what evidence there was concerning the relations of the granitoid rocks and the Holyhead schists.

The President said that the conglomerate contained fragments of the granitoid series, of schists similar to those of Holyhead, and of other rocks of comparatively unaltered character. He believed that all the true schists in Anglesey are of Archæan age, though there were schistose beds of later date, which it was difficult in the field to distinguish from them.

Dr. Callaway said that, on the authority of Sir A. C. Ramsay and Mr. Etheridge, *Neseuretus* occurs in the Silurian. He accepted Dr. Woodward's identification of the Trilobites as of Ordovician age. He had before shown that the so-called "gnarled schists" consist of two series, one little altered and the other truly metamorphosed, but both Archæan. He believed the rocks with Bala fossils in the north of Anglesey were let down into the midst of the Archæan by faults. He had always held that the schists underlay the granitoid rocks.

40. *On the* Fructification *of* Zeilleria (Sphenopteris) delicatula, Sternb., sp.; *with Remarks on* Urnatopteris (Sphenopteris) tenella, Brongt., *and* Hymenophyllites (Sphenopteris) quadridactylites, Gutbier, sp. By Robert Kidston, Esq., F.G.S. (Read May 28, 1884.)

[Plate XXV.]

So much confusion has arisen between *Sphenopteris delicatula*, Sternb., *Sphenopteris tenella*, Brongt., and *Sphenopteris quadridactylites*, Gutbier, that in dealing with *Sphenopteris delicatula*, Sternb., it is also necessary to give a list of the synonyms of the two other species, which, in the barren condition, approach it somewhat closely.

The small-pinnuled members of the genus *Sphenopteris*, Brongt., are, under the most favourable circumstances, from the delicate nature of their fronds, extremely difficult to determine. As they usually occur in a very fragmentary condition, and the segmentation of their pinnules varies considerably according to the position held by the pinnæ on the frond (the pinnules of the upper pinnæ being generally more simple than those on the lower pinnæ), the difficulty of discriminating the species is considerably increased.

When the specimens have suffered any lengthened maceration, the limb of the pinnules usually disappears entirely, and there is nothing but the veins left. In this state, the specific identification of these delicate Sphenopteroids is very unsatisfactory, if not quite useless.

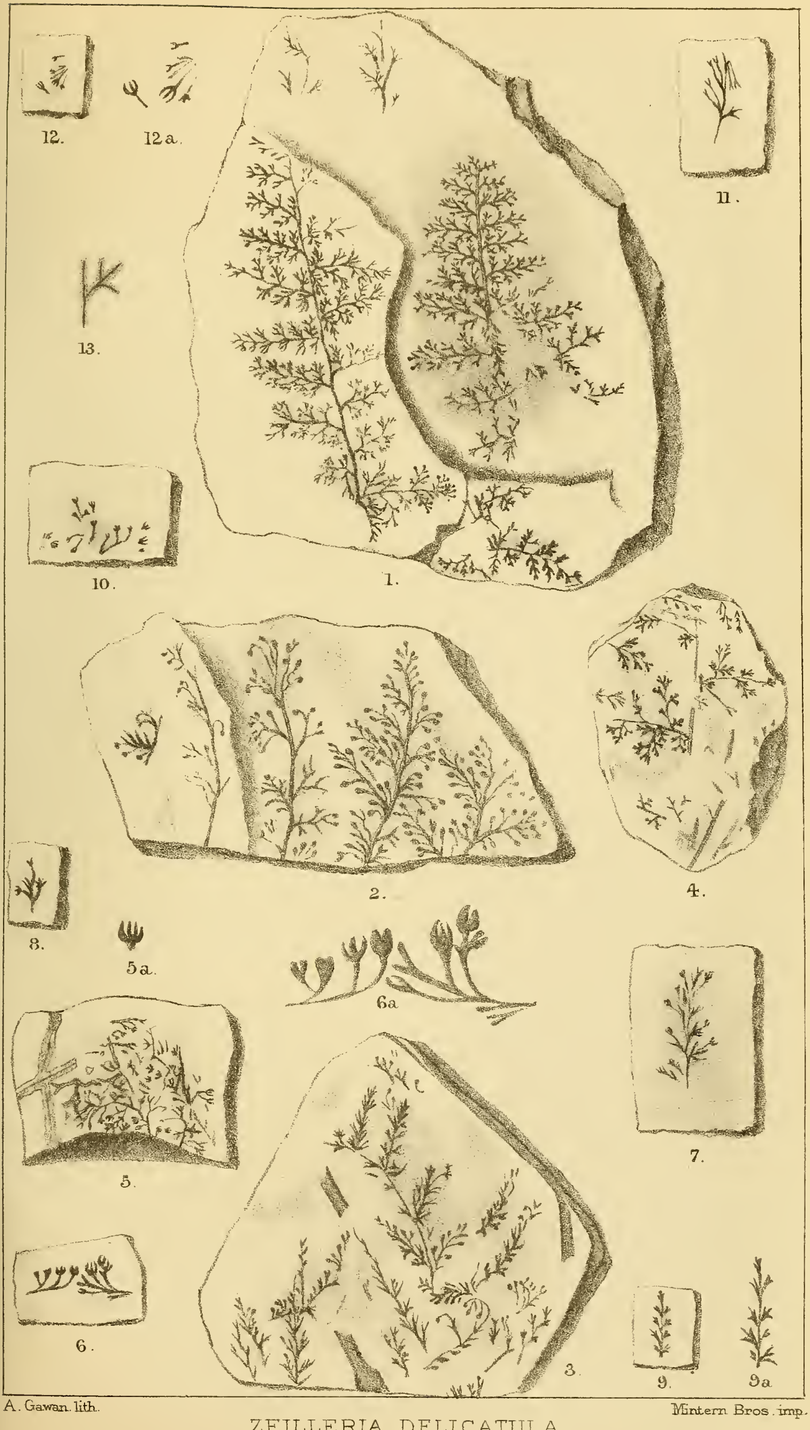
Fortunately the fruit of *Sphenopteris delicatula*, Sternb., *Sphenopteris tenella*, Brongt., and *Sphenopteris quadridactylites*, Gutbier, is known; and though their barren fronds may possess a considerable likeness, their fructification is very distinct; but even the barren fronds, when well preserved, are sufficiently marked to enable one to determine the species with absolute certainty.

Zeilleria, nov. gen.

Involucres borne at the extremities of the pinnule-segments, which are more or less produced to form a pedicel; in the earlier condition the involucres are globular, but at maturity they split into four valves.

The ferns for which this genus is proposed have been included by Stur, in his last work on the classification of Carboniferous Fossil Ferns*, in his genus *Calymmatotheca*; but from the ferns originally placed by him in this genus they differ so materially in certain structural points that it is necessary to place them in a new genus.

* Stur, "Zur Morph. u. Syst. der Culm- u. Carbonfarne," Sitzb. der k. Akad. d. Wiss. in Wien, vol. lxxxviii. Abth. i. p. 799 (1883).



A. Gawan. lith.

Mintern Bros. imp.

ZEILLERIA DELICATULA.

The fructifications originally included in *Calymmatotheca* are composed of a number of elongated sporangia, arranged in a circle round a common point of attachment. In the fossil state the sporangia more commonly appear as if they radiated in a fan-like manner from their common support; but this is due to the circle having been broken, as many specimens I have seen show them to radiate from a central point, and some in this state have been figured by Mr. C. W. Peach*, under the name of *Staphylopteris Peachii*, Eth. and Balfour, and later by Zeiller†. The explanation of the true structure of the fruit of *Calymmatotheca* was first pointed out by Renault‡, and has been corroborated and more fully explained by Zeiller. Stur, indeed, regards these sporangia as the split-up remains of an involucre or indusium. This view, however, from the explanation of the structure given by Renault and Zeiller, and the figures of the last-mentioned author, as also from the specimens I have seen, appears to me to be quite untenable.

In the ferns for which I propose the genus *Zeilleria*, we have an indusium which is, whilst immature, globular, but at maturity splits into four valves. On the specimens of *Zeilleria* (*Sphen.*) *delicatula*, in the British Museum, one is able to trace the several stages of development. In this new genus must also be placed the two species lately described by Stur, *C. avoldensis* and *C. Frenzli* §.

There is still another difference between *Calymmatotheca* and *Zeilleria*. In the former genus the fructifying portions are entirely destitute of foliage-pinnules, whereas in the latter genus the fructifying fronds differ little in appearance from the barren, the fruiting segments being only slightly produced to form a pedicel on which the indusia are supported.

Calymmatotheca, as here restricted, is probably related to the *Marattiaceæ*; whereas *Zeilleria* appears to have affinities with the *Hymenophyllaceæ*.

* C. W. Peach, " On the Circinate Vernation, Fructification, and Varieties of *Sphenopteris affinis*, and on *Staphylopteris ? Peachii* of Etheridge and Balfour," Quart. Journ. Geol. Soc. vol. xxxiv. pl. vii. viii.

Mr. Peach has kindly allowed me to examine the specimens from which most of his figures were drawn. What he regards as the fruit of *S. affinis*, L. & H. (pl. vii. f. 2.), is, I believe, merely a roughness on the back of the pinnules, but not of organic origin. The real fruit of this fern is *Staphylopteris Peachii*, which was regarded by Mr. Peach as a parasite; but from abundant evidence it is proved beyond all doubt that the supposed parasite is the fruit of *S. affinis*, which must now be placed in *Calymmatotheca*, as originally used by Stur. I have also seen a Calymmatothecous fruit attached to the stem of *Calymmatotheca* (*Sphenopteris*) *bifida*, L. & H., sp. Mr. Peach's fig. 4, pl. viii. probably belongs to *C. bifida*, L. & H., sp., which has a much greater number of elongated sporangia than *C. affinis*, L. & H.

† Zeiller, " Fructifications de Fougères du terrain houiller," Ann. des Sci. Nat. 6e sér. Bot., tome xvi. p. 182, pl. ix. f. 10, 11.

I have great pleasure in naming this genus after M. R. Zeiller, who has done much to elucidate the fructification of the Carboniferous Ferns. I am also personally indebted to him for kind assistance given me in regard to the synonymy mentioned in this communication.

‡ Renault, 'Cours de Botan.' vol. iii. p. 198 (1883).

§ Stur, *l. c.* pp. 171, 172.

ZEILLERIA DELICATULA, Sternb., sp.

Sphenopteris delicatula, Sternb. Versuch, i. fasc. 2, p. 30, pl. xxvi. fig. 5, fasc. 4, p. xvi. ; Brongt. Prodrome, p. 50.

Sphenopteris meifolia, Sternb. Versuch, ii. p. 56, pl. xx. f. 5 ; Unger, Syn. Plant. Foss. p. 61 ; id. Genera et Species, p. 112 ; Giebel, Deutschl. Petrefacten, p. 40 ; Schimper, Traité de Paléont. Végét. vol. i. p. 383 ; Stur, Jahrb. d. k.-k. geol. Reichsanstalt, vol. xii. p. 143, 1861–62. Feistmantel, Steinkohl. u. Perm-Ablager. p. 74.

Cheilanthites meifolius, Göpp. Syst. Fil. Foss. p. 241; var. *trifidus*, Göpp. Syst. Fil. Foss. p. 241, pl. xv. f. 3, 4 ; ? Ettingsh. Steinkohlenflora von Radnitz, p. 36, f. 3. pl. xviii.

Description.—Frond tripinnate, pinnæ alternate, pinnules opposite or alternate. Barren pinnules deeply divided into 3–6 narrow segments with retuse apices, each segment having a single vein.

Segments of fertile pinnules slightly produced to form a pedicel, on which the involucres are borne. Involucres globular in the early state, but split up into four valves towards maturity.

Rachis flexuous and slightly winged.

Remarks.—Two tolerably perfect primary (?) pinnæ are shown in Pl. XXV. fig. 1 ; from the position they hold to each other, they in all likelihood spring from a common rachis. At several points of this specimen indications of the fruit are shown ; but the involucres have been removed, and the point to which they were attached is only indicated by a small dark spot.

The ordinary form of the barren frond undergoes but little alteration in the fertile condition.

The fertile segments of the pinnules become slightly elongated, to form, as it were, a little pedicel for the involucres, as seen in Pl. XXV. figs. 2, 3, 5, 6, 7, 8, 10, 11, & 12.

The young state of the fruit is shown in Pl. XXV. fig. 2, where it appears as a little globular involucre placed upon a short stalk. Several of the pinnules in this figure are barren ; thus it shows one of the generic differences between *Zeilleria* and *Calymmatotheca*, as the last-mentioned genus is restricted in this communication.

The same character is seen in figs. 3, 6, 7 of the same Plate.

Figures 3 & 9, Pl. XXV., show the form which has been distinguished as *Cheilanthites meifolius*, var. *trifidus*, Göpp.

In fig. 3 many of the segments of the pinnules are produced in a setaceous manner. These were probably soriferous, as the involucres shown in Pl. XXV. figs. 2, 6, 7, 8, 10, 11, & 12 are supported on stalk-like pedicels.

The involucres, split into four valves, are shown in Pl. XXV. figs. 5, 5 *a*, 6, 7, 12, 12 *a*. Generally, only three valves are visible ; but one capsule, which has been split and flattened out, shows distinctly the four segments (fig. 5 *a*). This figure is an enlarged view of an involucre on the small slab, fig. 5.

The barren pinnules consist of a narrow border of delicate tissue on each side of the midrib ; but it is only in well-preserved specimens that any trace of this is seen (fig. 13). The rachis of the primary and secondary pinnæ appears to be slightly winged.

The pinnules towards the middle of the specimen in Pl. XXV. fig. 1, have 6–7 approximated segments; but on the lower pinnæ of the same figure, as well as in fig. 4, the segments of the pinnules are placed further apart and almost appear as bifid or trifid pinnules on a tertiary rachis.

It will also be observed, that the pinnules are opposite in fig. 9, Pl. XXV., and alternate in most of the other specimens.

Remarks.

HYMENOPHYLLITES DELICATULUS, Zeiller.

The plant figured by Zeiller as *Hymenophyllites delicatulus*, in the Ann. d. Sciences Nat. vol. xvi. pl. x. figs. 22–32, is referable to *S. quadridactylites*, Gutbier, which this author has regarded as a synonym of *Zeilleria delicatula*, Sternb., sp. Though the barren fronds of the two species have considerable resemblance, they are, however, essentially distinct.

In *Hymenophyllites quadridactylites*, Gutbier, sp., the pinnules are rounder and the lobes not so narrow. The fructification also is of a different type. In *H. quadridactylites* the sporangia appear in the fossils to have been situated *beyond* the apparent margin of the pinnule, and M. Zeiller informs me that he has observed what he believes to be traces of a column in the middle of some of the groups of sporangia of this fern, to which they were probably attached; but owing to the indistinctness of this structure he refrained in his descriptions from affirming its presence, although he believes the appearance could not have been accidentally produced*.

In the figure of *Sphenopteris meifolia* given by Ettingshausen in his 'Steinkohlenflora von Radnitz,' the pinnules appear to be rounder than represented in Sternberg's original figure; but the specimen from which Ettingshausen's figure has been taken seems to have been indifferently preserved, so it cannot be critically considered.

Sphenopteris meifolia, Ludwig†, is not Sternberg's plant, but is probably only a small form of the fern he has identified as *Asplenites lindsæoides*, Ett., from which, however, it also seems specifically distinct.

The specific identification of the specimen figured by Gutbier as *S. delicatula*‡, owing to the imperfect state of its preservation, is also subject to doubt.

The specimens from which my figures are taken are in the collection of the British Museum, and my thanks are due to Dr. H. Woodward, F. R. S., for permission to figure and describe them.

Position. Upper (?) Coal-measures.

Locality Forest of Wyre, Worcestershire.

* Letter dated Paris, 30 Sept. 1883.

† Bull. de la Soc. Impér. de Nat. de Moscou (1876, p. 21), pl. i. f. 6.

‡ Gutbier, 'Verst. d. Zwick. Schwarzk.' p. 38, pl. v. f. 22.

URNATOPTERIS, nov. gen.

Barren and fructifying fronds dissimilar. Pinnæ of fructifying fronds bear two rows of alternate urceolate sporangia, which open at the apex by a small circular pore.

This genus is formed for the reception of *S. tenella*, Brongt., which, from the peculiar structure of its fruit, cannot be referred to any existing genus.

URNATOPTERIS TENELLA, Brongt., sp.

Sphenopteris tenella, Brongt., Hist. d. Végét. Foss. p. 186, pl. xlix. f. i.; Unger, Syn. Plant. Foss. p. 61 (excl. syn. *S. cysteoides*, L. & H.); Genera et Species, p. 112 (excl. syn. *S. cysteoides*, L. & H.); Weiss, Flora d. jüng. Stk. u. d. Roth. p. 56; Catalogue of Hutton collection, p. 108, Newcastle-on-Tyne; Sternberg, Versuch, ii. p. 60; Lesquereux, Geol. of Pennsyl. vol. ii. p. 861; Weiss, Verhandl. d. naturh. Vereines d. preuss. Rheinl. u. Westph. p. 79, 1868.

Cheilanthites tenellus, Göppert, Syst. Fil. Foss. p. 240.

Sphenopteris lanceolata *, Williamson, "Anomalous Oolitic and Palæozoic Forms of Vegetation." Royal Institution of Great Britain, Feb. 16, 1883.

Sphenopteris multifida, L. & H., Foss. Flora, vol. ii. pl. cxxiii; Morris, in "Geol. of Coalbrook Dale," Trans. Geol. Soc. 2nd Ser. vol. v. p. 488; Sauveur, 'Végét. Foss. de la Belgique,' pl. xxiii. f. 3, 4.

Sphenopteris delicatula, Brongt., Hist. d. Végét. Foss. p. 185, pl. lviii. f. 4; Sauveur, Végét. Foss. de la Belgique, pl. xxiii. f. 5, pl. xxv. f. 2; Schimper, Traité d. Paléont. Végét. vol. i. p. 415.

Trichomanites delicatulus, Göpp. Syst. Fil. Foss. p. 267; Unger, Syn. Plant. Foss. p. 72; Unger, Genera et Species, p. 134; Giebel, Deutschl. Petref. p. 47.

Hymenophyllites delicatulus, Lesqx. Geol. Survey of Illin. vol. iv. p. 412 (gives as ref. Brongt. Hist. pl. lviii. f. 4).

* In a letter to Prof. Williamson on the subject of the fruit of this fern, I stated that I regarded *S. lanceolata*, Gutbier, and *S. tenella*, Brongt., as the same plant. Since then I have seen an authentic specimen of *S. lanceolata* from Zwickau, and notwithstanding the great similarity of the figures of Gutbier and Brongniart, when actual specimens are examined, the plants are seen to be quite distinct. Fig. 18, pl. v. of Gutbier's work (Verst. d. Zwick. Schwarzk. p. 34), is almost undistinguishable from Brongniart's figure of *S. tenella*, and it was on this figure that I proposed their union. Some continental botanists, with good reason, unite the beautiful figure given as *S. acutiloba*, Andræ (not Sternb.), with *S. lanceolata*, Gutbier. This figure shows the real differences between *S. lanceolata* and *S. tenella*. Gutbier's fig. 4, pl. iv., gives the form of *S. lanceolata*, which Andræ had identified as *S. acutiloba*, Sternb., in error.

To distinguish the *S. acutiloba*, Andræ, from the true *S. acutiloba*, Sternb., Andræ's plate (Vorweltl. Pflanzen, pl. vi.) has been designated *S. Coemansii*, which name must now be suppressed (Crépin, "Notes Paléophytologiques," Soc. Roy. d. Bot. de Belgique, vol. xix. p. 16). (*S. tenella* = *S. lanceolata*. See also Neues Jahrbuch, 1884, part ii. p. 295.)

Rhodea delicatula, Sternberg, Versuch, ii. p. 111.

Eusphenopteris tenella, Kidston, Trans. Roy. Phys. Soc. Ed. vol. vii. p. 129, pl. i. f. 1–6; *Id.* Annals & Mag. Nat. Hist. Ser. 5. vol. x. p. 7, pl. i. f. 1–6.

Sphenopteris, sp., Lebour, 'Illustrations of Fossil Plants,' p. 79, pl. xxxix.

Description.—Barren fronds tripinnate or decompound; pinnæ and pinnules alternate, linear-lanceolate; pinnules divided into narrow segments, which end in a blunt point; those on the basal part of the pinnule bifid or trifid, those on the upper portion undivided. Fertile fronds: pinnæ reduced to a rachis having two alternate rows of urceolate indusia, which open at their apex by a small circular pore.

Remarks.—Since writing my previous paper on the fructification of *S.* (*Eusphenopteris*) *tenella*, Brongt., I have had many opportunities of examining numerous specimens of this fern, both in the barren and fertile condition, from the Coal-measures, Furnace Bank, near Sauchie, Alloa.

The plant figured as *S. delicatula* by Brongniart is only one of the forms of *S. tenella* of the same author. That it is not the *S. delicatula*, Sternberg, has long been recognized*. This variety was not uncommon at Furnace Bank.

I have been enabled to examine the specimens of *S. multifida*, L. & H., in the Hutton collection, Newcastle-on-Tyne, and to compare them with the type of *S. tenella*, Brongt., which is fortunately preserved in the collection of the British Museum, and I find the two plants are identical and in all probability from the same neighbourhood.

It has been suspected for some time that *S. multifida*, L. & H., and *S. tenella*, Brongt., were the same fern, and a comparison of Brongniart's type with Lindley and Hutton's plants, affirmatively settles this point; hence *S. multifida*, L. & H., must be eliminated from our lists of fossil plants, and *S. tenella*, Brongt., substituted as being the earliest name of the species.

This plant has been figured as *S. delicatula* by Sauveur. That on his plate xxiii. fig. 5 corresponds to *S. delicatula*, Brongt. (not Sternb.), and that on his plate xxv. fig. 2 to the form figured by Lindley and Hutton as *S. multifida*.

Notwithstanding the great similarity between certain forms of the barren fronds of *Urnatopteris tenella*, Brongt., sp., and *Zeilleria delicatula*, Sternb., sp., which has frequently given rise to errors of identification, their fruit is quite distinct. In *U. tenella*, Brongt., sp., the urceolate sporangia are borne upon modified fronds, the spores escaping through a small pore at their apex; whereas in *Zeilleria delicatula*, Sternb., sp., the globular involucres are borne upon fronds of the ordinary type, and at maturity split into four valves for the distribution of the spores.

In my former paper describing the fruit of *S. tenella*, I indicated

* Göpp. Syst. Fil. Foss. p. 267.

that the affinities of this fern were probably Hymenophyllaceous; but Prof. Williamson, referring to my remarks in his lecture on 'Anomalous Oolitic and Palæozoic Forms of Vegetation,' has pointed out the identity of the sporangia of *U.* (*Sphenopteris*) *tenella* in all essential features with those of recent *Daneæ*, and my further investigations have led me to adopt this view and to regard the fern as undoubtedly Marattiaceous.

Sphenopteris tenella, Heer, Vorweltl. Flora d. Schweiz. p. 16, pl. i. f. 9, 10.—Judging from the figure, there is no evidence to show that this specimen belongs to *S. tenella*. The fossil appears to me to have been too imperfect for any satisfactory determination.

Sphenopteris linearis, var., Lebour, 'Illustrations of Fossil Plants,' p. 65, pl. xxxii.—This is probably only an indifferently preserved example of *S. tenella*, Brongt.

S. delicatula (Brongt.), Boulay, Terr. houill. du Nord de la France, p. 28.—Abbé Boulay includes this species in his list of fossil plants from the Coal-measures of the north of France; but as it does not appear in a later publication by Zeiller (Fougères du terr. houill. du Nord de la France), it is likely that Boulay's plant is the *Hymenophyllites quadridactylites*, which occurs in that coal-basin. This is the more probable, as Zeiller, to whom I submitted specimens of *S. tenella*, Brongt., informed me that he had not met with it in the north of France.

Position.— Coal-measures.

Localities.—Scotland: Furnace Bank, near Sauchie, Alloa, Clackmannan; roof of the Kiltongue Coal; Bailieston, Lanark.

England: Bensham Horizon, Jarrow Coll.; Gosforth.

HYMENOPHYLLITES, Göppert, 1841.

Gattungen der fossilen Pflanzen, p. 53.

HYMENOPHYLLITES QUADRIDACTYLITES, Gutbier, sp.

Sphenopteris quadridactylites, Gutbier, Verst. d. Zwick. Schwarzk. p. 36, pl. xi. f. 5.

Sphenopteris tetradactyla, Unger, Syn. Plant. Foss. p. 66; Genera et Species, p. 121; Giebel, Deutschl. Petref. p. 43.

Sphenopteris tridactylites, Geinitz (not Brongt.), Verst. d. Steink. in Sachsen, p. 15, pl. xxiii. f. 13, 14.

Sphenopteris opposita, Giebel, Deutschl. Petrefacten, p. 40; Gutbier, Verst. d. Zwick. Schwarzk. p. 36, pl. xi. f. 6; Unger, Syn. Plant. Foss. p. 62; Genera et Species, p. 113; Gutbier, Gaea v. Sachsen, p. 75; Sternberg, Versuch, ii. p. 128.

Sphenopteris minuta, Giebel, Deutschl. Petrefacten, p. 40; Gutbier, Verst. d. Zwick. Schwarzk. p. 39, pl. iv. f. 9, pl. vi. f. 10; Unger, Genera et Species, p. 114; *Id.* Syn. Plant. Foss. p. 62; Gutbier, Gaea v. Sachsen, p. 75; Sternberg, Versuch, ii. p. 128.

Sphenopteris delicatula, Zeiller, Princip. Végét. Foss. de la France, p. 42; Zeiller, Bull. de la Soc. Géol. de France, 3e ser. vol. xii. p. 193.

Hymenophyllites delicatulus, Zeiller, "Fruct. d. Fougères Houill." Ann. d. Sci. 6e ser. vol. xvi. p. 196, pl. x. f. 22–32.

?*Sphenopteris laciniata*, Gutbier, Verst. d. Zwick. Schwarzk. p. 76, pl. xi. f. 4; ? Unger, Syn. Plant. Foss. p. 66; *Id.* Genera et Species, p. 122.

Description.—Frond tripinnate; pinnæ alternate or opposite; rachis flexuous, winged; barren fronds, pinnules divided into 4–7 obovate lobes, which have 3–6 rounded lappets, each having a simple vein; fruit borne at the extremity of the lobes; but placed beyond the limb. Sporangia provided with an annulus.

Remarks.—I have already, while making a comparison between this species and *Zeilleria delicatula*, Sternb., sp., entered into all the details of the structure of the fruit of this fern, so far as is at present known, so need not repeat here what has already been said on that point.

Sphenopteris tridactylites, Geinitz (not Brongt.).—M. Zeiller has pointed out* that the *S. quadridactylites*, Geinitz, is essentially distinct from Brongniart's plant of that name, and is to be referred to *S. quadridactylites*, Gutbier. The true *S. tridactylites* of Brongniart is a much more robust plant, with a firmer texture.

That Geinitz's figure of *S. tridactylites* is not Brongniart's plant of that name, but is *S. quadridactylites*, Gutbier, will be admitted by any one who may examine into the subject.

There are two other species which seem to be identical with *S. quadridactylites*, Gutbier. These are *S. opposita*, Gutbier, and *S. minuta* of the same author.

Sphenopteris minuta, Gutbier.—This I believe to be only the upper portion of a specimen of *S. opposita*.

Sphenopteris opposita, Gutbier.—This I am inclined to regard as only a form of *S. quadridactylites*. It is true that in the figures of these two plants, the pinnæ are alternate in *S. quadridactylites* and opposite in *S. opposita*; but in many species, the pinnæ are opposite or alternate according to the position they hold on the frond, and, as numerous examples show, little or no value can be placed in such characters as "pinnæ opposite" or "pinnæ alternate"†.

The differences between the large drawings of these two species (*S. minuta* and *S. opposita*), as given by Gutbier, seem to me to be *individual*, not *specific*.

After a careful examination of the descriptions and figures to which I have referred, I can only regard *S. opposita*, *S. minuta*, Gutbier, *S. tridactylites*, Geinitz (not Brongt.), and *Hymenophyllites delicatulus*, Zeiller, as belonging to *Hymenophyllites* (*Sph.*) *quadridactylites*, Gutbier.

* *l.c.* 'Fructifications de Fougères,' p. 196.

† Compare *S. Höninghausi*, Andræ, Vorw. pl. iv. & pl. v. f. 1; *S. acutiloba*, Andræ, Vorw. pl. vi; *S. artemisiæfolia*, Brongt. Hist. d. Végét. Foss. pl. xlvi., xlvii; *S. Gravenhorstii*, Brongt. Hist. pl. lv. f. 3 *b*; *Neur. gigantea*, Brongt. Hist. pl. lxix.; *Pecopteris Davreuxii*, Brongt. Hist. pl. lxxxviii.; *Pec. arborescens* (*P. cyathea*), Brongt. Hist. pl. ci. f. 1–2; *Pec. arborescens*, Brongt. Hist. pl. cii. &c.

Hymenophyllites quadridactylites has not, so far as I am aware, been yet discovered in Britain.

In concluding these somewhat lengthy notes, I have only to express the hope that those who have the opportunity of collecting fossil plants, will avail themselves of it, as at present our knowledge of the British fossil flora is very imperfect.

EXPLANATION OF PLATE XXV.

Zeilleria delicatula, Sternberg, sp.

Fig. 1. Two pinnæ, mostly barren, but showing places from which sporangia have fallen, which were indicated on the fossil as darker points.
2. Portion of frond, showing the fruit in an early state of development. They occur here as closed globular involucres.
3. Portion of another frond, bearing barren and fructifying pinnules mixed with each other on the same pinnæ.
4. Small portion of a barren frond.
5. A small specimen, showing the opened indusia.
5 *a*. A split indusium, showing the four segments : enlarged.
6. A few open indusia.
6 *a*. The same enlarged, showing the valves into which the indusia split.
7, 8. Small specimens, showing mature and split indusia.
9. Barren pinna. The form named var. *trifida*, Göpp.
9 *a*. The same, enlarged.
10. Small specimen, showing the split indusia.
11, 12. A few indusia supported on their elongated pedicels.
12 *a*. The same, enlarged.

Discussion.

Mr. Carruthers remarked that the discovery of fructification in fossil ferns was of great importance, the characters presented by the fronds in both recent and fossil forms being so similar. Generic distinctions to be of value must be founded mainly upon the fructification, and without it the classification was to some extent mere guesswork. He said that he had formed rather different opinions from the author on some of the points referred to, but the subject required much caution. *Calymmatotheca* was probably a Hymenophyllaceous fern, like *Cyclopteris hibernica*. About *Zeilleria* and *Urnatopteris* it was more difficult to decide.

Dr. Murie congratulated the author upon the interesting nature of his communication.

Mr. Kidston, in reply, pointed out the distinction between the sporangia of the different forms referred to in the paper, and said that he was sure, if Mr. Carruthers would examine the specimens, he would recognize the importance of these distinctions.

41. *On the* New Railway-Cutting *at* Guildford:—*The* Pleistocene Sands *and* Drift-Gravels *observed there.* By Lieut-Col. H. H. Godwin-Austen, F.R.S., F.G.S., *&c.* *With* Introductory Notes *on the* Eocene Beds, *by* W. Whitaker, B.A. Lond., F.G.S.

(Read May 28, 1884.)

1. *London Clay, Woolwich and Reading Beds.*

In December 1880 the following note of the southern end of the cutting on the Main Line just north of Guildford station was taken, the eastern side having been recut to widen the line:—

Basement bed of the London Clay. Brown loam and clayey sand, with scattered flint pebbles, resting irregularly on the bed below, the junction falling northward.

Clay shell-beds, weathering to a brown clay at the outcrop ... From less than	1 foot to 3 feet.	Woolwich and Reading beds.
Very dark grey clay with dark crimson mottling	about 8 feet.	
Light grey clay mottled of a deep crimson	3 feet or more.	
Grey clayey sand or sandy clay	2 feet	
Dark plastic clay, with signs of bedding. This occurs only at the end of the cutting on account of the northerly dip	several feet.	

This section, though not so clear as it was when fresh cut, is still well displayed, and the shell-bed is very distinctly seen.

This cutting was described long ago by Prof. Prestwich *; but the details of the Woolwich and Reading beds may be useful for comparison with the section on the other side of the valley.

The new cutting north-east of Guildford, on the Guildford and Surbiton direct Line, now in process of formation, is of great interest, not only as showing a thick mass of drift, resting very irregularly on the Chalk, but also as again opening up the Reading beds, which are so rarely seen in this neighbourhood. It begins near the eastern end of King's Road (Stoke road), and in a sharply curving course cuts the London road just north of Alderney Place, and then runs roughly parallel with that road to the south of Oak Lodge; so that it is about a mile long.

Owing to the northerly dip the Eocene beds occur only at either end, the central and deeper part of the cutting being more to the south, and showing only chalk beneath the drift, the thickness of which latter, moreover, may have some effect in carrying the boundary-line of the Eocene beds to the north.

At the western end, near King's Road, there is clay, which must be London Clay; for about 35 yards from the road a little of the

* Quart. Journ. Geol. Soc. vol. vi. p. 201 (1850).

usual brown clay occurs, and is underlain by the brown loam of the basement-bed, which is several feet thick, but apparently without fossils or pebbles.

Gravel comes on above about 40 yards further, and, after another 20 yards, the Woolwich shell-bed rises from beneath the basement-bed of the London Clay, but is only a few inches thick, and seems to consist chiefly of broken *Cyrenæ* *, with *Ostrea* and, rarely, *Melania*.

The London Clay seems to end off some 25 yards further, when the gravel and sand gets thick, and mottled clays come up from under the shell-bed, first dark, then bright red, then pale green, and lastly reddish.

Unfortunately the junction of the Reading bed with the Chalk is nowhere to be seen, the gravel hiding it, and, about 175 yards beyond where the London Clay ends, sinking sharply below the line.

About 50 yards further a mass of brown clay, over 4 feet thick, and with those small calcareous concretions known as "race," occurs in the gravel, and seems to extend for some distance. Up to this point the notes were taken on the northern and higher side of the cutting only.

Beyond this there is a chalky layer near the base of the gravel, and then that base consists of worked-up chalk and flints.

Just before getting to the bridge that carries the London road over the line, rubbly chalk appears beneath the gravel; but at the bridge the gravel sinks below the line, the Chalk rising up again on the other side.

2. *The Pleistocene Sands and Drift-Gravels.*

Perhaps the most interesting deposits exposed in this cutting are those of a much later age than the Eocenes which Mr. Whitaker has described above; for we have here a remnant of beds, no doubt formerly of far greater extent, laid down, at this ancient level, in front of the gorge of the Wey, and which were spread out over the area on the north, before it became again denuded to its present level, and at a time when probably the Lower Bagshot sands extending further south bounded the left bank opposite Stoke.

The lowest bed of these older stratified gravels is first seen on entering the cutting at its west end, near the King's-Road bridge (vide Main Section, fig. 8, 15 miles 30 chains†), and rests upon the denuded surface of the London Clay, and, in succession, the shell-bed, and the different-coloured clays of the Woolwich and Reading series. From the commencement it is to be noticed that water-worn ironstone from the Lower Greensand formation (Folkestone beds) composes

* These were originally unbroken, as a number of specimens can be found with both valves entire: they are broken by the slipping and sliding of the clays. The *Melaniæ* are scattered among them, but not abundant.—G.-A.

† Every chain-mark is printed on the post and rails on the north side of the line, and indicates distance from the Surbiton end of the line.

the bulk of the lowest stratum, mixed with only a few angular or slightly worn flints, these last derived from the vicinity of the gorge, not having travelled sufficiently far to receive much abrasion. I have traced this lowest bed as far as the old chalk-quarry to the south, where on the top of the cliff it is distinctly seen, though now a mere remnant, resting on the Chalk, at the same level; and it is interesting to observe that the present line of drainage intervenes and separates this outlying portion.

At about 100 yards eastward, the gravels and sands are seen in full force on both sides of the cutting (vide Main Section, fig. 8) and continue for about 260 yards, up to 15 miles 18 chains. These show that up to 14 feet, material referable to the Lower-Greensand hills towards the sources of the Wey still forms the principal part of the sands and gravels, which are coarse below, very fine at top, with no pebbles, and some, formed in rapid water, presenting false-bedding, and unmistakably fluviatile (figs. 1 & 2, *a–f*). Above this level the beds (*g*), although here still horizontal, are far coarser, and are exclusively derived from the Chalk, marking a considerable change in the conditions of their formation and the area from which they have been derived. At their extreme limit eastward, the lower sands and gravels bend gradually over, and pass below the level of the railway line up to this, ascending 1 in 100; the lowest well-marked dark bed of gravel here, 64 feet above the Wey, or 164 above the sea, was followed in excavating the ballast for the line to 12 feet lower, at a point some 60 yards further east, and near the western end of the new railway-station. Where these sands fall over, the Tertiary clays also disappear; and it seems to me that the former owe their displacement, not to any depression such as a pot-hole in the chalk, but to their lying, and not improbably having been deposited originally, against a bank of the clay, which would have a natural tendency to slip, particularly if subjected to pressure from above; water too would act upon the surface of the chalk and reduce its level, while it would not produce the same effect on the adjacent stiff clays. The strike of this displacement of the sands lies upon a line drawn thence to the reappearance of the clays beyond the three-arch bridge at Cross Lanes; and it is interesting to note that here, again, the superincumbent sands also showed a slight displacement from the horizontal, even a miniature fault of two or three inches being visible in the sands; and the dark gravel, but not so thick, was again met with, at five feet below the level of the line, as I am informed by Mr. Wills.

It is not unlikely that the junction of the two formations, so unlike in composition and power of withstanding the effects of denudation as the Chalk and Tertiary clays, was a line of old drainage, a lateral tributary from the east previous to the deposition of the sands; there is some evidence of this under Watford Farm at their eastern limit, where they abut sharply against the clays.

Before reaching the railway-bridge at the London road a very different set of beds has been cut into (*vide* sections, figs. 1 *g* & 2 *a'*, *b'*, and figs. 5 & 6), irregularly bedded, coarse, loamy sands, thick

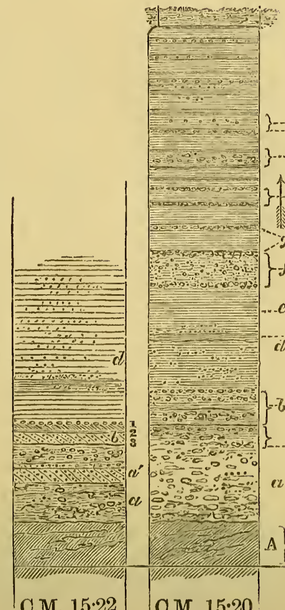


Fig. 1.—*Sections North of Line at Chain-marks* 15·20 *and* 15·22. (Scale 10 feet to 1 inch.)

beds of flints (exclusively, only a Tertiary pebble here and there) of large size, whole or broken, with an admixture of broken chalk, and also some red-clay beds; this also occurs in nests or large lumps. As the bridge is neared it rests on and against a steep scarp of chalk, being almost entirely angular chalk rubble or breccia. These are undoubtedly Glacial drifts*, and the unconformity of the junction with the older sands and gravels is well seen at chain-mark 15 miles 18 chains (vide Main Section, fig. 8, and fig. 2). Slight crumpling in the coarsely stratified material does not extend to the beds below; and all along the north side of the line for about 200 yards W.N.W. to S.S.E. these beds dip low southward, thus indicating the continuation of the underlying sands in this direction. After passing the bridge the horizontal pure sands are again met with low down on the line, and abut against a steep scarp of the solid chalk having a slope of about 20°–22° (fig. 4), and being the true continuation westward of the old Tertiary clay surface on which these same sands repose, already seen uncovered on the west; but this old chalk-scarp is perfectly clean, with no flint-gravel or even chalk-rubble intervening between it and the pure sands, thus presenting an extreme contrast to its surface where reached subsequently by the denuding drift. Passing off the Chalk at a point 130 yards from the London road, the base of the sands is not seen, but up to the three-arch bridge at Cross Lanes, on the north side of the cutting, all is sand; the chalk scarp

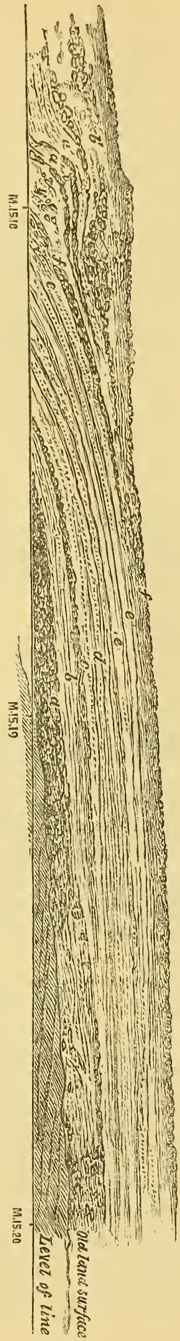


Fig. 2.—Section looking S.S.W. (True scale 1 inch=25 feet.)

* They lie at a lower level, and are, I consider, much older than the flint and loam beds that cap the sands west of the new railway-station.

going down to the north below the line, and trending directly eastward from it, is lost to sight. It is near this portion, on the level of the rails and close upon the Chalk, 60 yards from Cross-Lanes bridge and 40 yards or so to the east of it, that the greatest number of the Mammalian remains (*Elephas*, *Equus*, and *Bos*) were found. If we take the level of the basement-bed of the gravels (Greensand) at the King's Road, which is 60 feet above the river Wey, supposing that no alteration of level has taken place since their deposition, their base should be found some 9 feet below this and extending to the north; and Mr. Wills informs me that 5 feet below the line at the three-arch bridge, in digging the foundation, they came on the dark ironstone-gravels. The sands continue for another 200 yards, and at Watford farm, on the south side of the line,

Fig. 3.—*Cross Section at* 15 *miles* 19·5 *chains.*
(Scale 60 feet to 1 inch.)

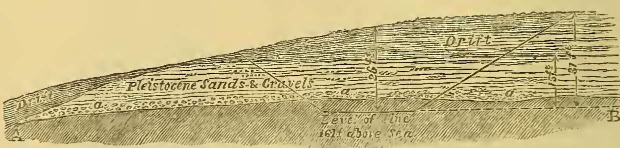
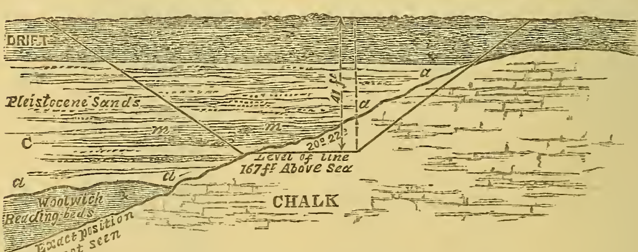


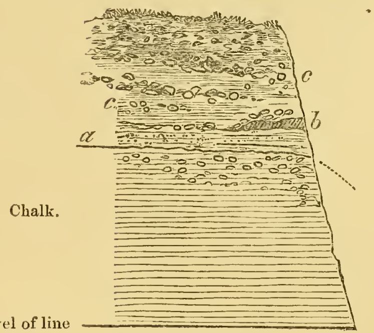
Fig. 4.—*Cross Section at* 15 *miles* 1 *chain, looking eastward, and about* 600 *yards east of Fig.* 3.



aaa. Old Terrestrial surface.
mm. Remains of Mammoth &c.

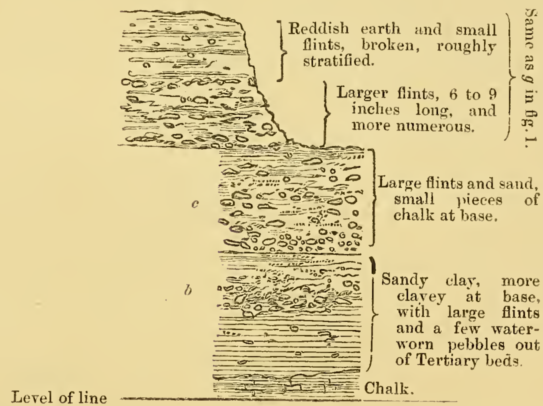
they end abruptly against a steep bank of the red clay of the Woolwich and Reading beds, which cross the line diagonally here. Unfortunately the slopes of the cutting had been cut clean and spread over with earth before I saw the section here. In all this last portion of the cutting, from the London road eastward, the sands are very fine, with very few pebbles and those small. One bed becomes rather clayey; it occurs at about 12 feet above the line on the south side, near Cross-Lanes bridge, and passes under it; it is now marked by drainage-cuts, filled in with chalk, to catch the water which collects above it.

Fig. 5.—*Section west of the London Road Bridge, south side of Line, looking westward.* (Scale 15 feet to 1 inch.)



a. Sandy bed.
b. Clay bed representing *b* in fig. 6.
c. Flint-rubble with fragments of chalk, representing *c* in fig. 6.

Fig. 6.—*Section west of the London Road Bridge, north side of Line, looking westward.* (Scale 15 feet to 1 inch.)



What I have endeavoured to describe, together with the details of the sections at different points, is sufficient, I think, to show that there are several questions of extreme interest pertaining to these high-level gravels and sands of the ancient Wey. They are:—1st. What was their relation to the topography of the country in the past? 2nd. What relation do they bear to the outlines of the neighbouring country at the present day? 3rd. What is their age?

As the cutting shallows at Watford Farm (fig. 8, facing p. 612), reddish clay occurs at the bottom. With a few pebbles and green flints, it is here the lowest of the Reading beds. The gravel and sands seem to reach about 80 yards beyond, gradually thinning out.

Further on, at 14 miles 52 chains, near the next bridge over the line, the clay shell-bed was seen near the bottom on the north-western side, while close by, on the other side, the basement-bed of the London Clay, consisting of the usual brown loam, but here containing a few shells and with black flint-pebbles at the bottom, occurs overlying the shelly clay of the Woolwich beds, here more than 3 feet thick.

The beds sink to the north-east, so that very soon only London Clay is to be seen. (For further details of the Eocene here, see main section, fig. 8, eastern half.)

These questions could, I feel, be better treated by our older geologists, who have devoted years of their lives to the geology, particularly the Tertiary and Post-tertiary geology, of this part of England and the neighbouring continent—Messrs. Prestwich, Evans, Morris, Rupert Jones, and others, and among them my father, Mr. Robert Godwin-Austen. Many a mile has been walked in the examination of the country, and vast stores of knowledge and unpublished experience thus acquired, of which I possess but a fractional part, have been brought to bear on this subject. I cannot hope ever to be able to examine and study what so many geologists have seen and described, and many of the sections so described will probably never be exposed again. We can, however, all assist in the work. It is only by piecing together all the scraps of information collected from time to time in the few good sections accidentally presented to us that we can arrive at any thing like a history of the sequence of events in Post-tertiary, Glacial, and Post-glacial times. Even in these recent-looking sands we are brought face to face with very considerable changes in this part of England, and a great lapse of time that has elapsed since those changes were effected. In these later periods of the earth's history the mind seems to realize the length of bygone time even more vividly than when we are dealing with older epochs.

We have here the very unusual opportunity afforded us of seeing a considerable exposure of an old land-surface unaltered by the effects of denudation during the last phase of extreme cold conditions; we can to a certain extent reconstruct the features that the country presented previous to that denudation, and which were evidently very different from those of to-day, although the main drainage was the same (see fig. 9, facing p. 612).

Our southern downs had not then been travelled and swept over by drift, and rounded down by ice-action for the last time, and the country must originally have presented far sharper and steeper features and numerous ravines. The relief of the former features now brought to light, the irregular closely undulated surface of the Tertiary clays here exposed for many yards, is in remarkable contrast to the regular, long, beautifully sweeping curves of the present surface; and the greater part of the valley of the Wey and its tributaries, south of the chalk range, has been lowered certainly to the extent of 60 feet since the sands preserving this old terrestrial surface were deposited.

The impression made upon my mind by the contemplation of these sands is, that they were deposited in an old re-entering bend on this side of the gorge at a time when the old river-bed of the Wey stood at about 60 feet above its present level, which river then washed the base of a steep scarp of chalk on this side. The ancient level, if extended south, is close upon the site of the old castle, and crosses the High Street, Market Street, top of North Street to the old quarry east of Chertsey Street; and I imagine that the chalk point or spur then existing and overlooking the ancient river occupied a position between the Quarry and Aldersey Place, thrown off from much higher hills with sharper outline where the Merrow Downs now are. As the fluvial deposits were carried through the gorge and spread out over the flats to the north, the slope of the bed was becoming less: this is evident from the fact that the upper beds are the finest. (The Thames valley itself was rapidly filling with detritus on the north.) Such a re-entering bend of a river is precisely the spot where the carcasses of animals that have lived on the higher reaches of a river are occasionally floated in, sink and become buried in the silt; and this is where, in the present case, nearly all the mammalian remains have been exhumed. They are to be distinguished from remains of the same fauna found in the later drift, often, I imagine, derived from an intermediate resting-place. I would in this place call attention to the fact that this re-entering bend of the old river has its counterpart in a similar bend of the river now, and due north of this point.

The greatest thickness seen of these high-level sands is 32 feet, which gives the highest bed an altitude at Cross Lanes of 100 feet above the river Wey, or 200 above the level of the sea, the height of the base being very constant, only varying with the slight original north-westerly slope of the old clay surface and its minor undulations.

On the deposition of these sands coming to a close, and towards the end of the period, the river had, from being broad and rapid, passed to more sluggish conditions; there was a change. An elevation of the country probably took place to the south, possibly, though not necessarily, with a corresponding depression upon the axis-line of the Thames valley, which led to the removal of the greater part of these earlier old river-gravels and sands in front of the gorge, leaving the remnant lately disclosed. Then commenced the further deepening of the tributaries on the south, and that of the gorge itself. Thus, I conceive, at one time, previous to the deposition of the next set of lower-level gravels (Pease Marsh and Tillingbourne) and lastly the drift, these high-level beds presented the character of a much more extensive flat alluvial terrace, bounded by a low scarp, jutting out towards the bend of the river, over what is now Stoke Park and Woodbridge.

Still confining ourselves to section No. 1, we may note that another great change of conditions took place, indicated by the upper strata of loam and flints (*g*) that rest, apparently in a conformable manner, on the Lower-Greensand gravels (*f*) derived from the south. A great lapse of time, however, and the removal of many feet of the lower set of beds may be interpolated here. This is shown by a comparison of these two sections. At 15 miles 19·5 chains (at a point west of the new railway-station, fig. 3) the total thickness of the gravels and sands (*a–f*, fig. 1) is only 14 feet; they rest on the Tertiary clay, here two feet above the line, which at this point is 61·23 feet above the Wey; therefore the highest level is 77·23 ft., or, taking the level of the Wey at the railway-bridge at 100 ft. above the level of the sea, we have 177·23 from that datum-line.

At the three-arch bridge, Cross Lanes, the depth of the cutting is 44 feet in the same sands, and deducting the 12 feet of drift-gravel (precisely similar to the surface-beds in the first section), the total thickness of sands exposed is 32 feet; and it would be a little more if the base were seen. Adding the height of line above the Wey, here 69·37 feet, we have 101·37 for the top of the sands, or a difference of 24 feet at least, lost by denudation.

Let us now see what relation this section bears to the country on the south, and what has been observed there. My father, in a paper entitled "Land-surfaces beneath the Drift-gravel"*, with which was given a map of this area, refers to the fact that the gravel-beds of the valley of the Wey are underlain by an old terrestrial surface, indicated by peat, trees, and sedimentary deposits, and that the remains of extinct Mammalia are usually associated with this old surface. He gives, as an example, the Pease Marsh, and mentions the fact that these beds are usually about 30 feet above the level of the present drainage-level: he says, p. 114, "The older terrestrial surface does not occur anywhere, that I know of, on the immediate banks of the Wey or Mole; these rivers and their affluents now flow at levels much below the general outspread of the transported gravel:" such sections as are above described occur in the valley of the Tillingbourne, at East Shalford and Tangley Pond; they are lower than the terrace above the outcrop of the Neocomian clay, and rest upon this formation; in some instances† "the roots of the larger trees descended into the subjacent clays." The old terrestrial surface north of the gorge of the Wey, lately brought to light, must not be confused with this much later one of the Tillingbourne, overlain near East Shalford Farm by 8 feet of drift-gravel. My father remarks, p. 116, "This old land-surface supplies us with a definite and valuable, though isolated, date

* Quart. Journ. Geol. Soc. vol. xi. p. 112 (read December 13, 1854).
† *Loc. cit.* p. 114.

in the geological history of a large area north of the Wealden denudation." The older land-surface now exposed at Guildford is another and still earlier phase of those conditions, a link in the chain of evidence which renders the first less isolated, and may lead eventually to the correlation of geological events of this age as displayed in other areas more easy of interpretation.

I have already connected the level of the basement gravels with the narrow terrace or step on the side of the hill overlooking the Wey on its right bank just within the gorge at Quarry Street; and if we follow this level round the valley to the south-east, we see it showing again at the points or spurs of the Lower Greensand near the opening of the Tillingbourne valley; it is represented very plainly, from near the base of the steep slope of the Greensand up to the next fall to the present stream (the outcrop of the Neocomian clay), by the well-marked high-level terrace which extends as far as Halfpenny Farm and Chilworth Manor; this terrace is not so defined higher up the valley, where the ground is much more broken and cut into by lateral drainage-lines. If we suppose the drainage-fall of the country to have remained tolerably constant (though the character of the sands north of Guildford would show that the fall was greater) whilst the streams worked into it, and apply about 60 feet to the level of the Tillingbourne at the Chilworth Mills, which are 140 feet above the sea, the 190-feet level lies on the terrace above, and the 200-feet level is as nearly as possible that of the base of the next and principal escarpment of the sands. The discovery by Dr. Buckland, accompanied by Mr. Godwin-Austen, of the bone of a Rhinoceros * in loam on the side of the Greensand escarpment, and at some height above the massive slopes of drift on the banks of the Tillingbourne, was not improbably in a small remnant of beds of the age of the Guildford high-level sands, which in such a position would, from their sandy nature, be very difficult to distinguish from the subjacent Greensand, that being probably covered by surface-wash of the same sands. I think this is a more likely explanation of the different levels at which the gravels have been noticed in the above valley than that alluded to in a footnote on the same page, viz. of longitudinal fractures having occurred in it since the deposition of the drift and gravel. In the diagrammatic section (fig. 9), where the elevation of the hills has been greatly exaggerated, I have attempted to show the different drainage-lines of old surface (No. 1, the oldest; No. 2, the intermediate; No. 3, the present) and their corresponding gravels (No. 1, the high level north of Guildford, and No. 2, the Pease Marsh), as well as the drift, distinguishing the difference of outline or probable relief of the country in past and present times.

On the right bank of the Wey, within the gorge, the same line of level shows itself on the Portsmouth road on passing St. Catherine's Hill by Brabœuf. The high-level gravels of the Tillingbourne at Shalford, near its junction with the Wey, range from 110 to 130 feet above the sea, and are therefore of a later date, and to these belong the

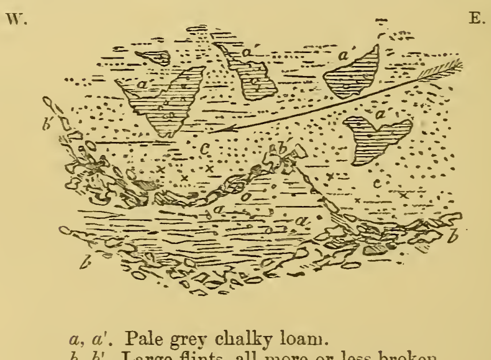
* Murchison, Quart. Journ. Geol. Soc. vol. vii. p. 378 (1851).

gravels and sands of Shalford Common east of Stonebridge, Bradstone Brook, &c., all deposited since a further excavation of the valley took place. Near Chilworth Station, on the South-Eastern line of railway, we have some gravels as high as 200 ft.; these might be referred to the age of the Guildford sands. We may also refer to these last certain high-level sands indicated thus by my father (*loc. cit.* p. 115, fig. 1):—"The gravel beds pass into fine sand, horizontally bedded, in the valley west of Pease Marsh, where the dotting of the plan is discontinued." These I have not had time to examine, and I do not know the level at which they occur.

Returning to the upper gravels (*g*) in section (fig. 1), derived exclusively from the Chalk, it is at once evident that this enormous quantity of flints did not arrive from the side of the gorge. It points to some such change of drainage-lines or conditions as to render the gorge of the Wey no longer an outlet to the north, and to a transport of materials derived from the Chalk and Tertiary formations all along the north face of the hills here, that is the North Downs. The alternate beds of loam and flints are so regular and horizontal in places, that still water seems indicated; while in other places (see fig. 7) the displacement of the beds indicates great pressure and lateral pushing, combined with a semifluid state, remarkably like the glacial deposits of Alpine valleys. This section is very similar to fig. 2 at Wilton, Salisbury, given by Professor Prestwich, Quart. Journ. Geol. Soc. vol. xi. p. 102.

The occurrence of land-shells in the loamy sands indicates that these have been brought down from off the old land-surface they lived upon. This part of the section, where the beds are so very coarse and irregular and nearer to the chalk (fig. 7), shows, as

Fig. 7.—*Section on North side of Line at* 15 *miles* 9·75 *chains* 8 *yards from London Road Bridge, west side.* (Scale ¼ inch to 1 foot.)



a, a'. Pale grey chalky loam.
b, b'. Large flints, all more or less broken.
c. Sand, coarse, earthy.
** Shells of *Helix* and *Pupa*.

The arrow shows the direction of the Drift.

denoted by the arrow, that the movement of the mass was from E. to W., or down the line of present shallow valley or combe from Warren Farm, near the top of the Downs, the portion *a'* having been forced out from *a* into the watery sands, when perhaps in a frozen state, the upper surface of the flints, *b'*, having at the same time been forced onward and separated from *b*. There is also a very different condition of things indicated by the great contrast between the extremely coarse nature and bedding of the drift resting on the angular chalk-rubble and the finer angular loamy beds that cap both this and the older sands (*vide* section at London Road, figs. 5 & 6, and fig. 1).

Through the two phases of old terrestrial surface there are indications of quite a temperate climate, of the existence of great Mammalia living through both, and of a probable connexion with the continent of Europe, at least during the first phase. The change to the cold era we can imagine to have been gradual, killing off by degrees the large pachyderms and the associated fauna, whose remains are found invariably in the lowest beds and, as in the Tillingbourne, lying among the stools of the trees that grew on the old surface there. This surface was eventually covered up and perhaps destroyed by the valley-drift, which to a certain distance and level is found on the surface of all the formations running parallel with the North Downs on both sides of the ridge. I cannot see that it is necessary to introduce any forces indicating such violent action as the breaking up of the surface, or even any great alteration of general level. The steady denuding action of land-ice appears to me quite sufficient to have scoured and planed the surface of the Chalk and neighbouring formations as we now see them, and to have distributed and carried the deposits of flints to the distances at which we now find them. There seems to be good evidence too, or even proof, that, for a part of this cold period at least, there was a complete change in the drainage of the country for a considerable distance east and west, which might have been caused either by the partial damming up of such gorges as those of the Wey and Mole, or by a slight elevation on the north, or a depression south, on the English Channel area. Such a late depression is indicated on the Sussex coast; and Sir Roderick Murchison, in the following paragraphs, considered such to have taken place in Kent on the Medway *:—" The loam-drift with flints extends indeed all down the banks of the Medway to Maidstone, and, occasionally spread over flats, is exposed near Yalding Station, capping a small elevation of Lower Greensand (Neocomian)." " The arrangement of the drifted material also shows that the waters, whatever they were which translated them, acted in an opposite direction to the present Medway; for in proportion as you approach to Maidstone and the North Downs, the fragments of flint become larger and much more abundant;" and again, at the conclusion of a paragraph on p. 387, with regard to the valleys having assumed their present form prior

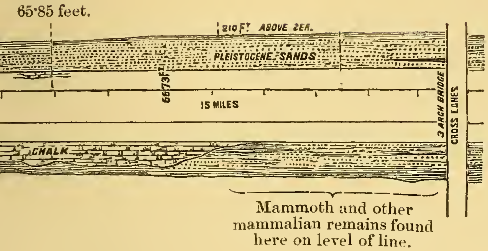
* Quart. Journ. Geol. Soc. vol. vii. pp. 382, 383.

to the Drift, Sir Roderick Murchison repeats " . . . in some cases the old drift has been carried *up* the present valleys." I do not agree with Sir Roderick Murchison as regards the vast volumes of moving water occupying the valleys, although lakes may very possibly have been formed for a time in such positions as the Pease Marsh, or from Petteridge downward on the Mole drainage. Yet in this paper all his excellent observations and the facts are brought before us; and I would emphasize the transit of material to which he refers by adding that the drift was invariably from north to south all along the line of the North Downs from Kent to Farnham, and that on the elevated ridge of Leith Hill, also subject to like cold conditions, the local transport of drift was down its northern slope towards the main valley.

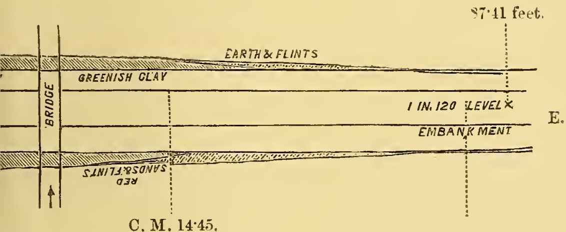
What would be the effect of a reduction of the mean annual temperature on this undulating flat country? There would be an excessive snow-fall in winter which would accumulate to a great depth, with much drift-ice in the streams and rivers. It is not necessary to suppose any thing of the nature of a glacier as we know them in Alpine regions; but what would result, if the cold were great enough, would be the formation of frozen snow-beds on the higher grounds lasting through the heats of summer, and such would be the exact counterparts of those patches of ice, many square acres in extent, that are to be seen at the present day on the wide level plateaux of the Chang Chingmo in Thibet—that is to say, solid ice not more than 20 feet thick, with a flat but much broken surface and with a wall-like margin in most places. These I noticed lasted until the winter snows began again, and in very warm summers they may almost entirely disappear. A very slight lowering of the annual temperature would soon cause these thin ice-sheets to thicken and extend on all sides. Such, I conceive, was very much the state of all our high grounds in the south of England at the time of the Drift deposits, when in parts of Scotland, the north of England, and Wales glaciers of considerable size existed and erratics were carried south. Such snow and such frozen snow-beds would have quite a sufficient force to act on the surface of the country, wearing it down to the even beautiful curves it now presents, and distributing the waste over the adjacent lower lands. In summer the streams would have been in a state of extreme flood, transporting much larger material than now down their courses, and distributing it further from its source. Supposing the existence of any sort of obstruction in the gorge of the Wey, it might be by ice or by change of level, drift or detritus from the Chalk would thus extend into the Pease Marsh and Tillingbourne, Mole, &c. On the north face of the downs these conditions may have been combined with the proximity of an arm of the sea and coast-ice, as put forward by Mr. Godwin-Austen *. The question of relative age, as compared with similar deposits elsewhere in the south of England, such as the former sea-beaches of Brighton and Folkestone, and the valley-gravels of Chichester and the Medway,

* *Loc. cit.* p. 119.

are above the river Wey.)



e. Red clay.



o 1 mile.)

N.

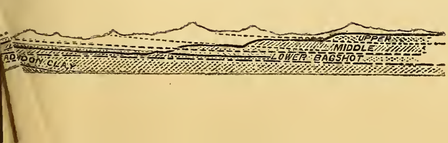
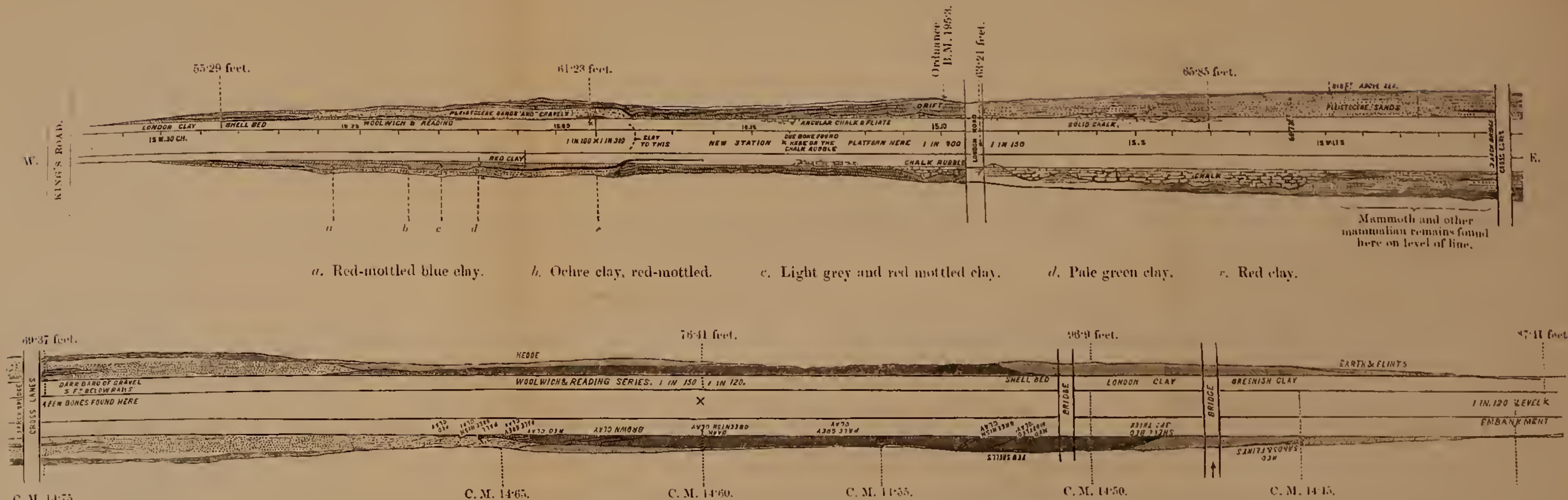
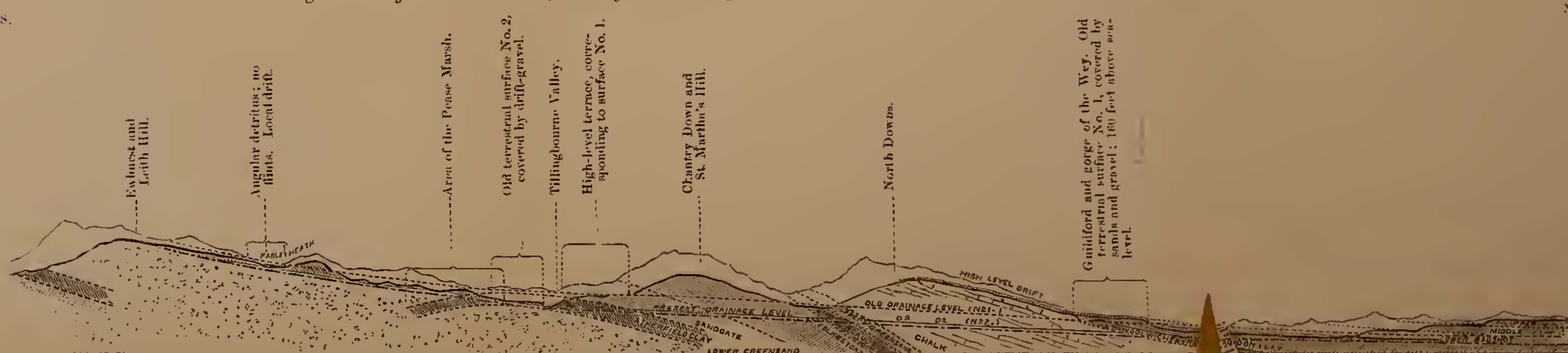


Fig. 8.—*Sections on the North and South sides of the Railway-cutting.* (Scale, 1 inch to 240 yards. The heights in feet are above the river Wey.)



a. Red-mottled blue clay. *b.* Ochre clay, red-mottled. *c.* Light grey and red mottled clay. *d.* Pale green clay. *e.* Red clay.

Fig. 9.—*Diagrammatic Section, showing the relative position of the River-gravels.* (Horizontal scale, ½ inch to 1 mile.)



and even beyond our area on the French coast, is one that would make this communication far too long; I have neither the experience nor the knowledge to treat of such a subject in the manner it deserves. There are, however, many geologists capable of taking it up, and whose subject it is, and to them I must leave it.

In conclusion, I take this opportunity of acknowledging the very great assistance I have received from James H. Mangles, Esq., representing the Board of Directors, and the South-Western Railway Staff. Particularly I am indebted to the Contractors' Engineer of the new line, — Wills, Esq., who placed all the working-plans in his office at my disposal. I recall with pleasure the attention I received from all the overseers, gaugemen, and labourers with whom I came in contact during many hours spent upon the Sections they were opening up.

Discussion.

Prof. Prestwich said that a similar railway-section north-west of Guildford exhibited no Drift, hence the peculiar interest of this section. He referred to Mr. Godwin-Austen's paper on Pease Marsh, and remarked that results therein arrived at were strikingly confirmed by those obtained by the study of the new cutting. The height above the river showed that the high-level gravels resemble those of the Bagshot district, which have no relation to any present drainage, although gravels at lower levels are so related. He was not aware that any gravels at this level had before been recorded at Guildford.

Mr. Topley said that the correlation of the higher gravels with those of Tillingbourne was satisfactory, as this rendered the introduction of Post-tertiary faults unnecessary.

Colonel Godwin-Austen, in reply, said that there was no proof of faults in the Tillingbourne valley having disturbed Post-tertiary gravels. The lower-level gravels of Pease Marsh could be traced throughout at the same general level. Those higher up the valley about Gomshall might possibly correspond to the higher-level gravels and sands at Guildford.

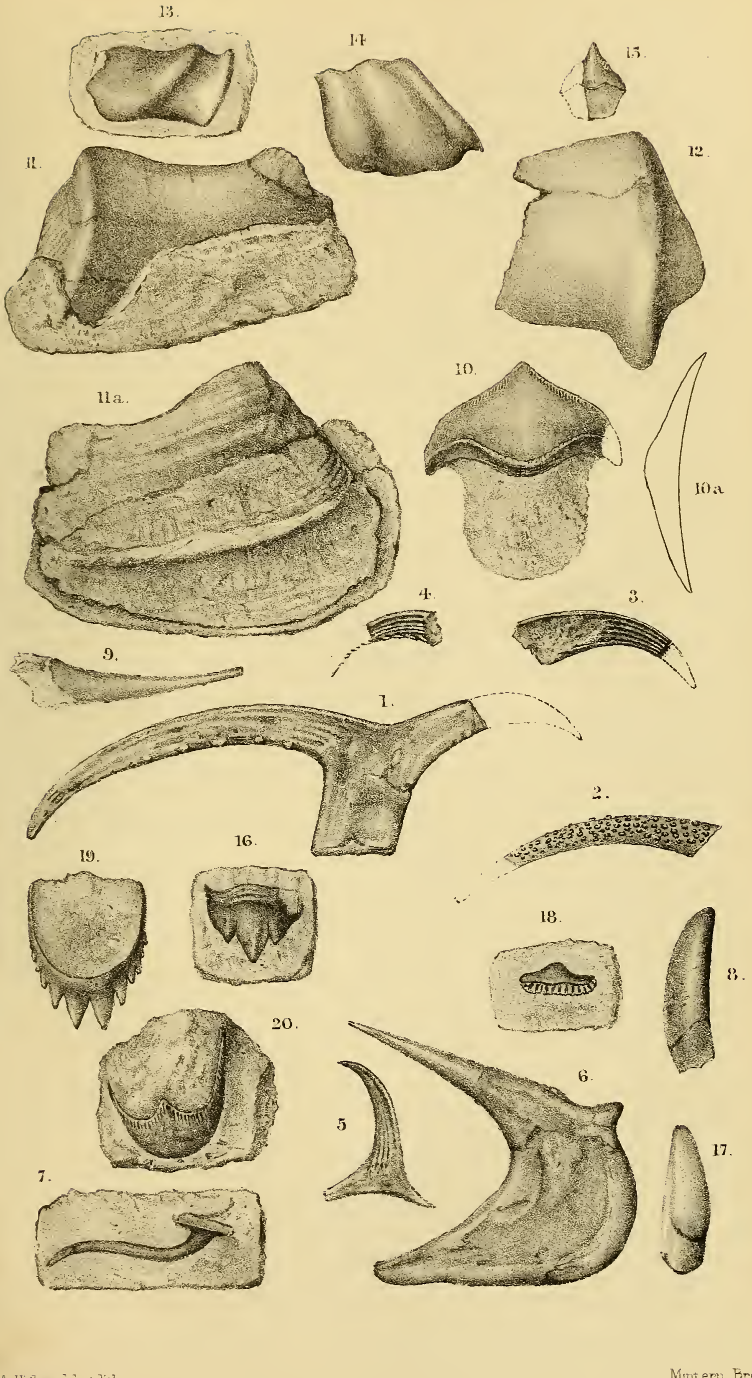
42. *On some* Remains *of* Fossil Fishes *from the* Yoredale Series *at* Leyburn *in* Wensleydale. By James W. Davis, Esq., F.G.S., &c. (Read December 19, 1883.)

[Plates XXVI. & XXVII.]

In Yorkshire the fossil remains of fishes in Carboniferous strata other than those of the Coal-measures are comparatively rare. Some species have been found in the Millstone-grit series, notably in a calcareous bed of sandstone at Hebden Bridge, near Halifax. Immediately below the Millstone Grit in Wensleydale there are a number of alternating beds of limestone, shale, and sandstone, about 1000 feet in thickness, to which Prof. Phillips applied the term "Yoredale Series." In the uppermost bed of these rocks, namely the Crow Limestone, a number of fish-remains have been discovered, and in the next limestone, about 60 feet lower in the series, a most important stratum has been found, which contains an immense assemblage of the remains of fossil fishes of extremely varied and, in some instances, extraordinary types. The limestone was named by Prof. Phillips the "Main Limestone," and is locally known by the term "Red Beds," derived from the reddish colour of the limestone. It has a crystalline texture and presents a coarse and rough appearance. It has been worked at the Harmby limestone-quarry near the railway-station at Leyburn, and it is from this quarry that the greatest number of fossils have been obtained. They principally occur on one horizon about 30 feet below the original surface of the ground; and when a fresh exposure of this horizon or stratum is made during the operation of quarrying, the fish-remains, consisting for the most part of teeth, and an occasional spine, may be seen scattered over the surface in large numbers. They are nevertheless extremely difficult to detach, and fracture with the limestone in a most tantalizing manner, so that comparatively few good specimens can be secured.

I am indebted to Mr. J. A. Rodwell, mining engineer, for the following section of the strata in Wensleydale, taken at the Keld Head lead-mines. It will show the relative position of the beds more clearly than a description in words:—

		fms.	ft.	in.
Millstone-grit Series.	Grits	6	0	0
	Plate or shale	1	0	0
	Millstone-grit	6	0	0
	Hasle-grit	1	0	0
	Plate and girdles	4	0	0
	Stone plate	1	0	0
	Coal ......6 inches to	0	3	6
	Grits and shales alternately in thin beds	11	0	0
	Crow chert	3	1	6
	Crow limestone (fish-remains)	2	4	6
	Gritstone	6	0	0
	Plate	3	0	0
	Girdles and shale	2	0	0



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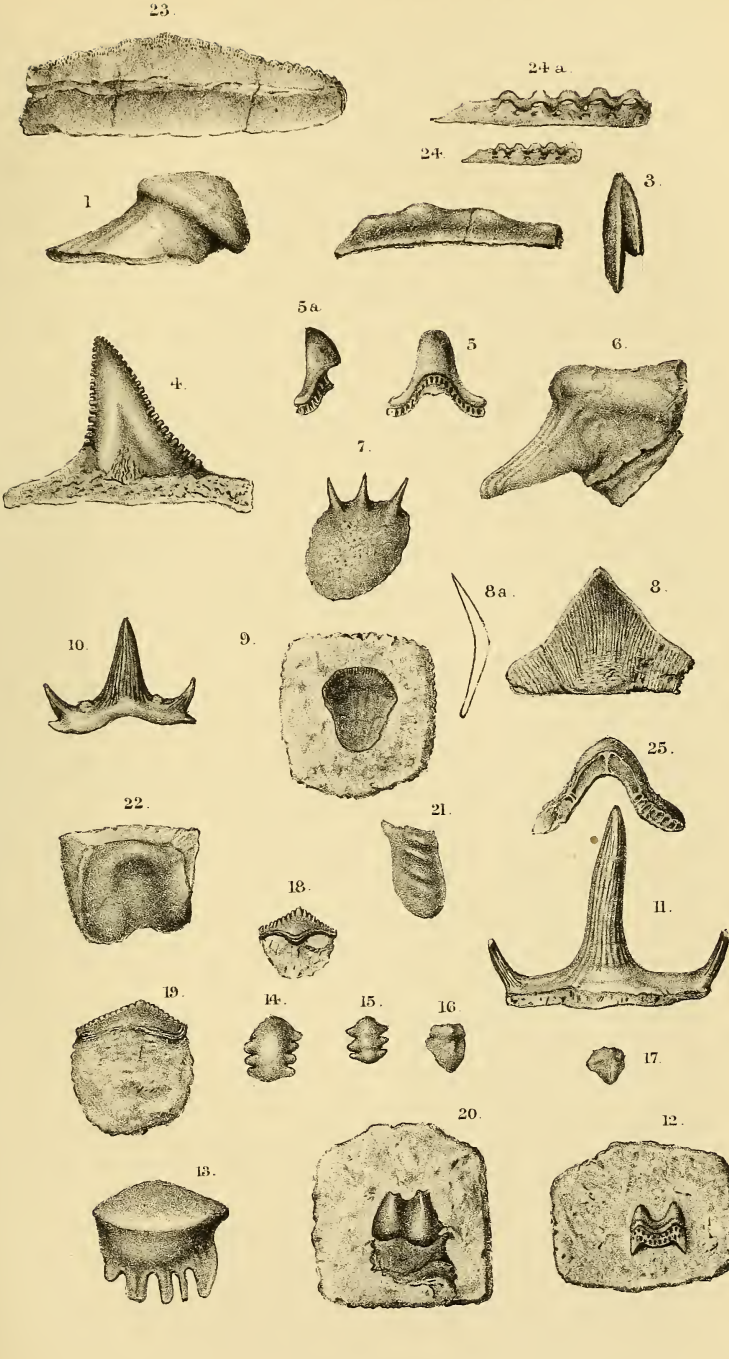
YOREDALE FOSSIL FISHES.



Berjeau & Highley del. et lith.

Mintern Bros. imp.

YOREDALE FOSSIL FISHES

	fms.	ft.	in.
Main chert or "Red Beds" (fish-remains) (Harmby limestone quarry)	7	0	0
Thin limestone	1	1	6
Shales (Black quarry)	1	1	0
Main or twelve-fathom limestone (Leyburn Scars)	10	3	0
Grit	5	0	0
Plate or shale	4	0	0
Sandstones with coal 6 inches thick in Leyburn Shawl.	2	4	6
Plate	4	4	6
Undersett limestone (fish-remains)	2	1	6
Plate	4	3	0
Soapy gritstone	3	3	6
Plate	4	3	0
Thin limestone	1	3	0
Preston gritstone	6	0	0
Plate and shales	1	0	0
Limestone (fossiliferous)	9	4	0
Sandstones and shales in alternate beds	10	0	0
Keld Heads limestone	10	4	0
Flagstone (Gilbert Scar)	3	0	0
Plate	1	5	0
Gritstone and shale	8	5	0
Grit and limestone	2	1	0
Plate and shale	4	0	0
Ash-bank limestone	7	0	0
Alternations of shale and sandstone	10	3	0
Six-fathom limestone	10	1	0
Shales and limestone	5	0	0
Limestone (thickness not proved, estimated)	15	0	0
Grit (at West Burton)	4	0	0
Limestone, thickness not known.			

The fish-remains from the Crow and Undersett limestones are rare both in numbers and species; nearly all those described in this paper have been obtained from the upper beds of the main limestone or "Red Beds." I wish to express my obligation to Mr. William Horne, of Leyburn, for his kindness in placing his large collection, the result of many years of well-directed energy and persistent labour, at my disposal. Nearly all the specimens described or figured are from his cabinet.

It is proposed very briefly to draw attention to one or two features in the character of the Yoredale series of rocks, and to some peculiarities of the fish-fauna contained in them, and then to give a detailed account of the genera and species which have been determined.

The thick-bedded massive limestone which occupies the surface of the county in the northern parts of Craven, attains a thickness varying between 600 and 1000 feet. The upper part of this great mass a little further north becomes intercalated with beds of shale, and the latter in its progress still further northward becomes of increasing thickness and importance, and in addition strata of sandstone and grit also make their appearance. In the same localities the limestone holds a proportionately less important position, diminishing in thickness as the shales and sandstones increase. In Wensleydale the variety of alternations reaches its maximum, and in the upper beds there are one or two thin seams of coal.

The inference to be drawn from these facts appears to be, that, during the period when the thick Mountain Limestone was in process of formation in the southern area, water constantly occupied the space, and whilst the ground was lowering and the limestone increasing in thickness in a more or less gradual and regular manner, a very much more complicated series of changes was taking place in the district to the northward. The alternations of limestone, shale, and sandstone, indicate repeated changes in the level of the land. At one time the water was deep enough for the existence of the animal forms of life which originated the limestone; at others, the mud, brought from some adjacent land, formed accumulations represented by the shales, probably in water shallower than during the formation of limestone. The sandstones point to extensive shore-deposits and the immediate proximity of land, whilst the coal-seams are the result of the decomposition of plants which grew on the land, the disintegration of which supplied the materials for the accumulated deposits of shale and sandstones.

The fish-fauna preserved in these strata presents some peculiarities which distinguish it from that of the thick-bedded Mountain Limestone below, as well as from that of the Coal-measures above. The remains of large predaceous fishes common in the Lower Limestone, such as *Ctenacanthus major*, *Phoderacanthus*, and the large species of *Orodus*, are absent; on the other hand, the similarly large representatives of the Coal-measures, such as *Gyracanthus* and *Ctenacanthus hybodoides*, are also absent from the Red Beds of Wensleydale. Several genera found in these beds are, however, common to the Mountain Limestone, such as *Petalodus*, *Lophodus*, and *Cladodus*; but they are for the most part of different species. *Polyrhizodus*, *Psammodus*, *Copodus*, and *Pœcilodus*, typical forms in the Mountain Limestone, are also represented; but the specimens hitherto discovered have been comparatively small, and they appear to be almost, or quite, the last representatives of their respective genera just on the point of extinction. Their remains do not occur, so far as present evidence exists, higher in the series. The Coal-measure genus *Pleurodus* appears for the first time in Yorkshire strata in the Red Beds; and the Ganoid fish *Megalichthys* appears to be represented by a small jaw found in the limestone of Wensleydale, probably its first appearance. In addition there are numerous genera which, so far as at present known, are peculiar to these beds, and which do not possess any distinctive character in common with those either of the Limestone or the Coal-measures.

All these circumstances taken together appear to indicate that the fauna characteristic of the older limestones was gradually becoming extinct; that some species, only previously found in the Coal-measures, already existed during the deposition of the Yoredale rocks; and that there was also a considerable number of new forms which now appear for the first time, and, so far as present observation has shown, do not seem to have survived during the deposition of the Millstone Grit or the Coal-measures.

Genus Cladacanthus, Agassiz.

Cladacanthus, Agassiz, Rech. sur les Poiss. Foss. vol. iii. p. 176 (1833).

Erismacanthus, McCoy, Ann. & Mag. Nat. Hist. 2nd ser. vol. ii. p. 119 (1848).

Cladacanthus paradoxus, Agass.; Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 365 (1882). (Plate XXVI. figs. 1–5.)

The examples of this species from the limestone near Leyburn are only about half the size of those from Armagh in the Enniskillen collection, but in other respects they correspond essentially with the description given of the species in the Trans. Roy. Dublin Society referred to above.

Cladacanthus paradoxus, Agass., which has hitherto been found only in the Armagh limestone, by its discovery in the Red Beds of Wensleydale, has an extended range in locality, and also, what is perhaps of greater importance, an extension in the vertical series of strata from the lower massive limestones to the uppermost beds of the Yoredale series of Phillips, representing a long period of time. So far as observation has been made, however, *Cladacanthus* appears to be confined to the Mountain-Limestone series, and does not seem to have survived the advent of the period during which the Millstone Grit was being deposited.

In the description of this species by Prof. McCoy *, the posterior or shorter arm of the spine is stated to have a double row of posterior denticles. In examples from Leyburn, it is clearly demonstrated that there is only one row, which occupies a median position along the compressed posterior margin of the spine. The denticles are large, compressed laterally, and their apices point towards the base of the spine. The opposite anterior margin is formed into a broad and thick keel, more prominent than in the specimens from Armagh.

Messrs. St. John and Worthen describe a species very similar to, if not identical with, the one described above, as *Erismacanthus McCoyanus* (Palæont. of Illinois, vol. vi. p. 461, pl. xxii. fig. 1–5). "It is chiefly distinguished by the more restricted posterior extension of the tuberculose surface, and the less numerous costæ, which reach to an oblique line descending from the angle of divarication."

Genus Physonemus, Agass.

Physonemus, Agassiz, Rech. sur les Poiss. Foss. vol. iii. p. 176 (1833); McCoy, Brit. Palæoz. Foss. p. 638 (1855).

Physonemus hamatus, Agass.; Davis, *l. c.* p. 370, pl. xlvii. fig. 9 (1882). (Plate XXVI. fig. 6.)

Onchus hamatus, Agass. Rech. Poiss. Foss. vol. iii. p. 9, pl. i.

Spine marked by its acutely rounded curvature. Greatest breadth

* Loc. cit. sub nomine *Erismacanthus Jonesii*.

0·7 inch at the median portion, from which the spine tapers rapidly anteriorly to an acutely pointed apex; in the opposite direction the basal portion decreases in diameter with a somewhat pointed termination. This specimen does not indicate what length of the basal portion was open; but a second one, which is in great part fractured and exhibits a longitudinal section of the spine, appears to show that the basal portion imbedded in the body of the fish had an open cavity for about an inch from the basal end on the outer margin. The walls of the spine were thin, and in the specimens are crushed; they have a large internal cavity, which extends to the apex of the spine. The surface exhibits traces of striæ; and a number of tubercles, apparently without definite arrangement, are scattered over the upper part of the spine. Ichthyolites, apparently of the same species as this one, obtained from the Mountain Limestone of Bristol, were regarded by Prof. Agassiz as spines of the genus *Onchus*. The spines, however, are so divergent from the characters of that genus, that there can be no hesitation about removing the species and placing it with others in the genus *Physonemus*.

This species differs considerably from the type species of the genus, viz. *Physonemus subteres*, Agass., and *P. arcuatus*, McCoy. The former consists only of a fragment of a spine from the limestone of Armagh, which is a very doubtful example of the genus. The latter, also from the Armagh limestone, was described by Prof. McCoy (Brit. Palæoz. Foss. p. 638, pl. 31. fig. 29). It is much larger, less arched, regularly tuberculated on the surface, and has a double row of denticles on the posterior concave margin of the spine, each particular distinguishing it from the species now described.

Messrs. St. John and Worthen describe several species of this genus from the Kinderhook limestone (Palæontology of Illinois, vol. vi. p. 451, pl. xviii. figs. 1, 2). The specimens are for the most part fragmentary, and have been much abraded; they are consequently somewhat difficult to determine. *Physonemus proclivus*, St. J. and W., approaches nearer than any other form to the one here described. It is not, however, nearly so much curved, and, in proportion to its size, appears to have been thicker and more robust. The anterior apex is shorter and less acuminate. The same remarks apply with greater force to *Physonemus parvulus*, St. J. & W., from the fish-bed horizon of the Keokuk limestone (*op. cit.* p. 453, pl. xviii. figs. 11, 12).

Genus Gomphacanthus, Davis, g. n.

Spine broad at the base, rapidly contracting in width towards the apex, which is pointed. Transverse section more or less circular. Internal cavity probably terminal, without posterior sulcus. Surface uniformly striated.

Gomphacanthus acutus, Davis, sp. n. (Plate XXVI. fig. 9.)

Spine small, 1·25 inch in length, greatest width at base ·25 of an inch; imperfect, tapers rapidly upwards to the point; upper portion of spine circular in transverse section; nearer the base the walls are thin, and the section is laterally compressed. The surface is uniformly but minutely striated.

Genus Cladodus, Agass.

Cladodus, Agassiz, Rech. sur les Poiss. Foss. vol. iii. p. 196 (1833); McCoy, Brit. Palæoz. Foss. p. 619 (1855).

Cladodus mucronatus, Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 380, pl. xlix. fig. 21 (1882). (Plate XXVII. fig. 10.)

Numerous teeth of this species, for the most part considerably smaller than the specimen described as above, occur in the limestone near Leyburn. As may naturally be expected, they offer considerable diversity of form. A specimen 0·5 inch in breadth across the base has a median cone wider at the base and shorter; it is somewhat widely expanded midway towards the apex as compared with the type. The lateral extensions of the base are deeply channelled vertically and highly polished on the surface. The base is considerably more rectangular than in the type. The cones are quite smooth. The divergence of this specimen is marked and it may possibly have belonged to another species; but for the present, and until more distinctly confirmatory evidence shall be obtained, it appears advisable to place it with *Cladodus mucronatus.*

In a third specimen, of about the same breadth as the last, the median cone is longer than usual, it is smooth with a deep and wide sulcus at the base, extending upwards more than half the length of the cone; antero-posteriorly the cone is somewhat depressed, and the surface at each side thins out, so as to form a pointed keel. The keel descends to the basal portion, and is continued along the base and joins a similar projection from the sides of the secondary cones. Of the latter there are two on each side; they are large, acuminate, and partake generally of the character of the central one.

Cladodus Hornei, Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 380, pl. xlix. fig. 20 (1882). (Plate XXVII. fig. 11.)

Cladodus Hornei is readily distinguished from its nearest ally, *Cladodus elongatus,* Davis, by the absence of secondary cones. *C. elongatus*, which is found on the Mountain Limestone at Settle, many hundreds of feet lower in the series, is larger, and between the central cone and the two extreme lateral ones is possessed of several small intermediate denticles. The same difference also serves to distinguish this species from *C. striatus*, Agass., and in addition its central and lateral cones are proportionately very much longer and more attenuated.

Cladodus striatus, Agassiz.

This species appears to be somewhat doubtfully represented in the limestone of Wensleydale. It occurs in considerable abundance in the lower massive limestone of Ireland, Derbyshire, in Northumberland, and near Kendal; it has also been found in the Lower-limestone series of the west of Scotland. Specimens are usually found about 1 inch to 1·23 inch in breadth across the base, and with the central cusp about half an inch in height. The examples which have been found near Leyburn are not more than half the size of the above. The central cones are more or less striated, and the small lateral cones are numerous and arranged somewhat in clusters as in the type specimens; they appear to indicate that this species, which must have been a formidable and destructive fish during the period occupied in the formation of the lower strata of the Mountain-limestone series, was generally becoming much less so, and the circumstances point to the inference that the species was gradually approaching extinction.

Genus Hemicladodus, Davis, g. n.

Tooth or jaw consisting of several rows of minute teeth. The latter are broad at the base, rapidly acuminate and ending in a pointed apex; the several bases apparently anchylosed.

Hemicladodus unicuspidatus, Davis, sp. n. (Plate XXVII. figs. 24, 24 *a*.)

Teeth. Apparently a portion of a jaw containing three rows of teeth placed one behind the other. There are six or seven teeth in each row; those behind are placed in apposition to those in the front row. The teeth in each row are attached laterally and present the appearance of being anchylosed together. They are slightly less than 0·1 inch in breadth at their base, short, triangular in outline, and pointed at the apex. The points are worn, in some cases considerably; they are coated with enamel, which exhibits traces of minute punctures. The bases of the several teeth assume an even, very slightly concave form.

This series of teeth approaches more nearly to those of the genus *Cladodus* than any other in the pointed form of their apices, but they diverge in not possessing lateral denticles, which the teeth of *Cladodus* do, and in the character of the bases of the teeth, which are never joined so closely together in *Cladodus* as they are in this genus.

Reed collection, York Museum.

Genus Pristicladodus, McCoy, British Palæozoic Fossils, p. 642 (1854).

Pristicladodus dentatus, McCoy, *l.c.* p. 642, pl. 3 G. fig. 2 (1854). (Plate XXVII. fig. 4.)

Several specimens of this species have been discovered in Wensleydale. The most perfect specimens afford no indication that lateral denticles have been present. The size of mature examples reaches nearly one inch and a half in breadth across the base, and three quarters of an inch in height. The teeth appear to be all more or less curved or bent over towards one side, a feature which may be seen in the example figured. The base is strong and fibrous, and extends backwards from the crown in a horizontal position. It possesses very similar characters to the base of the teeth of *Cladodus*, and has probably been attached to a cartilaginous jaw, in the same manner as the teeth in that genus were.

PRISTICLADODUS CONCINNUS, Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 385, pl. xlix. fig. 23 (1882). (Plate XXVI. fig. 15.)

This species is very rare. It is easily distinguished from *P. dentatus*, McCoy, by the acutely prolonged upper extremity of the crown, by the lateral denticulations, which are acuminate and small compared with the semiglobose and rounded denticulations of *P. dentatus*.

Genus GLYPHANODUS, Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 386 (1882).

The teeth referred to this genus are extremely thin and slender, and possess characters which appear to indicate an intermediate form between the Cladodonts on the one hand and the Petalodonts on the other. By the acuminate apex of the crown and its sharp cutting-edge they are closely related to the former; whilst the root is devoid of the broadly expanded, more or less horizontally extended, base of the Cladodonts, and descends vertically, to an equal depth, in many cases, to the height of the crown, and in this respect they approach the Petalodonts.

GLYPHANODUS TENUIS, Davis, *l. c.* p. 386, pl. xlix. figs. 24, 25 (1882). (Plate XXVII. fig. 8.)

The base extends downwards from the crown, varying in depth, generally equalling or exceeding the height of the crown. It is thin and laterally coextensive with the base of the crown.

The several teeth referred to this species vary slightly in form, whilst agreeing in the principal characteristics. Examples are occasionally met with in which the posterior surface is not only laterally concave, but they are vertically concave, the apex of the crown having a decided flexure backwards. The majority of the teeth are straight between the base and the summit of the crown; the latter is frequently much reduced by attrition, the sharp point giving place to a more or less rounded margin.

Genus PETALODOPSIS, Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 498 (1882).

The genus *Petalodopsis*, as its name indicates, bears a close relationship to *Petalodus*; but whilst in its general characters it nearly approximates to that genus, it exhibits striking divergences in several minor points. The cutting-edge of the crown is deeply divided into three large and pointed denticles, the centre one being the most prominent and rendering the outline more or less triangular. The triangular form is similar to that occurring in the genus *Glyphanodus*, excepting its tripartite division. The tooth differs also in the semicircular form of its transverse section from that of *Glyphanodus*, which is straight or nearly so. The crown of the tooth in *Petalodopsis* bears some resemblance to that of *Pristodus*, but only a superficial one; it is distinguished from the latter by the absence of the horizontal palate, the imbricating folds of the surface at the junction of the crown with the base, the small number of denticles and the shortness of the root. The teeth of *Pristodus* form each a complete palate, whilst those of the genus now under consideration require the combination of several teeth for the same purpose.

PETALODOPSIS TRIPARTITUS. Davis, *l. c.* p. 499, pl. lx. figs. 6, 6*a* (1882). (Plate XXVI. fig. 16.)

Genus POLYRHIZODUS, McCoy, Ann. & Mag. Nat. Hist. ser. 2, vol. ii. p. 125 (1848).

POLYRHIZODUS COLEI, Davis, *l. c.* pl. lx. figs. 9, 10 (1882). (Plate XXVII. fig. 13.)

Tooth. Small in comparison with the type specimen from Armagh; it is 0·6 inch from the crest of the crown to the tip of the root, and 0·8 inch across the crown. The anterior surface is exposed. The crown forms an angle of 45° with the vertical axis of the tooth, is oval in outline with decumbent lateral prolongations, bounded by the cutting-edge and the anterior ridge; the latter is prominent and smooth, without transverse folds. The surface from the transverse anterior ridge to the base of the radicles forms a right angle with the surface of the crown, and is about equal in extent. The surface of the crown is slightly worn, and has a punctate appearance not well defined. The root is divided into five rootlets, less than one third the total height of the tooth-rootlets, very unequal in size, second and third being apparently double, formed by the anchylosing of two rootlets; from the base the rootlets extend prominently forward; they are semiglobose, with rounded terminations, and apparently about the same diameter laterally as antero-posteriorly; surface coarsely punctate.

The teeth of this species more closely resemble those of *P. Colei*, from Armagh in Ireland, than any others. The principal differences lie in the diminished size of the crown, the great depth from the anterior ridge to the denticles, and the shortness of the rootlets as well as their smaller number. So far as can be ascertained, the specimen from Leyburn is mature; it appears to have been considerably worn by attrition, and, if so, it probably belonged to a much smaller specimen of the fish than the great teeth of Armagh represent; and it seems probable that it may indicate that the genus which flourished and attained its greatest size during the period when the Lower Carboniferous Limestone was formed was gradually becoming extinct. The thin upper limestones of Wensleydale are the highest beds in which it has been recorded. In the more recent members of the Carboniferous series it appears to be quite extinct.

Genus Pristodus, Agass. MSS.; Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 519 (1882).

Pristodus falcatus, Ag.; Davis, *l. c.* p. 519, pl. lxi. figs. 17–22. (Plate XXVI. figs. 19, 20.)

Genus Copodus, Agass. MSS.; Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 464 (1882).

Copodus cornutus, Agass.; Davis, *l. c.* p. 464, pl. lviii. figs. 1–5. (Plate XXVII. fig. 22.)

Psammodus cornutus, Agass. Poiss. Foss. vol. iii. p. 174 (1838).

Teeth. Subquadrate, anterior margin more or less circular, lateral ones nearly straight and diverging posteriorly. Posterior margin concave. Postero-lateral angles produced beyond the tooth and forming horn-like processes. Crown slightly convex where unworn, but central portion deeply concave, and considerably worn by attrition towards the anterior extremity. A slight depression extends inside each lateral margin, which is slightly elevated. Surface enamelled, closely covered with minute punctures. Base: surface roughly striated longitudinally, slightly concave, thickest in the centre and thinning off towards each side; posteriorly, it extends beyond the surface of the crown, apparently to afford support to the anterior portion of a succeeding tooth.

This species is extremely rare in the limestones at Leyburn.

Genus Ctenopetalus, Agass. MSS.; Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 511 (1882).

Ctenopetalus crenatus, Davis, *l. c.* p. 513, pl. lxi. fig. 9. (Plate XXVII. fig. 18.)

This species is readily distinguished from *C. serratus*, Ag., from the Armagh limestone, by its more graceful form and generally more fragile appearance. The serrations or small denticles forming the apex of the crown are smooth and rounded, whilst those of *Ctenopetalus serratus* are subdivided into still smaller serrations. The plications or folds of ganoine forming the anterior base of the crown are in greater number, and they form an acute angle, pointing towards the base in the species now described, whilst in *C. serratus* the base of the crown is more or less curved.

Genus Diclitodus, Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 410 (1882).

Diclitodus scitulus, Davis, *l. c.* vol. i. p. 410, pl. li. fig. 29 (1882). (Plate XXVII. fig. 12.)

This species resembles *Orodus* to some extent in structure, but its peculiar form clearly separates it from any other species hitherto described.

Genus Pleurodus, Agass.; Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 458 (1882).

Pleurodus Woodi, Davis, *l. c.* p. 458, pl. lix. figs. 12–15 (1882). (Plate XXVII. figs. 14–17.)

In the British Islands the remains of this genus have previously been found only in the Coal-measures. The vertical distribution is now extended to the Yoredale beds or the upper beds of the Mountain-limestone series. The specimens found near Leyburn are considerably smaller than those of *Pleurodus affinis*, Agass.*, from the Coal-measures. The latter are frequently three quarters of an inch in length and, compared with *P. Woodi*, are much longer in proportion to their width. The surface of the limestone species is evenly traversed by well-marked bilateral ridges extending from the central one towards each lateral extremity. In *P. affinis*, the surface is often beautifully reticulated, and the connexion, if any, between the median ridge and the lateral projections of the margin is very slight.

The arrangement of the teeth, and even the form of the body, of *P. Rankinii*, Ag., have been indicated from fairly good specimens† by Messrs. Hancock and Atthey, and corroborative evidence given by myself with regard to *P. affinis*, Ag., from which it has been found that the body of the fish was very deep in proportion to the length, that a broad spine extended from the body in front of the dorsal fin, immediately behind the occipital region of the head, and that the body was covered with shagreen. The skeleton appears to have been entirely cartilaginous. The gape of the mouth was comparatively wide, and the teeth arranged in a single row on each ramus of the jaws, probably about twelve in number.

The teeth now described are very rarely met with, only about half a dozen specimens having been discovered; and hitherto no example of the spine of this genus has been found.

Genus Petalodus, Owen, Odontography, p. 61; Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 492.

Petalodus acuminatus, Agass. (Plate XXVI. figs. 10, 10*a*.)

Chomatodus acuminatus, Agass. Poiss. Foss. vol. iii. p. 108, pl. lxix. figs. 11–13 (1833), and Poiss. Foss. vol. iii. pp. 174 and 384 (1840); Davis, *l. c.* p. 494, pl. lix. figs. 22–24.

The specimens from the Yoredale Rocks of Leyburn differ in several important particulars from the type specimens described in the works cited above. The lower margin of the anterior surface of the crown is circular, and projects rather boldly forward; the lateral

* Quart. Journ. Geol. Soc. vol. xxxv. p. 181, plate x. figs. 1–11.

† See Hancock and Atthey, Nat. Hist. Trans. of Northumberland and Durham, vol. iv. part ii. p. 408. And James W. Davis, Quart. Journ. Geol. Soc. 1879, vol. xxxv. p. 181, pl. x. figs. 1–11.

portions of the crown are deeply arched downward. The apex of the coronal cutting-edge is quite acuminate, much more so than in the specimen from Derbyshire figured by Prof. McCoy. Posteriorly the crown is very deep, being quite double the anterior face in extent; the largest portion of the posterior coronal surface is occupied by a number of broadly expanded imbricating folds of the ganoine surface, eight to ten in number. The root is thick, openly porous in structure, and, compared with the crown, the root is much contracted in breadth,

Whilst the teeth from the Upper Limestones near Leyburn differ in so many respects from those of the Lower Limestones of Derbyshire and other localities, they possess many characters in common, and for the present will be considered as being somewhat modified forms of the same species, rather than as representing a separate one.

Genus Chomatodus, Agassiz, Poiss. Foss. vol. iii. p. 108 (1833); Worthen, Geol. Survey of Illinois, vol. ii. p. 31 (1866); Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 507 (1882).

Chomatodus lamelliformis, Davis, sp. n. (Plate XXVII. fig. 23.)

Teeth. Broad in proportion to the height, straight transversely, breadth 2 inches, slightly imperfect at one end. Depth of anterior face of crown 0·25 inch; depth of base equal to that of the crown. Crown thin, cutting-edge acuminate, with a very slight sigmoidal curvature; where not too much worn the cutting-edge is crenulated; it is raised in the centre, and gradually tapers with a circular outline to each lateral extremity. Anterior surface of the crown concave, bounded by a ridge extending in a straight line across the tooth. Ridge prominent, formed by four imbricating folds of the surface. Posterior surface near the cutting-edge convex, corresponding to the concavity of the anterior surface; lower, towards the base, it is concave. Whole surface considerably worn. Base short, thin, equal in breadth to the crown.

This species differs very much from those previously described from the massive Lower Mountain Limestone of Britain, such as *C. linearis*, Agass., and *C. acutus*, Davis, both of which have been found in the limestone near Armagh, and the former also at Bristol and Richmond. *Chomatodus linearis*, Ag., is a broad tooth in comparison to its height, and does not possess the knife-like cutting-edge of *C. acutus* or *C. lamelliformis*, Davis. From *C. acutus*, Davis, the present species may be readily distinguished by its great breadth, the concavo-convex arrangement of its antero-posterior surfaces, as compared with the doubly concave surfaces of *C. acutus*, its serrated cutting-edge, and the greater prominence of the imbricating ridges.

Genus Pœcilodus, Agass. MSS.
Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 441 (1882).

Pœcilodus corrugatus, Davis, *l. c.* p. 444, pl. liii. fig. 25 (1882). (Plate XXVII. fig. 21.)

This differs from the anterior tooth of *P. Jonesii*, Ag., in having the surface raised only into four folds; the latter has eight. It has also a much flatter and more even surface.

Genus SANDALODUS, Newberry and Worthen,

Geol. Surv. Illinois, vol. ii. p. 102 (1866); Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 436 (1882).

SANDALODUS MINOR, Davis, sp. n. (Plate XXVI. fig. 17.)

Teeth. The specimen apparently consists of two teeth in natural position. Anterior tooth 0·6 inch in length and 0·25 inch across. It is widest posteriorly, gradually narrowing towards the anterior extremity to form an obtusely pointed angle. External margin convex; internal one slightly concave. The posterior margin is thin, with a circular outline, and overlaps a second tooth, which extends 0·2 inch backwards, and is quite as wide as the anterior one. The surface of each tooth is longitudinally and transversely convex, with an abrupt depression on the inner margin; anteriorly it is somewhat convoluted after the manner of the less inrolled Cochliodonts. The surface is deeply punctate, the pittings presenting a slightly quincuncial arrangement. The base is hidden in the matrix.

This tooth, though small, possesses all the characters of *Sandalodus*, a genus instituted by Messrs. Newberry and Worthen in 1866. A species of large size has been added to the genus from the Mountain Limestone of Oreton, in Shropshire, viz. *S. Morrisii*, Davis (Trans. Roy. Dubl. Soc. n. s. vol. i. p. 437, pl. liv. figs. 1–6). The specimen described above is not so deeply convoluted as those of the larger species, and its apparent division into two parts is peculiar.

Genus LOPHODUS, Rowanowsky,

Bull. d. l. Soc. Impériale des Naturalistes de Moscou, p. 160 (1864); Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 403 (1882).

LOPHODUS RETICULATUS, Davis, *l. c.* p. 407, pl. li. fig. 22 (1882). (Plate XXVII. fig. 2.)

This species is found more frequently than any other in the beds of limestone near Leyburn, and offers considerable variation from the type. In some examples, the arrangement of the coronal prominences is modified so that all the cones are on one side of the principal one; whilst in others there are no distinct projections, the cones only being indicated by a slight waviness of the superior surface of the crown. The anterior base of the crown is occasionally expanded much beyond the extent of an average specimen, preserving, however, its reticulate surface-markings. The tooth mentioned above as almost devoid of cones is, on the contrary, much compressed antero-posteriorly. The section in that direction is acutely pointed.

No specimen has hitherto occurred which has exhibited the basal portion of the tooth with sufficient clearness for description, but it appears to be thin and not very deep.

Lophodus læyis, Davis, *l. c.* p. 409, pl. li. figs. 26, 27 (1882).

The specimens from the Leyburn limestone are similar to those obtained lower down in the stratigraphical series. The surface is covered with deeper punctæ, and does not present quite so smooth an appearance. In rare instances from two to four or five teeth have been found connected; and a mass of what may be fossilized cartilage has been found attached to the base of one such group.

This species approaches *Lophodus mammillaris*, Ag., in contour; but is easily distinguished by its smaller size, and by the absence of the two small tuberosities, one before and the other behind the basal portion of the median cone, which Prof. de Koninck considers the distinguishing characteristic of *L. mammillaris*. From *Lophodus didymus*, Ag., it is separated by the absence of the deep notch or groove in the apex of the median cone.

Lophodus serratus, Davis, *l. c.* p. 408, pl. li. figs. 23, 24 (1882). (Plate XXVII. fig. 19.)

This species is distinguished from *Lophodus lævis* by the tuberculated apex of the crown, which also separates it from *L. mammillaris*. It is also more angular and graceful in appearance than *L. lævis*.

Lophodus conicus, Davis, sp. n. (Plate XXVI. fig. 18.)

Teeth. Small, transverse diameter 0·4 inch; antero-posterior diameter 0·1 inch; height of crown 0·1, and depth of base 0·05 inch. Crown, central portion rounded, prominent, gibbous, bending slightly from the centre towards one extremity. Lateral extension of the coronal surface in the same direction rapidly depressed from central cone, rounded antero-posteriorly, and terminating abruptly. On the opposite side, the lateral extension of the crown slopes gradually from the summit of the central cone to the base, with which it forms an acute angle. Surface uniformly punctate. Base equal in extent with the crown; composed of a considerable number of small rootlets, separated by vertical interstices, extending from the junction with the crown to the bottom of the root, where the whole of the rootlets are connected together by a lateral extension of their substance.

The crown in this species bears some resemblance to that of *Lophodus lævissimus*, Ag., except that it is narrower from back to front, and that its subcentral cone is more prominent, and is bent over to one side considerably more than any of the specimens hitherto observed, belonging to that species. The great difference which distinguishes it from all other British species hitherto described, the peculiar form of the root, in some measure appears to make it a connecting link between *Lophodus* and *Polyrhizodus*. It presents the appearance of a flat plate, from which rise a number of small columns supporting the crown. The small columns being connected at their extremities distinguish it from *Polyrhizodus*.

This species in form seems to approach *Helodus* (?) *gibbosus*, N. and W., from the Keokuk limestone of Illinois (Palæontology of Illinois, vol. ii. p. 79, pl. v. fig. 3). It may be distinguished, however, by the absence of the conspicuous conical gibbosity protruding on one side opposite the highest point, which characterizes the American species; the latter has also a much deeper base, which, though coarse and porous, does not present the peculiar columnar appearance seen in *L. conicus*.

LOPHODUS BIFURCATUS, Davis, *l. c.* p. 408, pl. li. fig. 25 (1882). (Plate XXVII. figs. 5, 5 *a*.)

LOPHODUS ANGULARIS, Davis, sp. n. (Plate XXVII. fig. 25.)

Teeth. Subpyramidal in outline; diameter across the base 0·8 inch; height of crown from base-line 0·45 inch. Crown 0·2 inch wide antero-posteriorly; central portion forming an acutely pointed triangular apex; the major portion equally and rapidly depressed on each side, but towards the lateral extremities extending almost horizontally, and ending in an obtusely angular point. From the apex an acutely angular projection of the coronal surface forms a carina, situated slightly anteriorly to the median line; anterior and posterior margins prominent, slightly rounded, and more or less corrugated, especially towards the extremities. The corrugations occasionally extend upwards towards the submedian carina, those on the posterior surface being inclined diagonally between the base and the apex. Surface smooth and polished, with minute pittings. Base apparently small, mostly hidden in the matrix, but, like the tooth, deeply concave.

The characters pertaining to this tooth distinguish it readily from all the hitherto described species of *Lophodus*.

Genus DELTOPTYCHIUS, Agass. MSS.;

Davis, Trans. Roy. Dubl. Soc. n. s. vol. i. p. 432 (1882).

DELTOPTYCHIUS PLICATUS, Davis, sp. n. (Plate XXVI. figs. 13, 14.)

Teeth. Of upper jaw (Plate XXVI. fig. 14) subtriangular in outline; convoluted, expanding radially from the inside of the jaw outwards; greatest diameter 0·8 inch. Surface raised in central part, forming a large and prominent median ridge, widening as it approaches the outer margin of the tooth. Anterior ridge separated by a wide sulcus from the central one. It is narrow, but well-developed, and marks the point of contact between the teeth on each ramus of the jaw. The posterior ridge, coinciding with the posterior margin, is most divergent from the central axis of the tooth; it is comparatively small, and separated from the central one by a well-defined, but narrow and somewhat deep concavity. The under surface of the tooth is concave, and conforms generally in outline to the convex surface of the crown.

Teeth of lower jaw (Plate XXVI. fig. 13) more or less oblong in outline, about the same length as those of the upper jaw, but considerably narrower. Surface composed of three ridges as in the teeth of the upper jaw; they are more acute, and separated by wider interspaces. The central one is extended obliquely from the inner to the outer margin; it is prominent, rounded, and considerably worn by attrition, especially midway between the inner and outer margins, where the ridge is considerably raised above the parts before and behind. The anterior ridge defines the margin of the tooth; it is well-developed and straight. The posterior ridge is small, and very obliquely extended, giving to the posterior extremity of the tooth a pointed character. The under surface of the tooth is concave, and exhibits the characteristic convolution peculiar to the group.

These teeth are distinguished from those of *Deltoptychius acutus*, Ag., by their smaller size and thinner and more delicate form; they are more regularly oblong and the posterior extremity of the tooth of the lower jaw is considerably less pointed than in the type species. The teeth of the upper jaw are broader and more expanded on the outer margin, and the ridges of the crown are more prominent. In all these particulars the present species differs still more from *Deltoptychius gibberulus*, Agass.

Genus Psammodus, Agassiz.

Psammodus rugosus, Agass. Poissons Fossiles, vol. iii. p. 111, pl. xii. figs. 14–18; pl. xix. fig. 15 (1833).

One or two teeth of this genus have been found; they are comparatively small. The finest example is slightly less than an inch in length, and 0·3 inch in breadth. The root is thick and massive. The margins of the crown of the tooth along its longer axis are prominent and rounded, the central portion hollowed. Coronal surface worn, and covered with coarse punctures.

The teeth of *Psammodus* are much smaller than those found in other localities, in the limestone occupying a much lower horizon; and whilst they are similar in every other respect to the larger teeth of the Mountain Limestone, they appear to indicate that the genus was gradually dying out. In the Millstone-grit beds above, it appears to have disappeared entirely.

Genus Astrabodus, Davis, g. n.

Teeth of medium size, saddle-shaped, prominently raised near one end, diminishing in breadth and thickness very rapidly anteriorly, much more gradually posteriorly to less than half the greatest diameter. Outer lateral margin convex; inner one concave; apparently conforming to the contour of the jaw, to which the under surface, by its concavity along the longer axis of the tooth, is adapted for attachment. Crown thickly enamelled, punctate. Under surface of tooth striated or rugose.

ASTRABODUS EXPANSUS, Davis, sp. n. (Plate XXVI. figs. 11, 11 *a*, 12.)

Teeth. More or less lingulate in shape; greatest length 2·5 inches, breadth 1·5 inch. At a distance of one sixth the length from the anterior extremity the surface is raised, and forms a prominent convexity across the tooth at its greatest breadth. From this prominent part the diameter and thickness of the tooth rapidly diminish, terminating posteriorly in a subrotund outline 0·4 inch in diameter. The anterior portion of the crown is short, depressed at an angle of 90° to the anterior margin, which is more or less circular in outline. The outer lateral margin is convex, and considerably longer than the opposite inner one, which is concave. Coronal surface antero-posteriorly concave and transversely convex, assuming a saddle-shaped form thickly coated with enamel or dentine, and uniformly punctate. Under surface hollow and concave, apparently for attachment to the surface of the jaw, roughly punctured or fibrous in structure.

These peculiar teeth resemble those of *Psammodus*, Ag., in the widely expanded surface of the crown. Other and more important characters indicate some relationship to the less convolute forms of the Cochliodont group. The convex upper surface with the corresponding concavity beneath, and the greater extent of the outer compared with the inner margin, afford considerable evidence that the teeth grew or increased in size along the outer edge in a radially convolute manner, similar to the growth of the Cochliodonts, so that the teeth, in place of being arranged over the surface of the whole palate as was probably the case in *Psammodus*, were restricted to the jaws, which they enveloped as in the Cochliodonts.

The number of teeth in Mr. Horne's collection is about half a dozen. They are all of the same form, but in some of the number the long posterior extremity extends towards the right, in others towards the left, indicating that they enveloped the opposite rami of the jaw. There is no evidence to show that more than one tooth was attached to each ramus of the jaw; and though, considering the paucity of the material, it might be premature to venture on a definite opinion that the fish possessed only two teeth to each jaw, such appears to have been the case.

Genus CYRTONODUS, Davis, g. n.

Teeth. Anteriorly prominent, gibbous, rounded towards the extremity. Surface behind and parallel with the gibbosity much depressed, forming a deep hollow extending transversely across the surface; posterior portion of crown more or less triangular in outline, rapidly narrowing to a point. The coronal surface uniformly punctate and enamelled. The under surface concave. Teeth probably palatal and not very thick.

Cyrtonodus gibbus, Davis, sp. n. (Plate XXVII. figs. 1 & 6.)

Teeth. Semirhomboidal in outline, greatest length 1·25 inch, breadth 0·75 inch. Anterior portion of tooth raised transversely, forming a prominent gibbous ridge, from which the surface descends gradually, with a gentle convexity, to the anterior margin; posteriorly the surface is first depressed, forming a deep sulcus, and thence extends evenly to the posterior extremity. The anterior margin is rounded, forming an obtuse angle with that of the superior portion of the posterior one. The latter narrows rapidly, and forms with the opposite margin an acutely pointed extremity. The lower edge of the ridge is broad and terminally imbricated. The surface is uniformly enamelled, and covered with small punctures; parallel with the superior margin there are four or five broad imbricated folds of enamel, possibly indicating the direction in which the tooth has increased in size. The under surface is slightly hollowed or concave. A superficial observation of the specimens would lead to the inference that the posterior portion of the tooth was the base or root, the gibbous part being the crown; but that this is not the case is demonstrated by the extension of the minutely punctured enamel uniformly over the whole surface.

Genus Echinodus, Davis, g. n.

Teeth. Base consisting of a more or less circular mass, convex laterally; surface enamelled and coarsely punctate. From the upper part of this base spring rows of denticles, probably three in number, one along the central line and one parallel with this on each side. The denticles are about equal to one third the diameter of the tooth in length; they are conical, laterally compressed, acuminate, enamelled and smooth.

Echinodus paradoxus, Davis, sp. n. (Plate XXVII. fig. 7.)

Teeth. A comparatively large mass, more or less circular in form, from which spring three small, conical, acutely pointed denticles. Greatest diameter 0·6 inch. The surface from which the three denticles arise is flat and 0·4 inch across; remaining portion convex, its surface covered with rugose punctures. At a distance of 0·15 inch from the denticulated margin there are two or three circular depressions, of the same diameter as the base of the existing denticles or cusps, and apparently the impressions of previously existing denticles which have been broken off. The denticles are all similar in size, and extend radially from the surface, 0·1 inch in length, their diameter at the base being equal to about half the length; they are smooth, round at the base, becoming laterally compressed and flattened nearer the apex. They are separated from each other by a distance slightly greater than the diameter of the base.

This example is unique in Mr. Horne's collection. Its relationship to other groups of fish-remains is extremely problematical. There is no genus hitherto described from the Mountain Limestone to which it appears to possess affinity. The teeth of the genus *Periplectrodus*, St. J. & W. (Palæontology of Illinois, vol. vi. p. 324), from the Lower Carboniferous beds of Iowa and Illinois, are described as being symmetrically inrolled from within outward, the crown consisting of a transverse series of strong median cusps, flanked by at least one row of small denticles on each side, which regularly increase from the outer to the inner extremity. The symmetrical or exact vertical inrolment in *Periplectrodus*, the authors consider would indicate that the teeth held an isolated position, either constituting the sole dental element of the fish by which they were possessed, or restricted to some part of the mouth other than the maxillary elements; or, if they were associated with other teeth, that they may have occupied a symphysial position upon the jaws.

The genus now described offers some points of resemblance to *Periplectrodus*, for, in addition to the cusps or denticles occupying the central line of the tooth, it is probable that others existed on the lateral portions, their position being marked by the circular depressions already mentioned. There is also some indication that a fourth cusp existed in a line with the central row, which when present would have extended in a more or less horizontal direction as compared with those still present. Whilst agreeing in these particulars with the American genus, it differs in one or two important particulars. The rounded basal portion does not possess the convoluted character of *Periplectrodus*, whose inrolled form appears to partake very much of the character of the second or smaller tooth of the lower jaw of *Deltodus sublævis*, Ag. (see Trans. Royal Dublin Soc. n. s. vol. i. pl. lii. fig. 9 *a*), or of the middle tooth of *Cochliodus contortus*, Ag. (*op. cit.* pl. lii. figs. 5, 5 *a*), in the manner of its growth. Messrs. St. John and Worthen state, after the examination of a large number of specimens, that the teeth of *Periplectrodus* increase in size with age, and that the cusps on the earlier growth of the dental plate become hidden from view by being inrolled and enveloped by the older extremity of the dental plate. Excepting the fact that these teeth have longitudinal series of cusps or denticles, they do not differ very much from the teeth of the Cochliodonts named above; and may possibly have been somewhat nearly related to them. The tooth from Mr. Horne's collection exhibits none of these peculiarities; the basal portion is quite solid and homogeneous in structure. It also appears to be thinner or narrower than that of *Periplectrodus*.

Genus Diplacodus, Davis, g. n.

Teeth. Of medium or small size, twice as long as broad; crown divided by a deep sulcus into two unequal parts. Anterior portion forming a prominent transverse convexity, more or less pointed on the inner margin and expanding outwardly; behind the sulcus there is a second and similar convex protrusion of the surface, the posterior portion of which extends a considerable distance backwards, the lateral margins gradually converging to half its greatest breadth and terminating in a rounded extremity. The surface is covered with small pustulations: base not observed.

The teeth comprised in the above description appear to offer some indication that they are allied to some extent with the Cochliodont group of fishes. As with the genus *Cochliodus*, the concave margin is shorter than the convex one, and the two prominent portions of the coronal surface are narrow and somewhat pointed at first, and expand with the growth of the tooth. These characters, combined with the general appearance of the tooth, point to a surface more or less convolute and expanding radially with the increase in size.

Diplacodus bulboides, Davis, sp. n. (Plate XXVII. fig. 20.)

Teeth. Possessing the generic peculiarities already indicated; length 0·7 inch, breadth 0·4 inch. The anterior portion of the tooth is characterized by a doubly convex projection of the surface of the crown, divided by a deep transverse groove from the second projection. The surface of the tooth is prolonged backwards for a length equal to half that of the tooth; the sides converge to 0·2 inch in diameter, the posterior extremity being obtusely rounded. The margin of the anterior portion of the tooth is deep and slightly convex; the inner lateral margin sinuously concave, with more or less pointed projections from the border, corresponding to the two prominences of the crown; the outer margin is convex, with rounded projections of the surface similar to the inner ones. The surface of the crown is generally convex, expanding with growth. It is coated with dentine, which is uniformly and minutely punctate; root or base not exposed.

The figure shows a mass of matter attached, which may be a portion of the bony or cartilaginous jaw.

Genus Megalichthys, Agassiz.

Megalichthys Hibberti, Ag. (Plate XXVI. fig. 8.)

A jaw and a few separate teeth and scales of this fish have been found. The jaw is rather less than an inch in length, and 0·3 inch in depth at the posterior end, becoming narrower towards the anterior symphysis. It is covered with glistening black enamel; the surface of the latter being covered with pittings similar to those of the *Megalichthys* abundant in the Coal-measures. Along the upper or alveolar surface a row of minute teeth may be distinguished. The specimen is represented, natural size, by fig. 7.

Several other fossils, apparently belonging to fishes, also occur, but in too imperfect a condition to allow their precise nature to be made out. One is a small, circular, convex plate covered with comparatively large pustules, with the base entirely hidden by the matrix. It was probably the palatal tooth of some fish, and indeed it has some resemblance to the teeth of the genus *Peltodus*, Newb. and Worth. (Pal. Illinois, vol. iv. p. 362, pl. ii. fig. 7), but, unlike these, it appears to be quite round, and not to have the posterior portion truncated.

There is also what appears to be part of the jaw of a fish, which is represented in Plate XXVII. fig. 3. The under surface only is exposed; it is 0·6 inch in length; the alveolar surfaces are buried in the matrix. It consists apparently of the two rami of the lower jaw of a small fish, probably related to the genus *Amphicentrum*. The anterior portion of the jaw is consolidated into a homogeneous substance for about half its length; the posterior half is divided. The rami are rather more than 0·1 inch in depth; the diameter between the outer edges of the two on the alveolar surface is 0·2 inch; exteriorly their sides are inbevelled, forming with those of the inner side of the jaw an acute angle. The diameter is reduced to 0·1 inch on the lower surface of the posterior portion of the rami. A deep channel divides the right and left rami of the jaw; it is deepest posteriorly, gradually becoming shallower as it nears the anterior portion, and disappearing before reaching the extremity. The surface is covered with small punctures.

EXPLANATION OF PLATES XXVI. & XXVII.

Plate XXVI.

Fig. 1–5. *Cladacanthus paradoxus*, Agass.
1. Spine nearly complete. 2. Anterior extension. 3, 4, 5. Posterior extensions.

6. *Physonemus hamatus*, Agass.
7. Spine of fish, sp. nov.?
8. Jaw of *Megalichthys*.
9. *Gomphacanthus acutus*, Davis.
10. *Petalodus acuminatus*, Agass. 10 *a*. Vertical section.
11, 12. *Astrabodus expansus*, Davis. Fig. 11 *a*. Underside of same.
13. *Deltoptychius plicatus*, Davis. Lower jaw.
14. ——— ———, Davis. Upper jaw.
15. *Pristicladodus concinnus*, Davis.
16. *Petalodopsis tripartitus*, Davis.
17. *Sandalodus minor*, Davis.
18. *Lophodus conicus*, Davis.
19. *Pristodus falcatus*, Agass. Upper jaw.
20. ——— ———, Agass. Lower jaw.

Plate XXVII.

1 & 6. *Cyrtonodus gibbus*, Davis.
2. *Lophodus reticulatus*, Davis.

Fig. 3. Jaw of fish ?
4. *Pristicladodus dentatus*, McCoy.
5. *Lophodus bifurcatus*, Davis. Fig. 5 *a*. Side view of same.
7. *Echinodus paradoxus*, Davis.
8. *Glyphanodus tenuis*, Davis. Fig. 8 *a*. Vertical section.
9. *Petalorhynchus* ?
10. *Cladodus mucronatus*, Davis.
11. —— *Hornei*, Davis.
12. *Diclitodus scitulus*, Davis.
13. *Polyrhizodus Colei*, Davis.
14–17. *Pleurodus Woodii*, Davis.
18. *Ctenopetalus crenatus*, Davis.
19. *Lophodus serratus*, Davis.
20. *Diplacodus bulboides*, Davis.
21. *Pœcilodus corrugatus*, Davis.
22. *Copodus cornutus*, Agass.
23. *Chomatodus lamelliformis*, Davis.
24. *Hemicladodus unicuspidatus*, Davis. 24 *a*. The same enlarged.
25. *Lophodus angularis*, Davis.

43. *On a* New Species *of* Conoceras *from the* Llanvirn Beds, Abereiddy, Pembrokeshire. By Thomas Roberts, Esq., B.A., F.G.S., Woodwardian Museum, Cambridge. (Read June 25, 1884.)

[Plate XXVIII.]

Whilst working in the Llanvirn series, near Abereiddy Bay, in Pembrokeshire, in June and again in September last, I found some fossils in a quarry which had apparently been but recently opened. This quarry is about half a mile N. of W. from the Llanvirn quarry, which has yielded such an interesting fauna to the researches of Dr. Hicks and others during the last few years, and from which too Prof. Hughes and his students, myself amongst them, obtained a good collection during the last Easter vacation.

The rocks exposed in this new quarry are less fossiliferous than those at Llanvirn, and during both of my visits I succeeded in getting only eleven specimens, consisting of the following species, which Mr. Marr has identified for me :—

Phacops llanvirnensis (?), *Hicks.*	Didymograptus indentus, *Hall.*
Trinucleus, sp.?	Diplograptus, sp.?
Glossograptus ciliatus, *Em.*	Conoceras, nov. sp.

Only one specimen of *Glossograptus ciliatus** has been as yet recorded from St. Davids, while *Conoceras* is new to the district.

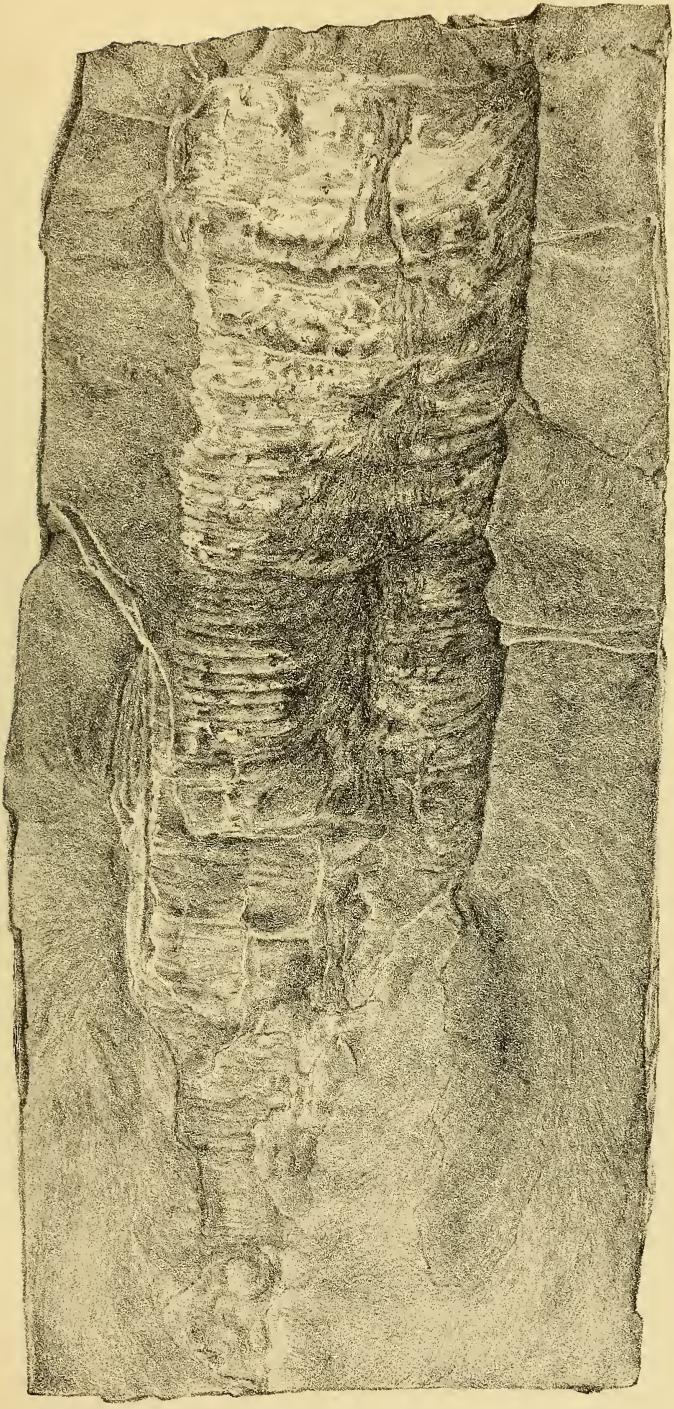
This *Conoceras* I obtained from one of the workmen in the new quarry, and the character of the matrix in which the fossil is imbedded completely confirms the statement of the quarryman that he had found it there.

The cleavage does not quite coincide with the bedding, and, as a result of this, the plane along which the *Conoceras* is exposed, cuts through the dorsal portion of the shell anteriorly, then, passing backwards, reaches its ventral border posteriorly. Hence the parts preserved consist, anteriorly, of a longitudinal section of the shell cut somewhat obliquely, while further back there is only a mould of the internal cast of the shell. The portion of the shell which is preserved is much compressed, and can be removed from its mould.

The specimen is about 7 inches in length, and its greatest width is $2\frac{1}{4}$ inches; there seems to be but little augmentation in its width in passing forward from its hinder extremity; the lateral portions of the shell, however, are not well preserved, so that its exact original width cannot now be ascertained.

The portion consisting of the mould only forms about three fourths of the entire length of the specimen, and on a part of it the disposition of the sutures of the septa is fairly well seen, especially their bending forward and meeting in an angle forming a band of

* Quart. Journ. Geol. Soc. vol. xxxi. p. 659.



A. S. Foord del. et lith.

Mintern Bros. imp.

CONOCERAS LLANVIRNENSE.

reduced one fifth.

superposed chevrons, which is situated mesially in this part of the fossil. The intervals between the septa vary from $\frac{1}{7}$ to $\frac{1}{8}$ inch, and the greatest width of the chevron-band is $\frac{3}{4}$ inch.

On removing the shell from its mould, the chevron-band appears to be somewhat distorted anteriorly, and is then continued forward as a narrow groove, partly disconnected and about $\frac{1}{8}$ inch wide, to the anterior margin of the fossil. On the shell itself there is a ridge corresponding to the above-mentioned groove, and when this ridge is cut open, it is seen to be filled with material differing somewhat from the rock in which the fossil is imbedded. This may, possibly, be the siphuncle, and, as already stated, the groove corresponding to it is apparently continuous with the chevron-band. The anterior portion of the fossil is, however, in such a bad state of preservation that but little can be made of it; the septa are not seen here; but some irregular coarse corrugations are present, running round the part of the shell which is preserved, and roughly corresponding to its lines of growth. The corrugations may represent an ornamentation on the external surface of the shell. On some parts of the shell small irregular ridges can be seen; but it is doubtful whether these represent original structure or not. The doubt that occurs on this point is due to the fact that the cleavage so nearly coincides with the bedding that it is possible some of these crumplings may be due to the cropping-out of the cleavage-planes along the plane in which the fossil lies.

No part of the body-chamber appears to be preserved in our specimen, because if the ridge on the shell, already described, represents the siphuncle, then the body-chamber must lie beyond it.

Five species of *Conoceras* (*Bathmoceras*) have been described:—

Conoceras eoum (Blake) * from the Arenig of the Shelve.
—— *angulosum* †, Bronn, from Lake Huron, America.
Bathmoceras complexum, Barr. ‡ } from D, *d*, 1. Wosek, Bohemia.
—— *præposterum*, Barr. }
—— *Linnarsoni*, Angelin §, from Kinnekulle, Westrogothia, Sweden.

In 1874, Kayser ‖ described, from the Devonian of Bicken, near Herborn, in Nassau, a fossil which he referred to *Gomphoceras*; it consists of a longitudinal section of a portion of the body-chamber, together with 15 segments immediately adjoining it. All the sutures of the septa in the chambered portion are peculiar, in that they bend *backward*, forming funnel-shaped depressions; but this bending is most marked in the last 11 septa. There is also a longitudinal groove uniting the apices of these depressions.

Kayser figures a surface-view of one of the septa from the middle of the fossil, showing (i) what he supposes to be a siphuncle placed

* Blake, Brit. Foss. Ceph. part i. p. 165, pl. xvi. fig. 5.
† Trans. Geol. Soc. 2nd series, vol. i. pl. 26. fig. 6; Bronn, Leth. Geogn. vol. i. p. 98, pl. i. fig. 7.
‡ Barrande, Sil. Syst. de la Bohême, vol. ii. texte iii. pp. 797 & 799.
§ Angelin and Lindström, Fragmenta Silurica, p. 8, pl. xvi. fig. 4.
‖ Zeitschrift der deutschen geologischen Gesellschaft, vol. xxvi. p. 671, pl. 16. figs. 1–4.

near the margin and possessing a radial structure, and (ii) a kind of cylinder, which is placed at the margin immediately beneath the curving backward of the septa. Kayser regards the peculiar character of the septa as a malformation due to a diseased development of the animal.

This fossil has many characters in common with *Conoceras*:—(*a*) the bending of the sutures of the septa forming a chevron-band, but in this *Gomphoceras* the apex of the chevron is directed backwards; (*b*) the longitudinal groove uniting the apices of the depressions is similar to what occurs in some specimens of *Conoceras* from Bohemia *; (*c*) the structure placed beneath the chevron-band appears to be much the same in both forms. What the subcentral structure (siphuncle of Kayser) may be it is difficult to decide. On the outside of the last three chambers of the *Gomphoceras* there is present a structure showing a radial arrangement of parts, and apparently occupying the same relative position to the chevron-band as that of the so-called siphuncle in the middle portion of the fossil, so that they seem to be continuous; if so, then Kayser's determination of its being the siphuncle is incorrect, as that which he believes to be the siphuncle has a subcentral position in one part of the fossil, and seems, in another part, to cut the shell itself obliquely, and must therefore be a foreign body.

The only English species as yet recorded is *Conoceras eoum*, in which the forward inclination of the septa is only feebly marked. It is doubtfully referred to this subgenus by Blake †.

Conoceras angulosum and *Bathmoceras Linnarsoni* differ from all the other known species by their sharply tapering shell.

To *Bathmoceras præposterum* and *B. complexum* the Llanvirn species presents considerable affinity. I have compared it with a specimen of *B. præposterum* from Bohemia, in the collection made by Mr. Marr, now in the Woodwardian Museum, and find that it agrees with it in most of its characters. Barrande distinguishes his two Bohemian species by the manner in which he considers that the septa are developed ‡; in *B. præposterum* the septa first appear at the sides of the siphuncle, whilst in *B. complexum* they are first formed on the dorsal side, or that opposite to the siphuncle; it is thus he accounts for the usual incompleteness of the last two or three septa. Blake points out that this character is of no value, "since many *Orthocerata* of ordinary character, *Phragmocerata*, and even *Ammonites* show similar incomplete septa, dependent probably on accidents of preservation" §. Barrande himself, too, states that in *Orthoceras imperficiens*, *O. styloideum*, &c., some of the septa are incomplete ||. The only distinction which I am able to make between the Llanvirn form and those of Bohemia, is the presence of corrugations of the shell in our species, and their absence

* Barrande, Sil. Syst. Bohême, vol. ii. texte iii. p. 794.
† Blake, Brit. Foss. Ceph. part i. p. 166.
‡ Barrande, Sil. Syst. Bohême, vol. ii. texte iii. p. 793.
§ Blake, Brit. Foss. Ceph. part i. p. 53.
|| Barrande, Sil. Syst. Bohême, vol. ii. texte iii. p. 793.

in Barrande's. As I consider that this character is due to an original structure and not to cleavage, it makes a sufficient specific distinction between them.

The geological horizon from which this new *Conoceras* was obtained is undoubtedly Llanvirn, because the fossils found with it are typical Llanvirn species.

Mr. Marr * correlates the Llanvirn beds with $Dd1\gamma$ of Barrande, in Bohemia, and amongst the fossils enumerated from the latter he mentions *Conoceras præposterum*. In the list of fossils quoted by Mr. Marr † from the *Orthoceras*-limestone of Sweden, we find *Bathmoceras Linnarsoni*, and the upper part of this limestone he also correlates with the Llanvirn beds.

Conoceras llanvirnense. (Plate XXVIII.)

Shell thin, cylindrical, marked with coarse corrugations corresponding to its lines of growth. Greatest width not less than $2\frac{1}{4}$ inches. Septa $\frac{1}{7}$ to $\frac{1}{8}$ inch apart; the sutures bent forward on each side of the siphuncle and meeting above it, forming a band of superposed chevrons. Siphuncle marginal. The specimen is much compressed, and the body-chamber is not seen.

EXPLANATION OF PLATE XXVIII.

Conoceras llanvirnense, Roberts, from the Llanvirn series, near Abereiddy Bay, Pembrokeshire: four fifths of the natural size.

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* Marr, Sedgwick Essay, p. 93.

† *Ibid.* p. 121.

44. *On the* Chemical *and* Microscopical Characters *of the* Whin Sill. By J. J. H. Teall, M.A., F.G.S. (Read June 25, 1884.)

[Plate XXIX.]

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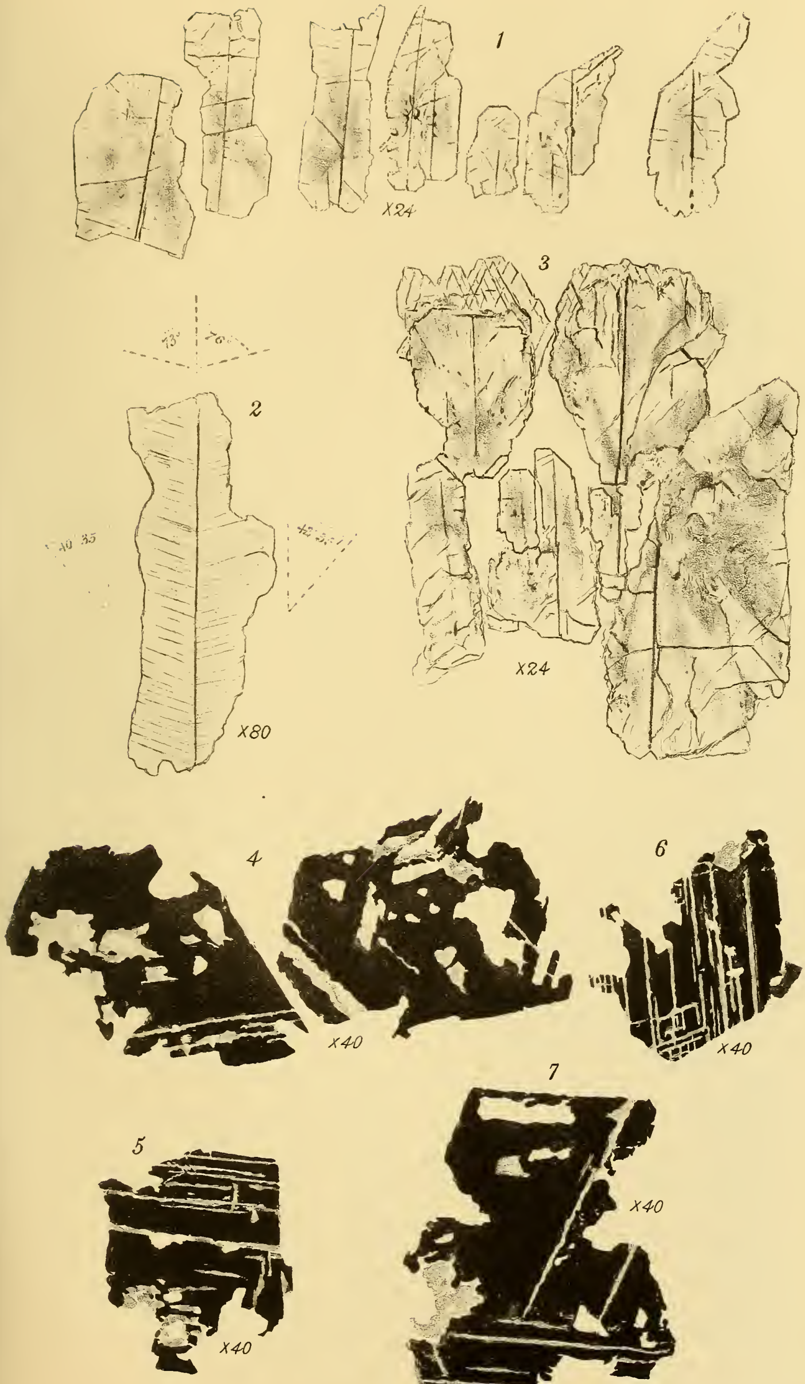
* This paper contains the following two analyses of the rock of the Whin Sill, made in Dr. Percy's Laboratory, which I quote for comparison with my own, given in the body of the present paper:—

	I.	II.
SiO_2	51·47	50·35
Al_2O_3	16·48	16·80
Fe_2O_3	3·61	3·51
FeO	8·49	8·36
MnO	0·46	0·41
CaO	8·22	9·01
MgO	5·10	5·73
K_2O	3·28	2·87
Na_2O	1·18	1·07
FeS_2	·17	·08
H_2O	1·70	2·00
	100·16	100·19
Sp.Gr.	2·82	2·84

I. From Tinkler's Syke, top of Widdy Bank Fell.
II. From Teward's Bridge, near Forest Church. TiO_2 was not estimated



Hanhart imp.

MINERALS OF THE WHIN SILL.

Topley and Lebour. On the intrusive Character of the Whin Sill of Northumberland. Q. J. G. S. vol. xxxiii. p. 406. 1877.
Lebour and Fryar. On the Harkess Rocks near Bamburgh. Trans. N. of England Inst. of Engineering, vol. xxvi. 1877.
Lebour. Outlines of the Geology of Northumberland. Newcastle, 1878.
——. Geological Map of the County of Northumberland.
Bonney, T. G. New Theory of the Formation of Basalt. Proc. Geol. Assoc. vol. vii. p. 104.

The term Whin Sill is applied in the north of England to the intrusive sheet of basic igneous rock which forms such a marked feature in certain portions of the Lower Carboniferous district of Durham, Cumberland, and Northumberland. It is unnecessary, on the present occasion, to describe the stratigraphical relations of the rock, because full details are to be found in the papers cited above, and especially in those by Prof. Sedgwick and Messrs. Topley and Lebour. For some time there was a discussion as to whether the rock was intrusive or interbedded, but this discussion may be regarded as having been closed by the publication of the able paper by Messrs. Topley and Lebour. It is now admitted on all hands to be intrusive. To give some idea of its extent, I may mention that it is exposed as an inlier in Teesdale for a distance of many miles. It reappears in the Cross-Fell escarpment in Cumberland, and may be traced thence, with slight interruptions, across the county of Northumberland, to the sea-coast at Dunstanburgh, following in a general way the strike of the beds with which it is associated. As the strike bends round to the N.W. in the northern portion of Northumberland, the Whin Sill reappears on the coast at Bamburgh, and may be traced from this point to Kyloe, where it is last seen.

The distance from the point in the Cross-Fell escarpment, where it first appears, to Dunstanburgh is about 60 or 70 miles. Speaking of its development in Northumberland, Prof. Lebour says * :—" Its thickness varies very greatly, being scarcely 20 feet in places, and 150 feet in others. On an average it is from 80 to 100 feet thick." Inasmuch as the outcrop follows on the whole the strike of the beds, we may reasonably infer that the horizontal extension of the sheet is very great, amounting, in all probability, to hundreds of square miles, and that it underlies a large portion of the counties of Durham and Northumberland. It is an unfortunate circumstance that we are unable to speak definitely as to the period of its eruption. It is later than the Lower Carboniferous, and earlier than most of the faults of the district †; but whether it is pre-Permian or post-Permian must remain, for the present, an open question. It would be a very curious circumstance if the Whin Sill should prove to be contemporaneous with the diabase of the Eastern States

in these analyses and was therefore weighed in part with the SiO_2, and in part with the Al_2O_3 and Fe_2O_3. The excess of potash over soda is a remarkable feature in these analyses.

* Outlines of the Geology of Northumberland, p. 55.

† " Intrusive Character of the Whin Sill," Topley and Lebour, Quart. Journ. Geol. Soc. vol. xxxiii. p. 418.

of North America, which it so closely resembles in its petrological character and mode of occurrence.

The object of this communication is to describe the chemical and microscopical characters of the rock of the Whin Sill. The observations are based on specimens collected by myself, at many points in Durham, including Middleton, High Force, and Cauldron Snout; at a point about half a mile south of the locality marked Tyne Head on the Ordnance Map (Alston Sheet); and at Hot Bank, near Crag Lough, Bourgovicus, Bamburgh Castle, and many other points in Northumberland. Mr. Comozenski, the borough engineer of North Shields, kindly supplied me with specimens from Greenhead near Haltwhistle, Longhoughton and Little Mill near Alnwick, and Barrasford on the North Tyne. I have also examined the Little Whin Sill of Weardale, which occurs at a somewhat higher horizon than the Great Whin Sill of Teesdale. It is identical in its petrological characters with the latter rock. It will thus be seen that material has been collected from a sufficiently wide area to justify general conclusions as to the character of the rock, although it cannot be expected that all varieties have been observed. In no case are there any marked variations from the common type except such as depend, in all probability, on rapidity of cooling, and these may generally be found in one and the same locality.

There is one aspect of the question to which I have paid scarcely any attention, although it is one of great interest and importance; I refer to the phenomena of contact-metamorphism. This metamorphism is most marked in many cases, both at the upper and lower junctions. Limestones have become crystalline, and the shales have been converted into a kind of porcellanite, with development of garnet and other minerals.

The subject has been referred to by Prof. Sedgwick, Mr. Clough, and other writers; but it would well repay further investigation, with both the microscope and the chemical balance *.

Petrological Characters.

The rock is dark grey or bluish grey when freshly exposed. In texture it varies from compact to coarsely crystalline, the most common variety being one in which the individual constituents are just recognizable by the naked eye. The compact variety occurs

* The following papers contain important observations on the contact-metamorphism produced by rocks similar in character to the Whin Sill:—

Lossen. Metamorphische Schichten aus der paläozoischen Schichtenfolge des Ost Harzes. Z. D. G. G. 1869, p. 281.

——. Ueber den Spilosit und Desmoisit Zinckens. Z. D. G. G. 1872, p. 701.

Kayser. Ueber die Contactmetamorphosen der körnigen Diabase im Hartz. Z. D. G. G. 1870, p. 103.

Schenck. Die Diabase des oberen Ruhrthals und ihre Contacterscheinungen. (Inaugural Dissertation.) Bonn, 1884.

The work of these authors appears to establish the important fact that the metamorphism is accompanied by an actual transfer of felspar substance from the magma of the diabase to the surrounding rock.

only at the junctions, and is never more than a few inches in thickness. It is especially interesting because it exhibits a very distinct type of micro-structure. The coarse-grained varieties occur only where the rock attains a very considerable development, as, for instance, at Cauldron Snout. There is one very remarkable variety in which crystals of pyroxene measuring an inch in length are by no means uncommon. I have observed it in two localities, viz. half a mile south of Tyne Head and at Cauldron Snout. It occurs in the form of irregular masses in the coarser varieties of normal whin. Speaking of this variety, Prof. Sedgwick says *:— "Among the hard and almost indestructible masses there may be found a few concretions or irregular veins of a much coarser and more decomposing variety of rock in which the crystals of pyroxene are large and abundant. This mineral in such cases often puts on the form of irregular prisms or lengthened tabular crystals, the planes of which are bent and undulating." Mr. Phillips examined these long crystals for Prof. Sedgwick, and ascertained "that they cleave easiest parallel to the plane P [$0P$ Naumann], which is uncommon, and that the broad surfaces of the long crystals are not primary planes but represent the plane h [$\infty P \bar{\infty}$ Naumann]." These determinations of Mr. Phillips will be verified later on. The junctions between the very coarse rock here referred to and the more normal whin are remarkably abrupt, notwithstanding the fact that the two varieties have the same mineralogical composition.

If we leave out of account one or two exceptional varieties, the statement holds good that the rock of the Whin Sill is remarkably uniform in general aspect. Its specific gravity is also fairly constant, as will be seen by the following list of determinations †:—

Hot Bank near Crag Lough	2·924
Longhoughton near Alnwick	2·903
Greenhead Quarry near Haltwhistle	2·945
Barrasford Quarry, N. Tyne..............	2·945
Crags near Bourgovicus	2·944
Middleton in Teesdale	2·959

Amygdaloidal varieties are not common, and where they do occur, as at the Harkess Rocks near Bamburgh, they are associated with other peculiarities which lead one to suspect that the rock has consolidated under conditions somewhat different from those which prevailed during the formation of the normal whin.

The only constituents distinctly recognizable with the naked eye or with the hand-lens are pyroxene, a light-coloured substance which is presumably either felspar or the result of its alteration, and a few specks of pyrites. Under the microscope a much longer list of minerals can be made out. The essential constituents are seen to comprise plagioclase of one or more species, and generally more or

* Cambr. Phil. Trans. vol. ii. 166.

† Mr. Clough (Geol. Mag. dec. II. vol. vii. p. 442), gives the Sp. Gr. of a specimen from Tinkler's Syke as 2·82, and that of another from Teward's Bridge, near Forest Church, as 2·84.

less altered, a monoclinic pyroxene having certain special characters hereafter to be described, and titaniferous magnetic iron-ore. In the coarser-grained varieties quartz may always be detected as an original, and probably also as a secondary, mineral. The original quartz is intergrown with felspar so as to produce the micro-pegmatitic structure of Lévy and Fouqué, or the granophyric structure of Rosenbusch. This micro-pegmatite plays the rôle of ground-mass, that is, it occurs between the interstices of the lath-shaped felspars. If a series of sections cut from rocks which vary in the size of the constituent minerals be examined, it will be seen that the micro-pegmatitic structure in the interstitial matter becomes less and less pronounced as the finer-grained varieties are observed, until at last it is incapable of definite recognition ; all that one then sees with the highest powers is an indistinct parallel fibrous structure. It is extremely interesting to trace this micro-pegmatite into a substance in which the minerals quartz and felspar are incapable of recognition by the aid of the microscope, but in which there is reason to believe that they exist.

Apatite can always be detected, though only in very small quantity.

The accessory minerals, or those which do not always occur in the thin sections, include a rhombic pyroxene, a colourless monoclinic pyroxene—the so-called salit of many authors—brown hornblende, mica, pyrite, calcite, and various green decomposition-products. Before proceeding to describe the characters of the individual constituents it will be well to say a few words about the general microscopic structure of the different varieties.

The compact rock which forms, in many cases, the actual junction, and which may be well seen at both the upper and under surfaces of the Whin Sill in the neighbourhood of Cauldron Snout, shows a micro-porphyritic structure. Small, more or less lath-shaped sections of felspar lie imbedded in a ground-mass, which is a veritable "Mikrolithenfilz," composed of minute and evenly distributed specks of opaque iron-oxide and somewhat ill-defined and extremely small colourless microlites. In the thinnest preparations these microlites are seen superposed on each other, so that it becomes impossible to speak with certainty as to the presence or absence of any isotropic glass. It is impossible to look at this ground-mass and not be struck with its resemblance to the ground-mass of many andesites and porphyrites.

The finely crystalline rock which occurs a foot or two from the junction presents a very different type of micro-structure. It appears at the first glance to be holocrystalline, and to consist of crippled augite granules, lath-shaped felspars, and grains of opaque iron-ore. On closer examination an extremely minute quantity of interstitial matter may generally be detected between some of the lath-shaped felspars.

The medium-grained rock which makes up the main mass of the Whin Sill differs from the above merely in the extent to which the individual constituents have developed. Instead of the crippled augite grains one now recognizes collections of such grains, and also definite crystalline plates into which the lath-shaped felspars frequently penetrate. In short the rock possesses the "ophitic structure" of Messrs. Lévy and Fouqué. The interstitial matter becomes more pronounced and takes on here and there the micropegmatitic structure. In the coarser-grained varieties both the ophitic and micropegmatitic structures become more and more developed, and the dominant pyroxene shows a peculiar striated appearance, which will be described more fully in another part of this paper. In the coarsest variety of rock the pyroxene is developed in the form of long and somewhat flattened prisms and the micropegmatitic structure is most strikingly shown. Having described the general types of micro- and macro-structure, it will now be advisable to consider the individual minerals.

Felspar.—This is probably, in all cases, the most abundant mineral. In the vast majority of cases only one generation can be detected. In three specimens, however, taken from Little Mill near Alnwick, Middleton in Teesdale, and Barrasford on the North Tyne, in addition to the prevailing felspars which give lath-shaped sections, a larger felspar, which is more evenly developed in the different directions, and which contains a nucleus with irregular ramifying inclusions, may be recognized. This evidently belongs to an earlier period of consolidation, and the rock is therefore not strictly granular in the sense in which that term is used by Rosenbusch *. The prevailing felspar, as already indicated, gives lath-shaped sections. When fresh it shows the fine striation of plagioclase. Whether it belongs to one or more species I am not able to determine with any degree of confidence. The extinction-angles referred to the twinning-plane are not large. In the majority of cases the felspar is more or less altered; and this alteration appears to affect all the individuals alike, a fact which tells in favour of the view that we are here dealing with a single species. For the purpose of isolating the different constituents a specimen of a moderately coarse-grained variety of the normal whin was broken up in an iron mortar, and the fragments passed through a series of sieves. The grains selected for further treatment were those which passed through a sieve having 50 meshes to the inch and were stopped by one having 100 meshes. These grains were so small as to consist, in a large measure, of the individual constituents of the rock. They were washed to remove the fine powder, dried and then placed in the Sonstadt solution having a specific gravity of about 3. The grains of pyroxene and titaniferous magnetic iron sank to the bottom, whereas the grains of felspar substance and many others of a composite character remained suspended. The grains of pyroxene and magnetic iron-ore were separated for further treatment, and then the solution was diluted down gradually. It was found that the felspar substance remained suspended in a solution of 2·70, and sank in one of 2·67. The grains which fell as the solution was diluted from 2·70 to 2·67

* "Ueber das Wesen der körnigen und porphyrischen Structur bei Massengesteinen," Neues Jahrbuch, Band ii. 1882.

were separated from the rest and analyzed with the following result:—

SiO_2	61·18
Al_2O_3	19·95
Fe_2O_3	3·20
CaO	5·45
MgO	·92
K_2O	2·83
Na_2O	4·70
H_2O	1·13
	99·36

Both microscopic and chemical analysis shows that we are not dealing with pure felspar substance, but a mixture of quartz, felspar, and decomposition-products.

The molecular ratio of Na(K) : Ca, according to the analysis, is 2·18 : 1; but we must remember that some lime has been removed from the rock. Nevertheless, by introducing the most favourable assumption as to the amount of lime which has been removed, we cannot make the ratio of Na(K) : Ca so low as 1 : 1, and we seem therefore driven to the conclusion that in the original felspar substance, whether it consisted of one or more species, this ratio agreed approximately with that of andesine. The large amount of K_2O may imply the existence of an independent potash felspar; but of this I am not able to give any definite microscopic evidence, and we must remember that some andesines are supposed to contain as much as 2 or 3* per cent. of this substance.

The dominant Pyroxene.—This mineral, in the thin sections and in a perfectly fresh condition, appears to be of a pale brown colour. In the finer-grained varieties it occurs in the form of grains, and in the coarser varieties either as grains or irregular plates. The usual prismatic cleavages are common, and twinning may not unfrequently be observed. External crystalline boundaries are, as a rule, absent. In the large irregular plates a fine striation may frequently be observed. This, however, is by no means a constant feature. In the freshest rock specimens it is absent; in the most altered specimens it is universally present where the pyroxenes attain any considerable size. Some sections of pyroxene show it in certain parts and not in others. It seems impossible therefore to avoid the conclusion that this structure is of secondary origin.

It reminds one at once of the corresponding structure in diallage; and an interesting question arises as to whether we are here dealing with true diallage—that is, with a pyroxene having a laminated structure parallel to $\infty \bar{P} \infty$—or with some other modification of augite. It has already been pointed out that in the coarsest variety of whin the pyroxene is developed in the form of elongated prisms, with more or less definite crystalline faces. If, then, this variety

* Rammelsburg, 'Handbuch der Mineral-Chemie,' Band ii. pp. 569–570.

shows the same striation, and we can identify the crystalline faces, it will furnish us with the means of determining this point.

Looking at a fractured surface of this extremely coarse-grained rock, one sees long bright black cleavage-faces, measuring, say from 2 to 3 centimetres in length, and from 1 to 3 millimetres in breadth. These are traversed by a fine striation, which runs at right angles to the length of the face, and which can be readily seen with a hand-lens. These faces represent the orthopinacoid, according to the determinations of Phillips. If, now, we break the specimen so as to obtain an end view of the prism, we see that it is bounded by two small faces which have a bronzy lustre, similar to that of diallage, and which are inclined at approximately the same angle as the basal planes in a crystal of augite twinned on the normal plan. We see, further, that a number of similarly twinned crystals are placed close to each other, with corresponding faces parallel. Now these small bronzy-looking faces are the basal planes of the crystals according to the determinations of Phillips, and they are also the planes of easiest cleavage. Owing to the size of the crystals it is easy to prepare sections in definite directions for microscopical and optical examination. Such sections establish conclusively the correctness of Mr. Phillips's determinations. Those cut parallel to the long black lustrous faces ($\infty P \bar{\infty}$) give straight extinction, and show a marked striation at right angles to the vertical axis; those cut at right angles to this axis (Pl. XXIX. fig. 1) show that the prisms are formed almost entirely of the ortho- and clino-pinacoids (the prismatic faces only appear as slight truncations), and that each individual is twinned in such a way that the face of composition is at right angles to the plane of the optic axes; that is according to the normal type. These sections also show that whereas the prismatic cleavages are well seen in the fresh crystals or portions of a crystal, they are obscure wherever alteration has taken place. Other and somewhat irregular cleavages parallel to the two vertical pinacoids, especially the clinopinacoid, may be observed. Sections cut parallel to the latter pinacoid (fig. 2) show an oblique striation, the striæ making with the twinning-line an angle of about 75°, *i. e.* the angle β (Naumann) of augite. In these sections the angle of extinction referred to the twinning-line is 42°. The facts mentioned above prove conclusively that the striation so frequently referred to is due to lamination parallel to $0 P$ and not to $\infty P \bar{\infty}$. The mineral therefore is not true diallage. That the striation observed in the pyroxene of the normal whin is of a similar character can be easily proved by the application of optical tests to the thin sections. We have now to deal with the chemical composition of this pyroxene.

In a former part of this paper (p. 645) the method of separating the pyroxene and titaniferous iron-ore from the felspar and quartz was explained. The two former minerals were separated from each other by means of a small bar-magnet. It was found that the iron-ore could be entirely extracted in this way. The pyroxene grains, after having been roughly sorted under the microscope, were analyzed, with the following result. They were not perfectly pure, for it was found impossible to remove all traces of the felspar, owing to the intimate manner in which it was intergrown with the augite.

Monoclinic pyroxene, Cauldron Snout, from a moderately coarse-grained rock (sp. gr. about 3·30):—

	Comp.	Mol. Rel.
SiO_2	49·03	8182
Al_2O_3	5·46	533
FeO	15·57	2167
MnO	·22	31
CaO	15·34	2746
MgO	11·66	2922
Na_2O (K_2O) .	1·24	200
H_2O	·81	
	99·33	

A portion of the alkalies and alumina in this analysis may certainly be referred to felspar. The total iron is reckoned as FeO. The most striking feature is the large excess in the number of molecules of Fe+Mg over the number of molecules of Ca. This cannot possibly be explained on the assumption that a visible mixture of two pyroxenes was analyzed, for care was taken to select a rock in which the rhombic mineral could not be recognized. To determine if possible somewhat more accurately the composition of the prevailing pyroxene, an isolation of the mineral from the coarsest variety of Whin Sill was effected. The greatest care was exercised, and every grain used in the analysis was passed before the eye under the microscope.

	I.	II.	III.	IV.	
SiO_2........	50·71	50·21	48·41	8079	54·2
Al_2O_3	3·55	3·24	4·05	395	2·6
Fe_2O_3			2·36	149	1·0
FeO........	15·30	17·40	15·08	2099	14·0
MnO	0·81		·37	52	·3
CaO	13·35	13·92	15·98	2860	19·1
MgO	13·63	14·05	12·14	3043	20·4
Na_2O (K_2O)..	1·48				
H_2O........	1·17 (loss)		1·19		
	100·00	98·82	99·58		

I. Pyroxene from West Rock, Newhaven, Connecticut. American Journal of Science, 1875, p. 185. W. Hawes on the Trap rocks of the Connecticut Valley.

II. Striated pyroxene isolated from a basaltic rock from Költer, Faröe Islands. Dr. A. Osann, "Ueber einige basaltische Gesteine der Färöer," Neues Jahrbuch, 1884, Band i. p. 48.

III. Striated pyroxene from the coarsest variety of the Whin Sill, $\frac{1}{2}$ m. south of Tyne Head. Sp. gr. 3·33 (approximately).

IV. Molecular relations of III.

In our pyroxene R : Si = 1 : 1. R : R = 1 : 14·8. Ca : Mg : Fe =

1·36 : 1·45 : 1. If we adopt the view of Tschermak and Dölter*, and regard the pyroxenes as isomorphous mixtures of double salts in which the sesquioxide bases are present in a silicate of the form RRSiO$_6$, then we may represent the composition of this mineral approximately by the formula—

$$\left.\begin{array}{l} 14CaFeSi_2O_6 \\ 5CaMgSi_2O_6 \\ 6MgMgSi_2O_6 \\ 3MgAl_2SiO_6 \\ 1MgFe_2SiO_6. \end{array}\right\}$$

This formula corresponds to the following percentage composition :—

SiO_2	48·97
Al_2O_3	4·65
Fe_2O_3	2·41
FeO	15·23
CaO	16·06
MgO	12·68
	100·00

The mineral is remarkable for the large amount of iron, existing presumably in a silicate of the Hedenbergite type, and for the excess of magnesia over that required to combine with the remaining lime and the sesquioxide bases. This excess implies the existence of the silicate $MgSiO_3$, written in the formula as $MgMgSi_2O_6$ for the sake of symmetry. Whatever theory we adopt as to the constitution of the pyroxenes, we seem driven to the conclusion that this silicate, known to us as the rhombic mineral, enstatite, exists in a monoclinic augite. One point is certain, viz. that the substance analyzed did not consist of a visible mixture of rhombic and monoclinic pyroxene. The mineral was uniform in appearance and in optical properties.

The point here raised is one of considerable interest, for two reasons—firstly, as bearing on the general question of isomorphism; and, secondly, because in other varieties of the Whin Sill a rhombic pyroxene occurs as an accessory constituent, and, in some cases, may even be observed intergrown with the monoclinic mineral in such a way as to show that its position was governed by general laws of crystalline growth. We know that the most powerful object-glasses do not enable us to approach the limits of molecular structure, and there is therefore no reason to believe that the microscopic limit of visibility corresponds with anything definite in the nature of crystalline growth. The intergrowth of two minerals which can be frequently observed may quite well take place on so small a scale as not to be capable of recognition; indeed we have in this paper traced micro-pegmatite† down to a substance in which

* "Ueber die Constitution der Pyroxengruppe" von C. Dölter, Tschermak's Mitth. Neue Folge, Band ii. p. 193. See also numerous other papers by the same author in the same journal.

† Consider also the case of perthite and micro-perthite.

the definite structure cannot be recognized, but in which there is every reason to believe that it actually exists. Is it possible that the mineral now under consideration is a submicroscopic association of monoclinic and rhombic pyroxene? The idea here thrown out was suggested to me in conversation by Prof. Rosenbusch.

Returning once more to the general consideration of the pyroxene, we observe that, so far as the ratios Ca : Mg : Fe are concerned, it is intimately connected with the pyroxene of the Connecticut diabase and with that of a basaltic rock from the Faröe Islands. Both these pyroxenes show the same tendency to develop a laminated structure parallel to ∞ P. To what extent this tendency is connected with the composition I am, of course, unable to state. Two other points require attention. The ratio of R̶ : R is greater in the Tyne-Head pyroxene than in that of the other two localities, and the amount of water is considerable. It is possible that the development of the laminated structure is connected with the addition of water. Thus the pyroxene of the Cauldron-Snout rock is less conspicuously laminated than that of the rock from Tyne Head, and it contains less water. A comparison of the two analyses of the Whin-Sill pyroxene shows that the coarse variety is closely allied to, though not identical with, the common rock-forming mineral.

Opaque Iron Oxide.—In the compact varieties, this substance occurs in the form of extremely minute specks, evenly scattered throughout the section. In the finely crystalline varieties it occurs in the form of grains, and in the coarse varieties in the form of extremely irregular ragged masses. Many of the sections, however, show forms which are supposed to indicate ilmenite (Pl. XXIX. figs. 4, 5, 6, and 7), and the white alteration produced may often be observed. All the grains, which consist either wholly or in part of the opaque iron-ore, may be extracted from the powder by a weak bar-magnet. True ilmenite is not attracted by a strong electro-magnet. Owing to the extremely ragged character of this titaniferous ore, the grains extracted by the method above referred to are largely composed of felspar and augite. An attempt was made to purify the substance by treatment with hydrofluoric acid, but the result was unsatisfactory, as the substance itself was more or less decomposed with separation of titanic acid. An analysis of the impure substance yielded the following result:—

SiO_2	12·16
TiO_2	24·51
Al_2O_3	3·36
Fe_2O_3	24·70
FeO	26·54
CaO	4·40
MgO	1·49
	97·16

This analysis leaves much to be desired; still it will give some idea of the composition of the ore. Since augite occurs as a visible impurity, we shall probably not err seriously if we assume that the magnesia is wholly present in that mineral. Deducting, then, an amount of iron oxide which corresponds to 1·49 per cent. of MgO, and assuming that the remaining iron is wholly associated with TiO_2 to form the magnetic ore, we have the composition of this ore as follows:—

			Mol. Rel.
TiO_2	24·51	33·30	4162
Fe_2O_3 ..	24·70	33·56	2101
FeO	24·39	33·14	4611
	73·60	100·00	

Another sample from the same rock was partially analyzed. ·6150 gramme gave ·1635 gramme TiO_2, and ·3639 gramme Fe_2O_3 (total iron). If we assume that the total Fe is associated with TiO_2 to form ilmenite ($FeO\ TiO_2 + nFe_2O_3$), then we have as the composition of the mineral—

TiO_2	31·99
FeO	28·72
Fe_2O_3	39·29
	100·00

These results can of course only be regarded as rough approximations to the truth. In the second case no determination of FeO was made. In the first case this was done, and the result shows that there is more FeO than is required to form the compound $FeOTiO_2$—that is, more than is required for true ilmenite.

The analysis and also the physical properties of this substance agree with the assumption that we are here dealing with a mixture of magnetite and ilmenite, and the question arises—Is there any evidence that these two minerals occur intergrown together? Such evidence is supplied by the work of Renard and De la Vallée Poussin*, Neef†, and Küch‡. Neef found, on treating a certain section of diabase with hot hydrochloric acid, that the opaque iron-ore was only partially destroyed; a fine network, due to two parallel series of lamellæ of ilmenite intergrown so that the angles between the lamellæ corresponded to the angles of the fundamental rhombohedron of ilmenite, remaining behind. The mineral removed was no doubt magnetite, as this substance is much more readily attacked by hot hydrochloric acid than ilmenite. Küch obtained precisely similar results in the case of a rock from West Africa. Renard and De la Vallée Poussin figure such a network as that referred to in plate i. fig. 6, of the work cited below. Lastly, the alteration of the Whin-Sill substance into leucoxene takes place along two sets of parallel planes (see Pl. XXIX. figs. 4, 5, and 6). We may conclude, therefore, that we are here dealing not with one definite mineral, but with an intergrowth of two, viz. magnetite and ilmenite.

It is not a little interesting to observe that we have in this rock three separate instances of the intergrowth of two minerals, viz.

* "Mémoire sur les roches dites plutoniennes de la Belgique et de l'Ardenne française." Mémoires couronnés de l'Académie Royale de Belgique. Tome xl. p. 50.

† "Ueber seltenere krystallinische Diluvium-Geschiebe der Marke," Z. D. G. G. xxxiv. p. 470.

‡ "Beitrag zur Petrographie des west-africanischen Schiefergebirges." Min. Mitth. Neue Folge, vi. p. 129.

quartz and felspar, a monoclinic and a rhombic pyroxene, and magnetite and ilmenite.

Rhombic Pyroxene.—This mineral is by no means uniformly present, but where it does occur several sections may usually be recognized in the same microscopic preparation. In its most typical development it takes on the form of elongated prisms, and shows a much more decided approach to crystalline form than the prevailing monoclinic pyroxene. Two terminal faces meeting at an obtuse angle may sometimes be detected. In the fresh condition this mineral appears nearly colourless when examined by ordinary light. It develops a fibrous structure parallel with the long axis of the prism by alteration, and finally passes over into a green serpentinous substance. Examined with a polarizer only, the longitudinal sections show a decided pleochroism, appearing colourless or of an extremely pale green when the long axis of the prism corresponds with the short diagonal of the nicol, and of a pale brown or reddish brown when the opposite relation holds. Longitudinal sections generally show irregular transverse cracks, and invariably give straight extinction. Another and a very characteristic feature is the low order of the interference-colours under crossed nicols. In sections in which the augite constantly gives the brilliant pinks and greens of the second and third orders of Newton's scale, the rhombic pyroxene gives the pale tints of the first order. In a section taken from a Middleton specimen I have observed intergrowths of the augite and the rhombic mineral. Thus, one crystal of augite cut approximately parallel to the clinopinacoid, shows a thin lamella of rhombic pyroxene in its centre. The latter mineral gives straight extinction, and polarizes in the pale yellow of the first order; the former mineral extinguishes at an angle of 43°, and polarizes in the brilliant green of the third order*. In another portion of the same slide two thin lamellæ of augite are seen to be enclosed in a good-sized crystal of the rhombic pyroxene.

What name is to be applied to this mineral? In the absence of more direct optical or chemical evidence the properties of colour and pleochroism are the only ones available for the purpose of distinguishing between enstatite, bronzite, and hypersthene. Typical enstatite appears devoid of pleochroism. Bronzite is slightly and hypersthene markedly pleochroic in thin sections. In other words, the depth of colour and the intensity of pleochroism increase with the amount of iron. Now the pleochroism of the mineral in question is decided, though much less marked than that of the hypersthene of the andesites, and therefore the term bronzite seems to be the most applicable. It must be admitted, however, that we want a general term for the rhombic pyroxenes which are now being recognized in so many rocks, and which are incapable of precise determination. Prof. Rosenbusch uses the term "Enstatite" to cover the entire group. Prof. Tschermak † and Dr. F. Becke ‡ on the

* The quartz wedge described by Sorby in the 'Monthly Microscopical Journal,' 1877, p. 209, was used for these determinations.

† Lehrbuch der Mineralogie, 1854, p. 436.

‡ "Ueber die Unterscheidung von Augit und Bronzit in Dünnschliffen." Min. Mitth. Band v. 1883, p. 527.

other hand use the term "Bronzite." There is therefore at present no general agreement on this point, and inasmuch as the test of pleochroism seems to show that the mineral of the Whin Sill is intermediate between enstatite and hypersthene, the term bronzite will probably not be considered inappropriate.

Colourless monoclinic Pyroxene.—In his paper on Swedish diabases Törnebohm* describes a colourless monoclinic mineral which he regards as a lime-magnesia bisilicate, and to which he gives the name Salit. It is distinguished from the prevailing pyroxene by the absence of colour, by the presence of more definite crystalline boundaries, and by its easy alterability. In a few specimens of the Whin Sill I have observed a colourless monoclinic augite which may possibly be this mineral. It appears to be developed in the form of long slender prisms. Cross-sections show the forms ∞P, $\infty P \grave{\infty}$, and $\infty P \breve{\infty}$, the pinacoids predominating just as in the exceptional variety of the common pyroxene above described. The individuals are, moreover, invariably twinned. I feel some doubt as to whether this is not, after all, a variety of the common pyroxene, which in the fresh condition and in a very thin section is frequently almost colourless.

Hornblende.—This mineral is often present in small quantity. It never occurs as an independent mineral, but is always attached to the augite, from which it may be distinguished by its deep brown colour, its cleavages, and its pleochroism. The usual mode of occurrence is in the form of small irregular patches on the margin of the augite. The boundary between the augite and the hornblende is abrupt but not sharp. The external boundaries of the hornblende are frequently formed of definite crystalline faces, and they project beyond the natural boundaries of the augite (see Pl. XXIX. fig. 3). The relation therefore of the brown hornblende to the augite is not such as we should expect if the former mineral were produced from the latter by a process of paramorphic change.

Mica.—A brown mica may occasionally be detected. It is by no means common, and when it does occur its characters are not such as to call for any special description.

Quartz.—This substance occurs in the form of crystalline grains, and also in the micro-pegmatite. In the latter case it is of primary origin; in the former it may be, and probably is in many cases, of secondary origin.

Apatite.—This occurs as definitely recognizable hexagonal prisms. Extremely long, thin, colourless needles are also abundant. These, I believe, are usually referred to apatite.

Chlorite and other green Alteration-products.—In most sections green fibrous minerals, resulting from the decomposition of the bisilicates, may be observed. These have not been subjected to any exhaustive examination.

Pyrite may be recognized both macroscopically and microscopically. It is extremely irregular both in form and distribution.

* Neues Jahrbuch, 1877, p 263. Many of the characters which Törnebohm gives as distinctive of the salit would apply to the bronzite, especially those depending on alteration.

We have now to discuss the bulk-analysis of the rock. Two specimens were analyzed—one a moderately coarse-grained variety from Cauldron Snout, composed mainly of monoclinic pyroxene, felspar, magnetic iron-ore, and quartz, with a very small quantity of colourless pyroxene, but no trace of bronzite; the other a medium-grained rock from the crags near the Roman station of Bourgovicus, which contained both bronzite and the colourless pyroxene, in addition to the ordinary constituents. Both specimens were somewhat altered, the felspars having here and there lost their individual action on polarized light, and chloritic minerals having been slightly developed.

The fine powder of the rock was dried at 110°*. The titanic acid in I. was determined with special care.

For purposes of comparison I have placed two analyses of the Connecticut diabase, and one of a rock of similar character from Spitzbergen, side by side with my own analyses of the Whin Sill.

	I.	II.	III.	IV.	V.
SiO_2 ..	51·22	50·71	51·78	52·68	49·78
TiO_2 ..	2·42	1·92	..	..	2·97
Al_2O_3 ..	14·06	14·78	14·20	14·14	14·05
Fe_2O_3 ..	4·32	3·52	3·59	1·95	14·86
FeO ..	8·73	8·95	8·25	9·79	..
MnO ..	0·16	0·31	0·44	0·44	0·13
CaO ..	8·33	8·21	10·70	9·38	9·44
MgO ..	4·42	5·90	7·63	6·38	5·65
K_2O ..	1·25	1·39	0·39	0·87	} 1·70
Na_2O ..	2·55	2·76	2·14	2·56	
H_2O ..	1·28	1·78	0·63 (loss)	1·60 (loss)	..
CO_2 ..	0·19	0·25	..	..	..
P_2O_5 ..	0·25	..	0·14	..	..
FeS_2 ..	0·49	..	..	..	..
Loss ..	..	..	..	..	1·42
	99·67	100·48	99·89	99·79	100·00
Sp. Gr...	2·98	2·944	3·03	2·97	..

I. Whin Sill. Cauldron Snout, Durham. Moderately coarse-grained variety.

II. Whin Sill. Crags near Roman station of Bourgovicus, Northumberland.

III. West Rock. W. of New Haven, Connecticut. Hawes, 'American Journal of Science,' 1875, p. 185.

IV. Mount Holyoke, Massachusetts. Hawes.

V. Diabase. Gänze Island, in the Eisfjord. 'Petrographisch-geologische Beobachtungen an der Westküste Spitzbergens,' Min. Mitth. Heft iv. 1874, p. 264.

If we assume that the magnesia in I. is wholly present in the monoclinic pyroxene (and microscopic examination shows that this assumption is very nearly correct, only a very small quantity of chlorite being present), we can then construct the following table,

* In all the original analyses contained in this paper the powder was first dried at 110° C.

which represents quantitatively both the chemical and mineralogical composition of the rock:—

Table illustrating the Composition of a Specimen of the Whin Sill from Cauldron Snout, Durham.

	SiO_2.	TiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MnO.	CaO.	MgO.	K_2O.	Na_2O.	H_2O.	CO_2.	P_2O_5.	FeS_2.	Total.
Augite	17·62	......	1·47	0·85	5·49	0·13	5·81	4·42	......	......	0·43	......	......	......	36·22
Titaniferous ore	......	2·42	......	2·44	2·41	......	......	......	......	......	......	......	......	......	7·27
Potash felspar	4·78	......	1·36	......	......	......	......	......	1·25	......	......	......	......	......	7·39
Soda felspar	14·80	......	4·22	......	......	......	......	......	......	2·55	......	......	......	......	21·57
Lime felspar............	4·78	......	4·08	......	......	......	2·23	......	......	......	......	......	......	......	11·09
Apatite	......	......	......	......	......	......	0·29	......	......	......	......	......	0·25	......	0·54
Pyrites	......	......	......	......	......	......	......	......	......	......	......	......	......	0·49	0·49
Remainder	9·24	......	2·93	1·03	0·83	0·03	......	......	......	......	0·85	0·19	......	......	15·10
Total	51·22	2·42	14·06	4·32	8·73	0·16	8·33	4·42	1·25	2·55	1·28	0·19	0·25	0·49	99·67

The excess of alumina, iron, and water, and a portion of the excess of quartz, are no doubt due to the alteration which has taken place, kaolin and chlorite both being present. A large portion of the silica, however, no doubt represents free original quartz. If the felspar molecules were associated with each other to form a single mineral, the ratio of Na (K) : Ca would be, according to the above, 2·72 : 1. But lime has certainly been removed from the rock; and if we allow for this, on the basis that the excess of Al_2O_3 was wholly present in molecules of anorthite, then this would make the above ratio 1·58 : 1. The discussion of the bulk-analysis leads us, therefore, again to the conclusion that the original felspar, if of one species, was andesine.

We cannot construct a table for the Bourgovicus rock, because the microscope shows that both bronzite and the colourless pyroxene occur, in addition to the common pyroxene.

Relations of the Whin Sill to other Rocks.

If we compare the rock of the Whin Sill with the dykes described in my former paper (Q. J. G. S. vol. xl. p. 209), we are at once struck with its resemblance to those of Hett and High Green. The figure which is given of the rock of the High Green dyke (*l. c.* pl. xiii. fig. 2) represents faithfully the general structure of the Whin Sill. The ilmenite of my former paper is, no doubt, the same mineral as the titaniferous magnetic iron-ore of the present paper.

There are some very interesting points both of resemblance and difference between the Whin Sill and the eruptive rock of Penmaenmawr, described by Mr. J. A. Phillips (Q. J. G. S. vol. xxxiii. p. 423). These two rocks are composed of the same minerals, associated in very different proportions. Thus the freshest specimens of the Penmaenmawr rock are seen under the microscope to consist of bronzite*, monoclinic pyroxene with lamination parallel to ∘P, plagioclase, titaniferous iron ore, and quartz, both in the form of grains and associated with felspar in micro-pegmatite. In the Whin Sill the monoclinic pyroxene is largely in excess of the bronzite; but in the Penmaenmawr rock the reverse relation holds—the bronzite is very largely in excess. A comparison of the bulk-analyses shows that the Penmaenmawr rock possesses a larger proportion of felspar than the Whin Sill.

Comparing our rock with the Carboniferous dolerites of central England we are struck by the absence of olivine. I have not seen

* I think this is the mineral that Mr. Phillips referred to hornblende. I have not seen any hornblende in the rock, and at the time that Mr. Phillips's paper was written the methods of distinguishing the crystal-systems by reference to the extinction-angles was not well known. It is not surprising, therefore, that he should have taken the pleochroic bronzite for hornblende. I may state that my attention was specially directed to the Penmaenmawr rock by the following sentence in Rosenbusch's work, 'Die massige Gesteine,' p. 352:—"Die Trappe von Conway und von Penmaenmawr in Wales gehören zu den enstatitführenden Diabasen und zwar zu den typischesten Repräsentanten derselben."

a single instance of this mineral in the Whin Sill, although Mr. Allport mentions it as occurring in the rock from Ward's Hill *, near Rothbury.

Outside this country, the nearest allies to our rock that I can find are certain Swedish diabases described by Törnebohm †, and the great masses of trap which occur as dykes and intrusive sheets in the Triassico-Jurassic strata of the Eastern States of North America ‡. I have a good series of the American rocks from New Jersey and Connecticut, and both macroscopically and microscopically they are in many cases identical with the Whin Sill. In mode of occurrence and chemical composition there is also great similarity. Lime-felspar, however, appears to be more abundant in the American rocks. Dr. Hawes separated the felspar substance, extracted from a rock from Jersey City, into two portions, one having Sp. Gr. $> 2{\cdot}69$, the other $< 2{\cdot}69$. The former, on analysis, proved to be labradorite, the latter andesine.

It is not a little interesting to observe, near the opposite shores of the Atlantic, rocks with so many points of close resemblance.

EXPLANATION OF PLATE XXIX.

Fig. 1. A row of twinned crystals of the dominant pyroxene, cut at right angles to the *c* axis, from a coarse variety of the Whin Sill near Tyne Head. The forms and mutual relations of the crystals are accurately represented. In the actual specimen the interspaces are filled with decomposed felspar and a little micro-pegmatite. If we speak of the sections as approximately rectangular for purposes of reference, then the optic axial plane lies parallel with the short side of the rectangle, which consequently represents the clinopinacoid. The long side of the rectangle is the ortho-pinacoid, and the prismatic faces are represented by the slight truncations of the angles. The crystals are seen to be twinned with the ortho-pinacoid for the face of composition. ×24.

2. Section of twin crystal of the same pyroxene cut approximately parallel to the clino-pinacoid. The striations of the two halves make with the twinning-line angles of 76° and 73° respectively. The mean of these is 74° 30′, and the angle β of augite, as given in Naumann-Zirkel's Mineralogie, is 74° 11′. The two halves extinguish at angles of 42° 35′ and 40° 35′ respectively. ×80.

3. Sections of two imperfect pyroxenes with marginal hornblende. The external form of the hornblende and the characteristic cleavages are well shown. The minerals in contact with the hornblende are chlorite and quartz. ×24.

4, 5, 6, 7 §. Forms of the magnetic titaniferous iron-oxide. The dotted spaces represent leucoxene. The mode of alteration reveals the structure of the substance. It consists of a framework of ilmenite lamellæ with the interspaces occupied by a different substance, probably magnetite. Middleton. ×40.

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* Quart. Journ. Geol. Soc. vol. xxx. p. 552.

† Neues Jahrbuch, 1877, p. 258.

‡ W. Hawes, "Trap Rocks of the Connecticut Valley," Amer. J. Science, 1875, p. 185.

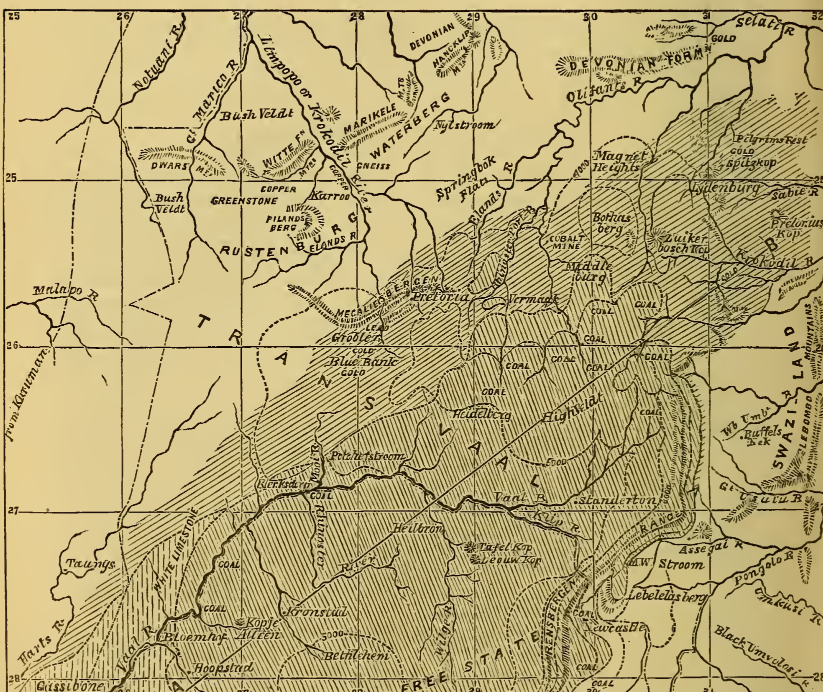
§ From a section kindly lent by Prof. Lebour.

45. *A* Sketch *of the* High-level Coal-fields *of* South Africa. By W. Henry Penning, Esq., F.G.S. &c. (Read March 5, 1884.)

[Abridged.]

The main high-level coal-fields of South Africa have an extreme length from north to south of not less than 400 miles; the breadth at the widest part is over 200 miles, but the average breadth is about 140 miles; therefore the coal-fields cover, wholly or in part, an area of about 56,000 square miles. The map (fig. 1) is intended to give only a general idea of the form and extent of the

Fig. 1.—*Map of the Northern Part of the High-level Coal-fields of South Africa.*



High Veldt beds (Coal-bearing). Kimberley beds. Megaliesberg beds.

coal-bearing rocks of this country, where they occur at the higher elevation. Its boundary-lines may include some outliers as parts of the main mass; but two known outliers are shown near the northern limit of the field. This area consists of an elevated plateau, having a precipitous face to the south and east, and a gradual undulating slope to the north-west, carved into broad deep valleys and rounded hills.

The south and east margin is formed by the Stormberg and the Drakensberg mountains, which have a general altitude ranging between 6000 and 8000 feet, with occasional peaks rising to 9000 or 10,000 feet above the sea. They have a "drop" of about 2000 feet, forming a precipice inaccessible, except by a few passes, on the seaward side. There are numerous minor ranges and spurs, more or less transverse to the direction of the main lines. The highest part of the slope west of the mountain has an elevation of from 4500 to 5500 feet; it is called the "High Veldt," in the Transvaal, and forms the immense plains of the Orange Free State.

Nearly all the chief rivers of S.E. Africa rise in these mountains (as well as the Orange river, which flows west to the Atlantic Ocean), drawing their main supplies from the coal-bearing strata.

The general contours of the area are shown upon the map by dotted lines, 3000, 4000, 5000, and 6000 feet above the level of the sea.

This coal-bearing formation rests unconformably upon a series (or it may be more than one series) of rocks which, as regards the northern part of the area, are probably of Upper Palæozoic age, and have been described as the "Megaliesberg beds." Towards the south-west it probably overlies what have been described as "The Lower-Karoo beds," also with an unconformity. It has been called "The Upper Karoo;" but as the break between it and the "Lower Karoo" is of unknown extent, it has been considered advisable to term the shales which form the lower part of it, provisionally, the "Kimberley beds."

The "Kimberley beds" are a great series of argillaceous deposits, with few arenaceous and still fewer calcareous beds.

The base of the formation, as seen about the junction of the Hart and Vaal rivers, consists of hard greenish-grey shales, stained with oxide of iron. Quartzites belonging to older rocks are exposed in a valley a short distance to the north.

In Kimberley diamond-mine the shales are exposed around the margin, and in shafts to a depth of 300 feet; they rest upon a mass of trap-rock, probably interbedded, and of unknown thickness. They are here black, dark grey, and indurated, rarely more than a few inches in thickness, and weather to various shades of grey, brown, and red. There are also intrusive masses of diorite by which the beds have been locally disturbed—this, however, only for a short distance, and over the whole district they are virtually horizontal.

About fifteen miles south-west of Kimberley, hard grey shales, in beds 2 or 3 feet thick, are seen in a quarry, whence this stone is taken for building-purposes. These have been indurated by contact with a dyke of trap rock.

At the "Blue-bank" Drift, across the "Riet river," south of Jacobsdal, there is a fine exposure of dark-blue shales, some soft, others hard, and with some thin slightly calcareous bands at intervals.

Hard grey fissile shales are exposed around the Koffy-Fontein and Jager's-Fontein diamond-mines, and similar rocks about Philippolis and the Orange river.

The Kimberley shales continue over this district, and all the points are within 200 or 300 feet of the same level. Films only of coal and seams of hard shale with fossil ferns have been found near Kimberley.

Towards the higher ground to the east the shales are somewhat different in character, at least as regards their weathering, due to the presence of a greater proportion of oxide of iron. Proceeding towards the Cape Colony, chocolate- and olive-coloured shales are met with; and Mr. Stow states that "red-chocolate shale is found underlying a sandstone zone near Bethlehem" (Report, 1879, p. 31).

At this higher level beds of a more sandy nature become frequent in the shales, which pass gradually upward into a series of fine and coarse sandstones with occasional thick-bedded grits and conglomerates. It is in this series of arenaceous rocks that coal occurs; it is therefore assumed that the boundary-line of these sandstones represents the western limit of the coal-bearing area, with possible outliers as already suggested. This line passes from Bamboes Berg on the south, by Aliwal-North, to the Caledon river, west of Winburg, and to the Vaal river above Bloemhof.

In the northern part of the coal-field (see map, p. 658) the sandstones rest directly on the "Megaliesberg beds;" therefore they overlap the shales in that direction (without any unconformity), as shown in the section (fig. 2) along line A B on the map. The northern extremity of the shales beneath the coal-bearing beds is probably somewhere about the junction of the Vaal and the Wilge rivers.

Throughout both series of the "Kimberley beds" and the coal-bearing sandstones, which for convenience may be provisionally termed the "High-Veldt beds," there are interstratified and intrusive trap-rocks; but as regards the shales, these have had little effect either upon their mineral character or their general horizontality.

The persistent horizontality of these beds, both shales and sandstones, is remarkable. The hills have been carved out of nearly level formations, the thickness of which may be approximately measured by mere differences in elevation. The fall in the base of the sandstones from near Middelburg (Cape Colony) to the Vaal river is equal to only $\frac{1}{10}$ of a degree—that is virtually level, and the shales have the same slight inclination (see fig. 3). The base of the shales at the Vaal river, near its junction with the Hart, is about 3000 feet above the sea; that of the overlying sandstones, on the line of strike from that point, is 5300 feet. The difference, 2300 feet, is the minimum thickness of the shales as they pass there under the sandstones; whether the old surface of the Megaliesberg beds beneath rises or falls makes no material difference. Towards the south the shales may be much thicker; it depends upon how far the Lower

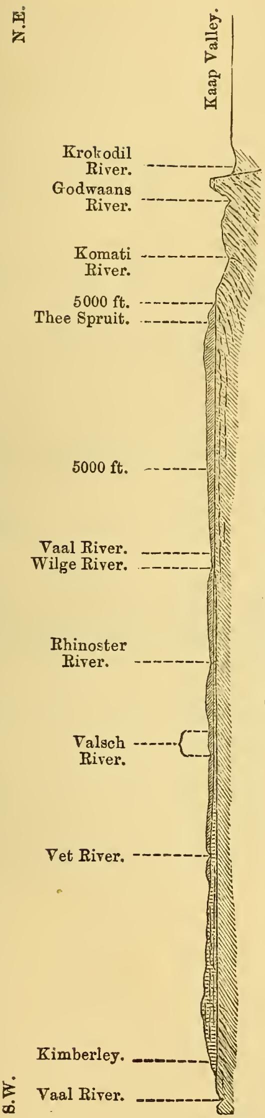


Fig. 2.—*Section from Kimberley to the Krokodil River, along the line A–B on Map, fig. 1.*

For explanation see Map, fig. 1.

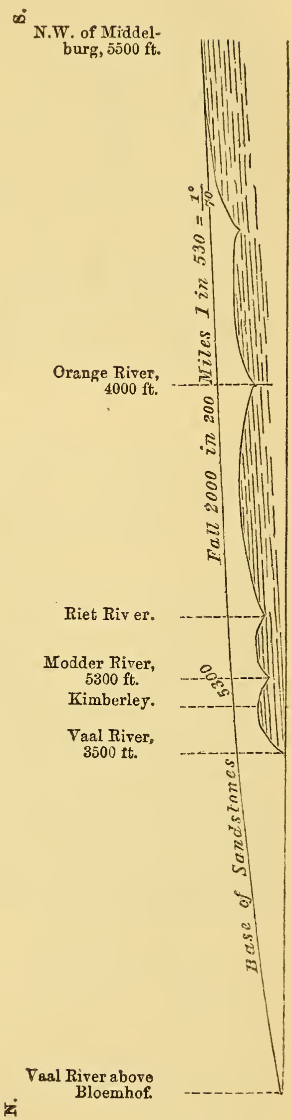


Fig. 3.—*Section from near Bloemhof to near Middelburg.*

Karoo beds extend northward below them; any such additional beds would thin out against the Megaliesberg beds before reaching this part of the Vaal river.

The shales and the trap-rocks, of course, weather very differently, the shales with a flat curve and rounded outline, the igneous rocks, when interbedded, forming steep "krantzes" or precipices; when occurring as dykes, with a rough stony outcrop resembling long lines of water-worn boulders. The rounded form of the loose stones is due to concentric decomposition and weathering; this feature and their brown, frequently glazed, coating have together given rise to two wide-spread errors—that they are "Ironstones" (as generally called), and that they are water-worn. Owing to this difference of weathering and the open nature of the country, beds and dykes may be distinguished by the eye, often for a distance of many miles, along the tops or flanks of the hills, although perhaps intersected by valleys or by steep "kloofs" (gorges), and falling into their proper place in outlying "randts" and "kopjes" (ridges and small hills).

The "High-Veldt beds" are mostly horizontal sandstones, enclosing seams of coal, and vary in texture and hardness from fine-grained crystalline sandstones to coarse grits and conglomerates, and from soft arenaceous beds to a hard rock resembling "Millstone Grit."

The general character of the lower coal-bearing part of the series will be gathered from the following sections; and it appears that similar beds occur to a great height above the lower beds, as the Sneeuwberg range (of which Compass Berg forms a part) consists of rocks of the same description.

An estimate of the thickness of these beds may be formed in the same manner as that employed for the Kimberley beds, that is, after making a slight allowance for dip by the mere difference of elevation. The base of the series, north-east of Middelburg, is about 5500 feet; the Compass Berg has an elevation of 8000 feet above the sea; deducting 200 feet from the difference (for the rise in twenty miles, at $\frac{1}{10}$ of a degree) the result gives a minimum thickness to the sandstone series of 2300 feet.

Tabular Comparison of the Terms used by some Authors.
In descending Order.

Dunn.	Stow.	Penning.
STORMBERG BEDS.	UPPER KAROO.	UPPER KAROO (*so-called*).
Cave Sandstones. Buff, pinkish, greenish-white, and grey, fine-grained, thick-bedded sandstones. 150 feet. (Fragments of Sauroid bones.)	*Uppermost Zone of Lacustrine Beds.* Coarse, rather friable, irregular-bedded sandstones.	*High-Veldt Beds.* As described. 2300 feet.
Red Beds. Friable, red, and purple arenaceous shale; friable red sandstone, mottled green, alternating with grey felspathic sandstones. 600 feet. (Fossil wood in lower beds.)		
Coal-measures. Grey and light-coloured sandstones, generally felspathic, alternating with beds of shale, in which coal-seams occur. Conglomerate beds. 1000 feet. (Casts of plants, fossil wood, &c.) (Coal, 300 to 400 feet above the Upper Karoo beds.)	*Lower Portion of Upper Karoo Beds.* Chocolate shales. Grey shales. "Black-band" (Coal) shales. (The Forest-zone is from 60 to 150 feet above the coal.)	
UPPER KAROO BEDS.		*Kimberley Beds.* Olive- and chocolate-coloured shales. Dark blue and grey and greenish shales. 2300 feet.

Mr. Stow considered that "the great lacustrine series, from fossil remains found in them, appear to be the equivalent of rocks similar to those called 'Triassic' in the northern hemisphere" (Report, 1878, p. 23). The only fossils I have seen in these sandstone beds are of a *Glossopteris* (?), in the sandstones upon a farm where the silver-lode occurs, referred to at page 666. Impressions of ferns were observed by Herr Carl Mauch, in the sandstones at the mouth of the Zinkerboschrandt river, from which he inferred that the High Veldt might prove to be on a coal-bearing formation ('Reisen im Innern von Süd-Afrika,' 1865–1872).

The "Forest-zone" referred to in the Table is described by Stow as "silicated wood imbedded in irregular-bedded coarse sandstones and grits, with various beds of light-coloured shales and sandstones occupying the upper ridges." This fossil wood came under my own observation especially between Brandfort and Winburg. It forms a beautiful fossil, perfectly silicified, in various colours to deepest black, with the texture of the wood preserved in different tints.

Mr. G. P. Moodie, the Surveyor-General of the Transvaal, stated that at Harrismith (about 5000 feet above the sea) there is a krantz of sandstone overhanging shales, in the uppermost of which are numerous fossil reptilian remains.

The volcanic rocks, mentioned by Mr. Dunn as occurring in the "Stormberg beds," are lavas, ash-beds, conglomerates, amygdaloids, and bombs in sandstone.

The "Black-band," as it occurs on the Sand river, near Winburg, and as described by Mr. Stow, is included among the following sections.

Sections.

Commencing at Newcastle, the sections will be taken in order around the outskirts of the coal-field, with occasional brief notes on sections towards its interior, following those upon the marginal point nearest to where they were observed.

Newcastle.—As the name implies, this has hitherto been considered the chief coal-district of this region, and, up to the present time, coal of better quality or in greater quantity is unknown. Baines gives the elevation here as 3800, and of the heights a few miles north of the town as 3936 feet above the sea. The word "Coal" is engraved on Jeppe's map, just *above* a point with an elevation of 3815 feet, and *below* the mountains on the west, which are 5065 feet. The coal-outcrops are therefore between 4000 and 4500 feet in this neighbourhood. Several mines are opened in seams of good coal from 3 to 6 feet in thickness, which I have not seen, but which have probably been described by previous writers.

Near Lang's Nek.—Two seams of coal, from 6 to 8 feet in thickness, occur within a few miles of this pass, where, at about 5000 feet, the main road from Natal to Pretoria crosses the Drakensbergen.

Lebelelasberg.—Coal, in a seam more than 10 feet thick, crops out along the flanks of these mountains, near Wakkerstroom (formerly Martinus-Wessel-Stroom), at 4000 feet or more above the sea. It is dug also on the commonage of that town, a royalty being paid of half-a-crown a ton. The coal is of good quality, yielding only 7 or 8 per cent. of ash.

Near New Scotland.—Lake Chrissie is situated at an elevation of 5755 feet, and coal crops out in both its east and west sides a few hundred feet lower down*. On the west side, near the head of the Vaal river, there are at least four seams, from 4 to 11 feet thick, with thin beds of sandstone between.

The High Veldt.—In some shafts sunk upon two farms near the edge of the plateau, by the road from Middelburg to the Komati, at about 5000 feet elevation, the following sections are exposed:—

No. 1.		No. 2.		
ft.	in.	ft.	in.	
7	0	10	0	Loose ground.
	10	2	0	Inferior, or fine, coal.
1	6	1	6	Black shale.
2	3	+2	3	Coal of good quality (not bottomed in shaft No. 2).

At a pan south of the road about 12 miles east of Middelburg are horizontal sandstones, grits, and ferruginous rock, and a breccia made up of shale, quartz, &c., with a protrusion of weathered trap-rock at the north-east corner†.

A "krantz" (small precipice) on the east side of the road from Heidelberg to the Kaap, where it crosses the Little Olifant's river at an elevation of rather more than 5000 feet, shows the following section:—

ft.	in.	
		Coarse, rather ferruginous grit.
		Fine, white, false-bedded sandstones.
1	0	Laminated sandstone.
1	0	Black shale.
2	0	Coal, of good quality, but much weathered.
1	0	Black shale.
		Coal, not bottomed, water being thrown out by a hard rock below (? trap).
		Fine grit at lower level, seen in the river.

A few hundred yards to the north-west another spring points to the extension of the coal in that direction; and about four miles south-west by the cross roads is another spring in dark peaty soil, presenting similar indications.

Seams of coal have been opened on the High Veldt in several places north of those mentioned, for instance, on the farms of R. O'Neil, J. Holzthuis, and others, also by the "Blink Pan," on Nieukirk's farm, one mile and a half N.N.W. of Koch's store.

Proceeding westward, a stream is crossed at an elevation of 4700 feet, on both sides of which seams of coal crop out in several places, a fact which has given to the stream the name of Steenkool Spruit. The coal is associated with fine-grained sandstones and beds of iron-ore. According to Dr. Atcherley it resembles "Arley Main," and the seams are from 6 to 8 feet thick ‡.

* According to Dr. Atcherley ('Trip to Boerland,' p. 219) there are two seams within a mile of each other, the upper one over 30 feet in thickness.

† Around the margin of this pan a great number of stone-weapons may be found.

‡ 'Trip to Boerland,' p. 219.

Some miles to the north, on Bridge Spruit (Landsberg's), good smiths' coal is said to have been proved and worked, the section being as under:—

ft.	in.	
11	0	Sandstone.
	10	Good bright coal, with thin dull layers.

Between Steenkool Spruit and the Wilge river some fine springs break out on the farm of Van Zweel; along one of the streams supplied by them, called "Dwars-en-de-weg," I observed fine-grained sandstones, with indications of coal not far beneath the surface. There are also beds of pisolitic and of finely granular iron-ore; the latter is easily smelted by the natives, and yields a good iron.

Following the road north-west towards Pretoria, the Wilge river is crossed not far from its source (4862 feet), and coal crops out along its banks here, on the property of Messrs. Moodie, Kruger, and others. Just west of the road a heading has been driven some way into the hill, along a horizontal seam of good coal, from 4½ to 5 feet in thickness; some of this coal has been sent all the way to Kimberley and sold at £15 a ton.

About 3 miles down the river, to the north, and at a much lower level, another seam has been opened just under the water-level, so that its thickness (apparently 2 feet or more) could not be ascertained. The right bank of the river here shows from 20 to 30 feet of crystalline sandstones, fine below, coarser above, in a horizontal position. The ridge above consists of coarse grits and conglomerate. About a third of a mile south these grits dip north-east 3°, and still further south are some false-bedded grits, and a bed like the "Millstone Grit" of England, with a dip similar in amount and direction.

About 6 miles north-west of the last coal-section, by the homestead of the farm upon which a silver-bearing lode has been opened, similar coarse grits are seen, dipping E.S.E. 20°; but a little further west the dip has decreased to 2° only. Further west, about 6 miles, by Power's canteen, rocks of similar character dip sharply to the N.N.E.; and a few miles south-east of this, along the road to Standerton (by Smith's) are again horizontal.

Where the Wilge river joins the Rhinoster-poort some good seams of coal have been worked; and sandstones and coarse grits occur a few miles further north, about the head-waters of the Eland's river, where coal also will probably be found.

Passing from the sources of the Wilge river, over the watershed by the town of Heidelberg, where coal is known to occur, we approach the sources of the Klip river, upon which, 24 miles from the town, and at an elevation of about 4300 feet, are the mines of the "Waldrift Coal-mining Company."

Vaal River.—Although somewhat diverging from the method followed thus far, it may be repeated here that at the head of the Vaal-river valley (about 5000 feet) four seams of coal are known, from 3 to 11 feet thick, with beds of sandstone between.

Next in order comes the Heilbron district (4300 feet), where are the mines of the "London and South-African Coal-mining Company," of which the late Mr. G. W. Stow was the manager. These are the mines from which a great deal of coal has been taken, over 200 miles, to the Diamond-fields, but they are now stopped, owing to bad trade. The beds at Taaibosch Spruit (4200 feet) are described by Mr. Stow as follows ('Report,' 1879, p. 11):—

	ft.	in.	
			Silt, clay, and gravel.
	1	2	Decomposed carbonaceous shale.
	3	2	Black carbonaceous shale, with leaf-impressions (some *Palæozamia*).
15½ feet	1	6	Dull coal.
	1	0	Bright coal.
		9	Dull coal.
		10	Bright coal.
	10	0	Bright and dull coal interlaminated.
	1	4	Bright coal.

At Boschbank the beds are very different (*op. cit.* p. 12), but "between the two localities there is an extensive outcrop of igneous rock forming a stony ridge," which may indicate a local fault, and thus account for the difference in contiguous areas. "The total thickness of the combined coal-seams found here is from 3 feet 6 inches to 3 feet 9 inches, and black carbonaceous shale 5¼ feet, considerable portions of which would be found to be rich as oil-shale."

Coal is asserted to have been found upon the farm "Bloemhof" in this district, the property of Mr. C. C. Kloppe.

Near where the Rhinoster river falls into the Vaal, at about 3800 feet, are the coal-mines of the Orange Free State Coal and Iron Company; the seams are thick and of good quality. Beneath the coal there is a thick bed of shale, so carbonaceous that it burns freely; there is also a bed of clay-iron-stone, or "black-band-ore," which should be valuable in this close connexion with coal.

Coal has been found on Knook's and several other farms in this neighbourhood.

There is said to be an outcrop of coal on Wolver Spruit, which runs into the Vaal from the north, not far from the junction of the Valsch river, and a few miles above Commando Drift.

Just west of Commando Drift, at about 3650 feet, soft black shales, often micaceous, are seen in the banks of the river beneath fine and coarse false-bedded sandstones. At the time of my visit the water was high, so that the seam or seams of coal stated to occur in the bed of the river could not be seen; but I have no doubt of the presence of the mineral.

Coal crops out in a "spruit" near Hoffman's Drift, a few miles further down the river, and must pass in under a "krantz" 70 feet high, of fine and coarse sandstone, with a well-defined bed containing fossil-wood near the summit.

Dark micaceous shales occur beneath similar sandstones, capped by the bed with fossil wood, at Leuw Krantz, a high precipice some few miles down the river. Further down, about the same distance, micaceous shales are seen, tilted by a volcanic dyke, at a sharp bend in the river.

There were good indications of coal observable at Bemhoe's Spruit; and since the time of my visit its discovery there has been reported.

It has been asserted that coal occurs as far down the Vaal river as Bloemhof; but this is doubtful, although it is reasonable to suppose that there may be remnants of seams that once stretched further westward upon the higher lands around the town. The Vet river joins the Vaal a few miles above Bloemhof, and about 12 miles from the junction there are good evidences of coal, which would, however, at the Drift where these were observed, lie below the bed of the Vet river.

Near Winburg.—At Sand Spruit, something over 5000 feet, the "Black-band" occurs, and is described by Mr. Stow as under ('Report,' 1878, p. 33):—

	in.	
The "Black-band"	6	Coal.
	5	Black carbonaceous shale.
	3½	Flaky coal.
	2½	Black shale.
	2½	Flaky coal.
	5½	Coal.
	12	Slate-coloured shale, full of plant-impressions (*Glossopteris*, *Palæozamia*, *Rubidgea*, &c.), and containing iron-pyrites.
	1	Coal.
		Shale as above.

At Brandfort (south-west of Winburg) the "Forest-zone" of Mr. Stow is seen on many of the hills, and can be traced for long distances, the surface of the ground below being strewn with many fragments of the silicified wood. Accepting his estimate as correct for this locality, coal should occur on the flanks of the hills or in the valleys at about 100 feet below.

At Cornet Spruit, at an elevation of over 5000 feet, Mr. Stow observed "two seams of coal, the one 9 inches, the other varying from 9 to 15 inches thick, with a belt of black carbonaceous or oil-shale from 2 to nearly 3 feet thick between them" ('Report,' 1878).

Burgersdorf.—Upon several farms a few miles east of this town, and at about 5000 feet elevation, is a seam of coal, proved upon Leuw Vlei to be 4½ feet thick, by a drive 60 feet into the hill. The mineral somewhat resembles anthracite; it is hard, heavy, and dull, and gives a great heat, burning with a small bluish flame. The formation is sandstone, and there is much intrusive trap-rock in the locality.

At a somewhat higher elevation, and about 30 miles south of Burgersdorf, is the Bamboes Berg, a mountain near the summit of which are several coal-mines. The most important of these is on the farm "Cyfergat," 5400 feet above the sea, where a drive has been opened, about a thousand yards from the foot of a hill 800 feet high, which discloses the following section:—

in.	in.	
		Hard Sandstone (about 20 feet thick).
7½		Coal.
	4	Shale.
8½		Coal.
	4	Shale.
4		Coal.
	6	Shale.
1		Coal.
	6	Shale.
16½		Coal.
		Fire-clay (about 5 feet).

Coal 3 ft. 1½ in.
(The beds dip to north-east at about 1°.)

The one-inch seam, being poor, is not used; but without this the aggregate thickness of good coal exceeds 3 feet. It is hard. bright, and bituminous, and yields about 23 per cent. of ash. The bottom layer is the best, about 7 inches of it being picked out for smiths' work, and equal, it is said, to any imported coal. There is much iron-ore on the surface here, and Mr. D. W. Jones, the manager for the Cyfergat Company, says in his 'Report to the Directors,' dated 30th June, 1883:—"In sinking a well on the flat below the cottages I discovered a seam of hematitic iron-ore, containing 50 per cent. of metal."

Molteno.—About 3 miles north-west of Cyfergat, and at about 200 feet lower level, are the mines of the Great Stormberg Coal-mining Company, upon the farm "Paarde-Kraal" and the town-commonage of Molteno. A drive into the side of the Molteno hill shows:—

in.	in.	
		Hard Sandstone.
8		Coal.
	4	Shale.
6		Coal.
	6	Shale.
14		Coal.
		Sandstone.

Coal 2 ft. 4 in.

(Beds horizontal, or nearly so.)

The Molteno coal yields, it is said, 33 per cent. of ash, and is very hard, but answers well for steam purposes; that from Paarde-Kraal is more like the Cyfergat coal in quality.

Coal crops out on several other farms in the Bamboes Berg, in 3- to 4-foot seams, similar to that from Molteno or Cyfergat. On one farm, called "Uitkyk," east of Cyfergat, there is a hill 600 feet feet higher than the mines, on which occurs an outlier of coal 3 feet thick, under sandstone, and about 2 acres in extent.

This hill overlooks a deep "kloof" or gorge, opening to the east and about 1800 feet in depth; part way down, perhaps 200 feet, some seams of coal crop out, which may be the same as those worked in the mines at Cyfergat. At the bottom of this gorge, on its north side, a 4-foot seam of hard coal has been worked which dips sharply to the north; the workings were abandoned owing to the difficulty of dealing with the water.

Noting the great difference in level between this and the other sections in close proximity, and the fact of the beds here being greatly tilted, whilst at the higher point (as generally throughout the area) they are horizontal, I am inclined to regard the presence of coal-beds here as due to a fault or series of faults, with a main downthrow to the east.

At *Indwe*, about 20 miles east of Dordrecht, a seam 11 feet thick has been mined by several hundred yards of drive between a floor and a roof of massive sandstone. The seam consists of about 7 feet of good coal, with shale partings, the upper 2 feet being of excellent quality.

It was stated above that coal has been found outside the boundaries of the High Veldt coal-fields. One of the places is to the north of Boshof and about 30 miles east of Kimberley. If the report be correct in this case, it will probably be found that the coal occurs either as an outlier of the sandstone or as a very small local seam in the lower (Kimberley) shales.

Bright cannel-like coal has been taken, I was also informed, from the neighbourhood of Bethulie, and used at the Jager's-Fontein Diamond-mine.

Sandstones similar in appearance to those of the known coal-bearing series occur between Philippolis and Colesberg, which may indicate a former extension of that series down the Orange river; but it is doubtful if the coal itself extended far in that direction. A similar remark applies to the sandstones between the Modder river and Kimberley.

A seam of bright coal, only 1 inch in thickness, occurs in the Doorn Hoek, west of Bamboes Berg, in the Zuurbergen.

It is well known that coal occurs at a much lower level in Natal on the east side of the Drakensberg, but I have had no opportunity of examining into its relation to the subject of this paper. It may belong to a more recent formation, or it may have been thrown down by a large fault or series of faults, the presence of which I suspect along the steep eastern side of that range.

Mr. A. C. Cruttwell, F.G.S., assures me that beds of the same character as those of the High Veldt occupy all the lower ground as far down as Pietermaritzburg, and down to about 1000 feet above the sea, with a Tertiary flow of lava over all, and that these rocks all dip to the south-west.

Coal occurs to the west of the "poort" by which the Umbelosi river passes through the Lebombo mountains. It is known also in the Oudsthorn, thus approaching the southern extremity of the continent.

The most northern point in the Transvaal at which coal has yet been observed is on the Letsobo river, where Carl Mauch discovered a seam 2 feet in thickness.

Hübner * records the occurrence of slightly upheaved sandstones, with imperfectly preserved remains of plants (which very likely belong to the Karoo formation), south-east of Shoshong—that is, between the Serorume and Limpopo rivers; also, much further north, in lat. 20° S. and long. 29° E., of rather brittle, horizontally-stratified sandstones, which show petrified woods.

"Are these latter perhaps of the same age as the sandstones which Livingstone found at Pungo Andongo (lat. 9° 40′ S., and long. 15° 30′ E.) at almost the same altitude, viz. 4000 feet, and in which he found petrified palms, or those near Tete (lat. 16° 10′ S., long. 33° 35′ E.) at an altitude of 1500 feet, which show horizontal layers of coal covered by strata of petrified palms and Coniferæ?" (Jeppe, 'Notes on the Transvaal'). If this be so, it would indicate an extension of the main high-level coal-field a long way towards the interior, with a coal-field at a lower level on the east, in an exactly similar relative position to that on the seaward side of the Drakensberg.

In conclusion, a few inferences may be briefly drawn from the above notes.

1. The coal-bearing rocks, although broken and disturbed in many places, are, upon the whole, nearly horizontal, the base of the formation resting on a slightly inclined plane, upheaved in some places, let down in others, by the intrusion of dykes, the influence of which has extended to no great distance. This is proved by the almost perfect coincidence of the coal outcrops and the boundary of the coal-bearing series with the contour-lines of the country.

2. The slight divergence of these lines from the contours shows that the basal plane is inclined somewhat more in the northern than in the southern part of the area, forming a gentle anticlinal from east to west across the centre; also that it is depressed westwards towards the Vaal river: but the divergence from horizontality is so slight that it may be due either to upheaval or to inequality of deposition.

The sections described show that:—

On the east the coal crops out from Newcastle to the north-east corner of the High Veldt, at an elevation of from 4000 to 5000 feet.

* See Petermann's 'Mittheilungen.'

It falls gradually across the northern rivers and along the Vaal to above Bloemhof, from 5000 to 3500 feet.

And (as shown on fig. 3, p. 661) from the Cape Colony to the same point, from 5500 to 3500 feet.

3. This approximate coincidence of the outcrops and contour-lines all around the high-level coal-fields, broken only by local fractures, indicates the continuity of beds similar to those exposed at the outcrop throughout the intervening area, interrupted probably by local disturbances, but quickly resumed. Therefore it may be safely concluded that seams of coal equal to those exposed in the sections occur (with small local exceptions) over the whole of the vast area upon the map *.

4. Although there is no evidence from deep shafts or borings, it is more than probable that there are many seams at different horizons in the lower part of this formation. This is indicated by the occurrence at different levels of horizontal seams, without any indication of faults between, as, for instance, in the sections about the head of the Wilge river.

5. The relative position of the basal plane at any point may be approximately ascertained by drawing a line through that point to the outcrop on either hand, and allowing for the proportionate rise or fall. The depth to the lowest coal-bearing rocks at such point will be the difference between the height of the basal plane thus ascertained and the surface-elevation.

Discussion.

Prof. T. Rupert Jones remarked that it was unfortunate that all Mr. Stow's observations had not yet been published in detail. In the present paper the author had brought together many useful observations; but he thought it was to be regretted that each writer on South-African geology should think it necessary to make alterations in the names applied to the deposits. Mr. Bain's "Great Karoo" formation had by degrees nearly disappeared.

Mr. W. T. Blanford said that there were two points in the paper to which he thought attention should be called. One was practical. The evidence of the seams scarcely justifies the conclusions stated as to the mineral wealth of the country. It is an error to suppose that beds of coal are continuous over great distances because they are so throughout comparatively small areas. Moreover, the quality and thickness of seams are very variable even over moderate areas, especially when the roof is of sandstone. Then as to the geology:—these beds are spoken of as lacustrine, but he thought there was no evidence upon this point, and that the beds are more probably subaerial and fluviatile. He could not agree with the author,

* In Dr. Atcherley's book, 'A Trip to Boer-land,' I find that at p. 220 he says:—"There can be little doubt that the whole High Veldt is one immense coal-field."

that the evidence brought forward indicated a subaqueous origin for the trap. Horizontal intrusions are very common in sandstones and coal, and, as a general rule, very slight alteration is produced by them.

Dr. Exton said, that the configuration of the country favoured the idea that the same lacustrine conditions had formerly existed in the south as were now present in central Africa. He called attention to a prognostication by Mr. Bain, that a great volcano would be found to have existed between the Orange and Vaal rivers, the evidence being the trap which remained on the summits of the table-mountains in that region. The Diamond-mines are now worked within the old volcanic chimneys. Dr. Exton further called attention to Mr. Stow's observations on the relative distribution of red beds and coal-bearing rocks, and to his belief that coal, which was first found in the south-east of the plateau, would also crop out in the north-west—a view since confirmed. Coal has been worked in the Orange Free State; but the carriage is too costly. The author's description of the country as one vast coal-field was an exaggeration.

46. Fossil Cyclostomatous Bryozoa *from* Australia. By Arthur Wm. Waters, Esq., F.G.S. (Read June 25, 1884.)

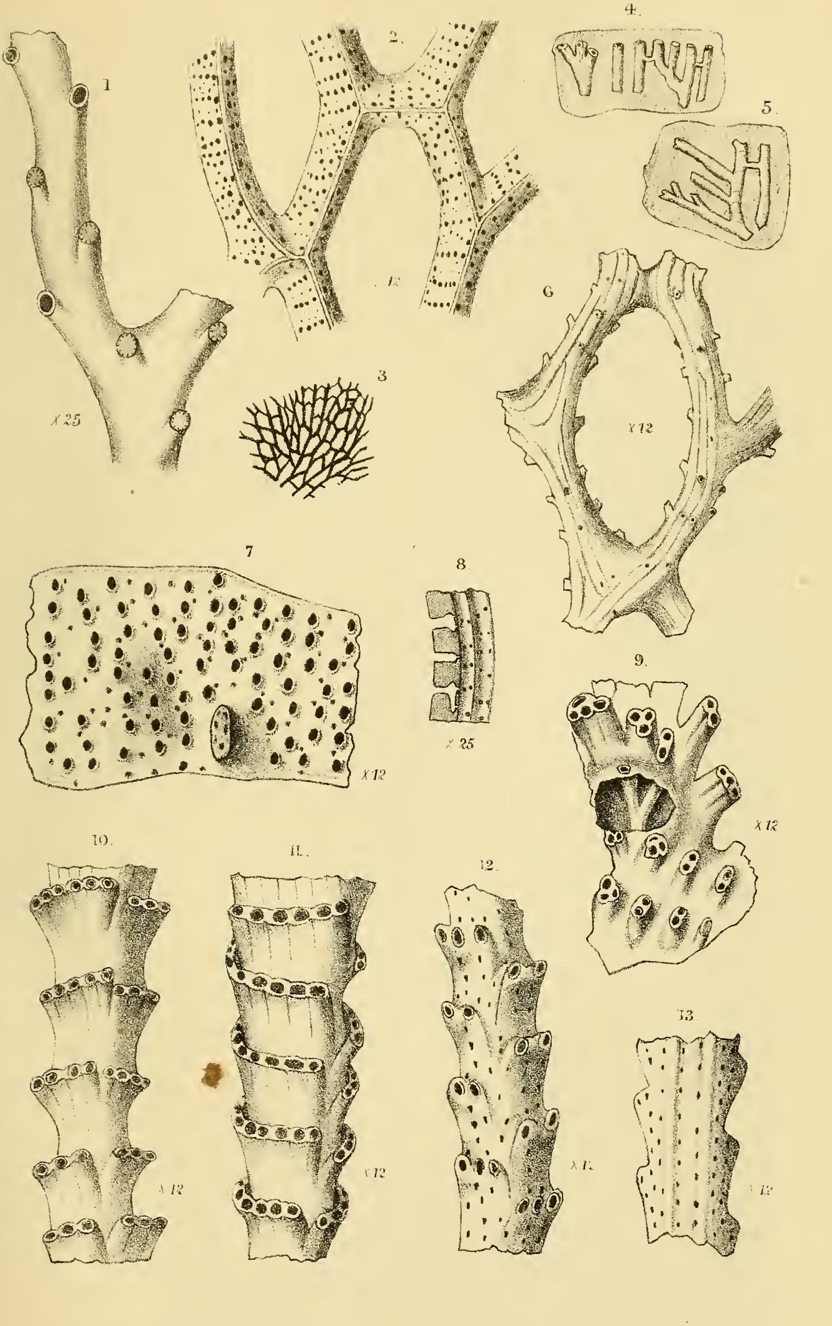
[Plates XXX. & XXXI.]

I have already described in the Journal of this Society the Chilostomatous Bryozoa from Curdies Creek, S.-W. Australia (vol. xxxvii.), Mount Gambier, South Australia (vol. xxxviii.), Bairnsdale, Gippsland (vol. xxxviii.), and Muddy Creek, Waurn Ponds, and Bird Rock, Victoria (vol. xxxix.). But the Cyclostomata I kept back, in order to deal with them all together; and since I completed my last paper I have received for description from Prof. Tate an interesting collection from Murray Cliffs and Aldinga *, South Australia, and all are now considered together. I have also in my hands a collection of fossils (belonging to Miss E. C. Jelly) from Napier, New Zealand, to which I allude in the text.

The determination of the Cyclostomata presents much greater difficulties, and is much more unsatisfactory than that of the Chilostomata, as there are fewer characters which can be used, so that classification has been made to depend principally upon the mode of growth—a character which has frequently proved of no value in the Chilostomata. Until within a recent period this was in both considered the main characteristic; but now, thanks to the labours of Smitt, Hincks, and other recent workers, it has been shown to be of secondary importance in the classification of the Chilostomata, which, however, possess many distinctive characters, such as the

* The Chilostomata from the "older Tertiary" of Aldinga and the River Murray Cliffs are very similar to those already described from the other Australian localities; and although they have not yet been thoroughly examined, a provisional list will show this similarity:—

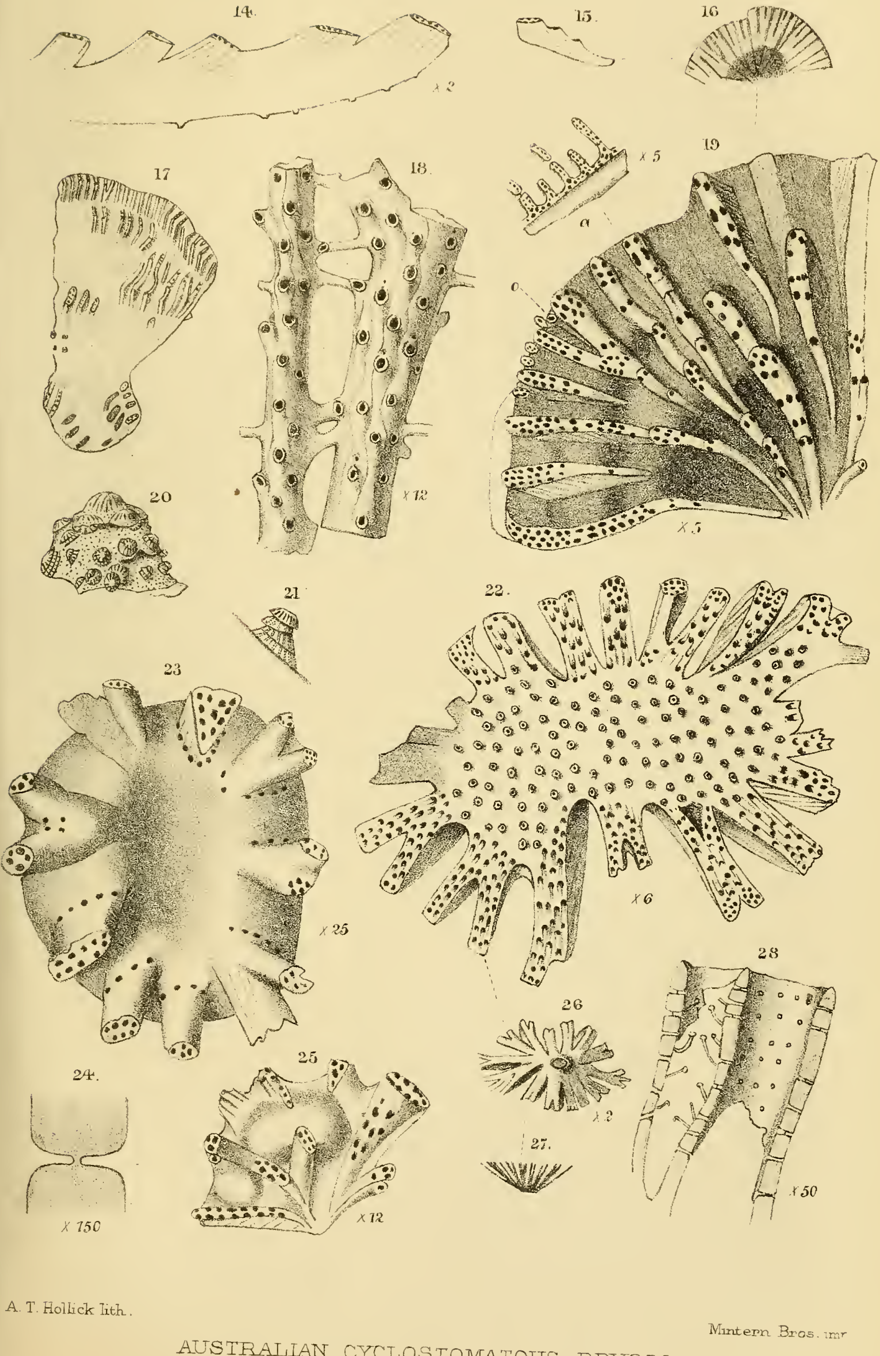
Membranipora cylindriformis, *W.*, M. Cl.
—— radicifera, *Hincks*, M. Cl.
—— rhynchota, *Busk*, M. Cl.
—— aperta, *Busk*, Ald.
Micropora patula, *W.*, Ald. and M. Cl.
Monoporella crassatina, *W.*, Ald. and M. Cl.
—— sexangularis, *Goldf.*, Ald.
Steganoporella magnilabris, *B.*, M. Cl.
Cribrilina terminata, *W.*, M. Cl.
—— figularis, *Johnst.*, M. Cl.
—— radiata, *Moll*, M. Cl.
Microporella elevata, *Woods*, M. Cl. and Ald.
—— coscinopora, *Rss.*, M. Cl.
—— symmetrica, *W.*, M. Cl.
—— introversa, *W.*, M. Cl.
Microporella (Lunulites) magna, *Woods*, Ald.
Porina coronata, *Rss.*, Ald. and M. Cl.
Lepralia burlingtoniensis, *W.*, Ald. and M. Cl.
—— edax, *Busk*, M. Cl.
—— depressa, var. as from Bairnsdale, Ald.
Smittia Tatei, *Woods*, Ald. and M. Cl.
—— seriata, *Rss.*, M. Cl.
Schizoporella simplex, var., Ald.
—— vulgaris, *Moll*, Ald.
—— phymatopora, *Rss.*, M. Cl.
—— striatula, *Sm.*, M. Cl.
—— fenestrata, *W.*, M. Cl.
Mastigophora Dutertrei, *Aud.*, M. Cl.
Rhynchopora bispinosa, *Johnst.*, M. Cl.
Retepora.
Cellepora fossa, *Hasw.*, Ald. and M. Cl.
—— verruculata, *Sm.*, M. Cl.
Lekythopora hystrix, *MacG.*, M. Cl.
Lunulites guineensis, *Busk*, Ald.
Selenaria maculata, *B.*, M. Cl.
—— parvicella, *Woods*, M. Cl.



A. T. Hollick lith.

Mintern Bros. imp.

AUSTRALIAN CYCLOSTOMATOUS BRYOZOA.



A. T. Hollick lith.

Mintern Bros. imp.

AUSTRALIAN CYCLOSTOMATOUS BRYOZOA.

form of the cell or zoœcium, together with the shape of the aperture (which is, perhaps, best indicated by the shape of the operculum); the presence, in a large number of cases, of a suboral pore or suboral avicularium, giving, in their various modifications, useful characters; and the position and nature of the avicularian and vibracular appendages furnish further means of recognition, though their presence or absence does not seem in all cases to be of much importance. Besides these we have the ovicell, which by its form frequently gives most valuable characters; and the shape, position, and number of the rosette-plates are also, where available, of the greatest value.

Before turning to the description of the Australian Cyclostomata, I have, during the last few years, spent a great deal of time in examining whether there are not other characters, besides the mode of growth, which may be used; and although the results are not encouraging, yet by means of more careful observation I believe that it will ultimately be possible to arrive at a more natural system than obtains at present. It will be best to consider the structures as far as possible in the same order that was adopted in discussing the characters of the Chilostomata.

The zoœcia being all tubular and quite simple, there is no variation here corresponding to the various shapes of the Chilostomata; and again, as the form of the aperture is always round or slightly elliptical, the only character here available is that of size (pointed out as useful by Smitt some years ago), which seems to be fairly constant in the same species. The variation in size is not very great, ranging only from about 0·03 millim. to 0·2 millim. in all species measured, but anything greater than 0·16 millim. or less than 0·07 millim. is very exceptional. There is also no operculum, which gives such useful characters in the operculated division; but, on the other hand, the zoœcial tubes are closed up by a calcareous plate, usually at a short distance from the aperture; and in a paper on the "Closure of the Cyclostomatous Bryozoa" (Journn. Linn. Soc. vol. xvii. p. 400, pl. xvii.), I have pointed out that the position of these closures, together with the nature of the perforations, is a character of considerable importance, although it is neither so available nor so important as the horny operculum.

Among the Palæozoic fossils there is in one or two a structure which may represent the suboral pore or avicularium; and as long as we do not know the signification of the "adventitious tubules" of *Diastopora obelia* &c., we may be justified in asking if they may not possibly have had an homologous origin.

No Cyclostomata have avicularia or vibracula, and there does not seem to be any structure to in any way take their place.

The ovicells are of the greatest value, but, unfortunately, are not found so frequently as in the other suborders. As yet but very few have been described, and with fossils the number known is extremely limited; but this to a certain extent arises from their having been neglected; for in my collection I have a much greater number of fossil ovicells than the total number which have so far been described fossil.

In a large number of Cyclostomata the ovicell is a nearly globular or pyriform sac, as in *Crisia*; in others it is an irregular inflation, partly enclosing some of the zoœcia; and in nearly all these cases the wall of the ovicell has small pores, of the same size as those in the zoœcial wall, but much closer together than in any other part of the zoarium. In *Idmonea radians*, Lamk., however, there is a much more elaborate structure; for here the front has large ridges and large openings, but at the side there are plates surrounded by raised borders, and these plates are perforated by very numerous pores placed close together *. In *Hornera* the ovicell is usually, or perhaps always, on the dorsal surface; and as this is the case in *Idmonea irregularis*, perhaps it should be removed to *Hornera*, for which there seemed before some reasons; in other genera the ovicell occurs on the front.

In the Lichenoporidæ the ovicell is, as a rule, an irregular inflation; but in a specimen of *Lichenopora* which no doubt is *L. novæ-zelandiæ*, Busk, the ovicell is considerably raised, and occupies the whole of the centre of the zoarium. The central part of this raised ovicell is flat, and is surrounded by a raised meandering line, and in this flat portion there is a semicircular opening.

There is considerable variety in the form and size of these ovicellular openings, and it seems that this character should always be given, if possible, in describing any species. The opening is very frequently infundibuliform; sometimes directed forwards; in other cases, as *Tubulipora*, sp., directed backwards. In *Hornera lichenoides*, Smitt, and in my specimens of *H. frondiculata*, the opening is lateral; but Mr. Busk gives it as superior.

The next character of the Chilostomata mentioned was that furnished by the rosette-plates, and I have shown that there is a great detail variety in the way in which the connexion between the various zoœcia takes place through these rosette-plates. In the distal wall the number of these plates varies from 1 to 4, and in the lateral wall from 2 to 8 or more; and further, the rosette-plate itself varies in shape and size, and also in the number of openings or connecting-points. Having made preparations of the rosette plates of a large number of species, I find that almost all show some characteristic points, and consider that they furnish most useful specific characters; but in the Cyclostomata there are no rosette-plates, and so we are led to ask What is the equivalent of so important a structure? and can it be used in classification? In order to answer this question, I have prepared a large number of sections of the calcareous framework of recent and fossil Cyclostomata, and find that in the walls of the tubular zoœcia there are usually two kinds of pores or openings: first, the very small ones which open to the exterior of the zoarium, and these we will call surface-pores; it is these which cause the dotted surface familiar in *Crisia*, most *Idmoneæ*, *Tubuliporæ*, *Stomatoporæ*, *Entalophoræ*,

* From Naples I have an *Idmonea*, perhaps *I. triforis*, Hell., with very curious ovicells. In the place of a series of zoœcia there is a raised chamber, in shape like the bag of a bagpipe, with a few large pores on the surface, giving it much the appearance of the ovicell of *Hornera frondiculata*,

Filisparsæ *, &c.; and further, I find that the size (0·008 millim.) of these pores varies but very little, having preparations of recent, Tertiary, Cretaceous, and even Palæozoic forms of many genera showing scarcely any variation in this respect. This structure is well shown in sections figured by J. Beissel, especially in pl. x. fig. 127, in his paper "Ueber die Bry. der Aachener Kreide," Nat. Verh. Holl. Maat. Weten. Haarlem, xxii[e] Deel—a most valuable work, which does not seem to have received the attention it deserves. These, I take it, are the homologues of the much larger pores in the front of nearly all Chilostomata, which there also cause the zoœcial ornamentation. Besides these, there are in the interior of the Cyclostomatous tube much larger pores, and these I have found to occur with a certain amount of regularity, and approximately at certain distances apart; so that when a zoœcial tube is cut open correctly along its axis, one or two rows of these pores are seen, and the position of the rows and the distance apart of these interzoœcial pores seem to be of specific importance. Having noticed this much, it is not unnatural to consider these pores the homologues of the rosette-plates of the Chilostomata, and upon more careful examination we find support for this view. This can best be studied where the pores are long, as, for instance, in *Heteropora pelliculata* †, Waters, in which a diaphragm or plate, seemingly perforated in the centre, occurs in the middle of the pore-tube (see Plate XXXI. fig. 24): and thus it seems entirely to correspond to the simplest of the rosette-plates among the Chilostomata.

As already indicated, probably the typical distance and the order of these pores will in most cases be distinguishable; yet there is not an absolute regularity, and it must be remembered that in the Chilostomata when the number of rosette-plates increases so does the irregularity; when there are four or six lateral plates it is by no means uncommon to find that one of these is replaced by two smaller ones; but then upon examining the walls of two or three cells the type can be made out.

In such genera as *Entalophora* &c. there are always the fine surface-pores ‡, although sometimes from the state of preservation or fossilization this is not apparent, and a great number have been incorrectly described as without this structure; but in some genera, such as *Hornera*, some *Idmoneæ*, such as *Idmonea radians*, and a number of others both living and fossil, there are, over part of the

* There are also such pores on the dorsal surface of *Lichenopora*; and as this dorsal surface is attached to stones, &c., it is in such cases difficult to understand their use.

† There is no doubt at all that *H. neo-zelanica*, Busk, is only a synonym for *H. pelliculata*. The New-Zealand specimens, for which I am indebted to Prof. H. A. Nicholson, had evidently been dead some time, and the exterior was slightly stained and corroded; but the interior was well preserved, and the internal characters are identical in these and the Japan specimens; and the difference in the shape of growth is not greater than in the series of Japanese specimens in the British Museum.

‡ In recent *Idmonea Milneana*, these "dots" are raised; but here also they are perforated, as pointed out by Mr. S. O. Ridley, so that this only indicates an elongation of the pore-tube.

surface at any rate, and sometimes over all, larger openings giving a peculiar ornamentation to the surface; these large surface-openings do not, however, enter directly as such into the zoœcial tube, but at the base there are one or more minute openings leading to the zoœcial cavity (see Pl. XXX. fig. 8). In *Idmonea radians* these large exterior openings all occur at the junction of two zoœcia; and in some *Horneræ*, as *H. reticulata*, the posterior surface is divided into reticulations, in each of which there is one or more of these large openings.

Still another character which may be of some use in testing the correctness of classification is the presence of "numerous minute rays" (Crag. Polyz. p. 122) in the zoœcia and canaliculi, or as I called them in *Lichenopora radiata* (Bry. Naples. p. 276) "delicate hair-like teeth," which occur in several *Lichenoporæ* and then have globular terminations.

In *Heteropora pelliculata*, Prof. Nicholson has figured them (Ann. & Mag. Nat. Hist. 1880, p. 8), but he does not seem to have noticed that they had globular terminations, though in sections made from a specimen which he kindly gave me I find this to be the case (see Pl. XXXI. fig. 28).

In what I call *Heteropora cervicornis* (Recent Heterop. Journ. R. Micr. Soc. vol. ii. p. 392), which MacGillivray has since described as *Densipora corrugata*, there are short obtuse teeth inside the zoœcia, and in some Cyclostomata these are still further reduced, so that the inner surface appears irregular without definite teeth. This is, however, a character that will probably but seldom be available in studying fossils.

The examination of the Chilostomata has shown that the mode of growth is in most cases of secondary importance, and that the form of the zoœcia must be considered as of far greater value. This not unnaturally leads us to see that with the Cyclostomata also slight differences of growth must not be used as generic characters; but we must not allow this to carry us too far, though what has been learnt in the Chilostomata will convince us that so long as the classification of the Cyclostomata is based upon so few characters we may yet be far from a natural one.

Such characters as whether there is one layer of cells, as in the *Lepraliæ* of the older writers, or two, back to back, as in *Eschara*, or whether the zoarium is reticulate, have been unhesitatingly abandoned as of no generic value; and in the same way there are reticulated *Idmoneæ*, *Horneræ*, *Filisparsæ*, and many other genera, and the differences between *Diastopora*, and *Berenicea* or *Mesenteripora* cannot be considered as very great; but in the Cyclostomata there are some such characters as the occurrence of definite bundles of zoœcia in *Frondipora*, *Fasciculipora*, &c., which must be looked upon as of far different importance, and in the same way the presence of interspaces *, forming cancelli, between the zoœcia does so far seem a character of great value, and these seem to indicate a different origin of the zoœcial tube.

* By using the word "interspaces" it will be seen that I do not accept Prof. Nicholson's suggestion that the cancelli "were occupied by a set of zoöids."

There is in certain Chilostomata a tendency for one layer of zoœcia to grow superposed upon the preceding one, as, for instance, in *Schizoporella sanguinea*, *Micropora impressa*, Moll. In *Nodelea*, from the Chalk, this is also the case, and upon this peculiarity the genus *Multinodelea* was founded; but from specimens of *Nodelea angulosa* I collected from the Chalk of Royan it is clear that it occurs in both forms, and the same thing is frequently found in the Cyclostomata, and probably should but seldom be used as a generic character.

In a specimen of *Diastopora lamellosa*, Mich., from the Oolite, there is the usual growth, consisting of two layers of zoœcia growing back to back, but on one side there are two other layers superposed on the original one.

This is not the place to fully discuss the various classifications of the fossil Cyclostomata, but none yet seems at all satisfactory. Beginning with d'Orbigny's, although many of the principles adopted were undoubtedly good, yet he carried it out so unsatisfactorily that what is good in it has been too much neglected; and coming next to Busk's in the Crag Polyzoa we certainly cannot now accept any classification which separates under two quite distinct divisions *Pustulopora* and *Spiropora*, the one falling under the section "cellulis distinctis" and the other under that "cellulis indistinctis," and I must confess my utter inability to understand in the least what this division means, and what it is based upon. Again, while *Discoporella* and *Defrancia* are united in one family, *Fungella*, *Frondipora*, and *Fascicularia* are placed in three; and a study of Mr. Busk's synoptical table cannot fail to leave us impressed with the difficulty of the classification of the fossil Cyclostomata. Before the third part of the catalogue of British-Museum Bryozoa was written, Smitt's classical work had appeared, and of course was to a large extent followed; but I am inclined to look upon the removal of *Defrancia* from the Fasciculinæ as a slip on the part of Mr. Busk.

Next comes the work of my friend Mr. Hincks; but the range of recent British Cyclostomata is so small that it does not help us much in considering general classification. I certainly cannot follow him at present in separating *Hornera* from *Idmonea* in the families Horneridæ and Tubuliporidæ.

Although it would be impossible here to give a complete history of all that has been attempted in the way of arrangement, we must mention the efforts of Dr. H. Hamm; but certainly the thesis (Die Bry. des Mastr. Ober-Senon. 1 Th. Cyclost. Berlin, 1881), does not deal with the difficulties in a way which recommends itself to my mind; for it is not new genera and families that are wanted, but to show the connexion of those now used, instead of creating on a slender basis fourteen new genera of fossil Cretaceous Cyclostomata, where genera already exist in overwhelming superabundance; and further his third type, the Stigmatoporina, is certainly doubtful, as it is largely, if not entirely, composed of Chilostomata*, *Multelea magnifica*, d'Orb., and

* *Elea*, *Myriozoum* and some others may possibly have to be grouped together as a division of the Chilostomata; but, with opercula and avicularia, they have nothing in common with the Cyclostomata.

others having distinct avicularia; and probably *Meliceritites* should be entirely abandoned. On the other hand, however, Dr. Hamm has done service in showing the importance of the manner in which the new zoœcia arise in the colony.

Mr. Vine has brought together in the British Association Reports a vast amount of material bearing upon the classification of Cyclostomata up to the age of the Cretaceous, and it must be of great use for future workers. For my own part I much doubt if we are yet in a position to frame anything approaching to a natural and final classification of the older forms; but this opinion may arise from my extremely small acquaintance with Palæozoic Bryozoa; but neither do I think we have nearly arrived at that point with the recent and neozoic forms, and until this is the case we can hardly expect to be quite sure about the older ones; and I have often urged upon my friend Mr. Vine that more information concerning the minute structure would be most valuable from so good a worker.

For my own part I must at present be content with making known further material which should be of some use in assisting towards more definite ideas of the group, and while I have given some indications as to various directions for investigation, a collection like the present, where many are not perfectly preserved, where few have ovicells, and where there is often only an isolated specimen, is not favourable for testing any system.

However we attempt to arrange the Cyclostomata, the divisions are found not to be very distinct, and many of the genera generally accepted must be discarded. To take an example, the growth of a typical *Spiropora*, such as *S. verticillata*, may seem marked enough to form a genus *Spiropora*; but in several specimens of *Spiropora conferta*, Rss., from Val di Lonte, there are parts of the colony where the complete circle of zoœcia is most typical, whereas in other parts of the same colony the cells are arranged irregularly quincuncially, and this is especially the case near the bifurcations. Here part of the colony might be determined as *Spiropora conferta*, Rss., and the other part as *Entalophora pulchella*; and on this account I have dropped the genus *Spiropora* and united it to *Entalophora*; again, *Filisparsa* comes very near to *Entalophora*, and in its turn *Filisparsa* approaches such a form as *Idmonea irregularis*, Meneg., which is most difficult to place, as sometimes the cells are so distinctly serial as to give it every appearance of *Idmonea*, while at other times the appearance is that of *Filisparsa*; but the ovicell of the Mediterranean *Filisparsa* is on the front of the zoarium, and that of *I. irregularis* on the dorsal surface, which would seem to indicate that it should probably be relegated to *Hornera*.

The available characters in the Cyclostomata being much fewer than in the Chilostomata, we are on this account not likely to find the first as useful palæontologically; and further as they are less highly differentiated, it should not surprise us to find them more persistent through various periods; and *Entalophora verticillata*, which may be said to be as simple as any known form, consisting as it does of the zoœcial tubes placed round an imaginary axis, each row having the openings at equal distances with the regularity of vegetative repetition, occurs widely from the Palæozoic to these Australian beds.

For the same reasons we cannot feel as sure that similar specimens from widely separated strata are identical, since there may have been differences in the organic structures which have left no record, and therefore there is more uncertainty than with the Chilostomata, because the correlation of a number of characters is a justification for considering the species identical. On the other hand I consider that so long as no difference is discoverable, the name already adopted must be used, however great the interval in space or time may be between the two. This may seem an unnecessary remark, for with shells and other fossils it is generally recognized; but the contrary mode of proceeding has occurred frequently with authorities on the Bryozoa; for instance, Ulrich names a fossil *Mitoclema cinctosa* (a new genus and species), because no Entalophoridæ are "known to occur in older strata than Jurassic." On page 685, I refer to this as apparently not differing from the European Chalk fossils. Again Dr. Fischer (in Bry. Echin. et Foram. p. 27) protests vigorously against giving the same name to specimens from different latitudes, and still more if from Secondary or Tertiary deposits. This he considers dangerous, and that we should doubt the perfection of our means of investigation.

The results, however, obtained by the leading workers during the last ten years have shown what an extremely surprising wide distribution many of the common and highly developed Chilostomata have; and to me it seems that to give two names to what we cannot distinguish because one is European and the other Australian, or because one is of Tertiary age and the other of Secondary, is only hiding our want of knowledge behind a name. Certainly one of the reasons that make d'Orbigny's 'Paléontologie Française' so difficult to use is, that however much the fossil Bryozoa might correspond, yet, if from different strata, they were almost sure to receive two christenings.

In the fossils now described many are found to have a wide range, and this has already partly been dealt with; but another factor lies in the fact that the genera of Cyclostomata to be mentioned are, apparently, mostly not shallow-water forms, whereas many of the Chilostomata no doubt lived at a less depth. With the exception of occasional *Crisiæ*, *Tubuliporæ*, and *Stomatoporæ*, I did not find any Cyclostomata in the Bay of Naples in shallow water; and it seems that most of this suborder are found in comparatively deep water. This may arise to a large extent from the difference in structure, as probably the greater protection given by the horny operculum makes the Chilostomata more able to live in the shallower, and consequently more disturbed and less pure water; and any fauna from a deep zone is likely to be more persistent than one nearer the surface.

The various collections furnish 34 species, of which 12 at least are known living, and most of the rest are closely related to living species; and no doubt the number of these would be much larger if the living Cyclostomata had received adequate attention. One cannot be distinguished from a Palæozoic fossil, while nine are, as far as examination is available, identical with European Cretaceous species, and most of the others have Cretaceous representatives, from which they differ but little. But stress has already been laid on the want of details for comparison and classification; and although so many show in the calcareous framework so close a resemblance to those found in the European Chalk, yet no one is at present able to say that there have not been differences which we cannot now distinguish.

This, including a few additions in the list of the Chilostomata in Professor Tate's collection, brings the total number of Australian fossil Bryozoa discussed up to 197, of which 90 are already known living.

	Page.	Living.	Orakei Bay (*Stol.*).	Curdies Creek.	Mt. Gambier.	Bairnsdale.	Muddy Creek.	R. Murray Cliffs.	Aldinga.	Allies and Localities.
1. Crisia unipora, *d'Orb.*	683	...	...	*	...	...	...	...	...	European Chalk.
2. Idmonea atlantica, *F.*	683	*	*	*	*	*	...	...	...	Miocene, Pliocene of Europe.
3. —— Milneana, *d'Orb.*	684	*	*	*	*	*				
4. —— radians, *Lamk.*	684	*	...	...	*					
5. —— Hochstetteriana, *St.*	684	...	*	*	...	*				
6. —— bifrons, nov. sp.	685	...	...	...	...	...	...	...	*	Cretaceous.
7. Entalophora verticillata, *Goldf.*	685	...	...	...	*	...	...	...	...	Cretaceous, Palæozoic.
8. —— raripora, *d'Orb.*	686	*	*	*	*	*	*	*	*	Cretaceous.
9. —— neocomiensis, *d'Orb.*	686	...	*	*	*	*	*	...	...	Cretaceous and Miocene.
10. Filisparsa orakeiensis, *Stol.*	687	...	*	*	*	*				
11. Hornera frondiculata, *Lamx.*	687	*	...	*	*	*	...	*	...	Pliocene.
12. —— foliacea, *MacG.*	688	*	...	...	*	*	...	*		
13. Stomatopora granulata, *M.-Ed.*	688	*	...	...	...	*	...	...	...	Waurn Ponds; Cretaceous.
14. Diastopora suborbicularis, *H.*	689	*	...	...	*	...	*	...	...	Waurn Ponds.
15. —— patina, *Lamk.*	689	*	...	...	*					
16. Reticulipora, sp.	689	...	...	...	*	...	...	...	...	Allied to *R. dorsalis*, W.
17. —— transennata, nov. sp.	689	...	...	...	...	...	...	...	*	
18. Discotubigera clypeata, *Lamx.*	690	...	...	?	...	...	...	...	*	Oolitic.
19. —— iterata, nov. sp.	690	...	...	...	...	...	...	...	*	
20. Pavotubigera flabellata, *d'Orb.*	691	...	...	...	...	...	...	...	*	
21. —— dimidiata, *Rss.*	691	...	...	...	*	...	...	...	...	Miocene.
22. —— gambierensis, nov. sp.	692	...	..	...	*					
23. Defrancia exaltata, nov. sp.	692	*	...	...	*					
24. Supercytis digitata, *d'Orb.*	692	...	...	...	...	...	...	*	...	Cretaceous.
25. Fasciculipora, sp.	693									
26. Fascicularia conjuncta, nov. sp.	693	...	...	...	...	...	...	*		
27. Lichenopora hispida, *Flem.*	694	*	...	...	*	*	*	*	...	Waurn Ponds; Miocene, Pliocene.
28. —— radiata, *Aud.*	694	*	...	*	*	*	*	...	...	Napier, New Zealand (fossil).
29. —— aldingensis, nov. sp.	695	...	...	...	..	...	...	...	*	
30. —— cochloidea, *d'Orb.*	695	...	..	...	*	...	...	...	...	Cretaceous.
31. —— boletiformis, *d'Orb.*	695	...	...	...	...	...	...	...	*	Cretaceous.
32. —— variabilis, *d'Orb.*	696	...	...	...	...	...	...	...	*	Cretaceous.
33. Heteropora, sp.	696									
34. —— aldingensis, nov. sp.	696									

CRISIA.

There are fragments from Curdies Creek representing more than one species, some of which may be *C. eburnea* and *C. elongata*; but I am unable to identify the broken joints.

1. Crisia unipora, d'Orb. Pl. XXX. fig. 1.

Idmonea unipora, d'Orb. Pal. Franç. p. 737, pl. 613. figs. 1–10.
Crisina unipora, d'Orb. Prodr. p. 265.
Crisina elegans, d'Orb. Pal. Fr. pl. (only) 613.

A specimen from Curdies Creek is undoubtedly the same as d'Orbigny's, though a trifle larger, nearly $\frac{1}{4}$ of a millimetre, instead of $\frac{1}{5}$, and the zoœcial tubes project rather more. Whether this is to belong to *Idmonea*, *Filisparsa*, or *Crisia* is very doubtful. The puncturing is the same as that of some *Crisiæ* from the same locality, but the distance apart of the zoœcia is about double as great as we find in most recent *Crisiæ*, in which it is usually only a little greater or less than 0·25 millim., though in *Crisia cornuta* the distance is sometimes as great as in the fossil, in which it is about 0·45. On the other hand, the closure of the zoœcial tube is terminal, whereas in *Filisparsa* and *Idmonea* it is a little distance down the throat of the zoœcial tube. If it is to be looked upon as a *Crisia*, then it is interesting to find it unjointed; but if it is considered a *Filisparsa*, then it is interesting to find the regularity of a *Crisia*. Width of zoœcial aperture 0·1 millim.

Loc. Senonien: Fécamp (Seine-Inf.); Vendôme (Loir-et-Cher); Curdies Creek, Australia.

2. Idmonea atlantica, Forbes.

Idmonea radians, V. Ben. (non Lamk.) Bry. de la Mer du Nord. Bull. Brux. xvi. pt. 2. p. 646, pl. i. figs. 4–6.

Idmonea inconstans, Stol. Foss. Bry. Orak. Bay, p. 116, pl. xviii. figs. 7, 8.

For synonyms see Hincks, Brit. Mar. Polyz. p. 451, pl. lxv. figs. 1–4. The distance of the series of zoœcia apart is from 0·6 to 0·8 millim., which is about the same as figured by Smitt (Krit. Fört. pl. iv.). The main character seems to be that the zoœcial openings are all on the upper part of the branches, so that at each side the lower part is without zoœcial tubes. There are some stouter fragments which at first I thought should be called *I. serialis*, Stoliczka; but it seems as though they should only be considered a stouter variety, and perhaps may be *I. australis* of MacGillivray and *I. lineata* of Hagenow and Manzoni. I do not see that *I. communis* (d'Orb. pl. 750. figs. 6–10) differs in any structural particular from the present species.

In a specimen from Bairnsdale the ovicell which occurs near the bifurcation is elongate-pyriform, embracing the zoœcia, about 1·5 millim. long, and the position of the ovicell is the same in the typical *I. atlantica* and the stouter variety.

Loc. Living: Arctic and European seas; North Atlantic; Florida (*Sm.*); Madeira (*I.*). Fossil: Miocene, Eisenstadt, Steinabrunn, (*Manz*); Astian and Sicilian of Sicily (*Seg.*) and Pruma (*A. W. W.*); Canadian Postpliocene (*Dawson*); Orakei Bay (*Stol.*); Curdies Creek, S.W. Victoria; Mount Gambier, Bairnsdale.

3. Idmonea Milneana, d'Orb.

Idmonea Milneana, d'Orb. Voy. dans l'Amér. Mérid. vol. v. p. 20, pl. ix. figs. 17–21; Smitt (?), Floridan Bryozoa, p. 8, pl. iii. figs. 14–16; Busk, Cat. Mar. Polyz. pt. iii. p. 12, pl. xi; Haswell, on Cyclost. Polyz. Port Jackson, Proc. Linn. Soc. N. S. Wales, vol. iv. p. 351; MacGillivray, Zool. of Victoria, decade vii. p. 29, pl. lxviii. fig. 1; Busk, Note on Foss. Polyz. near Mt. Gambier, Q. J. G. S. vol. xvi. p. 261; Ridley, Zool. Coll. of 'Alert,' Proc. Zool. Soc. 1881, p. 56.

Idmonea Giebeli, Stoliczka, Olig. Bry. von Latdorf. p. 81, pl. i. fig. 6.

Idmonea Giebeliana, Stol. Foss. Bry. Orakei Bay, p. 115, pl. xviii. figs. 4, 6.

Idmonea notomale, Busk, Cat. Mar. Polyz. pt. iii. p. 12, pl. xii. A.

The specimens from Curdies Creek show the minute pores on the front and dorsal surface to be quite similar in size and frequency. Although this is widely distributed, the ovicell is, as yet, only known in the Capri specimen, in which it occurs very little raised, mostly in the centre of the zoarium, embracing the zoœcia. Zoarium 0·8–1·5 millim. wide, width of zoœcial tube about 0·15 millim. The thickness of the margin of the tube must, to a large extent, depend upon the locality of growth. In a specimen from Mt. Gambier, in the collection of Mr. Etheridge, jun., there is a spine on the dorsal surface, as described by Mr. Ridley.

Loc. Living: Iles Malouines (*d'Orb.*), Terra del Fuego; Patagonia, 30 fathm.; Chonos Archipelago? (*B.*); Florida? (*Sm.*); Sydney (*Hasw.*); Port Phillip Heads, Victoria, 10–15 fathm. (*MacG.*); Tom Bay, S.W. Chili, 0–30 fathm. (*Ridley*); Capri. Fossil: Oligocene, Latdorf; Orakei Bay (*Stol.*), Mt. Gambier, Curdies Creek, Bairnsdale.

4. Idmonea radians, Lamk.

Retepora radians, Lamk. Anim. sans vert. ii. p. 183.

Idmonea radians, Stoliczka, Foss. Bry. d. Orakei Bay, p. 116, pl. xviii. figs. 9–10.

I thus name, with some doubt, a few delicate specimens from Mt. Gambier, about 0·3 millim. wide, and with the series 0·4–0·5 millim. apart.

5. Idmonea Hochstetteriana, Stol. Pl. XXX. figs. 12, 13.

Crisina Hochstetteriana, Stoliczka, Foss. Bry. der Orakei Bay, p. 113, pl. xviii. fig. 3.

Branches of zoarium triangular; zoœcia projecting in alternate series of 2–3 zoœcia, long pores down the centre of the zoarium, and also along the centre of the zoœcia; dorsal surface slightly ridged, with long pores in longitudinal lines.

This is related to *Idmonea radians*, Lamk., a living species, which is more slender; and the series of zoœcia are in that species nearer together. There are in *I. Hochstetteriana* at least eight double series of zoœcia without any fresh bifurcation; whereas in my specimens of *I. radians* the branching is much more frequent.

The ovicells are unknown, but in *I. radians* they occur at the bifurcation as an elongate raised protuberance, with very large pores on the front, between which there are irregular ridges; at the sides there are two large areas surrounded by a double line, and these areas are perforated by a very large number of minute pores.

I am doubtful whether *Crisina Hochstetteriana*, Smitt, from Florida, is identical with the fossil, though it is, at any rate, closely allied to it; but neither of these are closely allied to *I. marionensis*, Busk.

Loc. Orakei Bay (*Stol.*); Curdies Creek, Bairnsdale.

6. Idmonea bifrons, nov. sp. Pl. XXX. figs. 10, 11.

Tubigera disticha, d'Orb. Pal. Fr. p. 723, pl. 746. figs. 2–6.

Idmonea disticha, Hag. Bry. Maastr. p. 30, pl. ii. fig. 8.

Zoarium nearly round, slightly compressed laterally, with series of 7–10 zoœcia on each side of two mesial lines, one of which must be considered as on the front, the other on the dorsal surface, series 0·7 millim. apart; zoœcia fairly exserted, diam. 0·1 millim.

The genus *Tubigera* was made by d'Orbigny for forms of which this is the most typical, and there seems to have been much confusion concerning that genus and also this species; for it is not the same as the *Idmonea* named *disticha* by Goldfuss, Reuss, Manzoni, or Michelin. If the genus *Tubigera* is retained, then perhaps *Bisidmonea*, d'Orb., should be joined with it. The figure of *Idmonea* (*Retepora*) *disticha*, Goldf., apparently relates to two or three species, but certainly not the present; and subsequently d'Orbigny calls the *Idmonea disticha* of Reuss *Crisina disticha*, so that he uses the specific name in two of his genera; but now both are considered to belong to *Idmonea*.

This looks like a connecting-link between the *Spiropora* form of *Entalophora* and typical *Idmoneæ*. It differs from most *Idmoneæ* by the series nearly meeting at the back, so that there is no dorsal surface.

Loc. Les Loches (Loir-et-Cher) (*d'Orb.*); Maestricht (*Hag.*), Aldinga.

7. Entalophora verticillata, Goldf.

Ceriopora verticillata, Goldf. Petr. Germ. i. p. 36, pl. ii. fig. 1.

Spiropora antiqua, d'Orb. Pal. Fr. p. 710, pl. 615. figs. 10–18, pl. 745. figs. 15–19.

Spiropora neocomiensis, d'Orb. loc. cit. p. 708, pl. 784. figs. 1, 2.

Spiropora verticillata, Novak, "Beitr. z. Kenntn. der Bry. der böhm. Kreide," Denkschr. k. k. Akad. Wien, vol. xxxvii. p. 34, pl. viii. figs. 7–12.

Spiropora calamus, Gabb & Horn, Monogr. Foss. Polyz. Second. and Tert. Form. of N. America, p. 166, pl. xxi. fig. 55.

Mitoclema cinctosa, Ulrich, Amer. Pal. Bry. Journ. Cincinn. Soc. Nat. Hist. vol. v. p. 159, pl. vi. figs. 7, 7 *a*.

For further synonyms see d'Orbigny and Novak.

Specimens in the collections of the Geological Society and of

Mr. Etheridge, jun., are exactly similar to some I have from the Valangian of St. Croix (Jura), and also to specimens collected from the Chalk of Maestricht and of Royan. The internodes are about 0·1 millim. long, and there are usually 8–10 in a complete circle. The ovicells are as yet unknown. The size of the Palæozoic form is, according to Ulrich's description, about the same size as the European specimens.

Loc. This species was very common and widely distributed in the European Chalk. It is found in almost all localities in the Senonian of France and Belgium and also in the Cretaceous of N. America (*G. & H.*), in the Pläner of Plauen and Strehlen (*Nov.*), in the Greensand of Essen, in the Valangian of the Jura, and in the Trenton strata, High Bridge, Kentucky (*Ulr.*). Mt. Gambier.

8. ENTALOPHORA RARIPORA, d'Orb.

Entalophora raripora, d'Orb. Prodr. Pal. Strat. p. 267; Pal. Franç. p. 787, pl. 621. figs. 1–3, pl. 623. figs. 15–17; Beissel. Bry. Aachener Kreidebildung, p. 82, pl. x. figs. 120–128; Novak (pars), Beitr. z. Kenntn. d. Bry. der böhm. Kreide, p. 32.

Pustulopora virgula, Hag. Bry. Mästr. p. 17, pl. i. fig. 3.

Entalophora icauensis, d'Orb. Pal. Franç. p. 781, pl. 616. figs. 12–14.

Entalophora attenuata, Stol. Bry. von Latdorf, p. 77, pl. i. fig. 1; Reuss. (?) Bry. Crosaro, p. 74, pl. xxxvi. figs. 1, 2.

Entalophora anomale, Manzoni, Bri. Mioc. Austr. ed Ungh. p. 10, pl. ix. fig. 33.

Entalophora Haastiana, Stol. Bry. Orakei Bay, p. 102, pl. xvii. figs. 4, 5.

Pustulopora proboscidea, Busk, Cat. Mar. Polyz. pt. iii. p. 21, pl. xvii. *a* (right figure). Also Milne-Edwards; Heller; and Waters, Bry. of Bay of Naples, Ann. & Mag. Nat. Hist. ser. 5, vol. iii. p. 274, 1879.

I have prepared sections of recent specimens, and also some from the Chalk, Miocene, and Pliocene, without being able to find any difference. The aperture is about 0·16 millim. diam.

Loc. Fossil: From the Valangian of St. Croix and Pontarlier (Cant. Vaud), general in the European Senonian. Miocene: Austria, Hungary, and Italy. Pliocene: Italy, Sicily; also from Orakei Bay (*Stol.*), Curdies Creek, Muddy Creek, Bairnsdale, Mt. Gambier, Aldinga, and River Murray Cliffs.

9. ENTALOPHORA NEOCOMIENSIS, d'Orb.

Entalophora neocomiensis, d'Orb. Pal. Fr. p. 782, pl. 616. figs. 15–18.

? *Bidiastopora neocomiensis*, d'Orb. loc. cit. p. 800, pl. 784. figs. 9–11.

Cricopora pulchella, Rss. Polyp. Wien, p. 40, pl. vi. fig. 10.

Spiropora pulchella, Rss. Foss. Anth. u. Bry. von Crosaro, p. 287 (75), pl. xxxvi. figs. 4, 5.

Pustulopora pulchella, Manzoni, Bri. del Mioc. Austr. ed Ungh. p. 11, pl. ix. fig. 35.

Bidiastopora Toetoeana, Stoliczka, Foss. Bry. der Orakei Bay, p. 100, pl. xvii. figs. 2, 3.

The zoœcial tubes are about 0·08–0·09 millim. in diameter, and there is about 0·6 millim. distance between the aperture of a zoœcium and the following one on the same axial line. Some specimens that I collected from St. Croix and Pontarlier are over 0·1 millim. in diameter, and I have still larger specimens which are identical with *Bidiastopora neocomiensis,* and sometimes they are quite compressed, and these seem in the Jurassic fossils to indicate a transition from the ½-millim. *Entalophora* to the large *Bidiastopora.*

A specimen from Curdies Creek is slender (0·5 millim. diam.), with only few zoœcia round the zoarium; but some specimens from Bairnsdale are twice as large, and consequently have more zoœcia.

Loc. Fossil: Valangien, St. Croix and Pontarlier (Jura) (*A. W. W.*). Miocene: Austria and Hungary, and Crosaro, Val di Lonte (*Rss.*); Orakei Bay (*St.*), Curdies Creek, Mt. Gambier, Bairnsdale, and Muddy Creek.

10. Filisparsa orakeiensis, Stol.

Filisparsa orakeiensis, Stoliczka, Foss. Bry. der Orakei Bay, p. 111, pl. xviii. figs. 1, 2.

The zoœcial tubes are about 0·08 millim. in diameter, which is about half the size of those of *F. tubulosa,* from the Mediterranean and from Holborn Island, Australia. I now find upon examination of specimens, that *F. tubulosa,* Busk, and *F. varians,* Rss., are closely allied, if not identical.

In a badly preserved specimen from Mt. Gambier there is a raised subglobular ovicell on the dorsal surface, near the bifurcation, with the aperture terminal. This ovicell, consisting of a distinct chamber, corresponds with that of *Idmonea? irregularis,* Menegh., while in *Filisparsa tubulosa* the ovicell is on the front surface, and instead of being a distinct chamber, is an irregular enlargement. The ovicell is only known in these two species of *Filisparsa,* and possibly when more are known they will have to be differently classified. In the recent Australian *Filisparsa,* the closure, which is near the end of the zoœcial tubes, has minute perforations just similar to the surface-pores.

Dr. Jullien * proposes to make a new genus *Tervia* for the *Filisparsa* of d'Orbigny; but I do not see what reason there can be for this change of name.

Loc. Fossil: Orakei Bay (*Stol.*); Curdies Creek, Bairnsdale, and Mt. Gambier.

11. Hornera frondiculata, Lamx.

Hornera frondiculata, Lamouroux, Expos. Méth. p. 41, pl. 74. figs. 7, 8, 9; Busk, Crag. Polyz. p. 102, pl. xv. figs. 1, 2, pl. xvi.

* Dragages du Travailleur; Bryozoaires; Bull. Soc. Zool. de France, t. vii. 1882, p. 500.

fig. 6; Cat. Mar. Polyz. pt. iii. p. 17, pl. xx. figs. 1, 2, 3, 6; Waters, Bry. of Naples, p. 275.

Hornera porosa, Stoliczka, Olig. Bry. von Latdorf, p. 79, pl. i. f. 3.

From the River-Murray Cliffs there is a well-preserved specimen which exactly corresponds with some recent ones I have from Naples, and this served as a key to the Curdies-Creek collection, from which there are a number of fragments, which, viewed separately, might have been considered as representing several species. Towards the growing end the ridges forming the lozenge spaces are smooth, whereas towards the base they are transversely nodulated. On the dorsal surface this nodulation occurs equally in the younger and older portions. In some cases the mouths of the tubes are much exserted, and often cut away towards the dorsal end, thus giving a bifid appearance; in other parts they are entire, and sometimes scarcely at all raised. The closure, with one pore, is near the termination of the zoœcial tube. This is closely allied to, if not identical with, *Hornera verrucosa*, Rss. (Septarienth. p. 81), and it is also allied to *H. striata* and *H. lichenoides*.

Loc. Oligocene: Latdorf. Pliocene: of Italy and Sicily, English Crag; Curdies Creek, River Murray Cliffs, Bairnsdale, Mt. Gambier. Living: Mediterranean.

12. Hornera foliacea, MacG. Pl. XXXI. fig. 18.

Hornera foliacea, MacG., Australian Polyzoa, R. Soc. Vict. 1868, p. 17.

Retihornera foliacea, Busk, Cat. Mar. Polyz. pt. iii. p. 19, pl. xiii. figs. 1, 2, pl. xix.

Zoarium in *Retihornera*-form. In the fossils the aperture seems to be about 0·04 to 0·05 millim. broad; the fenestræ are sometimes as much as 1·8 millim. long and 0·4 millim. broad. According to Mr. Busk's figures the fenestræ were rather shorter in the specimens he represents.

The transverse tubules do not seem to have any oral apertures, though as they often arise from the immediate vicinity of the apertures in the main branch, it frequently appears as if they belonged to the transverse bar; but this is not the case.

Loc. Living: Portland Bay; Wilson's Promontory; Tasmania (*MacG.*). Fossil: Bairnsdale, Mt. Gambier, River Murray Cliffs.

13. Stomatopora granulata, M.-Edw., var. minor.

There is a small specimen of uniserial *Stomatopora* from Bairnsdale, with aperture about 0·06–0·07 millim., but from one such specimen it is impossible to speak confidently about the identification. A specimen in my collection, from the Valangien of St. Croix, which I believe to be *S. granulata*, has the aperture about 0·12 millim.

There is a second specimen of this from Waurn Ponds, which seems sometimes to become biserial.

14. Diastopora suborbicularis, Hincks.

Diastopora suborbicularis, Hincks, Brit. Mar. Polyz. p. 464, pl. lxvi. fig. 11.

I am not yet quite sure as to what must be looked upon as specific characters in *Diastopora*, and therefore call this *suborbicularis* with some hesitation.

The zoarium is growing on *Microporella cellulosa*, form *Adeona*, from Muddy Creek, and is about 5 millim. in diameter.

The apertures of the zoœcia are about 0·08 millim. in diameter, which is about the same as in Mr. Hincks's specimen, and slightly smaller than in specimens from Naples, which I called *D. flabellum*. The zoœcia are separated by distinct lines, but probably this depends upon the conditions of growth. The oœcia are about 0·5 millim. in diameter, and are circular rather than oval, and I have not found any oœcial tube. The surface of the oœcia is punctured with very fine pores close together. The *D. flabellum* of the Mediterranean has a tangential inflation of considerable width, and the oœcial tube is directed inwards, namely, towards the centre of the zoarium. There is also a specimen from Mt. Gambier, but this is not so well preserved. A specimen from Waurn Ponds has an ovicell similar to that of my Naples specimen.

15. Diastopora patina, Lamk.

From Mt. Gambier there is a fragment consisting of about half of a caliculate colony which must have been the same size as specimens in my collection from the coast of France and from Capri (dredged at about 200 metres). This is closely allied to *Discosparsa laminosa*, d'Orb., from the Cenomanian.

Loc. Living: British, Northern, and French seas; the Adriatic and Capri.

16. Reticulipora, sp.

There is a compressed branch from Mt. Gambier, about 0·7 millim. wide, with series 0·5 millim. apart, and with 7 or 8 zoœcia in a series, which does not seem to differ in any way from my *Reticulipora dorsalis* from Naples; but from the one fragment I am not prepared to say that they are identical.

17. Reticulipora transennata, nov. sp. Pl. XXX. figs. 2, 3, 6, 7. Section also figured in "Closure of the Cyclostomatous Bryozoa," Journ. Linn. Soc. vol. xvii. pl. xvii. fig. 5.

Zoarium reticulated, large. The specimen sent over from Aldinga must have been at least 6 inches in diameter. The fenestræ of the reticulations are 2–4 millim. long, and average about $\frac{2}{3}$ as broad; branches (laminæ) much compressed, about 0·5 millim. in section, and about 2 millim. deep, covered transversely with subparallel rows of 8–12 slightly exserted tubular zoœcia, 0·07–0·08 millim. diam., 0·4 millim. apart. Besides the zoœcial openings, there are smaller non-tubular ones; sometimes these are below the zoœcia, at others at the side, and there may be three or four to each zoœcium; on the dorsal surface of the zoarium there are smaller openings than these lateral ones just mentioned. On the front the lamina is very marked, and rises above the zoœcia on each side, and there is a tendency for this to divide up the centre of the lamina, and I find the same tendency in the *Reticuliporæ* from the Chalk of Royan. In *Biflustra* the two layers of cells being readily separable was made a generic characteristic, but perhaps it depends to a large extent upon the condition of fossilization.

The closure occurs at some little distance before the zoœcial tube becomes free (see Journ. Linn. Soc. vol. xvii. pl. 17. fig. 5), viz. about 0·13 millim. from the termination of the zoœcia, and in one or two cases there is a second closure a very short distance behind the first.

This species is closely allied to *Reticulipora obliqua*, d'Orb. Pal. Franç. p. 906, pl. 610. figs. 1, 6, pl. 768. figs. 1–2, from the Senonian, but I do not think they can be considered the same species.

18. Discotubigera clypeata, Lamx. Pl. XXXI. figs. 15, 16, 19.

Pelagia clypeata, Michelin, Icon. Zooph. p. 229, pl. lv. fig. 3.
Apseudesia clypeata, Haime, Bry. Form. Jur. p. 202, pl. vii. fig. 7.

This genus was first described as *Pelagia* by Lamouroux; but as the name had already been used for an Acaleph, it had to give way, and was partly replaced by *Defrancia*; but this seems to have been used for such various things that it is not always clear what has been meant, nor can we feel satisfied whether both *Defrancia* and *Discotubigera* should be retained.

The zoœcia are raised up in rays in the same way as in *Lichenopora*; but there are no interstitial pores, and therefore I believe the genera are widely separated.

We must extend d'Orbigny's definition of *Discotubigera* to species growing more or less free.

The specimen from Aldinga is 20 millim. in diameter, with about 40 principal bi-triserial rays, with zoœcial openings about 0·12 millim. The rays near the centre are very narrow, and one or a pair of cells often terminate at a short distance from the centre, and others also terminate before the fasciculine openings. Near the circumference there are short rays inserted between the main ones. Near the border there is a slight ovicellular inflation, and there is one tubular opening (see *o*, fig. 19). The general resemblance to such a coral as *Montlivaltia discus*, Woods, is extremely striking.

As the description of Lamouroux is not sufficient for certain specific comparison I do not quote his locality.

Loc. Oolitic: Lebisey, Ranville (*M.*), Luc (*H.*), Nantua and Marquise (*d'Orb.*), Aldinga. A small fragment from Curdies Creek apparently belongs to this species.

19. Discotubigera iterata, nov. sp. Pl. XXXI. figs. 14, 17.

The specimen from Aldinga is only a fragment of a colony which was clearly more or less discoid; the radius of the part preserved is about 35 millim. The multiserial rays must be very numerous, as there are 24 in 20 millim. The zoœcial apertures are not continuous along the ray, but, instead, the ray becomes elevated at intervals, forming elongate fasciculi, with their openings directed upwards. These interruptions take place with considerable regularity, so that the fasciculi of neighbouring rays rise up at equal distance from the centre of the zoarium, which may be a constant character, or it may merely arise from the growth at the circumference being arrested and then recommencing simultaneously at all points. The position of the zoœcia is marked by faint lines on the flat surface of the ray. It will be seen that the structure of this species closely resembles that of *Pavotubigera flabellata*, d'Orb. Pal. Fr. p. 767, pl. 752. figs. 4–8.

20. Pavotubigera flabellata, d'Orb.

Pavotubigera flabellata, d'Orb. Pal. Franç. p. 767, pl. 752. figs. 4–8.

? *Semitubigera lamellosa*, d'Orb. loc. cit. p. 749, pl. 750. figs. 16–18.

This does not seem to differ from the Meudon specimen, except in there being two or three confluent colonies, and perhaps on that account it might be called var. *extensa*.

The mode of growth of this species is very similar to that of *Tubulipora*; but in that genus the zoœcia are freer, and the rays are not multiserial.

One of the colonies is much more symmetrical than the others, and therefore approaches nearly to the figure of *Semitubigera lamellosa*, d'Orb. Zoœcia 0·1 millim. diam.

Loc. Cretaceous: Meudon; Aldinga.

21. Pavotubigera dimidiata, Rss. Pl. XXXI. fig. 25.

Defrancia dimidiata, Reuss, Foss. Polyp. d. Wien. Tert. p. 39, pl. 6. fig. 6.

The specimen from Mt. Gambier is but badly preserved and incomplete, and it is therefore impossible to speak with certainty as to the structure, but in the fragment the zoœcia are bi-multiserial in fanlike rays, with a large inflation about the width of two rays, forming the ovicell.

I do not think the *Tubulipora dimidiata*, Manzoni, is the same as the *Defrancia dimidiata* of Reuss, though perhaps *T. pluma*, pl. xvii. fig. 68 (only), Manz. Bri. Mioc. Austr. ed Ungh., may be. No undoubted recent *Tubulipora* has biserial rays, and therefore at first it seemed advisable to separate it from that genus on this account; but the examination of a fossil from Napier, New Zealand, which is closely allied to *Multifascigera campichiana*, d'Orb., shows that this is not a sufficient reason. This New-Zealand fossil, and also a recent specimen of the same, resemble an adnate *Idmonea*, with outlying rows of zoœcia beyond the main ones, and in some the rows are all bi-multiserial, and this was at first taken to be a marked character of the species; but in one large growth the rows are nearly always uniserial, though here some few colonies and parts of colonies occur with biserial rows. This is extremely important in helping us to appreciate the classificatory importance of this character.

If, however, all these are to be called *Tubulipora*, it would become a most unwieldy genus, certainly with intermediate forms, but many, seen apart, would, at first sight, seem widely divergent. Although it may be only an arbitrary division, it will, I think, assist us in study if we for the present confine *Tubulipora* to those species only in which the end of the zoœcial tube is free, and in which there is no symmetrical arrangement.

22. Pavotubigera gambierensis, nov. sp. Pl. XXX. fig. 9.

Zoarium apparently adnate. Zoœcia in bundles of two or more, erect, connate; ovicell an inflation of a portion of the surface between the zoœcia; surface of zoœcia evidently finely punctate.

23. Defrancia exaltata, nov. sp. Pl. XXXI. fig. 23.

Zoarium incrusting, oval, with the rays rising from near the centre, and sometimes dividing, and much raised round the border; rays multiserial, large pores round the base of the rays.

This, like most of the Mt. Gambier fossils, is but badly preserved, and therefore it is impossible to feel quite sure about the determination, but it seems to be the same as an undescribed species from the Bay of Naples, which, however, may be the *D. verrucaria* of Heller (non Fabr. or M.-Edw.). In the Naples specimen an inflation of one half of the central portion forms the ovicell, and the ovicellular opening is tubular, a little larger than a zoœcial tube, and occurs between the base of two rays.

This is related to the *Defrancia diadema*, Goldf., Hag., and d'Orb. I have also a colony from the Miocene of Brendola colle Berici, N. Italy, which has eight rays which do not divide. In *Tubulipora Brongniarti* (Manzoni, Mioc. Austr. ed Ungh. pl. xviii. fig. 73) there are more rays, and these are figured as starting from the centre of the colony.

24. Supercytis? digitata, d'Orb, Pl. XXXI. figs. 22, 26, 27.

Supercytis digitata, d'Orb. Pal. Franç. p. 1061, pl. 798. figs. 6–9.

Zoarium stipitate, fasciculi bifurcated, starting from the base, laterally compressed, the upper surface forming a horizontal plane. The fasciculi consist of a number of parallel zoœcia, usually three or four side by side, directed obliquely upwards so that the openings of these tubes are seen all along the fasciculi. The central portion of what must be called the capitulum is flat and covered with a finely perforated calcareous wall, out of which rise the ends of the central zoœcia slightly exserted, giving this portion the appearance of a *Diastopora*, such as *D. sarniensis*. Central zoœcia 0·1 millim. in diameter. Zoarium about 11 millim. in the longer diameter, and about 7 millim. in the shorter.

This is very closely allied to *Pelagia insignis*, Michelin, from the grès verts of Mans, and possibly may be identical.

It is unfortunate that Busk should have named a species *Fasciculipora digitata*, seeing that the specific name was already employed by d'Orbigny. The species described by Busk is very similar to this, and is apparently described from an imperfectly preserved specimen, and therefore we cannot be sure of the relationship *. A recent specimen of *F. digitata*, B., from New Zealand has no central covering, and is much smaller than the present specimen, as are also those described by d'Orbigny and Busk. There is also a fossil from Napier, New Zealand, which has a number of capituli in shape like the present, but grouped together, and arising from a common base; but there the central portion seems covered with a calcareous wall, without any zoœcial openings.

This is, as far as I am aware, the first time that any central covering like the present has been found; and until more perfect specimens of allied species have been examined there will be some doubt as to its relationship, and the generic and specific name can only be used provisionally.

Loc. Cretaceous of Meudon, Sainte Colombe, Lavardin, Fécamp (France); Murray Cliffs.

25. Fasciculipora?

There are small fragments from Curdies Creek, Bairnsdale, and Mt. Gambier, which might be *F. ramosa*, d'Orb.; but as I have pointed out ("Bry. of the Bay of Naples," Ann. & Mag. Nat. Hist. 1879, iii. p. 279), the young colonies of *Frondipora* have this form.

26. Fascicularia conjuncta, nov. sp. Pl. XXX: figs. 4, 5.

? *Fasciculipora ramosa*, J. E. Tenison-Woods, Corals and Bryozoa of Neoz. Period in New Zealand. Pal. of New Zealand, pt. iv. p. 31.

The specimens from the River-Murray Cliffs do not seem to differ from Mr. Wood's description; but the fossil in my hands is so much imbedded in matrix that it is impossible to give exactly the zoarial form, though I think that it must have been more or less globular, and many inches in diameter. The fasciculi are nearly round, about 1·5 millim. in diameter, connected here and there by small multitubular connexions at right angles to the fasciculi. The zoœcial tubes are about 0·15 millim. internal diameter, and there are at irregular long intervals plates (tabulæ) across the tubes. There are minute pores on the surface, as in *Frondipora* and most other Cyclostomata.

* Since this paper was read I have received from Professor Hutton some fossil specimens of *Supercytis* (?) from Shakespeare's Cliff, Wanganui (New Zealand), in which the central part has a calcareous cover; but instead of the zoœcia rising through the finely punctured cover, they only come up to it, and that in long rows or fasciculi, as seen by the outlines of the zoœcial walls. The outer surface is, in the upper part, striated, showing the outlines of the zoœcia; the basal part shows irregular hexagonal divisions.

This, I believe, is the *Fasciculipora digitata* of Busk.

The dilatation of the fasciculi at the summit occurs in these specimens only where the fasciculi are beginning to branch.

This differs from *Fascicularia tubipora*, Busk, in not having the fasciculi united by what Busk calls "horizontal tabular concentric laminæ;" these are probably represented by the small multitubular connexions, and in a specimen of *Fascicularia tubipora* collected in Rametto, near Messina, Sicily, from the Pliocene, there is, besides the larger "laminæ," an occasional connexion like that of *F. ramosa*.

F. tubipora also occurs from Napier, New Zealand.

The genera *Fascicularia* and *Fasciculipora* seem most closely allied.

Loc. Mt. Brown beds (Upper Eocene of Hector), New Zealand, River Murray Cliffs.

27. LICHENOPORA HISPIDA, Flem.

For synonyms see Hincks's Brit. Mar. Polyz. p. 473; but as to *Discocavea aculeata*, d'Orb., I am in doubt. *Discoporella echinulata*, Rss., Die foss. Polyp. des W. Tert. p. 50, Taf. vii. fig. 6; Manzoni, I Brioz. foss. del Mioc. d'Austr. ed Ungh. p. 15, pl. xiv. fig. 56.

Specimens from Muddy Creek, Murray River, and Waurn Ponds correspond most closely with a simple colony from Naples.

In each case the zoœcial openings are about 0·1 millim. to 0·2 millim. in diameter, and in the Naples and River-Murray specimens the central cancelli are rather over 0·07 millim., while the interradial cancelli are 0·06 millim.; but in the Muddy-Creek specimen the central and interradial cancelli are of about the same size, viz. 0·06–0·07 millim.

In the Muddy-Creek specimen I am able to see a distinct row of spicular denticles a short distance down the zoœcial tube. This small colony of about 2 millim. diam. is not well preserved, whereas those from Murray Cliffs are less damaged, and are about 5–6 millim., and the radial arrangement of the zoœcia is more distinct. A specimen from Waurn Ponds may be a variety. The zoarium is 10 millim. in diam., and the zoœcia are 0·07 in regular uniserial distinct rows towards the centre.

In the central part of the Naples specimen there is at the junction of the wall of each opening a small protuberance reminding us of the "Spiniform corallites," of Prof. A. Nicholson ("Structure of Heteropora," &c. Ann. & Mag. Nat. Hist. 1880, p. 14, fig. 4).

Loc. Miocene: Eisenstadt and Mörbisch (*M.*). Pliocene: Crag, Italy (Reggiano in the Zanclian, Astian, Sicilian, and Saharian of *Seguenza*); Scotch Glacial deposits (*Geikie*). Post-Pliocene of Canada (*Dawson*). Mt. Gambier, Bairnsdale, Muddy Creek, Murray River, Waurn Ponds. Living: European seas generally.

28. LICHENOPORA RADIATA, Aud.

The zoœcial opening in specimens from the Mediterranean and also in the fossils is 0·07–0·08 millim., and in the specimen from Adelaide is only a trifle smaller.

Loc. Living: British, Mediterranean, Holborn Islands, Queensland (*A. W.*), Semaphore (Adelaide) (*A. W.*). Fossil: Pliocene, Bruccoli, Sicily; Curdies Creek, Muddy Creek, Bairnsdale, Mt. Gambier, Napier (New Zealand).

29. Lichenopora aldingensis, nov. sp.

Zoarium depressed in the centre, with about 20 primary biserial rays, with about 50 zoœcia in each ray. Mouths of the zoœcia about 0·12 millim. in diam., which is half the size of the openings of the cancelli.

This is much larger than *Discoporella californica*, B., but is allied.

30. Lichenopora cochloidea, d'Orb. in *Domopora*-form.

Domopora cochloidea, d'Orb. Pal. Franç. p. 990, pl. 781. figs. 5–7.

Defrancia cochloidea (?), Hag. Bry. Maastr. Kreide, p. 42, pl. iv. fig. 8.

In a specimen from Mt. Gambier, one colony grows out of the top of another. Each colony is considerably raised, but concave in the centre, about 2–4 millim. in diameter. In the young colonies there are 10 rays of zoœcia, with large openings, and between these and round the border very small cancelli. The zoœcial tubes are about 0·8 millim., and the cancelli 0·3 to 0·4 millim. in diameter.

Loc. Fossil: Senonian of Sainte Colombe (Manche), Mt. Gambier.

31. Lichenopora boletiformis, d'Orb. (non Rss.), in *Tecticavea*-form. Pl. XXXI. figs. 20–21.

Tecticavea boletiformis, d'Orb. Pal. Franç. p. 991, pl. 781. figs. 8–12.

There are two colonies of this species from Aldinga; one forms a globular mass, slightly hollow in the centre, of about 30 millim. in diameter; the other is growing on a Chilostomatous Bryozoan, and forms a conical mass 14 millim. high. The fresh colonies commence by growing over the previous one in a tectiform manner, but afterwards they become confluent, forming continuous sheets over the whole previous growth. In the early stage, therefore, this entirely corresponds with the Belgian fossil.

The rays are biserial, with openings but little larger than the interradial and central cancelli. The apertures vary from 0·09 millim. to 0·13 millim.

Although this ultimately attains a form closely resembling *Radiopora*, the structure is different; for here each colony spreads from its own calcareous basis, whereas in *Radiopora* the zoœcial tubes of one layer are continued into the next. Reuss has named what appears, from the description and figure, a true *Radiopora*, *R. boletiformis*, which does not seem to be allied to our form. The mode of growth of the present species resembles that of *Defrancia prolifera*, Rss. F. Polyp. pl. vi. fig. 1.

Loc. Senonian; Cypli (Belgium); Aldinga.

32. Lichenopora variabilis, d'Orb.

Bimulticavea variabilis, d'Orb. Pal. Franç. p. 983, pl. 779. figs. 9–13.

A colony from Aldinga consists of a number of confluent zoaria, the raised part of which measures about 4 millim., the distance from the centre of each colony being about 5–6 millim., with six or eight multiserial rays. The central cancelli are but very slightly larger than the others. The width of the zoœcia is about 0·1 millim.

In the Australian fossil I am not able to make out that there are in any part two layers, as figured by d'Orbigny, but in a section which I cut I find in certain of the zoœcial tubes, at a distance from the surface, several tabulæ occurring at comparatively short intervals.

Loc. Cretaceous: Meudon (France); Aldinga.

33. Heteropora.

There are some small pieces of *Heteropora* from Curdies Creek which are too imperfect for determination. *Heteropora pelliculata*, W., occurs abundantly fossil at Napier, New Zealand.

Addendum.

34. Idmonea aldingensis, nov. sp.

The front of the zoarium is rounded, with the rows of connate zoœcia regularly placed 0·35–0·4 millim. apart, with five zoœcia to each lateral series. Zoœcia not much exserted; aperture about 0·13 millim.

The appearance is much the same as that of *Clavitubigera convexa*, d'Orb. (Pal. Fr. pl. 746. f. 12–15), with the exception that the dorsal surface is concave; but this is probably not a character of much moment.

Loc. Aldinga.

EXPLANATION OF PLATES XXX. & XXXI.

Plate XXX.

Fig. 1. *Crisia unipora*, d'Orb., ×25.
2. *Reticulipora transennata*, nov. sp., front surface, ×12.
3. Ditto, natural size.
4, 5. *Fascicularia conjuucta*, nov. sp., in matrix, natural size.
6. *Reticulipora transennata*, nov. sp., dorsal surface, ×12.
7. Ditto, frond, seen laterally.
8. Section of *Hornera frondiculata*, Lamx., from Naples, showing the large pores which are united to the interior by means of small ones, also showing the interzoœcial pores, ×25.
9. *Pavotubigera gambierensis*, nov. sp., Mt. Gambier, ×12.
10. *Idmonea bifrons*, nov. sp., front, ×12.
11. Ditto, dorsal surface, ×12.
12. *Idmonea Hochstetteriana*, Stol., front, ×12.
13. Ditto, dorsal surface.

PLATE XXXI.

Fig. 14. Ray of *Discotubigera iterata*, nov. sp., ×2.
15. Ray of *Discotubigera clypeata*, Lamx., natural size.
16. *Discotubigera clypeata*, Lamx., natural size.
17. *Discotubigera iterata*, nov. sp., natural size.
18. *Hornera* (*Retihornera*) *foliacea*, Mac G., ×12.
19. *Discotubigera clypeata*, Lamx., ×5, *a*, as seen from the side, showing the ends of the rays, ×5.
20. *Lichenopora boletiformis*, d'Orb., natural size
21. Ditto, growing colonies about ×2.
22. *Supercytis digitata*, d'Orb., ×6.
23. *Defrancia exaltata*, nov., from Mt. Gambier, ×25.
24. Interzoœcial pore of *Heteropora pelliculata*, Waters, ×150.
25. *Pavotubigera dimidiata*, Rss., from Mt. Gambier, ×12.
26. *Supercytis digitata*, seen from below, ×2.
27. The same, from the side, natural size.
28. Section of *Heteropora pelliculata*, W., recent, from New Zealand, showing the interzoœcial pores and the hair-like spines, ×50.

47. *A* Critical *and* Descriptive List *of the* Oolitic Madreporaria *of the* Boulonnais. By Robert F. Tomes, Esq., F.G.S. (Read June 25, 1884.)

[Plate XXXII.]

I have been favoured from time to time by M. Rigaux, of Boulogne, with specimens of corals for determination, which had been collected by him in the Great Oolite and Coral Rag of the Boulonnais. He has quite recently very kindly afforded me the additional opportunity of studying the whole of his collection of specimens; and the results of a comparison made between them and English species will form the substance of the present paper.

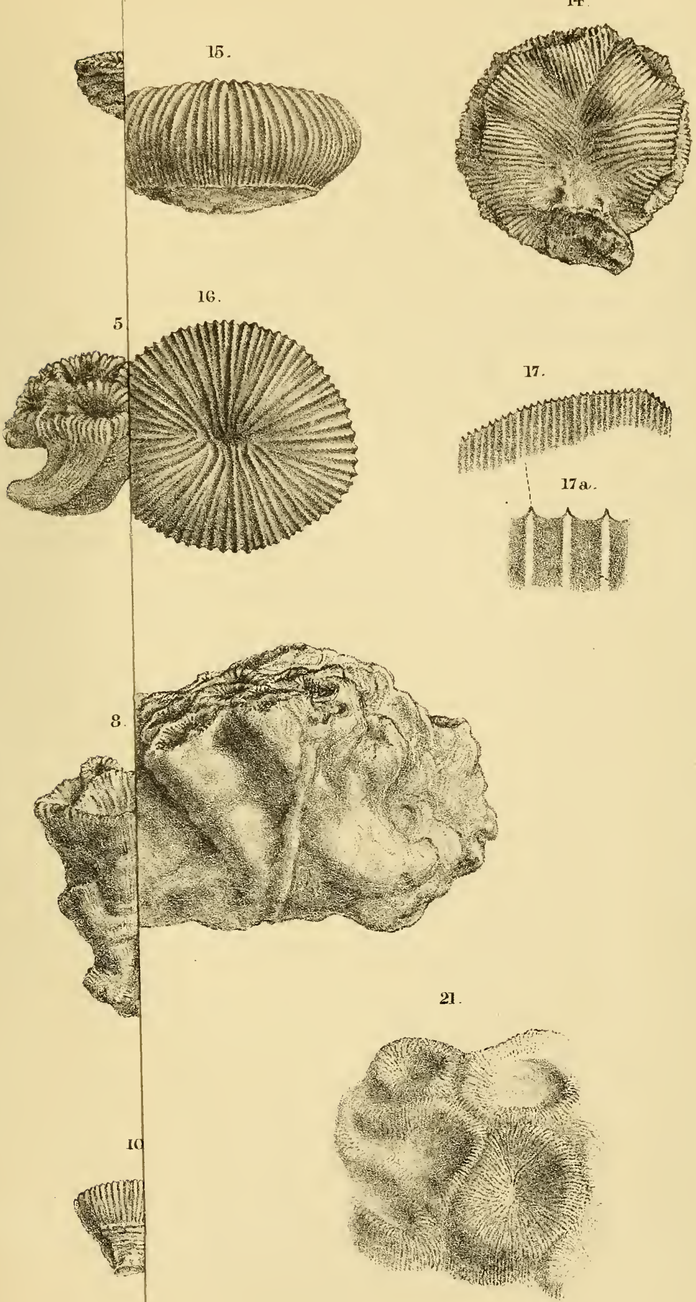
It will be observed that I now regard *Isastræa moneta* as a second species of *Bathycœnia*, its very great similarity to the Fairford species, *Bathycœnia Slatteri*, on which I founded the genus, having been already noticed by me. The discovery of some forms apparently allied to that genus, which nevertheless are found to possess well-developed tabulæ, renders the position of *Bathycœnia* in the Eusmilinæ more than doubtful.

In my paper on the Corals of the Great Oolite, I hazarded some remarks, accompanied by explanatory figures, on a species of coral from the bottom of the Great Oolite near Stonesfield, which from the presence of distinct tabulæ and the very feeble development of its septa, I placed, though not without some hesitation, among the Zoantharia Tabulata. For that species, if it proved to be distinct from the one on which was founded the genus *Cyathophora*, the generic name *Depaphyllum* was proposed. But I am still in uncertainty as to the proper generic nomenclature of the species, because I do not yet know whether the genus *Cyathophora* of Michelin is not possessed of *tabulæ*.

In the collection of M. Rigaux are three distinct forms which, though generically distinct from each other, are yet nearly allied, and which throw considerable light on the affinities of the Stonesfield coral, and most likely also on the genus *Bathycœnia*.

One of these has a very elongated form, like a long and curved horn, with a single terminal and deep calice, the floor of which is clearly formed by a tabula, and the septa of which are few in number, smooth and somewhat swollen. Another is lenticular or discoid, with septa which are swollen like those of the last, though they differ very materially in having little prominence. They meet in the centre of the visceral chamber, and there is no evidence of tabulæ. The third is a compound coral which, until I had detected the tabulæ, I regarded as closely allied to *Bathycœnia*, although differing from it in having external gemmation. These will be described in detail further on; but I may here suggest that there appears to be considerable similarity between their structure and that of the genus of recent corals, *Lophohelia*, as defined by Prof. Duncan in

Quart. Journ. Geol. Soc. Vol. XL. Pl. XXXII.



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JURASSIC CORALS OF THE BOULONNAIS.

1871*. While investigating the present collection I have met with great assistance from the comparison of a very considerable number of species from the Corallian of the Haute-Saône, France, for which I am especially indebted to M. de Fromentel. These and a good number of species from Nattheim have rendered me good service.

The conclusions of Dr. Lycett, based chiefly on the study of the Testacea, relative to the general palæontological uniformity which exists throughout the whole of the Great Oolite of the Cotteswold Hills, are considerably strengthened by my own observations on the coralline beds of that division of the Oolites. In my paper on the Great-Oolite corals of the counties of Oxford and Gloucester, I have shown that these successive coral-beds are merely a repetition of each other. That conclusion, however, although not at that time inaccurate, so far as the district mentioned is concerned, now demands some modification. Excepting for the species described under the name of *Bathycœnia solida*†, the precise stratigraphical position of which is not known, it would have been quite proper to have restricted the genus *Bathycœnia* to the Cornbrash. And in fact, as I shall here show, such a conclusion would have been inevitable if the Great-Oolite corals of the Boulonnais had been brought into immediate comparison with those from the corresponding deposits of this country. Not only is the genus *Bathycœnia* in the Boulogne Oolite peculiar to the Cornbrash, but the new and allied genus *Discocœnia* is also confined to it. Again, so far as present information goes, the genus *Scyphocœnia* is confined to the lower part of the Great Oolite.

The Great Oolite of the district now under consideration, resting immediately on Palæozoic rocks, precludes the existence there of any beds corresponding in age to the Inferior Oolite; but under the impression that some obscure Madreporarian form might have escaped observers, I looked with especial solicitude for some species which would, like the corals in the bottom of the Lias of the Glamorganshire coast, indicate the existence of a coralliferous sea of earlier date than that in which the Great Oolite was deposited. But not a trace appears of a species which could with certainty be identified as being proper to the Inferior Oolite. On the contrary, the species which have been met with near the bottom of the Great Oolite have a facies which would seem to assimilate them more or less nearly to those of our Cornbrash.

The following generalized section has been prepared by M. Rigaux, and the specimens forwarded by him having the locality attached to them, the several species, when determined, have been placed by me opposite their respective localities. A satisfactory stratigraphical distribution has been thus obtained, and it is interesting to observe the general correspondence which exists between the range in time of the Boulonnais and English species:—

* Trans. Zool. Soc. vol. viii. pt. 5, p. 303, 1873, read May 16th, 1871.

† Quart. Journ. Geol. Soc. vol. xxxix. p. 177.

Beds.	Thickness in feet.	Localities.	Species.
1. Upper Portland	30	Wimereux	Two *Isastrææ*, one very scarce, much worn, and only found in a pudding-stone at the top, 6 feet thick.
2. Middle Portland	30	Tour de Croy	No Corals.
3. Lower Portland or Upper Kimmeridge	75	Chatillon	*Thamnastræa* allied to *T. concinna*.
4. Middle Kimmeridge	180	Belledale	*Isastræa portlandica*, *Thamnastræa concinna*.
5. Lower Kimmeridge or Astartien	60	Questrecques	*Stylina*, sp., *Comoseris irradians*, *Microsolena*.
6. Clay	45	....	No Corals.
7. Coral Rag with *Cidaris florigemma*	18	Hourecq, Hesdin l'Abbé	*Stylina*, sp., *Isastræa helianthoides*, *I. explanata*, *Latimæandra sequana*, *Dimorphophyllia jurensis*, *Thecosmilia annularis*, *Rhabdophyllia Phillipsi*, *Calamophyllia pseudostylina*, *Thamnastræa concinna*, *T. foliacea*, *T. latimæandroidea*, *Comoseris irradians*, *Microsolena expansa*.
8. Clay	35	....	No Corals.
9. Calcaire des Boucards or Coralline Oolite with *Cidaris florigemma*	32	Mont des Boucards	*Thecosmilia annularis*, *Calamophyllia pseudostylina*, *Rhabdophyllia Phillipsi*, *Isastræa helianthoides*, *Thamnastræa concinna*, *T. foliacea*, *Comoseris irradians*, *Stylina*, sp.
10. Clay of Selles	130	....	No Corals.
11. Lower Grit with *Cidaris florigemma*	6	Houllefort	*Thecosmilia annularis*, *Isastræa helianthoides*, *Trochoseris oolitica*, *Thamnastræa concinna*, *T. gibbosa*, *Microsolena*, sp.
12. Oxford Clay	130	Le Wast	No Corals.
13. Cornbrash	25	Le Wast	*Stylina*, sp., *Bathycœnia moneta*, *Bathycœnia hemisphærica*, *Discocœnia bononiensis*, *Scyphocœnia staminifera*, *Confusastræa magnifica*, *Confusastræa*, sp., *Cryptocœnia plana*, *Montlivaltia caryophyllata*, *Montlivaltia Rigauxi*, *Isastræa limitata*, *Latimæandra lotharinga*, *Septastræa rigida*, *Enallohelia clavata*?, *Thamnastræa mammosa*, *Anabacia Bouchardi*, *Genabacia stellifera*.
14. Great Oolite, the corals confined to the lower part	50	Hydrequent, Rety, Blêquenèque	*Ceratocœnia elongata*, *Scyphocœnia excelsa*, *Convexastræa Waltoni*, *Cryptocœnia obeliscus*, *Cryptocœnia microphylla*, *C. Rigauxi*, *Isastræa limitata*, *Isastræa explanulata*, *Isastræa tuberosa*, *Montlivaltia caryophyllata*, *Confusastræa Rigauxi*, *Cladophyllia Babeana*, *Anabacia complanata*, *Thamnastræa mammosa*, *Microsolena excelsa*.
15. Great Oolite sands	30	Hydrequent	No Corals.

Palæozoic rocks on which the Oolites rest.

On the several beds of the foregoing section M. Rigaux has favoured me with the following additional and important remarks:—

Bed No. 1, Wimereux. "Two *Isastrææ* very much worn (one very scarce), only found in a pudding-stone of 6 feet thick, at the top."

Bed No. 3, Chatillon. "The same two *Isastrææ* very much worn, found in pudding-stone from 2 to 6 feet thick. It seems as if the *Isastrææ* lived in another sea, and were brought twice by special currents."

Bed No. 4, Belledale. "Corals are only found in a bed 6 feet thick, made up principally of worn-out corals and full of *Cidaris florigemma*. It is the highest real coral-bed in the Oolites, being found about the middle of the *Virgula*-beds."

Bed No. 5, Questrecques. "Corals occasional in a sandy oolite bed 3 feet thick."

Bed No. 7, Hourecq, Hesdin l'Abbé. "I look upon this bed as the representative of the English Coral Rag. It is entirely made up of corals and *Cidaris florigemma*."

Bed No. 9, Mont des Boncards. "Corals and *Cidaris florigemma* compose the lowest beds."

Bed No. 11, Houllefort. "A part of this bed is full of corals and *Cidaris florigemma*."

Bed No. 13, Le Wast. "The species of corals are numerous but the specimens very scarce, if we except the *Anabacia*, *Genabacia*, and *Isastræa moneta*."

Bed No. 14, Hydrequent, Réty, Bléquenèque. "Corals confined to the lower half, and common in the beds which correspond to the planking of Minchinhampton."

M. Rigaux further observes that he regards beds 6 to 9 inclusive as Corallian, and 10 and 11 as constituting the Lower Grit.

On looking over the foregoing it will be seen that one species of coral occurs in what must be regarded as the equivalent of the Lower Portland or Upper Kimmeridge deposits of this country. This is obviously affined to the very common and widely distributed Coral-Rag species *Thamnastræa concinna*; and when we observe that an unquestionable Portland species, *Isastræa portlandica*, has been found by M. Rigaux in the beds of the Middle Kimmeridge, we shall find no difficulty in deciding that the coral faunas of the Corallian and Portland Oolites graduate into each other.

Species from the Great Oolite.

Genus Discocœnia, n. g.

(Fam. *Astræidæ*; Subfam. *Eusmilinæ*.)

Two specimens of a coral from the Cornbrash of Le Wast, near Boulogne, have been received from M. Rigaux, the characters of which do not agree with those of any genus with which I am acquainted, and I therefore describe the form under the above name as follows:—

The corallum is discoidal, very thin, but becoming thicker by successive periods of growth, when the under surface becomes more or less convex, the calicular surface always remaining flat.

The calice is circular and the margin clearly defined but not projecting.

The wall is completely clothed with epitheca, which extends quite to the margin of the calice, but does not conceal the several stages of growth.

The septa are few in number, very stout, swollen, and without projections or ornamentation of any kind.

There is no appearance of endotheca, but it is quite possible that a vertical section would reveal tabulæ corresponding with the periods of growth.

The only recognized genera to which the present species could with any degree of consistency be referred, at least so far as external characters are concerned, are *Montlivaltia* and *Epismilia*. But the former, under no condition of wear, has septa resembling those of the present genus, which differs from both *Montlivaltia* and *Epismilia* in having no dissepimental tissue. And although the corallum becomes more or less massive by the addition of superimposed layers, yet each one of these really represents the corallum for the time being; and this mode of increase is quite unlike that of rejuvenesence, and is attributable to an entirely different cause. No such mode of growth occurs to my knowledge in either *Montlivaltia* or *Epismilia*.

It may be added that the general character of the septa is so very similar to that of the septa of *Bathycœnia* and another genus here described under the name of *Scyphocœnia*, as to leave little doubt that the present species represents a genus of simple corals which should be placed in the same family with those genera.

Discocœnia bononiensis, n. s. Pl. XXXII. figs. 1, 2.

The corallum is depressed and has a somewhat discoid form; but the calice is flat and its outer margin is well defined. The under surface has a moderate degree of convexity, somewhat as in *Montlivaltia Labechei*. The calice is circular, and the fossula is small and a little elongated. The septa are stout, but thin where they spring from the wall. They speedily increase in size, are a little flexuous, and the upper margins as well as the inner ends of all are smooth, and have a rounded or swollen appearance, which is most strongly pronounced in those which approach the centre and form the fossula. These latter come into contact with each other laterally at their inner ends but do not unite, and the fossula though very small is nevertheless distinct. The loculi are shallow, their depth being successively determined by the several periods of growth. As many as six of these are indicated by a corresponding number of superimposed layers, which are all of equal depth and are very shallow. There are forty septa. Of these the first two cycles are scarcely distinguishable the one from the other; the septa of the third are half the length of those of the first and second; and those of the fourth are wanting in some of the systems, and are very short in the others.

Genus Ceratocœnia, n. g.

(Fam. *Astræidæ*; Subfam. *Eusmilinæ*.)

The corallum is simple, much elongated, and horn-shaped, and appears to have been produced to a slender point at its inferior extremity.

It has a thin but regular epitheca.

The calice is very deep, round, and has a central level space upon which the septa do not encroach.

The septa are few in number, in six systems, and are thick, swollen, and wholly without ornamentation. The primary ones are considerably developed, while those of other cycles are small and irregular.

Only one example has been examined, the lower end of which, as well as one side of the calice, and the whole of its upper margin, has been broken away.

The exact relationship of this singular coral cannot be determined without better specimens than the one met with; but sufficient may be learned from this to establish its distinctness from any genus at present known, and to point out its resemblance to *Scyphocœnia*. The difference between the two genera consists in the one being simple while the other is compound.

Ceratocœnia elongata, n. s. Pl. XXXII. figs. 3, 4.

The corallum is elongated, curved, and the inferior extremity, which is broken off, appears to have terminated in a point, which was probably one of attachment.

In the present somewhat worn state of the corallum, the epitheca cannot be easily studied, but the rather numerous annular ridges which appear on the whole length of the corallum, indicate the existence of one, and the broad and rounded longitudinal ridges which correspond with the septa point out the number and form of the several costæ.

The calice is round, and very deep, and all the central part is free from the encroachments of septa, and nearly flat.

In the half of the calice which remains, there are six septa, of which three are primary and are prominent. The other three have very varying degrees of development, from a prominence only a little less than that of the primary ones, to an almost rudimentary condition. None of them pass on to the central floor of the calice.

The height of the corallum is 2 inches, and the diameter of the calice 5 lines.' It was obtained from the Great Oolite of Hydrequent.

Genus Scyphocœnia, n. g.

(Fam. *Astræidæ*; Subfam. *Eusmilinæ*.)

The corallum is composite, and the corallites are united by their walls, but are sometimes divided into clusters. It is peduncular, lobular, and expanding, and attached by a small point. The outer or common wall is either naked and costulated, or it has a small quantity of thin epitheca. The upper or calicular surface is irregularly convex; and the calices are few in number, large, open, very deep, and cup-shaped, and have thin margins. The septa are few in number, stout, smooth, and project but little into the calice, down the inside of which they pass, but lose themselves before reaching the fossular region, which consists of a smooth concave space. There is no appearance of endotheca, columella, or pali.

In one of the species here described, there are obvious though rather distant tabulæ, having very much the appearance of those represented by Prof. Duncan as characterizing a species of *Lophohelia,* to which I have already alluded.

Scyphocœnia staminifera, n. s. Pl. XXXII. figs. 5–7.

The corallum is small and was attached by a point, which in all the examples I have seen is a little curved, and from which it expands upwards and has a tendency to a flabelliform and lobular outline with an irregularly convex calicular surface. The common or investing wall is wholly without epitheca, and its costæ are distinct for the whole of its height. They are alternately large and small, rather closely placed, and either smooth or very finely granulated. At the margin of the calices where they join the septa they sometimes become somewhat cristiform, the larger ones uniting with the septa, but more frequently two or more run together before joining with the septa. This is chiefly observable in the younger calices, the older ones sometimes having their margins very thin, and both the mural costæ and septa reduced to a mere thread.

The calices are more or less round except when pressed by others, when they become rudely quadrangular, hexagonal, polygonal, or even triangular. They are very large, open, and deep: and those which have attained the greatest size have a smooth central space, or fossula, upon which the septa do not encroach.

In a full-sized calice there are three cycles of septa and part of a fourth, with faint indications of other rudimentary septa. At the edge of the calice they are generally very thin and thread-like, but the primary ones increase in thickness rapidly as they pass down the inside of the calice, and become very thick and bulging at their lower and inner ends, but without much prominence. The same peculiar formation is visible in those of the second cycle, but in a less marked degree. In those of the third cycle it is not observable. The septa of the first cycle occupy fully three fourths of the depth of the calice, those of the second are three fourths of the length of the first, and the remainder are short and irregular.

Gemmation takes place between the calices, as in *Bathycœnia*, and on the outside of the margin of the outer calices.

Height of the corallum of a full-sized example 1 inch; greatest diameter 1 inch; smaller diameter 9 lines. Diameter of a large calice 9 lines, and depth of the same 5 lines. It occurs, but is not common, as I learn from M. Rigaux, in the Cornbrash of Le Wast.

SCYPHOCŒNIA EXCELSA, n. sp. Pl. XXXII. figs. 8, 9.

The corallum has an upright subramose form, consisting of a few thick and short branches springing from a common root. Each ramus is formed by a bundle of corallites, which are the result of external gemmation, and are united and enclosed by a common wall. They have at intervals thick rounded swellings, and they terminate in three or four large circular and deep calices, which are on nearly the same level on the same branch. This gives to each branch a more or less capitate form.

The mural costæ are of nearly uniform thickness, and differ in this respect from those of *Scyphocœnia staminifera*, which are alternately large and small. They are most distinct at the edge of the calices, but are nowhere so much developed as those of *S. staminifera*, and their union with the septa is less distinctly cristiform. There is a little feebly developed epitheca.

The calices are circular, very deep, and their margins are very prominent, but not very thin.

The septa have much the same general disposition as those of *S. staminifera*, but they are much more regular, thinner throughout, and are not swollen in the middle. In appearance they closely resemble those of *Bathycœnia Slatteri*. The cycles are the same as in *S. staminifera*.

Height of the corallum 1 inch 5 lines; diameter of the largest calice, 5 lines.

A favourable fracture exposes some well-defined but distant tabulæ, closely resembling those of a coral from the Great Oolite of Stonesfield, which I have elsewhere figured*. Their presence, as well as the general similarity that exists between the general conformation of the corallum of this species and the young examples of the Stonesfield coral, leaves but little doubt as to their natural affinities.

One specimen only has been examined. It was taken from the Great Oolite of Hydrequent.

Genus BATHYCŒNIA, Tomes.

Although I have described this genus as one of the Eusmilinæ, I am now in some doubt as to its real affinities, the apparently allied forms here described obviously being possessed of true tabulæ. Provisionally, therefore, I leave it in its present place.

BATHYCŒNIA MONETA, d'Orb., sp.

Prionastrœa moneta, d'Orb. Prodr. de Paléont. t. i. p. 322 (1850).

Isastrœa? *moneta*, M.-Edw. & Haime, Pol. Foss. Terr. Paléoz. p. 104 (1851).

The comparison of specimens of *Bathycœnia Slatteri* with examples of the so-called *Isastrœa moneta* received from M. Rigaux, has convinced me that they are both referable to the same genus, though they are specifically distinct. Besides the perfectly hori-

* See Quart. Journ. Geol. Soc. vol. xxxix. pl. vii. fig. 4.

zontal or concave basal wall, which characterizes the latter species, it has much thicker septa, which, when entire, spring boldly inwards towards the centre of the calice, their free margins representing the segment of a circle, and they pass into the centre, and there form a spurious columella.

In the above-quoted work of MM. Milne-Edwards and Haime, the present species (which had been placed by M. d'Orbigny in the genus *Prionastræa,* after the examination of specimens from Boulogne) was doubtfully included in the genus *Isastræa.* In their later work*, however, it was placed in that genus without any such expression of uncertainty.

Bathycœnia hemisphærica, n. sp. Pl. XXXII. figs. 13, 14.

The corallum is regularly dome-shaped, and the under surface nearly flat, and, as in *B. moneta*, attached to a shell by a point. The common or basal wall is without a trace of epitheca, and the corallites, which are distinctly visible from below, have well-formed and regular mural costæ, which meet at an angle in the shallow radiating furrows between the corallites.

The calices are nearly circular, and very deep. Six principal septa project considerably into the calice, their inner margins being nearly vertical, and they pass quite to the bottom of the calice, but do not pass over the floor of it to the centre, as in *Bathycœnia Slatteri.* Six other septa, having much less prominence, pass also down the vertical inside of the calice, but diminish in size and project so much less that they barely reach the floor. Besides these, there are some rudimentary septa, which, however, like the others, are subcristiform on the mural region.

Height of the corallum one inch, and its diameter one inch. Diameter of the calices from two to three lines.

One specimen only appears in the collection. It is from the Cornbrash of Le Wast.

Genus Convexastræa, d'Orb.

Convexastræa Waltoni, Edw. & Haime, Brit. Foss. Cor. p. 109. pl. xxiii. figs. 5 & 6.

The exact resemblance which a specimen from the Great Oolite of Bléquenèque bears to English specimens from the neighbourhood of Burford, Oxfordshire, and Cirencester, Gloucestershire, leaves no doubt about the species, and furnishes an entirely new locality for it.

Genus Cryptocœnia, d'Orb.

Cryptocœnia obeliscus, Mich., sp.

Madrepora obeliscus, Mich. Icon. Zooph. p. 112, pl. 25. fig. 5.

A specimen from the Great Oolite of Bléquenèque, near Boulogne, received with other specimens here mentioned, agrees, both in out-

* Hist. Nat. Cor. vol. ii. p. 536.

ward form and in structural details, so closely with *Cryptocœnia obeliscus* as to leave no doubt of its identity with it. It was placed, though not without doubt, by MM. Milne-Edwards and Haime in the genus *Stylina*, in their monograph of Palæozoic Corals*, but afterwards, in their general work on Corals†, removed to the list of doubtful species. M. de Fromentel wholly ignores it.

CRYPTOCŒNIA PLANA, n. sp.

The corallum consists of a peduncle surmounted by a swollen and globular head, which has a diameter fully three times that of the peduncle.

The calices are large, circular, few in number, prominent, and the spaces between them are centrally depressed. The intercalicular costæ are very feebly developed, and are only observable near the margins of the calices, where they correspond in their relative size with the septa. The calices are deep, and their margins are thin. There are six principal septa, which also are thin, and pass nearly to the centre of the calice. Six others, forming the second cycle, are much less prominent, and are about two thirds the length of the primary ones. The remaining twelve have still less prominence, thickness, and length, and constitute the third cycle.

Gemmation takes place midway between the calices.

The height of the corallum is 1 inch 6 lines, of which the peduncle is one third. The diameter of the head is 1 inch 3 lines; of the calices 2 lines; and of the intervals between them 2 lines.

One specimen only, as I learn from M. Rigaux, has been met with in the Cornbrash of Le Wast.

CRYPTOCŒNIA RIGAUXI, n. sp.

With the *Cryptocœnia obeliscus*, and from the Great Oolite of Hydrequent, was received a small specimen of a *Cryptocœnia*, which, having the "octomeral" type of M. de Fromentel, is quite distinct from the *C. luciensis*, to which species it was probably referred by MM. Milne-Edwards and Haime‡.

The corallum is small and globular, and attached by a small space. The calices are about the size of those of *C. tuberosa*, but are rather nearer together. The principal septa, eight in number, are stout, pass nearly to the centre of the calice, and unite deep in it, but do not there form a spurious columella. In some of the calices there are eight other septa, which are merely rudimentary; they constitute, where present, the second cycle. The intercalicular costæ are stout, prominent, and cristiform, and so much crowded as to completely conceal the upper margin of the wall, as in *Convexastræa*. They decrease in size rapidly as they recede from the calice over the intercalicular space, in the middle of which they meet, but do not blend with those of other calices.

The present species seems to bear some resemblance to the one

* Pal. Foss. des Terr. Paléoz. p. 60.
† Hist. Nat. Cor. vol. ii. p. 247.
‡ Hist. Nat. Corall. vol. ii. p. 272.

described by M. de Fromentel under the name of *Cryptocœnia brevis**, which has also eight principal septa, but differs from it in several respects. The calices are larger, there are fewer cycles of septa. Moreover, in the description of *C. brevis*, no mention is made of the crowded and cristiform intercalicular costæ, which are so characteristic of the present species, and which at first sight led me to place it in the genus *Convexastræa*. That it is a *Cryptocœnia* I do not, however, entertain any doubt; but its resemblance to *Convexastræa* is so great as seriously to endanger the value of that genus.

Height of the corallum 1 inch 3 lines, its diameter 10 lines. Diameter of the calices $1\frac{1}{2}$ line; from centre to centre of the calices 2 lines.

Cryptocœnia microphylla, Tomes, Quart. Journ. Geol. Soc. vol. xxxix. p. 179, pl. vii. fig. 2.

A specimen of small size and globular form appears in the collection. It was obtained from the Great Oolite of Hydrequent.

Cryptocœnia, sp.

A single specimen of small size, and in a much damaged state, is all I have been favoured with of this species, which is obviously a well-marked one. I am unable further to describe it than to say that the corallum is small and nearly globular, and has a great many small and much-crowded calices, and that the intercalicular costæ, so far as may be observed, bear considerable resemblance to those of *Convexastræa*. I am unable to give its locality.

Genus Stylina?

Stylina, sp.?

A fragment only of a dendroid coral, in an unfavourable condition, is all I have seen to lead me to include the genus *Stylina* in the Cornbrash of Le Wast. It was received with other species from Le Wast by the kindness of M. Rigaux, and closely resembles in its details a coral figured by Quenstedt in his recently published work on the fossil corals of Germany, under the name of *Astræa corona*†. The specimen figured by Prof. Quenstedt was obtained from the Coral Rag of Menzières.

Genus Montlivaltia, Lamx.

It may be remarked of this genus, the representatives of which are so abundant in the Jurassic formations, that very few flourished in the sea of the period of the Great Oolite; and the species from the district now under consideration do not detract from the truth of that observation, two only appearing in the collection made by M. Rigaux.

* Introd. Etude Polyp. Foss. p. 199.

† Petrefact. Deutschlands, sechster Bd. p. 776, tab. 173. fig.25.

In a genus which, like *Montlivaltia*, contains a great many species, it is most important, if only for their proper determination, that the appearances exhibited at different periods of their growth should be carefully examined and well understood. And this applies more especially to a comparison of the respective periods of growth of such species as are broadly attached and those which are fixed by a point, as well as to the elongated fossula of others, as compared with the same part in those in which it is circular.

The earliest period of growth of some *Montlivaltiæ*, when nothing more than a superficial and attached star-like form is visible, presents the appearance of several rings, one within the other. These are nothing more than successively developed walls. Within the inner circle are the earliest or primary septa; in the second and other succeeding circles are the second and successively produced cycles, which, as well as the primary ones, take their growth in anticipation of the encircling walls. However, it not unfrequently happens, that more than one cycle is produced before the growth of the enclosing wall commences. Very beautiful illustrations of this may often be seen attached to some hard substance, such as a shell, which have not yet attained to any appreciable height, but present, in their periods of expanding growth, much the aspect of a section of an exogenous tree, the rings of growth and medullary rays being represented by the walls and septa of the coral. A very interesting instance of this is shown in a very young and attached example of *Montlivaltia Victoriæ* in the collection of my friend Mr. Beesley, of Banbury. More instructive still are the under or attached surfaces of certain *Montlivaltiæ* with broad bases from the *Trigonia*-grit of the Inferior Oolite near Cheltenham. When a fortunate detachment has laid the attached base of the coral open to view, it presents all the periods of growth which took place until the corallum had attained to nearly its full diameter, and all the cycles of septa, and the successively formed and superseded walls, with the clearness of an explanatory diagram drawn on paper.

Full-sized examples of the *Montlivaltiæ* just mentioned have a considerably elongated fossula; but the examination of the base shows that at first, and until several cycles of septa and several encircling walls had been produced, the fossula was represented by a mere point. It was not until the corallum grew in an upward direction, that the fossula lost its circular form, and became linear.

But in other species, which are fixed by a point only, the diameter of the corallum is not so much the result of a series of successively produced walls, as of the expanding and upward growth of an early formed wall, which growth must of necessity in such species take place before the whole of the cycles are produced, instead of afterwards. There are other species, again, which are attached by a base of intermediate size. These will increase in size by both methods of growth. Both the turbinate and the cylindrical or intermediate forms may have the fossula circular or linear; but from what has already been said, it will be readily understood that, when elongated, some idea of the age of the specimens is desirable before placing too much reliance on this as a specific character.

Montlivaltia caryophyllata, Lamx.

A considerable number of specimens of *Montlivaltiæ* are now before me, all of which, though differing considerably in their comparative height and diameter, are constant in having exsert septa, uniformity in the number of the cycles in all the larger examples, and in elongated fossula. They are specifically undistinguishable from English specimens from Fairford, and from Milton in Oxfordshire. The collection contains specimens from Marquise, Hydrequent, and Le Wast.

Montlivaltia Rigauxi, n. sp. Pl. XXXII. figs. 15–17.

The corallum has a more or less depressed form, as in *Montlivaltia lens*. It is ovoid, and the upper surface has a swollen or inflated appearance. The wall is horizontal, and does not extend to more than three fourths of the diameter of the corallum; but unlike that of *M. lens*, it is slightly convex, and is almost wholly without concentric wrinkles. The fossula is deep and considerably elongated in the direction of the greater diameter of the corallum, of the entire length of which it occupies about one third. The septa project beyond the basal wall considerably, and their upper margin is much arched. They are nearly straight, but curve a little at the fossula, and are thin, and have their sides ornamented with very thin vertical ridges, which are rather far apart, and terminated at their margins in very small and rather distant points. The intervals between these ridges are of twice the breadth of the ridges themselves. The cycles are rather difficult to trace, owing to the irregular development of the later ones; but there are about 120 visible septa. Of these the primary and secondary pass quite into the fossula. The tertiary ones are fully three fourths of the length of the primary ones, and those of the fourth cycle are about half the length of the primary ones.

Greater diameter of the corallum 1 inch 5 lines, shorter diameter 1 inch 2 lines. Height 8 lines.

From the *Montlivaltia lens* the present species differs very materially in its greater size, more inflated or bulging form, and longer fossula, and by its thinner septa and their thinner and more distant ridges, ending in smaller and more separated denticulations. Added to these differences is the comparatively small extent of the basal wall, which is never concave, as in *M. lens*. MM. Milne-Edwards and Haime have referred a species of flat *Montlivaltia* from Marquise, which is no doubt the present one, to their *M. depressa**; but specimens of the latter obtained from the type-locality by the late Mr. Walton, and obligingly given to me, differ very materially from the French specimens received from M. Rigaux. Of the specimens of *M. depressa* collected by Mr. Walton I shall have occasion

* Hist. Nat. Corall. vol. ii. p. 326.

to speak on some future occasion. *Montlivaltia Rigauxi* occurs in the Cornbrash of Le Wast.

Genus Cladophyllia, M.-Edw. & Haime.

Cladophyllia Babeana, M.-Edw. and Haime, Pol. Foss. Terr. Paléoz. p. 81 (1851); Brit. Foss. Cor. p. 113, tab. xxi. fig. 2.

From the appearance in the collection of M. Rigaux of only one small branch of the present species, obtained from the Great Oolite of Hydrequent, it would seem to be rare in the locality.

Genus Septastræa, d'Orb.

Septastræa rigida, n. sp.

The corallum is massive, but appears, so far as may be seen by the examination of a well-preserved fragment, to have a depressed form, with a thin outer edge.

The calices are remarkable for the small number of their angles, which varies from three to five. They are deep, and the walls are very clearly defined, straight and prominent.

The septa are stout, very uniform in thickness throughout, and project far into the calice, their margins describing a gentle curve, but they do not project far enough to obscure the deep and narrow fossula.

The interseptal loculi are only a little wider than the thickness of the septa. The latter alternate very regularly with those of adjoining calices, and do not conceal the wall from which they spring.

A single calice contains about twenty-six septa, of which six pass towards the centre of the calice, but leave it open; six others are three fourths the length of the first, and the remainder are less than half the length of the second. All of them have their edges papillated, and the papillæ, like the septa themselves, are very uniform in size throughout.

Fissiparity is frequent, and as two calices may be observed within one wall, the calicular surface has much the aspect of that of *Latimœandra*.

The present species appears to bear some resemblance to the *Septastræa dispar* of M. de Fromentel*, but the calices are not much more than half the size of those represented in his figure.

From the Cornbrash, probably of Le Wast.

Genus Confusastræa, d'Orb.

Confusastræa Rigauxi, n. sp. Pl. XXXII. figs. 20, 21.

The only specimen in the collection consists of a flake split from the side of a corallum, which must have been nearly globular, probably of somewhat similar form to the *Confusastræa magnifica* from the Great Oolite at Fairford, but of rather smaller size.

The calices are not more than half the size of those of the species just named. They are more or less circular or oblong, but sometimes assume a rotundo-triangular form, and are rather deep and

* Monogr. Polyp. Jurass. Sup. p. 48, pl. vi. fig. 2.

open, the septa being exsert only near to the mural line. Between all of them there is a well-defined and depressed line, corresponding with the upper margin of the wall. The septa are extremely delicate, having only the thickness of a hair. They do not exceed in this respect those of *Anabacia complanata*.

The costæ covering the common or investing wall (those of the side of the corallum alone being observable in the fragment) are continuous with the septa of the contiguous calices; but none of the septa join with those of other calices, there being a distinct break in the depression between the calices. Both septa and costæ are closely and regularly papillated, the papillæ having a direction across the septum.

The cycles are difficult to count, but in a full-sized calice there are more than one hundred septa, the greater number of which meet in the centre of the calice, but do not blend.

Gemmation is observable between the calices.

Diameter of the calices 3 to 4 lines.

Compared with *C. tenuistriata* from the Inferior Oolite, it differs in having the corallum more globular, the calices smaller and much deeper, and the septa and septal costæ much thinner, more numerous, and much more closely papillated. The extreme delicacy of the septa would alone distinguish the present species from all others.

The only specimen received was obtained from the Great Oolite at Rety.

Confusastræa magnifica, Tomes, Quart. Journ. Geol. Soc. vol. xxxix. p. 184, pl. vii. figs. 15 & 22 (1883).

After a careful comparison of a specimen forwarded by M. Rigaux with the type specimen of *C. magnifica*, I am unable to determine that there are sufficient differences to constitute a new species. The French specimen, however, differs from the one from Fairford in having a concave instead of a peduncular base, and in having the calices rather more prominent and their central region more open.

The specimen examined came from the Cornbrash of Le Wast.

Confusastræa, sp.

A very much worn coral from the same locality as the last; differs from it in having calices which are fewer in number and of twice the size. Two of these are so ill-defined the one from the other as to lead to the supposition that they are confluent, as in *Chorisastræa*. Better specimens are needed to determine the true affinities of this coral, though it may be confidently regarded as distinct from any other species here mentioned.

Genus Isastræa, M.-Edw. and Haime.

Isastræa limitata, Lamx., in Michelin.

The specimens from the Cornbrash of Le Wast, and the Great

Oolite of Hydrequent and Bléquenèque do not differ in any important respect from English specimens from Fairford, Burford, Glympton, and other localities.

ISASTRÆA EXPLANULATA, Milne-Edwards and Haime, Brit. Foss. Cor. pt. ii. p. 115, tab. xxiv. fig. 3.

A portion of a dendroid specimen in very perfect preservation has been forwarded by M. Rigaux, which he obtained from the Great Oolite at Hydrequent. It resembles with great exactness specimens from the Great Oolite of Burford. Another specimen was collected at Bléquenèque.

ISASTRÆA TUBEROSA, n. sp.

The present species possesses nearly the same characters as the one from the Great Oolite of Rollright and Fairford, to which I have given the name of *Isastræa Beesleyi*; but its calices are not more than one fourth the size of those of that species.

The corallum is oblong, and of moderate size. The calices are nearly circular, and the fossula, which is deep, is round and well defined.

The septa are much exsert and are continuous with those of other calices. They are rather thick, and their sides have numerous well-defined vertical and prominent ridges, which terminate at the edge of the septum and there form papillæ. When the calices are worn down, the septa are seen to unite in the centre of the calice, and form a spurious columella; but this is not visible in the unworn calices. In a well-formed calice there are twenty-four septa, twelve of which pass nearly into the fossula, and the other twelve are about half their length.

Greatest diameter of the corallum 2 inches 6 lines; diameter of the calices from 1 to $1\frac{1}{2}$ line.

It occurs in the Great Oolite of Hydrequent; but as only one specimen has been forwarded by M. Rigaux, it is presumably not abundant.

I have seen a coral in the Museum at Oxford which I believe is identical with this, and which Prof. Prestwich informed me came with Mr. Brown's collection, and was obtained near Cirencester. The present species and *I. Beesleyi* form a small group of *Isastrææ* which differs from ordinary *Isastrææ* in having the septa very much exsert and continuous with those of other calices, and in having an imperfectly developed wall. *Isastræa depressa* has the septa continuous also; but they are not at all exsert.

Genus LATIMÆANDRA, M.-Edw. & Haime.

LATIMÆANDRA, sp.

As with some other species in the collection, the present one is represented by one example only. It possesses some peculiarities in common with *Latimæandra Haimei*, such as the particular character of the septa, the union of the shorter of these with the longer, and the blending together of the principal ones in the centre of the calice. It differs, however, in having larger and deeper calices, very few of which are arranged in series, the series in all cases being short, and not containing more than two calices.

The state of preservation of the specimen is unsatisfactory, and I prefer for the present to abstain from giving it a specific name.

It was obtained from the Great Oolite at Werry.

LATIMÆANDRA LOTHARINGA, E. de From. Cat. Polyp. de l'Yonne (1856).

The species which I have already, in my paper on Great-Oolite corals, referred, though not without some hesitation, to the *Latimæandra lotharinga* of M. de Fromentel, occurs also in the Cornbrash of Le Wast. Compared with English examples from Burford, Rollright, and Stonesfield in Oxfordshire, and Fairford in Gloucestershire, the French specimens present no points of difference.

Genus THAMNASTRÆA.

In my paper on the Corals of the Coral Rag * I made some remarks on the non-perforate nature of the septa of the well-known *Thamnastræa arachnoides*, and hinted at the desirability of removing it from the genus *Thamnastræa*. This had, however, practically been done by Milaschewitsch, who, while placing it in that genus, did so with an expression of doubt; this I wholly overlooked.

The species on which the genus *Thamnastræa* was founded is a dendroid form from the Middle Oolite of Caen: this I have not as yet had the opportunity of examining; its near ally, *Thamnastræa Lyelli*, from Stonesfield, is, like most of the Great-Oolite corals, wholly without internal structure, and whether the tissues were perforate or not cannot be ascertained. In the absence therefore of direct evidence respecting the structure of both the type and the allied species, it is difficult to say whether *Thamnastræa* is a perforate or imperforate genus, but it may with the greatest confidence be asserted that, as at present accepted, it is made up of a mixed assemblage of forms which have little more in common than the one character of confluent septal costæ.

On this subject I shall have occasion further to remark when speaking of the Coral-Rag *Thamnastrææ*.

THAMNASTRÆA MAMMOSA, M.-Edw. & Haime, Brit. Foss. Cor. p. 119, pl. xxiii. fig. 3.

Specimens from the Cornbrash of Le Wast differ from others from the lower part of the Great Oolite of Hydrequent in having the corallum smaller and more globular; otherwise they are alike, and both have the calices rather smaller, and the septa more delicate than in the English specimens.

* Quart. Journ. Geol. Soc. vol. xxxix. p. 558.

Genus Anabacia.

Anabacia complanata, Defrance, sp.

Fungia complanata, Defr. Dict. Sc. Nat. t. xvii. p. 217 (1820).
Anabacia orbulites, Milne-Edwards and Haime, Brit. Foss. Cor. p. 121.
Anabacia complanata, Milne-Edwards and Haime, Hist. Nat. Corall. t. iii. p. 31.

Specimens of this abundant and widespread species have been forwarded by M. Rigaux from the Great Oolite of Marquise and Hydrequent.

Anabacia Bouchardi, Milne-Edwards and Haime, Polyp. Foss. des Terr. Paléoz. p. 122 (1851).

I fail to satisfy myself that this species is really distinct from the last. It is characterized by the greater number and the extreme delicacy of the septa; but in both these respects it is approached so nearly by some examples of *A. complanata* that it is very difficult to determine where one species ends and the other begins.

As it was from specimens from Boulogne that MM. Milne-Edwards and Haime first described this species, the specimens from M. Rigaux possess especial interest and value for comparison. Specimens have been received from Le Wast.

Genus Genabacia, Milne-Edwards and Haime.

Genabacia stellifera, d'Archiac, sp.

Fungia stellifera, d'Archiac, Mém. de la Soc. Géol. de France, 2me série, t. v. p. 369, pl. 25. fig. 2 (1843).
Genabacia stellifera, Milne-Edwards and Haime, Ann. des Sc. Nat. 3me série, t. xv. p. 92 (1851).

Specimens of this well-marked species from the Cornbrash of Marquise, one of the localities quoted by the original describers of the genus *Genabacia*, resemble in all respects examples received from M. de Fromentel, which he obtained from the "Bathonien" formation of Montarlot. I have long expected to meet with the genus *Genabacia* in our English Oolites, but have not as yet been successful in my search for it.

Genus Microsolena.

Microsolena excelsa, M.-Edw. and Haime, Brit. Foss. Cor. p. 124, pl. xxv. fig. 5 (1851).

A single example unquestionably referable to this species has been sent by M. Rigaux. It agrees in all respects with English specimens. From the Great Oolite of Hydrequent.

Species from the Coral Rag.

Genus Stylina, M.-Edw. & Haime.

Stylina, sp.

A species which is represented by a single worn specimen appertaining to the decameral type of M. de Fromentel, appears in the collection.

The calices are rather crowded, and have a diameter of one line, with rather thick and prominent margins. There are ten principal septa, which are of one length, and closely approach the columella. The remainder, ten in number, are very short. The columella is a little compressed. The intercalicular costæ are, so far as may be ascertained in the worn specimen, of nearly equal size.

I have compared this coral with *Stylinæ* from our own Coral Rag, and from presumably corresponding horizons at Nattheim and in the Haute-Saône, but fail to identify it with either species; nor can I refer it to any of those which have been described by MM. Milne-Edwards and Haime, MM. de Fromentel, Milaschewitsch, and others. It appears to come nearer to *Stylina constricta* and *S. bullata* of M. de Fromentel than to any others.

The specimen mentioned was obtained from the Coral Rag of Hourecq.

Stylina, sp.

Another worn specimen, specifically distinct from the foregoing, has calices which are not crowded, and which have a diameter of two lines. There are six primary septa, which closely approach the columella and end in a paliform enlargement, which is equal in size to the somewhat compressed columella. Six secondary septa are one third the length of the primary ones, and have no terminal enlargement. Those of the third cycle are half the length of the second. Neither the prominence of the calices nor the intercalicular costæ are observable from the worn condition of the specimen.

It was taken from the Coral Rag at Questrecques, at a somewhat higher geological level than the last-mentioned species, from which it is obviously distinct.

Genus Calamophyllia, Blainv.

Calamophyllia pseudostylina, Mich. sp.

Lithodendron pseudostylina, Mich. Icon. Zooph. p. 96, pl. 19. fig. 9.
Calamophyllia pseudostylina, M.-Edw. & Haime, Hist. Nat. Corall. vol. ii. p. 96, pl. xix. fig. 9.

Several clusters of broken corallites in parallel masses, having very equal non-papillated but granulated mural costæ, and frequently recurring and strongly developed annular expansions, occur in the collection. These, in the size of the corallites and in the equal development of the costæ, as well as in the particulars above stated, agree closely with the figure of *Lithodendron pseudostylina* of Michelin. The largest specimen consists of the terminal portion of a corallum: that is to say, of a good many corallites of small size placed rather closely side by side. In these, as well as in fragments having a greater diameter, a rather large and highly porous columella is observable. This I do not find mentioned by Michelin or by MM. Milne-Edwards and Haime. The species occurs at Hourecq or Hesdin l'Abbé.

Genus Rhabdophyllia, M.-Edw. & Haime.

Rhabdophyllia Phillipsi, M.-Edw. & Haime, Polyp. Foss. Terr. Paléoz. p. 83 (1851); Brit. Foss. Cor. p. 87, pl. xv. fig. 3 (1851).

Only one specimen, which agrees very closely with Steeple Ashton specimens, has reached me. The species has been obtained from Hourecq and the Mont des Boucards.

Genus Thecosmilia, M.-Edw. & Haime.

Thecosmilia annularis, M.-Edw. & Haime, Pol. Foss. Terr. Paléoz. p. 77 (1851); Brit. Foss. Cor. p. 84, pl. xiii. fig. 1, and pl. xiv. fig. 1 (1851).

A considerable number of specimens, chiefly in fragments, are in the collection of M. Rigaux, which, labelled with the names of Hourecq, Boucard, and Houllefort, determine the range in time of the species in the Corallian of the Boulonnais.

Genus Confusastræa, d'Orb.

Confusastræa, sp.

The collection contains a portion of a large specimen which, when entire, must have had a diameter of at least 8 or 9 inches. I am unable, from its present condition, to determine the species, but may state that the calices are larger and the septa stouter than in *Confusastræa magnifica*.

Genus Dimorphophyllia, Reuss.

Dimorphophyllia jurensis, Becker, Palæontographica, vol. xxi. p. 155, pl. xxxvii. fig. 8.

The only evidence of the presence of this well-marked species in the Coral Rag of the Boulonnais rests on a somewhat fragmentary but well-preserved and characteristic specimen sent to me by M. Rigaux several years since. It was obtained from Hourecq, and, until relieved of its enclosing matrix, was supposed to be a *Thamnastræa* with widely separated calices. Compared with specimens of *Dimorphophyllia oxylopha*, Reuss, in my collection, from the Upper Oligocene beds of Monte Grumi, the generic identity of the Jurassic and Tertiary species becomes evident. With the

Dimorphophyllia jurensis of Becker, from the Corallian of Nattheim, it is unquestionably specifically identical.

Genus Latimæandra, M.-Edw. & Haime.

Latimæandra sequana, E. de From. Bull. Soc. Géol. de France, 2me série, t. xiii. p. 862; Monogr. Polyp. Jurass. Sup. pt. i. p. 23, pl. ii. fig. 3.

M. de Fromentel has described a species of *Latimæandra* under the above name which, he observes, cannot, from the peculiar arrangement of the calices, be confounded with any other species. There are three specimens of a *Latimæandra* in the collection forwarded by M. Rigaux, all from the upper part of the Corallian, which in the number and conformation of the septa, correspond with the description and figure of the above species, as given by the original describer.

The arrangement of the calices in lines or in groups between distinct and well-developed ridges, much as in the genus *Comoseris*, observable in this species, is not, however, a character on which too much reliance can be placed; for not only are the ridges, as mentioned by M. de Fromentel, irregular on different parts of the corallum, but in two of the three specimens here mentioned they are wholly wanting. The peculiar though inconstant ridges in this species render my already expressed opinion that more than one generic form is included in the genus *Latimæandra*, all the more probable. Although given by M. de Fromentel as appertaining to the Portland Oolite only, it must now be added to the list of species of the Corallian, though so far as is known up to the present time, it is confined to the upper beds of that formation.

Genus Isastræa, MM. M.-Edw. & Haime.

Isastræa explanata, Goldf. sp.

Astræa explanata, Goldf., Petref. Germ. t. i. p. 112, pl. 38, fig. 14.
Isastræa explanata, M.-Edw. & Haime, Pol. Foss. Terr. Paléoz. p. 103.

Of this well-known species M. Rigaux forwards me a single example, which differs from Steeple-Ashton specimens only in having the calicular surface nearly flat instead of convex, and the underside almost peduncular, and furnished with a more fully developed epitheca. It was obtained from Hourecq.

Isastræa helianthoides, Goldf. sp.

Astræa helianthoides, Goldf. Petref. Germ. p. 65, pl. 22, fig. 4*a*.
Isastræa helianthoides, Milne-Edwards and Haime, Hist. Nat. Cor. t. ii. p. 538.

I have compared specimens received from M. Rigaux with others from the Coral Rag of Nattheim, and find that they do not differ in any essential degree from each other. Its habitats are Hourecq, the Mont des Boucards, and Houllefort.

Isastræa portlandica, E. de From. Monogr. Polyp. Jurass. Sup. p. 42, pl. iv. fig. 6.

A species of *Isastræa* having calices which bear some resemblance to those of our *Isastræa explanata*, both in their superficial character and in their size, occurs quite high up in the Oolitic formation, in a bed which corresponds, as I learn from M. Rigaux, with our Kimmeridge Clay.

In the number of cycles and in the relative length of the septa of the different cycles, as well as in the size of the calices, it agrees very well with the figure of *I. portlandica*, to which it must be referred.

Genus Trochoseris, M.-Edw. & Haime.

Trochoseris oolitica, n. sp. Pl. XXXII. figs. 10–12.

Several specimens of a species of *Trochoseris*, all from the "Lower grit of Houllefort," which were forwarded to me several years since by M. Rigaux, I believe to be undescribed. I therefore give them the above name, and describe them as follows:—

The corallum has the form of an inverted cone, the diameter of which somewhat exceeds its height, and it was attached by its point. The mural costæ are rather broad, equal in size, rounded and granulated, and placed closely side by side. They extend the whole length of the corallum; but there are occasional narrow bands of epitheca on some of the specimens, especially near to the point of attachment. The calice is irregularly round or ovoid, shallow, and the septa, which are not exsert, slope into the centre, which is depressed and occupied by a small and papillose columella. All the septa are rather stout, closely placed, and the shorter ones run into the longer ones, mostly forming pairs, though sometimes groups of three or four are formed. They are all thicker at their outer than their inner ends, and their margins have closely placed tubercles, the longer diameter of which is across the septa. There are four cycles and part of a fifth. All the septa have their sides ornamented by pointed tubercles (synapticulæ) which are rudely arranged in horizontal rows, and when these are near the margin of a septum they mix with those on its edge, and give to it the appearance of great thickness. The columella is small, depressed, and composed of about twenty papillæ.

The length of the corallum is from 6 to 8 lines, and the diameter from 7 to 9 lines.

The only species of *Trochoseris* to which the present bears resemblance is the *Trochoseris Morrisi* of Duncan *, from the Upper Greensand of Haldon; but the septa of *Trochoseris oolitica* are much more crowded, anastomose much less, and are less exsert.

M. de Fromentel † has described a *Trochoseris* from the Corallian

* Quart. Journ. Geol. Soc. vol. xxxv. p. 89, pl. viii. figs. 13, 14.
† Introd. Etude Polyp. Foss. p. 128.

of Champlitte under the name of *Trochoseris corallina*, which has as many as 120 unequal septa, or nearly double the number of those of the present species.

Genus Thamnastræa, Lesauvage.

Of the generic claims of the Coral-Rag *Thamnastrææ*, I can only speak definitely in so far as some of the species are concerned. The first on the list has true synapticulæ and imperforate septa, and most likely the same characters appear in the second. These are probably true Fungidæ; but the other species have not yet received that close attention which is essential for their proper determination. I prefer therefore, for the present, to leave the genus where I find it, rather than to make divisions which would perhaps render necessary a complete revision of the nomenclature of the group.

Thamnastræa ? latimæandroidea, n. sp. Pl. XXXII. figs. 18, 19.

In the external conformation of the corallum this species so closely resembles some species of *Latimæandra*, that I placed it in that genus until the discovery of synapticulæ rendered its presence among the Astræidæ impossible.

The general outline of the upper or calicular surface may be described as moderately convex, and as having an irregularly ovoid but lobular outline, the corallites being on some parts of the corallum divided into groups of 8 or 10, which are completely surrounded by an outer or common wall, somewhat as in the *Chorisastræa dubia* of Becker * and the *C. corallina* of M. de Fromentel †.

So far as may be observed from the condition of the specimen, there has been a thin epitheca, which, being for the most part lost, reveals mural costæ, which, though not strongly marked, are very uniform in size and persistent, and bear some resemblance to those of *Thamnastræa arachnoides*.

The calices are mostly simple, being in series in two parts of the corallum only. In one of these there are two calices, and in the other five. The walls enclosing the calices are well developed and prominent, and the latter are deep, and have a well-marked and spongy columella, which is rather large in size. The septa are thin and anastomose a good deal. There are about 60 in a simple calice; about 12 of these, constituting the first cycle, pass into the columella, and all the others, according to their rank, unite at different points with the primary ones, and occasionally with the secondary ones, and form groups, somewhat as in the *Trochoseris Morrisi* described by Prof. Duncan from the Cretaceous formation of Haldon ‡.

The synapticulæ are not very regular in their development, but are in distinct lines, which correspond to the margins of the septa. They are true synapticulæ, and very nearly resemble those of *Thamnastræa arachnoides*. I fail to detect pores in the septa; and if the latter are imperforate the species would fall within the definition proposed for the family Fungidæ by Milaschewitsch, that is to

* Palæontographica, vol. xxi. † Polyp. Corall. de Gray, pl. vii. fig. 5.
‡ Quart. Journ. Geol. Soc. vol. xxxv. p. 94, pl. viii. fig. 14.

say, it would be possessed of true synapticulæ and a non-porous structure of the tissue of the corallum.

The coral here described, while preserving the outward form and appearance of a *Latimæandra*, possesses a structure which approximates it to *Thamnastræa arachnoides*, from which it differs in having much thinner and much more numerous septa, and more fully developed walls.

I have already, in a former paper on Coral-Rag Madreporaria, suggested that the well-known *Thamnastræa arachnoides* possesses some peculiarities which render its place in the genus *Thamnastræa* * very doubtful. The present allied species, with its well-developed walls, occasions still more doubt as to its affinities with that imperfectly defined genus, and points to the necessity for its revision. It occurs at Hourecq, from which place a single specimen has been forwarded.

THAMNASTRÆA ? CONCINNA, Goldf. sp.

Astræa concinna, Goldf., Petref. Germ. t. i. p. 64, pl. 22. fig. 1A.
Thamnastræa concinna, M.-Edw. & Haime, Pol. Foss. Terr. Paléoz. p. 111.

From information supplied by M. Rigaux, I learn that this common species is as well known in the Coral Rag of Boulogne as in that deposit in this country. Several specimens kindly forwarded at different times for my use came from the middle Kimmeridge of Belledale, the Coral Rag of Hourecq, the Coralline Oolite of the Mont des Boucards, and the Lower Calcareous Grit of Houllefort. It has been placed in the genus *Thamnastræa* by Milaschewitsch, but with an expression of doubt. In that doubt I fully participate.

THAMNASTRÆA FOLIACEA, Quenst. sp.

Agaricia foliacea, Quenst. Handb. d. Petref. 1 Aufl. p. 651.

When compared with examples of *Thamnastræa foliacea* from the Corallian of Nattheim, several specimens which have been collected from the Coral Rag of Boucard and Hourecq by M. Rigaux are seen to agree so closely as to render their identification easy and certain.

THAMNASTRÆA GIBBOSA, Becker, Palæontographica, vol. xxi. p. 170, pl. xl. fig. 3.

A specimen from the Coral Rag of Houllefort differs chiefly from the figure given by Becker of this species in having the short septa sometimes passing into the longer or primary ones. The latter are from eight to ten in number, and the columella, as shown in Becker's figure, is styliform.

THAMNASTRÆA, sp.

A much worn coral, specifically undeterminable, but obviously nearly related to *Thamnastræa concinna*, has been met with by M. Rigaux at Chatillon in the Lower Portland Oolite or in the beds

* Quart. Journ. Geol. Soc. vol. xxxix. p. 558.

of the Upper Kimmeridge. It differs from all the specimens of *T. concinna* I have seen, whether from the Corallian of France, Nattheim, Steeple Ashton, Highworth, Lyneham, or Headington, in having the calices smaller, and all their parts more delicately formed. The calices in the worn example are circular, and rather far apart. There are 6 septa, and a columella which is rather less strongly developed than in *T. concinna.*

Although distinct from *T. concinna* (as may be at once seen by its having only one cycle of septa), the present species has so essentially a Coral-Rag aspect as to point at once to its being the lingering remains of the coral fauna of the Corallian.

Genus Microsolena, Lamx.

Microsolena expansa, Etallon, Etudes Paléont. sur le Haut Jura, p. 125.

In the very thin and plate-like form of its corallum, and in the small number and delicacy of its septa, and in their arrangement in groups, a single specimen from the Coral Rag of Hourecq corresponds very well with the *Microsolena expansa* of M. Etallon. The greatest thickness of the specimen does not exceed 3 lines, and its greatest expanse is 2 inches. Although so thin, it is composed of a great number of very thin and superimposed layers.

Microsolena sp.

A species from the Coral Rag of Houllefort which bears some resemblance to *Microsolena regularis* in the size and arrangement of the septa, differs considerably from that species in having much larger calices, which are, however, less distinctly defined. The corallum, too, presents considerable difference in its form, being subturbinate, and formed by a series of successive layers which have an irregular lobular outline.

Genus Comoseris, d'Orbigny.

Comoseris irradians, Milne-Edwards and Haime, Brit. Foss. Cor. p. 101, pl. xix. fig. 1 (1851).

Specimens from the Coral Rag of the Mont des Boucards and Hourecq do not differ in any important respect from those from the Coral Rag of this country.

In conclusion, I wish to record my very sincere thanks to M. Rigaux for the unreserved manner in which he placed in my hands, not only his collection of specimens, but also his notes of their localities and position, and allowed me to make such use of them as I found necessary. Excepting for his liberality, the present communication would have been most incomplete and unsatisfactory.

EXPLANATION OF PLATE XXXII.

Fig. 1. *Discocœnia bononiensis*, the corallum, natural size.
2. —— ——, the calice, magnified two diameters.
3. *Ceratocœnia elongata*, the corallum, natural size.
4. —— ——, the calice magnified, showing its broken margin, smooth inner margins to the septa, and its broad and smooth floor.
5. *Scyphocœnia staminifera*, the corallum, natural size.
6. —— ——, a calice magnified, showing the large, smooth, and peculiarly formed septa.
7. —— ——, another specimen of smaller size, showing external lateral gemmation.
8. —— *excelsa*, the corallum, natural size.
9. —— ——. the reverse side of the same specimen, from which a part of a corallite has been broken off vertically, revealing well-developed tabulæ. A comparison of this figure with figure 3 of plate vii. vol. xxxix. of the Quarterly Journal, will show how nearly the present species is allied to a coral from the Great Oolite of Stonesfield.
10. *Trochoseris oolitica*, the corallum, natural size.
11. —— ——, part of a calice magnified, showing some of the septa and the columella.
12. —— ——, some synapticulæ, magnified, exposed by the horizontal fracture of a small specimen.
13. *Bathycœnia hemisphærica*, the corallum, natural size.
14. —— ——, the base, showing the mode of attachment to a shell, and the well-developed mural costæ.
15. *Montlivaltia Rigauxi*, the corallum, natural size.
16. —— ——, the calice, natural size.
17. —— ——, a septum, magnified, showing the difference in the ornamentation in this and other lenticular *Montlivaltiæ*.
17 A. —— ——, a portion of a septum, more highly magnified.
18. *Thamnastræa ? latimæandroidea*, the corallum, natural size.
19. —— ——, a calice, magnified.
20. *Confusastræa Rigauxi*, a portion of a corallum, natural size.
21. —— ——, some calices, magnified.

48. *On the* Nature *and* Relations *of the* Jurassic Deposits *which underlie* London. By Prof. John W. Judd, F.R.S., Sec. G.S. With an Introductory Note *on a* Deep Boring *at* Richmond, Surrey. By Collett Homersham, Esq., Assoc. M. Inst. C.E., F.G.S. (Read February 6th and June 25th, 1884.)

[Plate XXXIII.]

Contents.

[The paragraphs in brackets have been added or modified since the reading of the paper.]

I. Introductory Note on the Richmond Well.

The well and bore-hole (see fig. 1, p. 744) which have revealed the particulars of the strata described in this paper are sunk on the premises of the Richmond Vestry Waterworks, situated about 160 yards below Richmond Bridge, on the right bank of the Thames. The common centre of the well and bore-hole is about 33 yards distant from the high-water line of ordinary spring tides. The altitude of the surface of the bore-hole is about 17 ft. above Ordnance datum.

The well, which has an internal diameter of 7 ft. at top and 5 ft. at the bottom, was sunk in 1876 for the purpose of supplying water to the town of Richmond, and was carried down to the Chalk, which was met with at 253 ft. below the surface.

From the bottom of the well a 24-in. bore-hole was further sunk to the total depth of 434 ft., thus penetrating 181 ft. into the Chalk. This well and bore-hole were completed in the summer of 1877.

The Tertiaries passed through were represented by 160 ft. of London Clay, 60 ft. of the Woolwich and Reading beds, and some underlying sands.

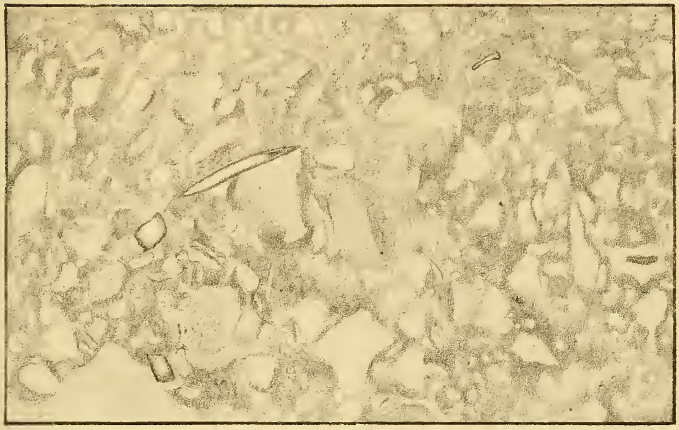


Fig. 1. *By Reflected Light.* × *2 diam.*

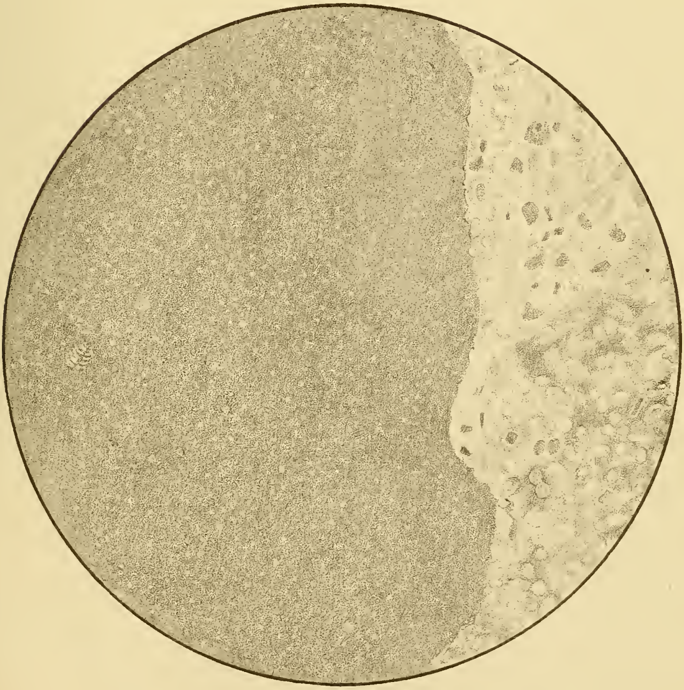
A  B.

Fig. 2. *By Transmitted Light.* × *23 diam.*

Parker & Coward del. et lith. Mintern Bros. imp.

CHALK OF THE ZONE OF BELEMNITES PLENUS
FROM RICHMOND WELL.

Down to 434 ft. the writer of this notice was in no way connected with the carrying out of the work; Messrs. Russ and Minns being the engineers under whose direction the well and bore-hole to the depth before stated were executed. Samples of the Tertiaries passed through were kept, and can be inspected at the office of the Waterworks, Water Lane, Richmond.

The water yielded by the above well and bore-hole (about 160 gallons a minute) is mainly derived from the Tertiaries, and in its normal condition rises 4 or 5 ft. above the surface; at present, however, the level of the water is always depressed about 130 ft. by pumping.

In 1881, a further supply of water for the town being needed, the Richmond Vestry, acting upon the advice of the writer's father, Mr. S. C. Homersham, M.Inst.C.E., determined to carry the bore-hole to a much greater depth; a contract was accordingly entered into to execute the necessary preliminary works, and to deepen the bore-hole by steam-machinery. The existing bore-hole was first enlarged and straightened to enable a line of cast-iron pipes with an internal diameter of 16½ in., having the lower end driven water-tight into the Chalk at a depth of 438 ft., to be carried up to the surface. An annular space between the circumference of the bore-hole and the outside of the line of iron pipes was left, of sufficient capacity to allow any water yielded from this bore to rise into the well in an uncontaminated state for the supply of the town during the time the bore-hole was being deepened. From the inside, and below the bottom of this line of pipes, a bore-hole 16¼ in. diam. was commenced in January 1882. The enlarging of the original bore-hole, and the subsequent deepening, proved the chalk to contain regular layers of flint down to the depth of 502 ft., as shown in the section (fig. 1, p. 744). Hard grey chalk was met with at 580 ft. 6 in., and chalk marl at 820 ft., the latter proving to be about 104 ft. thick.

The total thickness of the Chalk was thus 671 ft.; and below the depth (434 ft.) where the new boring commenced, it failed to yield any water.

The Upper Greensand was next encountered, and proved to be only 16 ft. thick, ranging between the depths of 924 and 940 ft. This bed was of a close and compact nature, and did not yield any water.

The Gault clay, 201 ft. 6 in. thick, was next successfully pierced, a thin bed of phosphatic nodules (of the type usually underlying the Gault stratum) being met with at its base at the depth of 1141 ft. 6 in. from the surface. A bed, which is probably of Neocomian age, was next reached; but further boring proved this series to be but meagrely represented by a bed only 10 ft. in thickness, unfavourable to the percolation of water; the samples and cores obtained showing it to be of a sandy and glauconitic nature, the harder portion much resembling Kentish Rag.

Another thin layer of phosphatic nodules was passed through at 1151 ft. 6 in., when a bed, at its first appearance of an abnormal type, was met with; this bed mainly consisted of hard limestone, and proved to be 87 ft. 6 in. in thickness, ending at the depth of 1239 ft. In this stratum a bed of clay, 3 ft. 6 in. thick, was passed through at the depth of 1205 ft., and from this Professor Judd procured many of the fossils he is about to describe, and which prove the bed to belong to the Great Oolite formation. A thin layer of Fuller's Earth was also met with at 1227 ft.

Two springs of water were struck in this bed at the respective depths of 1203 and 1210 ft. from the surface. The water thus tapped was found to rise into, and overflow from, the top of a tube which was raised 49 ft. above the surface of the ground. The yield near the surface of the ground was found to be $1\frac{1}{4}$ gallon a minute. This water is remarkably soft, being only about two degrees of hardness by Clark's scale, and contains 26 grains of chloride of sodium per gallon, besides other mineral matter, consisting of carbonate and sulphate of soda, with a small quantity of potash salts and carbonates of lime and magnesia.

A partial analysis of the oolitic rock at the depth of 1195 ft. from the surface showed it to be constituted as follows:—

Carbonate of Lime	87·40	per cent.
Sand &c. (insoluble in acid)	4·56	,,
Sulphide of Iron in the form of Pyrites .	2·40	,,

At the depth of 1239 ft. beds of a very different character were met with, viz. hard red sandstone alternating with beds of variegated sandy marl or clay. When the bore-hole had been carried down to a depth of 14 ft. into these beds, a further supply of water was met with, which rose to the surface and overflowed into the Thames at the rate of $1\frac{3}{4}$ gallon a minute.

After the depth of 1252 ft. 9 in. had been attained the yield steadily increased as the boring was deepened.

The following table shows the quantity of water that overflowed into the Thames as the respective depths named were reached:—

Yield of Water from the Red Sandstone Stratum.

Depth from Surface. ft.	in.	Overflowed Surface at rate of Gallons a minute.
1252	9	1·72
1254	5	2·0
1258	0	2·3
1260	0	2·76
1262	6	3·0
1276	8	3·24
1279	0	3·4
1294	0	3·8
1301	0	4·3
1310	0	4·3
1329	0	4·9
1359	0	5·8
1363	0	7·9
1368	0	9·5
1387	0	11·0

The water thus yielded was found by careful trial to rise in a tube to an altitude of 49 ft. above the surface and overflow, and a suitable pressure-gauge showed that the water rose with a force that would cause it to attain to a level of 126 ft. above the surface, or to a height of about 130 ft. above Trinity high-water mark.

[An analysis of the water yielded by the bore-hole when it had reached the depth of 1337 ft. was made by Dr. E. Frankland, F.R.S. The result of this analysis expressed in parts per 100,000, shows the water to be charged with mineral matter to the extent of 104·88 parts of solid matter in 100,000 parts of water, consisting of upwards of 30 parts of chloride of sodium and 57·2 parts of carbonate of soda. The water at this depth maintained the soft character found in the previous analysis, and was again under two degrees of hardness by Clark's scale.]

The steam-apparatus and tools used in sinking this bore-hole down to the depth of 1337 feet were those known as the "flat-rope system." A heavy boring-bar armed with steel cutters, secured at the end of the flat rope, strikes a succession of blows (about 20 a minute), and so cuts up the bottom of the bore-hole, the percussive action of the boring-bar being produced by a steam-cylinder above the surface of the ground. A ratchet-motion fixed to the boring-bar and the twist of the rope cause the steel-cutters to rotate whilst the percussive process is in operation. By this system excellent samples can be obtained, the round cores being produced by the inner edge of the steel chisels that radiate from the circumference towards the centre of the boring-head, and so cut out a solid portion from the centre of the bore-hole as the chisels fall and rotate. Sometimes these round cores are brought to the surface jammed between the steel chisels of the boring-head, at others they are brought up with the rest of the débris which is removed from the bottom of the bore-hole by means of a shell-pump, also lowered and raised by the flat rope; the shell-pump does valuable work in bringing to the surface, with little loss, the softer layers of clay and loam met with between the harder beds.

From 436 ft. below the surface down to the present depth, cores and other samples, every 2 or 3 ft. apart, have been carefully kept and labelled as the boring proceeded.

The size and nature of the cores varies with the diameter of the bore-hole and the character of the strata from which they are cut. In the Chalk, where the diameter of the hole bored was 16¼ in., the cores are very round and perfect, and about 3½ in. in diameter, and in some cases 8 or 9 in. in length.

From the Gault and Lower Greensand, where the diameter of the bore-hole was reduced to 13½ in., the cores are 2½ in. in diameter; and in the Oolitic limestone, where the boring was further reduced to 11¼ in., the cores were found less frequently, and were about 2 in. across.

[At the depth of 1334 ft. the bore-hole was reduced to a little under 9 in. in diameter, and the rock being very jointed and fissured few perfect cores were obtained by the percussive system of boring above described. At the depth of 1337 ft. it was found expedient to change the method of boring; the old machine was taken down, and a rotary diamond rock-boring machine erected in its place. This last machine has carried down the bore-hole with a diameter of $8\frac{1}{2}$ in. from 1337 to 1367 ft. 6 in., at which last depth, lining tubes having to be inserted, the diameter of the bore-hole was further reduced to $7\frac{1}{4}$ in., with which diameter it has now reached the total depth of 1409 ft. The cores obtained from the last 72 ft., being large and solid (from 5 to 6 in. in diameter), enable the different dips of the strata to be very accurately determined. These cores too show the rocks to be of much the same character as when these Red Sandstone beds were first reached.]

The bore-hole is now lined with strong iron tubes down to the depth of 1364 ft.; those portions of the tubes that are in proximity to the different depths where water was struck, are drilled with holes to admit the water into them.

Unfortunately, till the depth of 1337 ft. was reached, time could not be spared to make accurate observations as to the rise in temperature as the bore-hole was deepened; but the following table serves to show that the water at the different depths named had the temperature of deep-seated springs:—

Date.	Depth from Surface. ft.	in.	Degrees Fahr. °
Feb. 24th, 1883	1149	6	69
March 24th „	1175	7	70
April 7th „	1195	0	73
April 21st „	1212	0	73

The above are not the true temperatures at the depths named, but were ascertained by the following rough method:—A round vessel nearly the size of the bore-hole, having a valve at bottom opening upwards, was lowered to the bottom and brought to the surface. The valve of the vessel closing directly the winding-engine was reversed, collected the water from the bottom of the bore-hole, and the temperature of the water so collected was taken when the vessel had reached the surface. The raising of the water to the surface only occupied two or three minutes.

The three following observations on the temperature of the bottom were taken when the bore-hole had reached the depth of 1337 ft. below the surface. The bore-hole was full of water and overflowing at the rate of from 3 to 4 gallons a minute.

In all three cases it is clear that the results obtained are free from any error due to heat generated by the friction of the tools during the process of boring, as the results are identical, and in No. 1 there had been a cessation of boring operations for 3 weeks, in No. 2 for 4 weeks, and in No. 3 for 13 weeks.

In the first two cases the thermometer was simply lowered, and left in No. 1 for $1\frac{1}{4}$ hour, and in No. 2 for $5\frac{1}{2}$ hours; in both cases the temperature registered was $75\frac{1}{2}$° Fahr., the temperature of the air at the surface being respectively 51° and 53° Fahr.

In No. 3 the thermometer was lowered inside a wrought-iron tube, which was buried for its whole length (5 ft.) in a bed of sand 10 ft. in thickness, which had been washed in to the bottom of the bore-hole. To endeavour to prevent any heat being lost by convective disturbance, the bore-hole was plugged with cement and sand for several feet above the layer of washed-in sand. The thermometer was left at the bottom for 3 days (viz. from noon, Saturday June 7th, to noon, Tuesday June 10th), when it was hauled up and found again to have registered a temperature of 75½° Fahr.; the temperature of the air at the surface, when the thermometer was lowered, being 54° Fahr., and when brought to surface 57° Fahr.

Taking an assumed surface-temperature of 50° Fahr., and comparing it with 75½ Fahr. at the depth of 1337 ft., the result indicates an increase of temperature at the rate of 1° Fahr. for every 52·43 ft. in depth.

The thermometer used for the above trials was a Negretti's maximum, kindly sent to the author for the purpose by Prof. Everett, Secretary to the Underground Temperature Committee of the British Association.

Table of Trials.

Trial No.	Date.	Temperature of Air at Surface.	Time Thermom. was at bottom of bore-hole.	Temperature registered.
1	March 25th, 1884	51° Fahr.	1¼ hours	75½° Fahr.
2	March 31st, 1884	53° Fahr.	5½ hours	75½° Fahr.
3	June 7th, 8th, 9th, 10th	54° to 57° Fahr.	72 hours	75½° Fahr.

In conclusion, I may add that the boring, which is still in progress, had, at the date of this paper going to press, Oct. 15th, 1884, attained the depth of 1409 ft., being 107 ft. deeper than that of the deepest well or bore-hole hitherto sunk in the London Basin. The deepest well and bore-hole before this was sunk was that at Kentish Town, which reached to the depth of 1302 ft. from the surface.

When, however, we take the mean of high- and low-water as a datum (O.D.), and compare the relative depths, then it will be found that the bore-hole at Richmond has reached the depth of 274 ft. below that of Kentish Town (see fig. 2, p. 760). C. H.

II. General Remarks on the Geological Bearings of the Undertaking.

My attention was first directed to this interesting section some time after the Gault had been reached in the boring, and since then every facility has been kindly afforded me by Mr. S. C. Homersham, M.Inst.C.E., and his son, my former pupil, Mr. Collett Homersham, F.G.S., for studying the beds as they were successively passed through. This task has been rendered the more easy by my residence in the immediate neighbourhood of the well.

Fortunately I found, upon inquiry, that the records of the previous work had been so admirably kept, and the series of specimens obtained was so complete, that I had no difficulty whatever in recognizing the limits of the Tertiaries, Chalk, Upper Greensand, and Gault with the greatest exactness. Further than this, I had the good fortune to obtain evidence of the existence of remarkable "junction-beds," which enabled me to define the limits of those great divisions of the Chalk-series which have been established by the palæontological studies of that formation during the last twenty years.

The cores obtained from this well during the earlier stages of the work have neither the great diameter nor the length of those obtained when boring is carried on by the diamond rock-drill: but I am convinced that for the purpose of the geologist the evidence supplied by the specimens obtained at Richmond was far more valuable than that which would be yielded by boring with a crown set with diamonds. In the latter case, as has been so well pointed out by Mr. H. J. Eunson, F.G.S. *, though very perfect cores are obtained from the hardest rocks, yet, in part through the grinding of one section of a core upon another, and in part through the action of the powerful current of water forced down the bore-hole, large portions of the softer deposits are washed away and lost. Mr. Eunson shows, in the case of a boring near Northampton, executed with the diamond rock-drill, that where soft and hard rocks alternate, the cores brought to the surface represented in some cases only 64 per cent. of the depth bored.

In the case of the Richmond boring, satisfactory cores of the harder beds were procured, and, what is of more importance, samples of all the beds passed through, soft and hard alike, were brought to the surface in the shell-pump.

The specimens obtained were treated by various methods, according to their characters, in the geological laboratory of the Normal School of Science and Royal School of Mines. The harder rocks had thin slices cut from them for microscopic examination; the softer ones were broken up by water or by the action of frost, and all microscopic organisms in them carefully extracted by sifting and sorting. Wherever it was thought necessary, the specimens were submitted to partial chemical examination or to complete analysis.

In giving the results of this series of studies, I shall confine myself to the statement of such observations as appear to throw new light upon important geological questions.

III. The Tertiary Strata.

The upper portion of the well was made some years ago; but a series of carefully selected specimens of the beds passed through has

* 'Minutes of Proc. Inst. Civ. Eng.' vol. lxxiv. pp. 274 and 281.

been preserved in the office of the Richmond Waterworks by Mr. Peirce, the resident engineer, and these enable me to identify the limits of the several strata overlying the Chalk without difficulty.

The locality in which the well was commenced is in the oldest part of the town of Richmond, and materials which had evidently been disturbed were met with down to the depth of 10 ft. Of the very sandy gravel which covers all that part of the Thames Valley around Richmond and Kew, only a slight remnant, about 10 in. in thickness, was found undisturbed.

The London Clay, presenting its usual characters, was then met with, and the sinking was continued for 160 ft. in this formation.

The Lower London Tertiaries were represented by 44 ft. of the well-known variegated Plastic Clays of the Woolwich and Reading series, underlain by $12\frac{1}{2}$ ft. of sand and sandstone, the base of the series being formed by clays with a lignite-band and the usual layer of rounded flint-pebbles. The strata below this pebble-bed evidently belong to the Thanet Sand, which in its characters precisely agrees with what is seen of the formation at many points along its outcrop. The upper portion of the series at Richmond consists of light ash-coloured sands having a thickness of $13\frac{1}{2}$ ft.; while the lower portion, with a thickness of 8 ft., consists of darker-coloured greenish sands with a considerable admixture of argillaceous matter and many glauconite grains.

At the bottom of the Thanet Sand was found the band of unworn flints, coated with a dark green substance, which is everywhere so characteristic of the junction of the Tertiary strata with the Chalk. The whole thickness of the Thanet Sand, including the band of flints at its base, is $22\frac{1}{2}$ ft.

The complete section down to the Chalk is as follows:—

		ft.	in.
	Made ground	10	0
	Post-Tertiary sandy gravel		10
	London Clay	160	0
Woolwich and Reading Series.	Mottled (red and green) clays	44	0
	Yellow sand	8	0
	Hard sandstone rock	4	0
	Light-coloured clay	2	0
	Clay with much lignite and a band of well-rounded pebbles at its base.	1	6
Thanet Sand.	Light ash-grey sand	13	6
	Dark-coloured argillaceous sand with much glauconite	8	0
	Band of green-coated flints	1	0
	White chalk with flints.		

IV. The Chalk.

The Chalk was struck in the Richmond well at a depth of 253 ft. from the surface, or about 236 ft. below Ordnance datum line or mean level of the sea. In two other wells at Richmond, one at the old Waterworks and the other at the Star-and-Garter Hotel, the top of the Chalk appears to have been met with at about the same level.

It is a well-known fact that the level at which the Chalk has been reached in different wells within the London Basin has varied within very wide limits. Thus at Meux's Brewery the surface of the Chalk is only 71 ft. below O.D.; at Kentish Town it is 138 ft. and at Crossness 133 ft. below the same level.

At most places in Surrey near Richmond, such as Wimbledon, Mortlake, Morden, and Wandsworth, the surface of the Chalk is about 250 ft. below O.D.; but at Kingston it is said to be 346 ft. and at Claremont 458 ft. below that level.

As the thickness of the Chalk strata beneath London appears to be tolerably uniform, averaging about 650 ft., the irregularities in the surface of the formation must be due to the undulations into which the strata have been thrown. A fault or series of faults, very nearly coincident with the line of the Thames Valley, ranges east and west from Erith and Greenwich to Windsor, and there is evidence that, parallel with these, there exists a series of long folds accompanied in some cases probably by dislocations. These undulations of the strata are a result of that great system of movements which took place in Oligocene and Miocene times and were probably connected with the elevation of the Alpine chains. The effects of these movements upon the Chalk strata have been very carefully investigated by MM. Hébert and Barrois. Richmond appears to be situated on the downthrow side of the series of faults which traverse the London Basin from east to west.

At a depth 924 ft. from the surface, the Richmond boring reached strata which, as we shall presently show, unquestionably represent the Upper Greensand. Thus the whole thickness of the Chalk, including the white chalk, the grey chalk, and the chalk marl, is 671 ft. This thickness is slightly greater than that found in the more central parts of the London Basin. Thus at Kentish Town the Chalk is 645 ft. thick; at Meux's Brewery 655½ ft.; at Crossness 637½ ft. But on the other hand the thickness of the Chalk at Richmond is considerably less than at Turnford near Cheshunt in the northern half of the London Basin, where it was found to be no less than 730 ft. In passing still further northwards and eastwards we find that successively higher members of the Chalk have escaped the pre-Tertiary denudation, and thus the Chalk attains a thickness of 817 ft. at Coombs near Stowmarket, and of 1140 ft. at Norwich.

Those who are familiar with the sparse distribution of the larger fossil organisms in the Chalk strata, will be prepared to learn that but few fossils were detected in the comparatively small cores brought up from this boring; such occasional fossils as were found proved quite insufficient for defining the several palæontological zones which are now known to be represented in that great formation. The microzoa, which are so abundant in the Chalk, have not, up to the present time, had their vertical distribution so carefully studied as to render us much aid towards the same end. It is a fortunate circumstance, therefore, that by the study of the series of cores from the Richmond boring it has been found possible to recognize two very distinct horizons in the Chalk strata, and in this way to determine for the first time the limits and thicknesses of the principal subdivisions of the Chalk below London.

At a distance of 300 ft. below the top of the Chalk at Richmond, or 553 ft. from the surface, a stratum of very marked and peculiar character was met with. The rock is of a creamy yellow tint (the chalk above and below it being pure white) and is seen to be made up of a number of nodular masses of a hard variety of chalk, each of these nodules being coated with a greenish deposit, while the interspaces between the masses are filled with a somewhat argillaceous matrix. In consequence of the presence of this argillaceous matrix the rock when immersed in water easily breaks up, the nodular masses of which it is composed separating the one from the other. The thickness of this stratum cannot exceed 5 ft.

The nodular masses themselves contain 3·14 per cent. of matter which is not soluble in acids, while the portions of rock in which much of the matrix and the green coating of the nodules occurs were found to yield no less than 10·7 per cent. of insoluble matter.

This rock agrees so precisely in all its characters with the stratum which has been so well described by Mr. Whitaker as the "Chalk Rock," that I cannot doubt of our having in the Richmond well the representative of that interesting horizon. The Chalk Rock is not known immediately to the south of London, for I agree with Mr. Whitaker in thinking that the nodular bed recognized by Mr. Drew at several points in Surrey, and so well exposed in the "Rose and Crown" pit near Kenley, is at a considerably higher horizon. The Chalk Rock has been noticed, however, as a very thin layer in Devonshire, Dorsetshire, and the Isle of Wight, by Mr. Whitaker, and on the coast of Normandy by M. Hébert.

About 20 ft. below the Chalk Rock, another bed of an indurated, but not nodular, character occurred. It is probably one of those harder bands sometimes found intercalated between the softer beds of chalk, like that for example which forms the roof of the underground workings at Chislehurst.

At a distance of 137 ft. below the Chalk Rock, however, a second horizon of great importance can be recognized. Instead of the ordinary chalk, we find a yellowish limestone of markedly crystalline character. The material is so hard, indeed, that it often preserves perfectly slickensided surfaces, and it rings under the hammer. Some portions of the mass are nodular, with the nodules coated by a greenish deposit, as is the case with the Chalk Rock. Other portions of this mass are seen, in polished sections and in thin slices under the microscope, to be made up of more or less rounded fragments of an ordinary globigerina-chalk imbedded in a matrix composed of broken shells, Foraminifera, and Echinoderms; fragments of *Belemnites* can also be detected in this curious rock. The characters of this very remarkable rock are illustrated in Plate XXXIII. The whole stratum does not exceed 15 ft. in thickness.

A similar rock was met with in the shafts of the Marden Park Tunnel on the Croydon and Oxtead Railway, the sections in which have been so well described by Mr. Caleb Evans*.

The Melbourn Rock of Mr. Jukes-Browne† appears to be very similar to that found in the Richmond boring; and there can be no doubt that in this latter we have a representative of the Zone of *Belemnites plenus* in the *remanié* condition which has been so admirably described by M. C. Barrois. In the cliff-section at Folkestone, Mr. F. G. H. Price found the same bed with a thickness of 4 ft.‡ The Melbourn Rock contains 0·92 per cent. of insoluble matter, the rock from the Richmond well 1·3 per cent.

The detection of these two important horizons (the Chalk Rock and the Zone of *Belemnites plenus*) in the Richmond boring, furnishes us with the most valuable aid in classifying the Chalk strata of the London area.

The whole of the strata, 300 ft. in thickness, which lie above the Chalk Rock, belong to the Upper Chalk, or Senonian of Continental authors, and to the lower part of that division, the Chalk with Micrasters; the Upper Senonian, or Chalk with Belemnitellas, not being represented in the London area.

Through the upper 200 ft. of the Chalk with Micrasters in the Richmond well, layers of chalk flints occur at pretty regular intervals. In the lower 100 ft. the bands of flint are less regular and constant, and before the Chalk Rock is reached they cease altogether. Forty feet above the Chalk Rock a band of dark grey marl about 3 in. thick occurs in the midst of the Chalk.

The Chalk Rock itself is probably a diminutive representative of the Zone of *Holaster planus*.

The next 137 ft. of strata, consisting of chalk of a less purely white colour and with only few and scattered flints, but with occasional thin seams of marl, represents the Zones of *Terebratula gracilis* and of *Inoceramus labiatus*, but we have no means of estimating the thickness of the beds belonging to each of these divisions in the section under consideration.

The Zone of *Belemnites plenus* is, as shown by M. C. Barrois, the fragmentary representative of a great series of strata, which in some parts of France contains a remarkable and distinctive fauna. The three zones, having a united thickness at Richmond of less than 150 ft., are the diminished representative of the Middle Chalk, or Turonian of Continental authors.

The Chalk strata which lie below the Zone of *Belemnites plenus*, 220 ft. in thickness at Richmond, consist of grey marly chalk without flints. In passing downwards these strata become more and more argillaceous, and of a darker colour, the bottom beds being "chalk-marl;" but so gradually does the transition from grey chalk to chalk marl take place, that in the absence of any representative

* Proc. Geol. Assoc. 1870.

† Mem. Geol. Surv., "Geology of the Neighbourhood of Cambridge," p. 55 881).

‡ Quart. Journ. Geol. Soc. vol. xxxiii. (1877), pp. 439, 440, 445.

of the Totternhoe Stone, I find it quite impossible to say where the one division ends and the other begins. Doubtless the Zones of *Holaster subglobosus* and *Rhynchonella Martini* are represented in these beds, but their limits it is impossible to define. *Rhynchonella Martini* and numerous fish-remains occur in the higher part of this division; while the lowest 50 ft. of it certainly belongs to the Chalk Marl, as is shown not only by its lithological characters, but by the presence of *Ammonites varians* and *Hamites*. A specimen of the Chalk Marl from the Richmond well from a depth of 919 ft. was found to contain nearly 50 per cent. of insoluble material, among which were many curiously incrusted sponge-spicules.

These 220 ft. of grey chalk and chalk marl, with the underlying Upper Greensand, make up the Lower Chalk or Cenomanian of Continental geologists. At Dover this division is about 194 ft. in thickness*.

V. The Upper Greensand.

In the case of several of the deep borings in the London Basin considerable doubt exists as to the thickness and limits of the beds which should be referred to the Upper Greensand; but upon this point, fortunately, the Richmond boring affords perfectly satisfactory evidence.

At a depth of 924 ft. from the surface there was a decided change from the dark-grey rock of the Chalk Marl to more sandy strata with much mica and numerous glauconitic grains, which continued with little change down to the depth of 940 ft. These strata yielded a few fossils, chiefly fragments of Pectens (*P. orbicularis*, Sow., and *P. interstriata*, Leym.). The mineral characters of the beds, as seen in hand specimens and also in thin slices under the microscope, agree so closely with those of the Upper Greensand of Surrey, that not the smallest doubt can exist as to their belonging to that formation.

The Upper Greensand at Richmond consists of three portions, which may be distinguished as follows:—

		ft.
	Chalk Marl.	
Upper Greensand.	(1) Hard micaceous sandy rock	6
	(2) Softer and more marly beds	6
	(3) Harder rock, similar to (1), but containing more glauconite	4
	Upper Gault clay.	

The beds (1) and (3) are quite undistinguishable in character and appearance from the well-known "Firestone" of Godstone. They contain respectively only 14·5 and 12·5 per cent. of calcic carbonate; the insoluble residue consisting of fine quartz-sand, mica, and glauconite. A characteristic specimen of Firestone from Godstone yielded on analysis 16·2 per cent. of calcic carbonate.

The bed (2) is softer and approximates in character to the "Hearthstone" of the Godstone pits, a typical specimen of which was found to contain 38 per cent. of calcic carbonate. The Rich-

* See F. G. H. Price, Quart. Journ. Geol. Soc. vol. xxxiii. (1877), p. 445.

mond rock contains 19·5 per cent. of calcic carbonate, the insoluble residue containing less sand but more argillaceous matter than the beds above and below it.

VI. The Gault.

The change from the glauconitic sandy beds of the Upper Greensand to the marly clays of the Upper Gault is very well marked in the Richmond boring. The base of the Lower Gault is also unmistakably defined by the usual band of phosphatic nodules. In this way the Gault is proved to extend from the depth of 940 ft. to that of 1141½ ft. from the surface, and to have a thickness of 201½ ft.

It thus appears that the thickness of the Gault at Richmond exceeds that found in any of the other deep London wells, which gave the following results:—

	ft.
Kentish Town	130½
Loughton (Essex)	132½
Meux's Brewery	160
Ware	160
Turnford, near Cheshunt	161
Crossness, near Erith	176

For this result, however, we were not unprepared, for many facts point to the conclusion that along the base of the North Downs the Gault clay has a very considerable thickness, and that this thickness much exceeds that which is indicated on the maps and sections of the Geological Survey. This conclusion has been confirmed by the well at Shoreham, near Sevenoaks, where the Gault was found to be at least 226 ft. in thickness, and by that at Caterham Waterworks, where it was no less than 343 ft. The development of the Gault at Richmond is therefore just what might have been anticipated.

In the Gault of Folkestone, which is less than 100 ft. in thickness, there occur several bands with phosphatic nodules and *remanié* fossils, doubtless indicating interruptions of greater or less duration in the process of sedimentation. These junction-beds have proved of much service as indicating the limits of the different zones into which the Gault has been divided by Mr. De Rance and Mr. Price.

Fossils were tolerably abundant in the Gault cores from Richmond. The most common, with the exception of fragmentary and undeterminable fish, crustacean and echinoderm remains, which were found at many different horizons, are given in the following list, with the depth at which they occurred:—

Hamites armatus, *Sow.* (? elegans, *d'Orb.*) (940 ft.).
Ancyloceras spinigerum, *Sow.*, sp. (1104 ft.).
Ammonites splendens, *Sow.* (1128 ft.).
Ammonites Bouchardianus, *d'Orb.*? (1059 ft.).
Ammonites rostratus?, *Sow.* (1062 ft.).
Ammonites interruptus, *Brug.* (1100 ft.).
Inoceramus concentricus, *Sow.*, abundant (967 ft.).
Nucula, sp.
Pentacrinus Fittoni, *Aust.* (990 ft.).
Many species of Foraminifera.
Plant remains.

The vertical distribution of these fossils perfectly agrees with what has been made out by the study of the Gault in other localities, especially in the cliff-section at Folkestone. Microzoa were abundant in many of the beds, as was proved by washing them. But neither the evidence of the larger fossils, nor that of the microscopic forms, was sufficient to enable the geologist to define any of the numerous zones which have been established in the Gault series. It would appear, however, that while at Folkestone we have a thinner series owing to the fact that considerable periods were represented only by "Coprolite" beds, and in some cases possibly such layers indicate the denudation of strata already laid down, at Richmond the deposition of sediment, gradually changing in its characters, went on quite continuously from the beginning to the end of the Gault period.

In the Gault at Richmond I was not able to detect any "junction-beds" except the one at the base of the series. The upper portion of the formation exhibits clays of the marly composition and pale colour so characteristic of the Upper Gault of Folkestone. A specimen of this Upper-Gault clay at Richmond taken from a depth of 1026 ft. from the surface, was found to contain nearly 33 per cent. of calcic carbonate, a result in tolerable accordance with that obtained by Mr. Hudleston in his analysis of the Upper Gault of Folkestone *. The lower portion of the Gault at Richmond has the dark blue colour, due to excess of pyrites, which almost everywhere distinguishes the lower beds of the Gault. In this part of the series numerous nodules of crystallized pyrites, and others composed of argillaceous ironstone, of a pale tint and usually of small size, abounded. Between the pale-coloured marly Upper Gault and the dark-coloured pyritous Lower Gault there appears to be at Richmond the most perfect and insensible gradation.

The lowest bed of the Gault becomes very sandy and is filled with dark-green grains of glauconite. This sandy bed passes down into the well-known junction-bed, containing many perfectly rounded grains of white quartz, a considerable quantity of similar grains of red jasper, and many subangular fragments of quartzite, crystalline limestone, and other hard rocks, some of considerable size. Intermingled with these we find a few nodules of pyrites and many of phosphate of lime, the latter being sometimes dark coloured and apparently rounded and waterworn, and at others lighter in colour and irregular in form. A specimen of these phosphatic nodules was kindly analyzed for me by Dr. Percy F. Frankland, F.I.C., in the Laboratory of Agricultural Chemistry, attached to the Science Schools at South Kensington. The percentage of phosphoric anhydride was found to be 20·21.

One of the cores brought up from the well at a depth of 1141 ft. 6 in. exhibits the actual junction of this phosphatic bed with the rocks below.

* Quart. Journ. Geol. Soc. vol. xxx. (1874), p. 354.

VII. The Neocomian (?) Beds.

Down to this point the order of succession and the thicknesses of the several deposits were precisely such as were anticipated from the data already obtained concerning the strata of the London Basin. But below the base of the Gault certain rocks of a very remarkable and unexpected character were encountered in the Richmond well.

The "junction-bed" at the base of the Gault was found to rest directly upon beds of limestone of a somewhat peculiar character. The uppermost portion of this limestone was rather sandy in composition, and contained some particles of glauconite and a great number of brown grains which had the appearance of being formed by the decomposition of that mineral. In thin sections under the microscope, this rock was seen to be made up of waterworn fragments of shells, Foraminifera, Bryozoa, and corals, with a matrix of subcrystalline limestone. The rock very closely resembles, both macroscopically and microscopically, certain varieties of the Kentish Rag.

The insoluble residue of this rock, which varied in amount in different samples from 3 to 13 per cent. of the whole, was found to consist of glauconite grains more or less decomposed, fine particles of sand, and some clayey matter. In this respect it also resembled Kentish Rag, a typical example of which yielded $10\frac{1}{2}$ per cent. of insoluble matter of a like kind.

But as we proceed downwards, these limestones appear to gradually alter in their character and pass into a rock of a totally different appearance, when viewed in thin sections under the microscope. These lower beds of limestone are found to consist of a fine-grained calcareous paste, through which are scattered in greater or less abundance oolitic grains, fragments of bivalves, small univalves, and Foraminifera coated with a film of calcic carbonate, the whole being impregnated with finely divided iron-pyrites. These limestones make up a bed about 9 ft. 6 in. thick, which is interrupted at a depth of 4 ft. from its upper surface by a band of clay about 9 in. in thickness. The careful washing of this clay band yielded the following results. It contained an immense number of detached oolitic grains, a number of waterworn shells, Bryozoa, Foraminifera, and fragments of Echinoderms, often coated with a deposit of calcic carbonate. In lesser numbers are found grains of glauconite, particles of iron-pyrites (often oval in form and with beautifully bright surfaces), fragments of teeth, and spines of fish, and very much worn and eroded fragments of *Belemnites*. In addition to these were many particles of imperfect coaly material, and a few of anthracite, also some waterworn fragments of sandstone and other hard rocks.

A careful study of the substances contained in this clay band leads me to the conclusion that they are for the most part derived from the limestone strata which, as we shall presently see, underlie the curious series of deposits we are now describing. A few specimens of Foraminifera and Ostracoda appear to have belonged to the period of the deposition of these rocks, and not to have been derived from any older formation.

Prof. T. Rupert Jones, F.R.S., who has kindly examined these microscopic forms for me, has detected the following species:—

Ostracoda.

Macrocypris Bradiana, sp. n.
Cythere Schwageriana, sp. n.
Cythere juglandica, sp. n.
Cythere (Cythereis) quadrilatera, *Röm.*
Cythere, sp.

Foraminifera.

Cristellaria rotulata, *Lam.*
Cristellaria cultrata, *Montf.*
Cristellaria, sp.
Lituola depressa, sp. n. (probably derived).

Of these minute fossils Prof. T. Rupert Jones remarks that there is nothing particularly characteristic of any formation, similar forms ranging through Secondary, Tertiary, and Recent times.

At a depth of $1\frac{1}{2}$ ft. below this clay-band there occurred a thin layer of pyrites about half an inch in thickness, almost completely made up of small rounded or oval particles with a polished surface.

Three feet lower we reach a very remarkable "junction-bed" containing phosphatic nodules like those in the bed at the base of the Gault.

This junction-bed, which is only 6 in. in thickness, is of very peculiar character. Its matrix consists of clay containing many oolitic grains and fragments of fossils. Scattered through this clay are many subangular and rounded fragments, some of them of considerable size, of a micaceous sandstone, strikingly like that of the Coal-measures, of quartzite and indurated sandstone, of subcrystalline limestone, and of other hard rocks, with some particles of anthracite. Intermingled with these are a number of phosphatic nodules, one of which, analyzed by Dr. Percy Frankland, yielded 27·06 per cent. of phosphoric anhydride.

That the matrix of this remarkable "junction-bed" was derived from the denudation of the underlying Great-Oolite deposits, there cannot be the smallest doubt. Waterworn fragments of the oolitic limestone, oolitic grains disengaged from their matrix, and recognizable, though much waterworn, with Jurassic forms of Brachiopoda and Bryozoa, abound in it. Fragmentary and waterworn teeth of *Lamna*, *Pycnodus*, *Hybodus*, and other Jurassic genera of fish, with fragments of spines and teeth too imperfect for recognition, also occur in it in great numbers. The only fossils in the bed which were not manifestly derived were a few Foraminifera and Ostracoda.

The foreign rock-fragments in the mass appear to have been certainly derived from Palæozoic deposits, which must have been *in* *situ* at no great distance; but this question will be discussed more fully in a subsequent portion of the present paper.

The 10 ft. of remarkable strata which intervene between the base of the Gault and the Great-Oolite beds, about to be described, offer some very interesting, and at the same time difficult, problems to the geologist. They seem to have been formed to a great extent of materials derived from the subjacent rocks, some of the fragments of which had been subjected to much attrition. The presence of phosphatic nodules probably indicates the lapse of a considerable interval of time, during which sedimentation was suspended. The foreign fragments included in them, some of which are only rounded on their edges, suggest the proximity of land made up of the rocks in question.

The problem of the age of this 10 ft. thickness of beds is one which it is not easy to solve. The limestones contain a few oysters, having the appearance of being dwarfed from the unfavourable conditions of brackish water. They greatly resemble the small oysters found in the Punfield series, which I have elsewhere shown to be the dwarfed condition of *Exogyra sinuata** ; but the dwarfed forms of many species of the Ostreidæ are so similar to one another, that it is impossible to speak with any confidence concerning the geological age of these fossils.

The only other fossils, not manifestly derived, which I obtained from these beds were the microscopic Ostracoda and Foraminifera; these have been examined by Prof. T. Rupert Jones, F.R.S., and referred to the following species:—

Ostracoda.

Cythere subconcentrica, sp. n.
—— juglandica, sp. n.
Cytheridea subperforata, sp. n.
Cytherella symmetrica, sp. n.
Bairdia Juddiana, sp. n.
—— trigonalis, sp. n.

Foraminifera.

Cristellaria italica, *Defr.*
Cristellaria, sp.
Cristellaria rotulata, *Lam.*

Prof. Jones says of these forms that while some may be of any Secondary or Tertiary age, others, like *Cythere concentrica* and *C. virginea,* have Cretaceous allies or representatives.

Although it must be confessed that the 10 ft. of strata underlying the Gault at Richmond may be of any age between that of the Great Oolite and that of the Gault, yet I think that, taking all the facts into consideration, they may be most probably referred to some part of the Neocomian period.

In their nature and relations, though not in their age, these beds present some analogies with the "Tourtia," which in Belgium is so frequently found separating the rocks of the Palæozoic ridge from the overlying Upper Cretaceous strata.

* Quart. Journ. Geol. Soc. vol. xxvii. (1871), p. 214.

VIII. The Great Oolite.

The 10 ft. of peculiar and somewhat puzzling strata which we have just described, rest on a series of oolitic limestones alternating with clayey and sandy beds, the whole having a thickness of $87\frac{1}{2}$ ft. At first sight the upper beds of this series do not appear to differ in a very marked manner from those lying upon them, except in the absence of grains of sand and glauconite. But this probably arises from the fact that the upper series of beds is made up of rocks reconstructed for the most part of materials derived from the strata on which they rest.

From the examination of these oolitic strata, both in hand specimens and in thin sections under the microscope, the following succession of beds may be made out. It may be remarked that all the beds, as is so commonly the case with Jurassic limestones which have not been exposed to weathering action, are of a more or less marked deep blue colour. This colour is due to the presence of iron-pyrites, which was proved by chemical analysis in the case of one sample of these rocks to be present in it to the extent of 2·4 per cent.

	ft.	in.
(1) Dark-coloured very perfectly oolitic limestone, entirely made up of oolitic grains, with many small waterworn fragments of fossils and a few very imperfect larger portions of organisms. The upper part of this rock appeared to be much disintegrated and the fossils in it are quite undeterminable	5	0
(2) Limestones of a paler colour and more marly character, with scattered oolitic grains. Many Foraminifera, including *Rotalia*, *Cristellaria*, and *Textularia*, occur in this rock	22	6
(3) Highly oolitic limestones of the same colour as (1)	10	0
(4) Rock of more shelly character with fewer oolitic grains. Many Foraminifera	11	0
(5) Rock consisting of a compact calcareous paste with oolitic grains scattered through it. Fragments of shells, *Ostrea*, *Pinna*, and other Lamellibranchiata, with portions of Brachiopoda and small Gasteropoda and Foraminifera, abound in it	5	0
(6) Beds of dark blue clay, in places crowded with fossils, and with subordinate limestone bands	3	6
(7) Limestone of oolitic and shelly character	17	0
(8) Band of Fuller's Earth	0	6
(9) Very fine-grained oolitic limestone with much pyrites. In passing downwards this rock assumes a more and more sandy character, and at its base becomes a fissile calcareous and micaceous sandstone resembling the Stonesfield and Collyweston Slates (*Acrosalenia* and other fossils)	9	0
(10) Oolitic limestones with many fragmentary shells, *Ostrea Sowerbyi*, &c.	3	6
(11) Band of limestone of more open texture, made up of large waterworn fragments of shells with a few grains of quartz-sand and particles of anthracite	0	6
Total	87	6

In these limestones well-preserved fossils are very rare. The comminuted shell fragments of which so many of them are largely made up, are for the most part quite unrecognizable, and they are frequently coated with deposits of calcic carbonate.

But as the boring was carried downwards, and more or less perfectly recognizable fossils were brought to the surface, I became gradually impressed with the conviction that these fossils represent a Jurassic and not a Neocomian fauna, and all doubt on the subject was removed when the beds (6) were reached. In these an enormous number of fossils occurred; Brachiopoda, Bryozoa, Echinodermata, and many other forms being found in the richest profusion, and it soon became apparent that the forms of life represented in these beds were for the most part identical with those occurring in the Bradford Clay of Wiltshire, and in the "Calcaire à polypiers" of Ranville in Normandy, that is to say, that they were of Great-Oolite age.

Upon my communicating this very interesting and somewhat unexpected result to Prof. Prestwich, who from the first has taken the liveliest interest in this investigation, he agreed with me that it would be well, in order to minimize the risk of error in the identification of the fossils, to submit the forms representing certain groups to palæontologists who have made them their special study.

After obtaining as many specimens as possible by the most careful washing, sifting, and picking of every particle of the clays brought to the surface, I submitted the Brachiopoda to Mr. T. Davidson, LL.D., F.R.S., and the Bryozoa to Mr. G. R. Vine. In doing so I merely stated that the specimens were obtained from a well, and carefully abstained from any indication of my own conviction as to the age of the beds.

In reply to my letter, in which I especially asked if it were possible that any of the forms might belong to Cretaceous species, Mr. Davidson wrote as follows:—

[After identifying the three Brachiopods sent as *Terebratula coarctata*, *Terebratula maxillata*, and *Rhynchonella concinna*, he says:] "From the examination of the three species I should be under the impression that you have pitched upon Jurassic rocks, not older or younger than the Great Oolite, Forest Marble, or Bradford Clay."

Mr. G. R. Vine wrote concerning the Bryozoa which I sent him, "I found my opinion upon the fossils only; I know nothing of the circumstances of the find, other than the fact you furnish me with in the letter—that the material has been found in the boring of a well. The fossils are of the age of the Great Oolite, not earlier, and probably not later, than the Forest Marble or Bradford Clay."

The other fossils in the following list will be seen to fully bear out these views. The strata are of Great-Oolite age, and as the Bradford Clay and Forest Marble were deposited under conditions very similar to those which must have prevailed when these clays were formed, the nearest approach to their fauna is found in those formations.

Mr. Vine remarks upon the exquisite state of preservation of these Bryozoa as follows:—"Most of the Oolite species that I have gathered are either waterworn or broken from rocks. In this material the cell-mouth and the *zoarium* are as clear and sharp as in any of the Montechio (Eocene) Polyzoa."

The same is true of all the other fossils found in this bed of clay. It cannot be doubtful that the colonies of branching Bryozoa and Crinoids, with the Brachiopoda in every stage of growth lying among them, were overwhelmed and buried by a sudden influx of muddy sediment over the sea-bottom where they grew. So exquisitely are many of these fossils preserved, that, as will be shown in the appendix to this paper and in those which follow it, they serve in not a few cases to clear up difficulties which had hitherto existed concerning the structure of the species to which they belong.

List of Fossils from the Great Oolite under Richmond (Surrey).

Lamna (teeth).
Nerinæa Eudesii, *Lyc. & Mor.*
Natica, sp.
Pholadomya Heraulti, *Ag.*
Lima, sp.
Avicula, sp.
Pinna, sp.
Trichites, sp.
Pecten rushdenensis, *Lyc.*
Ostrea gregaria? *Sow.* (young of O. Marshii (?), *Sow.*)
—— Sowerbyi, *Lyc. & Mor.*
—— subrugulosa, *Lyc. & Mor.*
Terebratula maxillata, *Sow.*
—— (Dictyothyris) coarctata, *Park.*
Rhynchonella concinna, *Sow.* sp.
Stomatopora dichotoma, *Lamx.*
—— Waltoni, *J. Haime.*
Diastopora diluviana, *Lamx.*
—— microstoma, *Mich.*
—— microstoma, *Mich.* var. connectens, *Vine.*
—— Lamourouxii, *Haime.*
Idmonea triquetra, *Lamx.*
Entalophora straminea, *Phill.*
—— richmondiensis, *Vine.*
—— richmondiensis, *Vine*, var. pustulopora, *Vine.*
Terebellaria increscens, *Vine.*
Lichenopora Phillipsii, *J. Haime* (?).
Heteropora conifera, *Lamx.*
Fasciculipora Waltoni, *J. Haime*(?).
Serpula intestinalis, *Phill.*
—— lacinatus, *Phill.*
Vermicularia nodus, *Phill.*
Pentacrinus scalaris, *Goldf.*
Pentacrinus, sp.
Apiocrinus, sp.
Bourgueticrinus, sp.?
Astropecten (marginal, and eye-plates; spines?).
Cidaris bradfordensis, *Wr.* (spines and plates).
——, sp.
Acrosalenia pustulata, *Forbes*, sp. (spines).
——, sp. (spines).
Hemicidaris, sp. (spines).
Inobolia micula, *Hinde.*
Peronella nana, *Hinde.*
Blastinia cristata, *Hinde.*
—— pygmæa, *Hinde.*
Oculospongia minuta, *Hinde.*
Bairdia Hilda, sp. n.
—— jurassica, sp. n.
—— ——, var. tenuis, nov.
Cytheridea subperforata, sp. n.
Cythere Guembeliana, sp. n.
—— drupacea, sp. n.
—— Blakeana, sp. n.
——? tenella, sp. n.
—— Bradiana, sp. n.
—— (Cythereis) quadrilatera, *Röm.*
—— ? sp.
Cytherella subovata, sp. n.
—— jugosa, sp. n.
Miliola (Quinqueloculina), sp.
Lagena lævis, *W. & J.*
Frondicularia oolithica, *Terq.*
—— ——, var. regularis, nov.
Vaginulina lævigata, *Röm.*
Marginulina raphanus, *Lin.*
Cristellaria crepidula, *F. & M.*
—— rotulata, *Lam.*
—— cultrata, *Montf.*
Spirillina helvetica, *K. & Z.*
—— crassa, *Z. & K.*
Planorbulina Haidingeri, *d'Orb.*, [var.
—— farcta, *F. & M.*, var.
Pulvinulina elegans, *d'Orb.*, var.
—— tenella, nov.
Webbina?, sp.

The $87\frac{1}{2}$ ft. of Great-Oolite strata at Richmond are found resting directly upon rocks which, as we shall hereafter show, are probably of Poikilitic age; the Inferior Oolite, Lias, and Rhætic being quite unrepresented. In this respect the relations of the Lower

Oolites at Richmond are similar to those of the strata of the same age in the Boulonnais.

IX. The Great-Oolite Strata at Messrs. Meux's Well in the Tottenham Court Road.

In the deep well which was sunk in the year 1878 at Messrs. Meux & Co.'s Brewery at the junction of Tottenham Court Road with Oxford Street, some very interesting strata were met with after the Gault had been penetrated and before the Devonian rocks were reached*. These strata, which included limestones of a remarkably oolitic structure, had a thickness of 64 ft.

From some very imperfect casts of fossils which were found in these beds, they were, at the time of their discovery, referred to the Neocomian system. The late Mr. Charles Moore of Bath, by carefully washing portions of these rocks, obtained from them many minute fossils, most of which were crushed and fragmentary, while many among them were rendered more obscure by their being either waterworn or coated with a crust of calcic carbonate, which had been deposited on their surfaces as they lay on the sea-bottom. So imperfect were these fossils, that Mr. Moore for the most part contented himself with placing on record the genus or family to which they belonged. It is worthy of remark, however, that Mr. Moore was struck with the number of genera in these deposits which had not been found in strata younger than the Jurassic. Even some Jurassic species, such as *Thecidium triangulare*, d'Orb., were identified; but Mr. Moore, believing that the Neocomian age of the beds had been fully established, regarded the finding of Jurassic genera and species as simply proofs of an upward extension of the range of those forms.

The similarity of the undoubted Great-Oolite beds of Richmond to those found at Meux's Brewery between the Gault and Devonian, convinced me that the question of the age of these beds called for the most careful reexamination. This task was not an easy one, for unfortunately most of the specimens of these rocks obtained at Meux's Brewery are scattered or lost. Prof. Prestwich and the officers of the Geological Survey kindly placed at my disposal some of the specimens of these rocks which were in their possession; and the Rev. H. H. Winwood of Bath made the most careful inquiries concerning the specimens examined by the late Mr. Charles Moore. Although the minute fossils worked out by that palæontologist could not at first be identified, yet Mr. Winwood kindly lent me all the specimens from the well, with their depth marked upon them, which he was able to find. Lastly, Mr. Gilding, the manager to Messrs. Meux & Co., and Mr. Picking, their engineer, have furnished me with every information and assistance which was in their power.

There are some very serious and striking discrepancies between the accounts given by different authors concerning the nature and order of succession of the strata which in Messrs. Meux's well were found between the Gault and the Devonian. This has apparently

* See the papers of Prof. Prestwich (Quart. Journ. Geol. Soc. vol. xxxiv. (1878), p. 902), and Mr. C. Moore (ibid. p. 914).

Fig. 1.—*Section at Waterworks, Richmond, Surrey.*
(Scale, 150 ft. = 1 inch.)

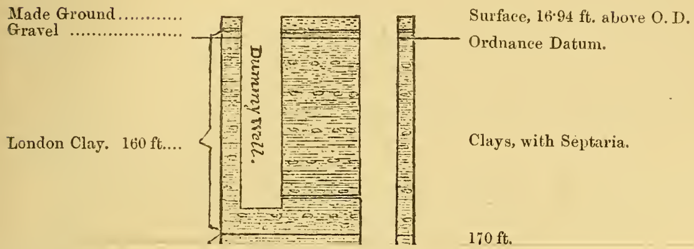
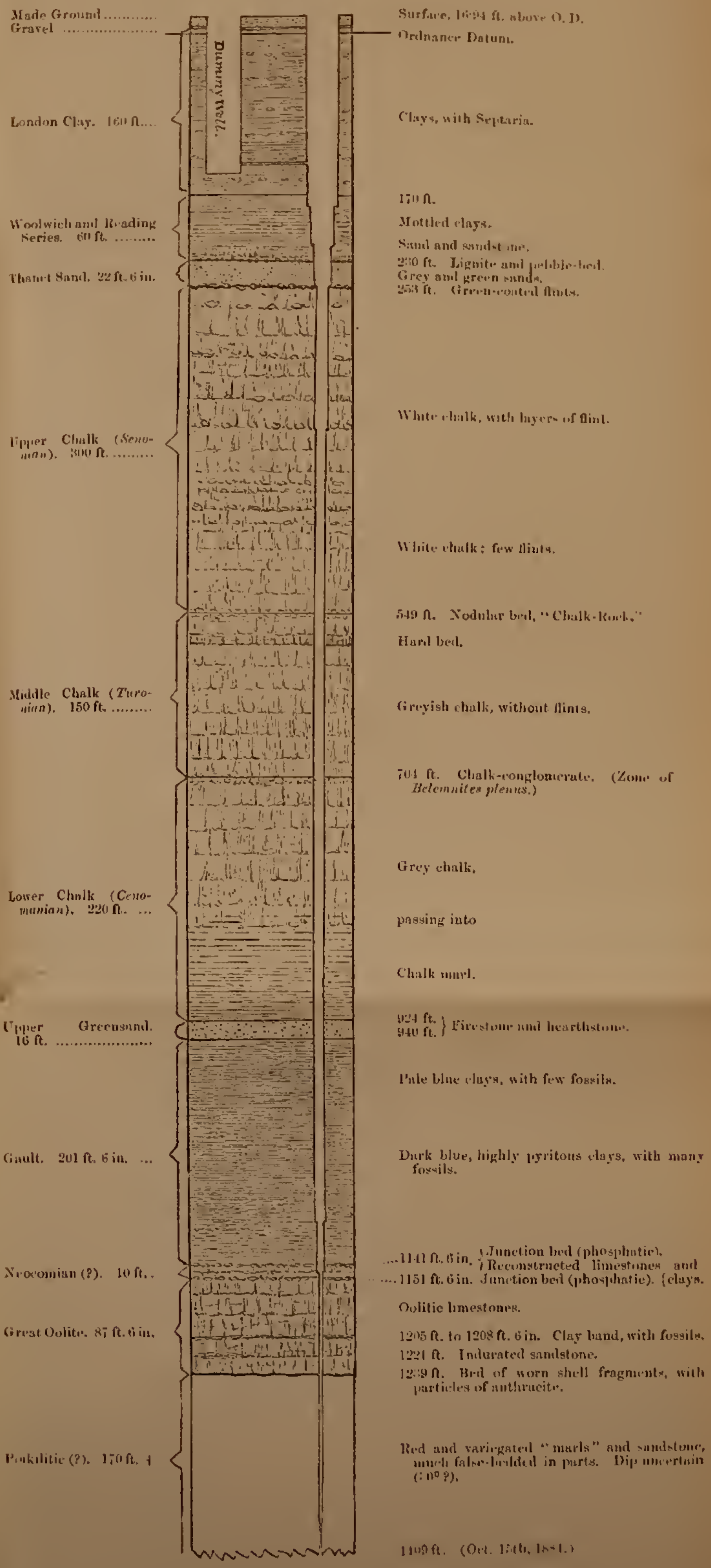


Fig. 1.—*Section at Waterworks, Richmond, Surrey.*
(Scale, 150 ft. = 1 inch.)



arisen from the circumstance that the strata in question consisted of hard and compact oolitic limestones alternating with marls of a more or less sandy character. Owing to the method of working by the diamond rock-drill the cores brought up consisted almost entirely of the former kind of rock, the softer marls being broken up and to a great extent washed away in the process of boring. As specimens of the oolitic limestone were found at short intervals, it was not unnaturally supposed by those who did not watch the boring and measure the cores brought up, that the boring was carried on almost wholly in that rock. Mr. C. Moore was, however, so fortunate as to obtain some small specimens of the softer and more marly deposits, which when broken up in water yielded him great numbers of minute fossils.

The fossils contained in the oolitic limestones at Messrs. Meux's well were nearly all in the condition of casts and most of them difficult of determination. Among them, however, I have been able to identify the following species:—

Trigonia costata, var. pullus, *Sow.*
Tancredia axiniformis, *Lyc.*
Nerinæa (probably N. punctata, *Voltz.*).
Cylindrites (probably C. excavatus, *Lyc.*).

On washing the softer beds, specimens of which I obtained from the Rev. Mr. Winwood and the engineer of the works, I found such a large number of the minuter forms so closely in agreement with those occurring at Richmond, though in a less perfect state of preservation, that no doubt remained, in my mind, as to the Great-Oolite age of the rocks in both localities.

Subsequently the Rev. Mr. Winwood had the good fortune to find the actual specimens of minute fossils which Mr. C. Moore had washed from the softer beds of Meux's well, and kindly placed them in my hands for examination. A careful study of all the specimens and a comparison of them with the fossils from Richmond, which are in a much better state of preservation, enables me to give the following list:—

Fossils from the Oolitic Limestones and Sandy Clays occurring in the Well at Messrs. Meux's Brewery, Tottenham Court Road, between the depths of 1000 *and* 1064 *feet.*

Natica cincta, *Phil.* (?).
Chemnitzia, sp.
Nerinæa punctata (?), *Voltz.*
Cerithium, sp.
Nucula, sp.
Trichites, sp.
Pinna, sp.
Pecten articulatus (?), *Schl.*
Lima duplicata, *Sow.*
Gervillia or Pteroperna (?).
Ostrea gregaria, *Sow.* (?), O. Marshii (young).
—— Sowerbyi, *Lyc. & Mor.* (young).
—— subrugulosa, *Lyc. & Mor.* (young).
Terebratula maxillata, *Sow.* (young).
—— digona, *Sow.* (young).
Rhynchonella concinna, *Sow.* (young).
Thecidium triangulare, *d'Orb.*
Zellania globata, *Sow.*
Stomatopora dichotoma, *Lamx.*
Diastopora diluviana, *Lamx.*
—— microstoma, *Mich.*
Idmonea triquetra, *Lamx.*
Entalophora richmondiensis, *Vine* (?).
Terebellaria increscens, *Vine* (?).
Lichenopora Phillipsii, *J. Haime* (?).
Fasciculipora Waltoni, *J. Haime* (?).
Pentacrinus scalaris, *Goldf.*
Pentacrinus, sp.
Apiocrinus, sp.
Cidaris bradfordensis, *Wr.* (spines).
Cidaris, sp.
Acrosalenia (spines).
Astropecten (marginal and eye-plates).

In addition to these are a number of Foraminifera, which were submitted by Mr. C. Moore to Prof. T. Rupert Jones, and which have not been since reexamined. Among the most interesting of these are the curious bodies identified by Mr. Moore and Mr. Carter as spiny processes of *Carpenteria.*

The shells referred by Mr. C. Moore to *Nucula planata*, Desh., and *Venus parva*, Mant., show but little resemblance to those Cretaceous forms, but are too imperfect for exact identification. I could find no trace in the collection of any shells which could be referred either to *Nucula impressa*, Sow., or to *Astarte formosa*, Sow.

As what may be a thin representative of Neocomian strata occurs at the Richmond well, it became a matter of much interest to determine if any beds of that age were found at Meux's Brewery, the more so as fossils of undoubted Neocomian age were asserted to have occurred in some of the cores from that place. It has sometimes been said that the upper portion of the 64 ft. of rock occurring at Meux's Brewery was of a sandy nature; but this is certainly a mistake. From the very top of the series, at a depth of 1000 ft., which was immediately under the Gault, Mr. C. Moore received a specimen of limestone, which on microscopical examination is seen to be perfectly oolitic in character. A specimen from the depth of 1003 ft. kindly supplied to me by Professor Prestwich is also a perfectly oolitic rock of somewhat open texture; and a specimen from the depth of 1004 ft. supplied to me by the engineer is one of the most strikingly oolitic rocks I have ever seen. From a depth of 1005 ft. Mr. Picking showed me a core of remarkably shelly oolite rock containing *Trigonia costata*, var. *pullus*, with other shells apparently of Jurassic affinities.

From depths of 1008 and 1012 ft. respectively, Mr. C. Moore certainly obtained specimens of an impure and somewhat sandy limestone. In the case of the specimen from a depth of 1008 ft. the insoluble matter amounted to 35 per cent. of the whole rock, and in that of the specimen from a depth of 1012 ft. to nearly 17 per cent. In both cases the insoluble matter consisted of clay with some sand-grains. On careful washing I found these impure limestones yielded the same forms of Bryozoa, Echinodermata, and Mollusca as occur in the oolitic limestones above and below them in the series.

Mr. C. Moore also examined specimens of a "coarse grey marl" from depths of 1018, 1024, 1031, 1044, 1050, and 1057 ft. respectively. Of these I have been enabled by the kindness of Mr. Winwood to study the variety from the depth of 1057 ft. This answers perfectly to Mr. Moore's description, and on washing yielded some of the organisms described in his paper, as did also a similar specimen from a depth of 1046 ft.

From many intermediate depths I have obtained specimens of perfectly oolitic limestone, and examples of such oolitic limestones from depths of 1015, 1022, 1038, 1044, and 1056 ft. have been studied in thin sections under the microscope. It thus becomes evident that the whole thickness of 64 ft. of strata found at Meux's Brewery, between the Gault and the Devonian, consisted of oolitic limestones with bands of marl between them, exactly answering in fact to much of the Great Oolite in other parts of this country. Of truly arenaceous strata, I have been able to find no evidence whatever, and there is but a slight admixture of sandy material in some of the marls.

With respect to the alleged discovery of Neocomian fossils in cores from Meux's Brewery I have made the most careful inquiries, and have been greatly aided by the officers of the Geological Survey, in whose custody the specimens now are.

The rock containing the fossils in questions is a perfect oolite, and has nothing of a sandy character in its composition. The fossils in it are all in the condition of casts. There is no indication on the core as to the depth at which it was obtained, and any label that may have formerly existed has unfortunately been lost. It is stated, however, in the section drawn up at the time by Professor Prestwich, that these fossils occurred between the depths of 1035 and 1059 ft. from the surface, that is in the *lower* half of the 64 ft. of rock between the Gault and the Devonian.

The fossils which it was thought could be specifically determined were *Cardium Hillanum*, *Trigonia alæformis*, and *Trochocyathus Harveyana*, a somewhat remarkable intermixture of Gault and Neocomian forms. Of these fossils no trace of the first mentioned could be found. The second, after the most careful study by the aid of the original specimen and casts from it, I find myself quite unable to identify with the Cretaceous species; but on the contrary, though speaking with the greatest reserve, on account of the imperfect character of the specimen, I incline to the view that it represents a Great-Oolite form, and is near to, if not identical with, *T. Moretonis*. With regard to the coral, which is only the fractured surface of a cast, I think it would be rash to hazard an opinion even as to its generic affinities.

But a very interesting fact was discovered by the officers of the Geological Survey by breaking some fragments from the block of limestone containing the supposed cast of *Trigonia alæformis*. In this manner there were revealed a number of casts of *Nerinæa*, belonging to a form of undoubtedly Great Oolite affinities, and in all probability identical with the *N. punctata* of Voltz.

Thus the identification of Neocomian fossils in the rock from Meux's Brewery completely breaks down upon reexamination, and as we have already seen there is abundant evidence of its Great-Oolite age.

If there were any beds at Meux's Brewery answering to the reconstructed strata which at Richmond have been doubtfully referred to the Neocomian, they must have certainly been very thin, and of their existence I have not been able to obtain a particle of evidence.

X. General Characters of the Great-Oolite Strata under London.

The Great-Oolite strata, which are $87\frac{1}{2}$ ft. in thickness under Richmond, and 64 ft. under the Tottenham Court Road, appear to have thinned out or to have been altogether removed by denudation at Kentish Town, a little to the north of the latter place, and no trace of them was found at Crossness, Turnford, or Ware. It appears, therefore, that whatever may have been the former extent of these Lower-Oolite strata, they are now confined to the southern part of the metropolitan area, and abut against the southern flank of the great Palæozoic axis.

Although, as we have seen, there is a general correspondence in the characters and fossils of the Great-Oolite strata in the two localities in which they have been found, yet, when critically examined, some very interesting and suggestive differences become apparent.

Under Richmond the strata consist of compact limestones, with a very thin interstratification of clay, the only sandy beds being found towards the base of the series. The fossils found at Richmond are not only all truly marine but are for the most part such as would inhabit moderately deep water. Nor do the fossils, as a rule, appear to be rolled and waterworn, as is the case with those found in littoral deposits, but they are quite fresh and unbroken. In this connection the evidence afforded by the thin but highly fossiliferous band of clay at Richmond is singularly valuable. This clay band, as was remarked to me by Mr. G. R. Vine, greatly resembles those found at Minera and elsewhere, intercalated among the beds of Carboniferous Limestone. The Bryozoa and Pentacrinites were evidently growing in profusion on the ocean floor at the time they were overwhelmed, and were killed and entombed by an influx of excessively fine muddy sediment.

Very different is the state of things found under the Tottenham Court Road. There the specimens are all much broken and waterworn, many of them being coated with a thick layer of calcic carbonate. It is evident that the beds containing these fossils were accumulated in much shallower water than those at Richmond. Among the fossils found at Meux's well Mr. C. Moore detected some which he suspected to be terrestrial, freshwater, and brackish-water forms, referable to genera like *Hydrobia*, *Valvata*, *Potamides*, and *Potamomya*; and to some extent Mr. Moore's views were borne out by the examination of these very imperfect shells by Dr. Gwyn Jeffreys and Mr. C. J. A. Meyer. This and the dwarfed condition of many of the Gasteropoda and other shells led Mr. C. Moore to the conclusion that while all the strata were of shallow-water origin, some of them were probably deposited in brackish water, while a number of the fossils might have been washed down by rivers.

A very interesting circumstance in connexion with the Great-Oolite deposits at Messrs. Meux's well, which was noticed by Mr. C. Moore, was the occurrence of coaly fragments in some of the beds. I have myself found a considerable number of such fragments in a specimen from a depth of 1046 ft. These fragments appear to me to be very similar to the imperfect Jurassic coals of Brora and the Western Isles of Scotland. The engineer at Messrs. Meux's Brewery informed me that at some periods during the boring in the Oolitic strata, the water forced down the well came up "as black as ink." It is not impossible, therefore, that actual Jurassic coal seams were passed through at this point.

From a careful comparison of all the facts of the case, it is clear that while the Great-Oolite beds under the Tottenham Court Road were deposited in comparatively shallow water, and in close proximity to the land, the beds of the same age under Richmond were laid down in much deeper water. Hence we may fairly infer that during the Great-Oolite period the northern half of the Palæozoic ridge under London formed dry land, while the southern half was submerged beneath the waters of the ocean, and became gradually buried under its sediments.

XI. The Poikilitic (?) Strata.

At 1239 ft. from the surface the boring at Richmond passed suddenly from the limestones and clays of the Great Oolite into red and variegated sandstones and clays (" marls ").

The sandstones vary in colour through different shades of red to white and greenish tints. They are sometimes excessively fine-grained and very perfectly laminated, having the surfaces of the laminæ covered with flakes of silvery white mica. At other times the sandstones are much coarser, so coarse indeed as almost to merit the name of grits, and their bedding is obscure. Clay-galls are found in some of the beds as well as impressions which may possibly indicate the former presence of plant-remains that have now been entirely removed. The sandstones are sometimes traversed by thin veins of calcic carbonate. Particles of galena were found in these sandstones at a depth of 1293 ft. 6 in.

The clays (" marls ") which alternate with these sandstones are of a dark red colour, mottled with green in blotches and spots. When brought up in solid lumps these clays are seen to be highly indurated and traversed by joints in various directions, the joints being coated with a green calcareous deposit.

In some portions of these strata the marls and sandstones alternate in thin layers; in other portions we have a considerable thickness of marls; while sometimes the sandstones constitute tolerably thick beds.

The following is the succession down to the lowest point reached :—

	ft.	in.
1. Alternations of red sandstone and variegated " marls "	16	0
2. Hard bed of sandstone	1	0
3. Marls with occasional beds of sandstone	10	0
4. Alternations of sandstone and " marls "	21	0
5. Solid sandstone rock	4	0
6. Red marls	2	6
7. Hard sandstone	4	6
8. Soft sandstone with many seams of "marl "	5	0
9. Hard red and white sandstone rock, coarse and gritty in some seams, with some bands of clay	17	0
10. Beds of sandstone and red " marls," the latter predominating and causing much trouble by falling in and impeding the boring-operations	15	0

(Owing to the difficulty of penetrating these rocks with the rope-boring machinery, in consequence of the falling in of the " marls," recourse was had to the diamond rock-drill.)

[The strata next in order are as follows:—

		ft.	in.
11.	Red sandstone	13	0
12.	Red and variegated marls	3	0
13.	Red sandstones	3	0
14.	Red and variegated marls	2	0
15.	Beds of red and white sandstone, sometimes finely laminated and sometimes exhibiting but little evidence of bedding. These rocks, which were extremely hard, were found to be traversed by very numerous and closely set nearly vertical joints, which rendered the work of boring through them with the diamond crown very difficult	19	0
16.	Grey sandstone, very hard	1	6
17.	Hard red sandstone	2	0
18.	Softer red and white sandstone, finely laminated in places	30	0]

The whole of the superincumbent Tertiary, Cretaceous, and Jurassic strata appear to be nearly horizontal in their position at Richmond, and it became a matter of much interest to determine if the underlying red sandstones and marls were conformable with them. Some specimens of cores showing a remarkably high dip appear at first sight to negative any such supposition. But a careful study of these apparent dips shows that they vary greatly in amount at different depths, and that therefore they are examples, not of true dip, but of oblique lamination or false-bedding. Some of the cores, indeed, exhibit clear evidence of false-bedding.

[The dips actually measured in these cores of red and variegated sandstones and marls were as follows:—

	Dip.
At a depth of 1255 feet from the surface	21°
" 1280 " "	26°
From 1288 to 1291 " "	$34\frac{1}{2}$°
At $1307\frac{1}{2}$ " "	32°
At 1319 " "	35°
At 1340 " "	30°
At 1348 " "	30°; obscure.
At 1352 " "	27°
At 1356 " "	30°
At 1364 " "	30°; somewhat doubtful.
From 1365 to $1367\frac{1}{2}$ " "	45°; very well marked.
At 1372 " "	40°
At 1375 " "	40°; nearly.
From 1395 to $1404\frac{1}{2}$ " "	38°
At 1408 " "	32°

It is worthy of remark that the most discordant dips are found in the finely laminated sandstones, in which false-bedding would be best exhibited. The cores, on the other hand, in which such marked lamination is not to be detected, give generally dips of about 30°. From these facts we may infer, with some probability, that the strata in question have a true dip of about 30°, which is often complicated and obscured by the oblique lamination. Of the *direction* of the dip no evidence could be obtained.]

It is hardly necessary to remark that these red sandstones and variegated marls have yielded no fossils. There are very marked differences in their characters between these beds and those met with in the Kentish Town boring, especially in the absence of quartzites and other peculiar rocks.

[That the strata met with in the deepest portion of the Richmond well resemble, in the most striking manner, the rocks of both the Old and the New Red Sandstones, every one who has examined them must be convinced. Some of the beds, it is true, appear to be of a somewhat more compact and indurated texture than is usual in the rocks of those formations when exposed at the surface; but this is no more than might be anticipated when we bear in mind the great thickness of superincumbent strata which has had to be pierced before reaching them.

Unfortunately the strata of the Old and the New Red Sandstones, in the absence of all fossil evidence, do not present any characteristic differences which we can rely upon as a means of discriminating the deposits of pre-Carboniferous age from those which are post-Carboniferous. Under these circumstances we are compelled to rely upon other considerations than those of general resemblance in trying to arrive at a judgment concerning the age of the red rocks at Richmond.

The possibly high angle of dip of these strata (though it must be remembered that this has not been certainly proved) may appear, at first sight, to afford an argument in favour of the Palæozoic age of the rocks in question; but when we remember the great stratigraphical break which undoubtedly exists at the base of the Great Oolite, it would not be surprising to find that strata of Permian or Triassic age had been greatly disturbed before the deposition upon them of the Bathonian beds. On the other hand, the presence of disseminated particles of galena, and the considerable proportion of chloride of sodium in the water obtained from these red rocks at Richmond, are obvious points of analogy with the Triassic strata.

In a subsequent part of this paper I have dwelt at length upon those general considerations which appear to me strongly opposed to the view that the Richmond beds are of Old-Red-Sandstone age, and which lead me to the conclusion that the balance of evidence is in favour of their being regarded as the New Red Sandstone, and therefore of post-Carboniferous age.]

As it would, I think, be hazardous to offer a suggestion with respect to the particular portion of the series between the Carboniferous and the Lias with which the red and variegated beds under Richmond should be correlated, I have ventured to call them doubtfully "Poikilitic."

Subsequently to the reading of the first part of this paper before the Society two discussions on the nature of the rocks found in the Richmond well took place in the Geological Society of the North of France, at Lille. In the first of these discussions the speakers were inclined to entertain the possibility of the variegated beds in question belonging to the Gédinnien (Lower Devonian).

At the request of M. C. Barrois, I sent a series of specimens of the different varieties of rock met with at Richmond, and in a second discussion M. Gosselet, M. Achille Six, and M. C. Barrois all maintained the view that these beds could not be referred to any part of the Devonian series, but really belong to the Trias *.

* Annales Soc. Géol. du Nord, vol. xi. p. 144.

XII. Conclusion.

These interesting discoveries at Richmond throw much new light upon some very important geological problems, among the chief of which we may particularize the following :—

A. The nature and position of the several rock-masses which constitute the great Palæozoic ridge underneath the London Basin, and the relations of the strata which have been subsequently deposited to these deep-seated rock-masses.

B. The question of the existence of deep-seated sources of water-supply in strata, older than the Chalk, under any portion of the metropolitan area.

C. The possibility of finding coal-seams at a workable depth under London, and the quality of the coal to be obtained from such sources.

We shall conclude this paper by a brief discussion of each of these problems.

A. *The Position and Nature of the "Palæozoic Axis" and its Relation to overlying Strata.*

The possible connexion of the Palæozoic axes of the Mendips and the Ardennes, and of the coal-fields which abut upon them, was suggested by Buckland and Conybeare in 1826, by MM. Elie de Beaumont and Dufrénoy in 1841, by Sir H. de la Beche in 1846, and by M. Meugy in 1852.

The French and Belgian geologists had long ago practically demonstrated the existence of the eastern parts of this great connecting ridge by actually working coal under the Tertiary and Cretaceous strata. But in 1855, Mr. Godwin-Austen, in his celebrated paper "On the possible extension of Coal-bearing strata beneath the South-east of England," gave to these arguments concerning the relations of the Palæozoic rocks to the Secondary strata a force and precision which they did not before possess.

In the interval between the reading of Mr. Godwin-Austen's paper and its publication in the Quarterly Journal of this Society, the completion of the experimental boring at Kentish Town went far towards verifying the predictions of geologists ; and since that time a number of deep wells have made us acquainted with the nature and position of different members of the Palæozoic series under the Secondary rocks of England and of the adjoining portions of the Continent.

Silurian strata have been reached at Ware at a depth of 796 ft. from the surface, and at Ostend at a depth of 985 ft.

Devonian strata have been reached at Tottenham Court Road at a depth of 1064 ft., and at Turnford, near Cheshunt at a depth of 980 ft.

Carboniferous strata have been found at Burford in Oxfordshire at a depth of 1184 ft., at Gayton in Northamptonshire at a depth of 635 ft., at Northampton, in the same county, at a depth of 830 ft., at Scarle in Lincolnshire, at a depth of 1900, at Harwich at 1025, and at Calais at a depth of 1032 ft.

At Kentish Town and at Crossness strata of a somewhat anomalous and doubtful character were met with at depths of 1114 and 1008 ft. respectively.

Now at Burford, Poikilitic strata appear to have been passed through and to have had a thickness of 428 ft. At the St. Clement's well at Oxford there is reason to believe, as shown by Professor Prestwich*, that Keuper beds were reached. At Gayton, about 5 miles S.W. of Northampton, Poikilitic strata with a thickness of 63 ft. were penetrated; while at Northampton strata, probably of the same age, but of very curious and anomalous character, were found lying between the Lower Lias and the Carboniferous rocks. These consisted of curious abnormal sandstones and conglomerates, often of a red colour, with some magnesian limestones, the whole having a thickness of 67½ ft. There is a great probability that these strata are all anomalous representatives of the Poikilitic series, and they agree in position and thickness with the normal Trias beds found at three localities near Northampton, which is only five miles distant from Gayton †.

The materials brought up in the boring at Crossness, near Erith, were so broken and mixed up, owing to the method of boring employed, that the utmost that can be said concerning them is that they resemble the sandstones and "marls" of both the Old Red Sandstone and of the New Red Sandstone series.

The rocks met with at Kentish Town have, ever since their first discovery, proved a puzzle to geologists. They are certainly far less like the typical Poikilitic strata than those met with at Richmond. On the other hand they present some resemblances in their characters to the curious and anomalous beds found overlying the Carboniferous strata at Northampton.

In recent years Professor Prestwich has felt constrained to abandon his former reference of the Kentish Town beds to the New Red, and has insisted on their resemblance to the Old Red of the Mendip Hills. Mr. Whitaker suggests an argument against the latter correlation, which I think is entitled to much weight. "There is a strong reason against the classification of the bottom beds at Kentish Town and Crossness with the Old Red Sandstone, which seems to have escaped notice. Having the series unmistakably present in the Devonian type at Cheshunt and at Meux's, it would be strange indeed were it to occur in its wholly distinct Old Red type at Kentish Town, between these two places, and at Crossness not very many miles from the latter of them! I believe that no such thing is known to occur anywhere, the two types of what is generally taken to be one great geological system being limited to separate districts, and not occurring together" ‡.

* Proc. Ashmol. Soc. 1876.

† [Since this paper was read, Mr. Eunson has given a very careful description of these interesting borings: see Quart. Journ. Geol. Soc. vol. xl. 1884, p. 482.]

‡ Guide to the Geology of London, third edition (1880), p. 21.

Whether we accept the lacustrine theory of the origin of the Old Red Sandstone or not, I think there will be equal difficulty in explaining the presence in close proximity of such remarkably different representatives of the Devonian period as the highly fossiliferous Eifelian type and the barren Old-Red-Sandstone type.

Every argument in favour of the Poikilitic age of the Kentish Town and Crossness beds applies *a fortiori* to those at Richmond, which certainly present all the peculiar characteristics of the typical Triassic strata in a marked degree, as I have already pointed out. With the new light thrown on the question by the borings at Gayton and Northampton, I cannot avoid the conclusion also that the strata found at Kentish Town and Crossness are more probably of post-Carboniferous than of pre-Carboniferous age. It may, indeed, be argued that as in the Ardennes we have the lowest member of the Devonian (the Gédinnien of Belgian geologists) underlying strata of the Eifelian type, the same may be the case under the London Basin. But against this view must be set the fact that MM. Gosselet, Six, and Barrois, who have such an exact knowledge of these Gédinnien strata of the Ardennes, fail altogether to recognize any resemblance between the Richmond rocks and those strata, but on the contrary believe the latter to be Trias.

To sum up the evidence on the age of these variegated rocks at Richmond, Kentish Town, and Crossness, we may admit that the resemblances to the Old Red and the New Red rocks are about equal: but considering the undoubted presence of Devonian rocks of the Eifelian type at Meux's well and at Turnford, the probabilities appear to be in favour of these variegated strata belonging to the Poikilitic rather than to the sub-Carboniferous formation.

The recognition of strata of Lower-Oolite age is a new, but not altogether unexpected fact, made known to us by the Richmond boring. Mr. Godwin-Austen was led by various considerations to regard it as probable that the great Palæozoic ridge had been submerged during a portion, at least, of the Oolitic period *.

The particulars which we have now been able to ascertain concerning the nature and relations of the Great-Oolite strata exposed in the borings at Meux's Brewery and at Richmond point to the following important conclusions:—

(1) The Great-Oolite strata under the metropolitan area rest directly on the Palæozoic rocks, as at Meux's Brewery, or on the Poikilitic strata, as at Richmond. In this we find an exact repetition of the conditions found in the Boulonnais, where beds of probably Great-Oolite age rest directly on far more ancient deposits.

(2) Both in the Boulonnais and in the metropolitan area, the whole of the beds of the Rhætic, of the several divisions of the Lias, and of the Inferior Oolite are altogether wanting. The absence of these formations was probably due to the circumstance that these districts and probably the whole area between them constituted dry land during the Rhætic, Liassic, and Bajocian periods. And this conclusion is confirmed by the manner in which the well-developed

* See Quart. Journ. Geol. Soc. vol. xii. 1856, pp. 65, 71.

strata of those ages in the West of England and in Normandy thin away and disappear as they are traced towards the east.

(3) But about the commencement of the Great-Oolite period the great ridge of Palæozoic rocks occupying what is now the south-east of England and the north of France began to be submerged, and the strata now for the first time described were then deposited. What was the original thickness of these Great-Oolite strata in the metropolitan area, we have no means of knowing, as these deposits appear everywhere to have had their upper beds removed during the great Neocomian denudation.

(4) The Great-Oolite strata which were thus deposited on the southern flanks of the great Palæozoic axis probably, however, never extended over the northern half of that axis. This is shown by the evidence of littoral, and even of estuarine and terrestrial conditions, in the Great-Oolite strata found at Meux's Brewery. At this period there appears to have been an extensive tract of dry land lying to the north of the Great-Oolite sea which covered what is now the south-east of England and the north-east of France. From this land were borne pebbles of various hard rocks, of coal-measure sandstone, and of coal, which we now find in the bands lying at the base and the summit of the series of Great-Oolite strata at Richmond.

(5) That the submergence of the Palæozoic ridge, which took place during the Great-Oolite epoch, was continued during the period of the Middle Oolites, we have sufficient evidence, as already pointed out by Mr. Godwin-Austen. The "Lower Greensand" beds of the North Downs, between Sevenoaks and Farnham, often contain fragments of considerable size, and sometimes become almost conglomeratic in character. The pebbles in these beds consist for the most part of quartzite and other hard rocks, evidently derived from the rocks of the great Palæozoic axis. But, mingled with these, we find a considerable number of fragmentary, waterworn, and evidently "derived" fossils of unmistakable Jurassic affinities. From an examination of great numbers of these derived fossils, I agree with Mr. Godwin-Austen and Mr. Meyer in considering that they represent both the Lower and the Middle Oolite. But I am at the same time convinced that the fossils of Middle-Oolite age occur in such situations in much greater proportions than those of the Lower Oolite. Taking these facts in connexion with that of the presence of Middle Oolites under the Weald, as revealed in the boring at Battle, and the evidence of the general deepening of the Jurassic sea after the close of the Lower Oolites in the Anglo-Parisian basin, we are led to the conclusion that the Middle-Oolite strata originally overlapped those of Great-Oolite age, and probably extended right across the Palæozoic ridge. Thus we should conclude that during the period of the Middle Oolite the great Palæozoic axis was completely submerged, and that the deep-water Oxfordian Clays of the north of France and of central England were deposited in a continuous sea wherein the rocks of the Palæozoic ridge formed at most only a shoal.

(6) As to whether the Upper Oolites—which exhibit such a thickness in the Wealden boring, and are again found as deep-water beds on the northern side of the axis—were also continuous over the latter, we have at present no certain evidence. Among the derived fossils in the Lower Greensand of the North Downs I have not been able to identify any as belonging to undoubtedly Upper-Oolite species. The beds at Shotover probably indicate that, during the Upper-Oolite period, the elevation which continued through a great part of the Neocomian period had already begun.

(7) As no beds of Middle-Oolite age have as yet been detected *in situ* beneath London, we are led to conclude that the whole of them were removed during the great upheaval and denudation of the Palæozoic ridge which undoubtedly took place during the latter part of the Neocomian period. This will account for the abundance of fragments derived from the Middle and Lower Oolites which are imbedded in the Lower-Greensand strata deposited along the southern flanks of the ridge. Of the importance of this movement of elevation, with its accompanying denudation, we have the clearest proofs. It was probably as this movement of elevation was gradually being replaced by one of subsidence, and while portions of the remnant of the Great-Oolite strata were still above the waters of the ocean, that the curious and anomalous strata lying between the Gault and the Great Oolite at Richmond were formed. These consist in part of the reconstructed materials of the Great Oolite, and in part of pebbles brought from the shores of the period, consisting of some exposed portions of the Palæozoic ridge.

(8) During the subsequent Gault and Chalk periods a continued submergence of the great Palæozoic axis went on, the movement of subsidence more than keeping pace with the work of sedimentation. But that this downward movement was not without interruptions, we have now abundant evidence within the metropolitan area itself. The rock of the Zone of *Belemnites plenus* and the Chalk Rock afford evidence that, at the close of the Cenomanian and Turonian periods respectively, pauses in the deposition of sediment took place, accompanied by some removal and redeposition of beds already formed. What the extent of this interruption to subsidence or partial re-elevation during these periods was, it may be difficult to determine; but it seems certain that thick and important deposits were, in certain portions of the continental area, deposited during these breaks in the succession of our Chalk strata, and that these movements, in which the great Palæozoic axis participated, were widespread in extent and important in their consequences.

B. *The Water-supply of the Metropolis.*

The general analogy between the strata of the Paris and London basins long ago suggested to geologists the possibility of obtaining for the latter city those deep-seated supplies of water which feed the great Artesian wells of the former. But, as Mr. Godwin-Austen showed by *a priori* reasoning, and several deep wells in the metropolis have since demonstrated, the great water-bearing deposit of the Lower Greensand does not occur under London itself, the Gault there resting on lower members of the Mesozoic series or directly upon Palæozoic rocks.

But although the hope of finding the Lower Greensand as an abundant source of water-supply immediately under London had to be abandoned, it nevertheless seemed possible that this important water-bearing stratum might be tapped by Artesian wells at places sufficiently near to the metropolis to supplement to a great extent, if not altogether to supersede, the use of the waters of the Thames for drinking-purposes. The thickness of the Lower Greensand at its outcrop in Surrey and Kent, the very pervious character of its beds, and its steady dip under the Chalk, pointed to the probability that at places within the ever-growing area of the metropolis, as at Sydenham or Croydon, such sources of water-supply might be easily reached *.

The discovery of a considerable thickness of what were supposed to be strata of Neocomian age, though of somewhat anomalous character, so far northward as the site of Meux's Brewery led to the anticipation that the more normal condition of the Upper Neocomian would be met with at no great distance, and that in the southern part of the London area Artesian wells might be put down into the pervious Lower Greensand.

The facts which have been described in the present paper, however, show that the 64 ft. of oolitic limestone at Meux's Brewery are of Jurassic, and not of Neocomian age, and that as far southwards as Richmond there is no trace of the normal type of the "Lower Greensand" strata.

The deposit which does probably represent the Upper Neocomian at Richmond is of a very peculiar character, resembling in fact the "Tourtia," which in Belgium separates the rocks of Palæozoic age from the overlying Chalk. In both cases the rock is made up of reconstructed and derived materials. This peculiar deposit at Richmond is less than ten feet in thickness; from its nature it can scarcely be expected to form a regular and widespread bed, and it does not yield any supply of water. It would be of much interest if a deep well were put down at Croydon, to prove whether the normal condition of the strata of Lower-Greensand age is maintained so far to the northward as that town. The possibility of finding large supplies of excellent water ought to be a sufficient inducement for the undertaking of this interesting experiment.

The Oolitic strata at Meux's Brewery and at Richmond have unfortunately proved useless as sources of water-supply.

But the discovery at Richmond of beds which are certainly of a somewhat pervious character, and are apparently of Poikilitic age, suggests the possibility, though I fear I cannot add the probability, of finding water there; and this suggestion receives some support from the fact that, after the red rocks were reached, small but

* See Prof. Prestwich's Anniversary Address to the Geol. Soc. 1872 (Quart. Journn. Geol. Soc. vol. xxviii. p. lx).

increasing quantities of water, having the high temperature of deep-seated sources of supply, rose to, and indeed far above, the surface.

Although the outcrop of the Poikilitic strata is situated at a distance from London not greater than that which separates the outcrop of the water-bearing strata from the Artesian wells in Paris, yet, considering the whole of the circumstances of the case, I cannot regard it as probable that supplies of water will be obtained under London through continuous strata of Poikilitic age outcropping at the surface. The variable nature of the Poikilitic strata, the doubt of their continuity over a considerable area (a doubt strongly suggested by their absence at the Tottenham Court Road, Turnford, and Ware wells), and the frequency of salt deposits which would vitiate the supply, all tend to destroy the hope of obtaining water from the Poikilitic rocks under London.

But as it is now proved that there exist pervious beds at great depths under London, and it is also certain that large supplies of water are carried down through the Lower-Greensand formation, it is just possible that the pervious strata may be saturated with water from other beds which, by overlap or faulting, lie in contact with them, and that such water may be made to rise to the surface in Artesian wells.

C. *The Possible Existence of Coal at Workable Depths under London.*

Some years ago I ventured to suggest that the deep borings under London had already thrown so much light on the nature and relations of the different rocks forming the great Palæozoic ridge, that the time had arrived when it was worth while to commence a series of systematic trials to the south of London, with a view to solve the problems of the presence and position of coal-bearing strata within the metropolitan area. I also endeavoured to determine the points at which such trial-borings might be most advantageously put down *.

Shortly after the appearance of these articles, M. Ad. Firket, an eminent geologist and engineer, published an abstract of the views which I had enunciated—in which he generally concurred—in a foreign journal, adding some valuable remarks of his own upon the subject †.

The deep well at Richmond has supplied one more of the desired borings running in a line from north to south across the London Basin. But it has at the same time afforded new data calculated to modify to some extent the conclusions at which geologists had previously arrived. These I shall proceed to discuss.

From the facts detailed in this paper it is now evident that, in the southern part of the metropolitan area, shafts in search of coal would probably have to be carried through a considerable thickness of Oolitic strata, and that these Oolitic strata probably increase in

* Nature, vol. xxv. pp. 311 and 361.

† Revue Universelle des Mines &c. tome xii. 2e série (1882), p. 457.

thickness as we proceed southwards. If we are right in referring the red and variegated beds at the bottom of the Richmond borehole to the Poikilitic, there will also be an additional and, at present, unknown thickness of strata of that age to be passed through.

In the other deep borings within the London area, the Palæozoic ridge was struck at depths of 1000 ft. or less beneath Ordnance-datum line; but at Richmond, at a depth of nearly 1400 ft. below that level, the rocks of Palæozoic age do not seem to have been touched, and under any supposition the overlying rocks are 1220 ft. thick. The considerations I have just stated lead one to fear that further to the south the distance of the Palæozoic ridge from the surface would be still greater.

It must be remembered, however, that unequal elevation and denudation in pre-Cretaceous times might bring about a set of conditions which, if known, would greatly tend to modify the above conclusions. Mr. Godwin-Austen suggested that old lines of disturbance often coincided with those of later date; and as a modern axis of disturbance is known to exist along the line of the North Downs, a coincident flexure of older date may have resulted in bringing the Palæozoic rocks nearer the surface. Hence Mr. Godwin-Austen has expressed himself in favour of a trial-boring for coal being made in the neighbourhood of the North Downs.

Taking into account the probable thickening of the Oolitic rocks as we go southwards, as indicated by the Battle and the Richmond borings, and the possibility that Wealden strata may also be found to overlie these, as we approach the North Downs, it must be admitted that a very great amount of pre-Cretaceous disturbance and erosion would be required to place the Palæozoic rocks within moderate distance from the surface.

Of course if the boring were commenced in any lower member of the Cretaceous series, there would be so much less rock to be passed through in the upper part of the boring. But in order to do this, it would be necessary to proceed southwards; and it is, to say the least, not improbable that the thickening of the Jurassic strata in passing southwards may more than counterbalance the removal of the Cretaceous beds by denudation. If the thick sandy beds of the normal Lower Greensand were met with, there would of course be a further, but probably not insuperable, difficulty encountered, that, namely, of sinking through very loose and pervious beds.

On these grounds I cannot help fearing that the prospect of finding coal at workable depths under the southern part of the London Basin is rendered less hopeful in consequence of the results which have been obtained through the Richmond well.

If the red rocks at Richmond belong to the Old Red Sandstone and not to the Poikilitic, it is still possible, bearing in mind the effects of the remarkable reversed faults in the old Palæozoic ridge, as proved by the researches of M. Gosselet, that Carboniferous strata might be found underneath them. The chance would, however, be probably regarded as too slender a one to encourage a prosecution of trials through such red rocks.

All who have paid much attention to the subject have been convinced that coal-seams, if found under London, would probably prove to be, as a whole or in part, of the anthracitic variety. This being the case, it is interesting to notice that in the junction-beds above and below the Great Oolite at Richmond, fragments of anthracite mingled with pebbles of Coal-measure sandstone and other hard rocks from the Palæozoic ridge were found in considerable abundance. That these fragments of anthracite occurred in the rocks and were not accidentally introduced I was able to prove beyond the possibility of doubt by actually taking them out of the hard calcareous matrix in which they were imbedded.

Hence we are irresistibly led to the conclusion that at the period when the Jurassic strata were being deposited, portions of the old Palæozoic ridge were above the sea-level, and that among the rocks of this old ridge were Coal-measure sandstones with seams of anthracite. That these fragments of anthracite were derived from no very distant locality may be inferred from the brittle nature of the substance.

From this interesting observation I think we may conclude that the "Coal under London" has really been found, though as yet, unfortunately, not *in situ*.

APPENDIX.

On the Great-Oolite Fossils *found in the* Richmond *and* Tottenham-Court-Road Wells.

As Prof. T. Rupert Jones has kindly undertaken the description of the Ostracoda and Foraminifera, Dr. G. J. Hinde of the Sponges, and Mr. G. Vine of the Bryozoa from these strata, it will only be necessary for me to give a short account of the peculiarities of some of the other forms of life found in these interesting deposits.

A complete series of specimens from the Richmond well will eventually be placed in the British Museum, with a set of duplicates from Meux's well. The original series of Mr. C. Moore belongs to the Bath Museum, and to these will be added for comparison a set, as nearly complete as possible, of the Richmond fossils.

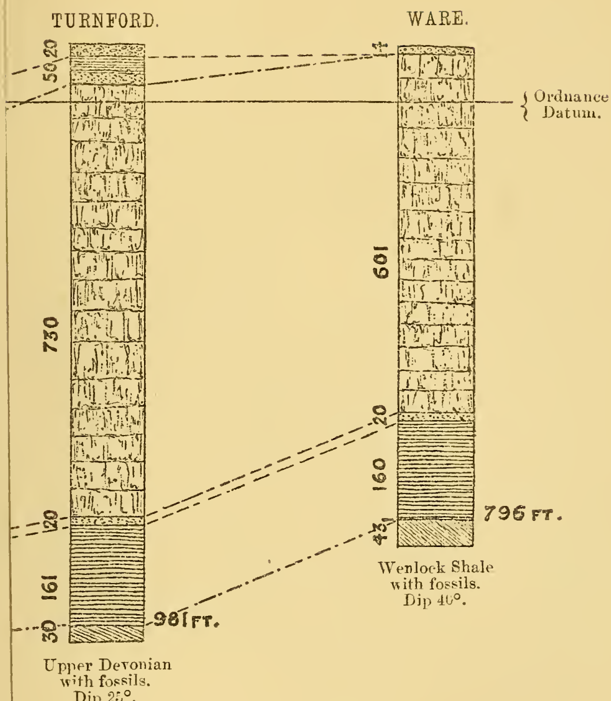
The fossils of the clay at Richmond, though unworn, consist for the most part of disjointed ossicles and spines, and of small and immature specimens. Those from Meux's well are much eroded and often covered with a thick coating of calcic carbonate, so that in many instances it is difficult to make out even the genera to which they belong.

Gasteropoda are extremely common in the Meux-well washings, but they are for the most part young shells, and very imperfectly preserved. With respect to the supposed freshwater forms, I am unable to add anything to the notes of Mr. C. Moore*. Some of the limestones from this well preserve good hollow casts of *Nerinæa,*

* Quart. Journ. Geol. Soc. vol. xxxiv. (1878), p. 920.

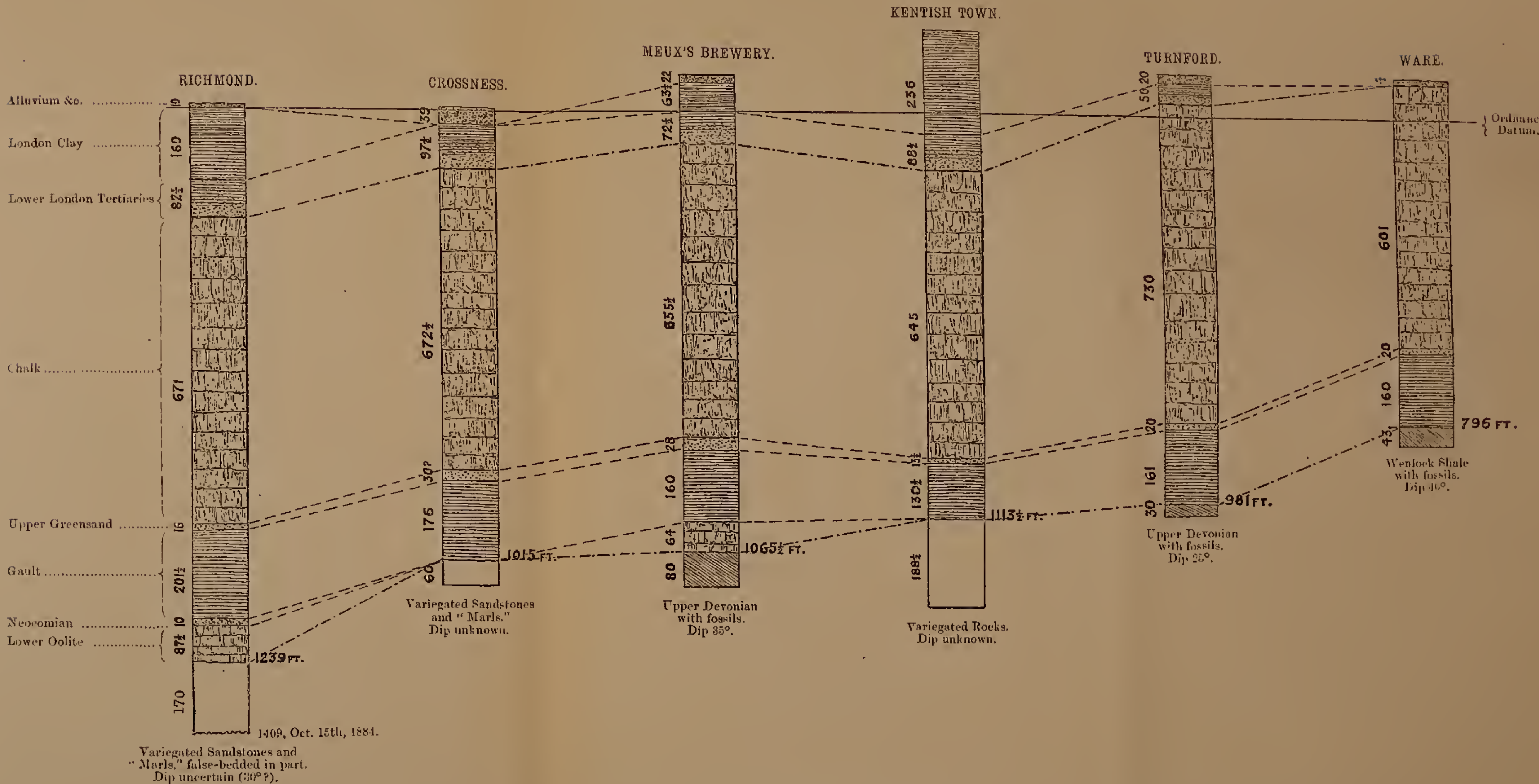
[To face page 760.

xis beneath the London Basin.



hs at which the Palæozoic axis was reached.

Fig. 2.—*Comparative Series of Vertical Sections exhibited in the deep Wells which have reached the Palæozoic Axis beneath the London Basin.*



The figures printed vertically show the thicknesses of the several formations passed through: those in a horizontal position indicate the depths at which the Palæozoic axis was reached.

Cylindrites, and other univalve shells. In the Richmond clays Gasteropoda are very rare, but a few are found in the limestones.

Fragments of full-grown Lamellibranchiate shells abound in the Richmond washings. Except, however, in cases like that of *Pecten rushdenensis*, Lyc. & Mor., where the surface-markings are of a very distinct and characteristic pattern, it is very difficult to determine the species to which they belong. The young forms which occur both at Richmond and at Meux's Brewery usually afford very unsatisfactory evidence concerning the species to which they should be assigned.

With the Brachiopoda, however, the case is different. Mr. T. Davidson, F.R.S., has kindly examined the specimens and supplied me with notes from which he has permitted me to quote.

The most characteristic shell in the Richmond deposits was the *Terebratula coarctata*, Park. A very perfect specimen, measuring 12½ millim. broad by 12 millim. high, was found with many fragments of adult shells, and young specimens in every stage of growth. The large and perfect specimen is described by Mr. Davidson as being "a very typical example of the species." The spines on its surface are exquisitely preserved. I have not found *T. coarctata* among the washings from Meux's well.

Terebratula maxillata, Sow., is also very abundant in the Great Oolite of Richmond. An adult shell of this species occurs in one of the beds of limestone beneath Richmond at a depth of 1219 ft.; it measures 48 millim. in breadth, and 45 millim. in height, but is slightly crushed. Fragments of this shell, often overgrown with Bryozoa, occur in the clays, with prodigious numbers of the young form of the shell. Of these young forms Mr. Davidson writes, "I have carefully compared these small specimens, and believe them to be the young forms of *Terebratula maxillata*, a form that occurs along with *T. coarctata*. At Hampton Cliff near Bath, in the Great Oolite, similar young forms may be collected by hundreds." Lhwyd, as Mr. Davidson points out, has figured a series of specimens from Hampton Cliff in his 'Lithophylacii Britannici Ichnographia,' pl. ix., showing the transitions from the young to the adult forms. Mr. Davidson failed to find among the Richmond specimens any that were referable to *Terebratula Buckmani*, a form which at Hampton Cliff occurs with *T. maxillata*. The young forms of *T. maxillata* occur in the washings from Meux's well, but are much rarer than at Richmond.

Terebratula digona? Sow. Among the small *Terebratulæ* from the Meux's-well washings are several which appear to be the young of *T. digona*.

Rhynchonella concinna, Sow., sp., is represented at Richmond by a few fragments of the adult shell and a number of young ones. Both were identified without hesitation by Mr. Davidson. The young forms occur in the washings from Meux's well.

The interesting forms of *Thecidium* and *Zellania* found by Mr. C. Moore in the material from Meux's well did not occur in that from Richmond.

The remains of Echinoderms from these two wells, consisting, as they do, for the most part of disjointed ossicles, plates, and spines, are very difficult to determine. Among the most common are marginal plates and eye-plates of an Asterid. Precisely similar forms, though less perfectly preserved, occur in the washings from the Bradford Clay. Eye-plates of like kind are figured by Quenstedt in his 'Petrefactenkunde Deutschlands'*. The marginal plates are so like those of *Astropecten*, that I have little doubt that they must be referred to that common Oolitic genus.

The Crinoids have been kindly examined for me by Dr. P. H. Carpenter, who states that they represent arm-joints and cirrus-joints of *Pentacrinus scalaris* and of another Pentacrinid. He refers other fragments with doubt either to *Bourgeticrinus* or *Thiolliericrinus*.

EXPLANATION OF PLATE XXXIII.

Chalk of the Zone of Belemnites plenus *from a depth of* 704 *ft. in the Richmond Well.*

Fig. 1. Shows the appearance of a polished surface of this chalk, magnified two diameters. The lighter portions are the included fragments of *Globigerina*-chalk; the darker portion shows the matrix made up of fragments of various organisms, some of these fragments being of considerable size.

2. Illustrates the appearance of the rock when seen in thin section by transmitted light with a low power. A is the *Globigerina*-chalk, of an included fragment of which the edge is seen in the slide. It appears to be almost entirely made up of fragments of minute *Globigerinæ*. A few other forms of Foraminifera occur, among which *Textularia* is conspicuous. B shows the character of matrix which encloses the fragment.

Discussion (February 6, 1884).

Prof. Prestwich spoke of the value of the paper and the good fortune that the excavation had been watched by such experienced geologists. He called especial attention to the two divisional and apparently denudational zones in the Chalk, and to the persistence of the total thickness of the Chalk in the London area. But the main interest of the paper consisted in the sub-Cretaceous strata. The specimens from the boring at Meux's Brewery, which were very fragmentary, were supposed to be Neocomian, and so led to the hope that the sand-beds might set in at a short distance to the south. It was, however, now clear that these calcareous beds were Oolitic. He did not, however, agree with Prof. Judd in thinking the red beds Triassic; they appeared to him more probably Old Red Sandstone, though doubtless it was difficult to say. If they were the former it would be less likely that Palæozoic beds, as evidenced in the conglomerate, should occur in the vicinity. If the water rose to

* Tab. 91.

so great a height as 130 ft. from the surface, he should expect the outcrop to be on ground of considerable height.

Mr. Etheridge said that few more important papers had been read before the Society. Our knowledge of the subterranean geology of the south-eastern and middle part of England had been greatly augmented of late, especially by borings near Northampton, the results of which would before long be brought before the Society. The great gap that existed in the London area between the Cretaceous and the Palæozoic rocks was remarkable. The discovery of Jurassic rocks and fossils in this Richmond area was important, as linking the British to the French area, the boring at Battle serving as a connecting link. As regards the Meux's Brewery, he felt convinced that the upper and sandy part of the so-called Neocomian was certainly of that age; of the lower part it was more doubtful. *Trigonia alæformis* and *Astarte formosa* occurred in the upper part, with one or two other distinctly Neocomian fossils. Of the occurrence of Devonian there and at Turnford there is no doubt, nor of the Wenlock at Ware. These dipped towards the south. He hoped that at Richmond they would attempt to reach something below the red beds, so as to prove the presence of undoubted Palæozoic rocks. There was no doubt, however, that the Great Oolite and Bradford Clay are represented in the boring.

Mr. Topley called attention to some specimens from the Kentish-town boring exhibited by permission of the Director-General, and some from Meux's boring. Recent examination of the latter had produced some evidence corroborative of Prof. Judd's view as to their Oolitic age, at any rate in part. As regards the occurrence of coal, he drew attention to the boulder of coal found in the Chalk near Dover, which was not anthracite. If the red rocks were not New Red, he hardly saw how they could be Old Red, as so near the beds had a true Devonian facies. He also called attention to a well at Chatham Dockyard, which had passed through 30 ft. of Folkestone beds, 9 ft. of Atherfield (?), and then, as he believed, Wealden beds. He thought all the evidence now brought forward by Prof. Judd showed that the boring in the Weald had been wisely abandoned. He also called attention to Prof. Judd's diagrams as illustrating the connexion between the thinning out of lower beds and the dip of the overlying beds, the latter being explicable by the former.

Prof. Hughes remarked that the compressibility of newer beds abutting against uncompressible older beds, by causing a dip away from the axis, would be another explanation of the amount of apparent dip of the same kind as that which Mr. Topley had last mentioned. He agreed with Prof. Prestwich in doubting whether the red beds were Trias. The base of the Oolite showed that the materials had come from some distance, and the Lias and Rhætic were wanting. Nowhere else did an unconformity so marked occur between Oolitic and Trias, and he thought it could not be inferred from the results of one boring. Also the finer beds generally occurred high in the Trias, and he should expect to find coarse beds in the lower or shore-deposits.

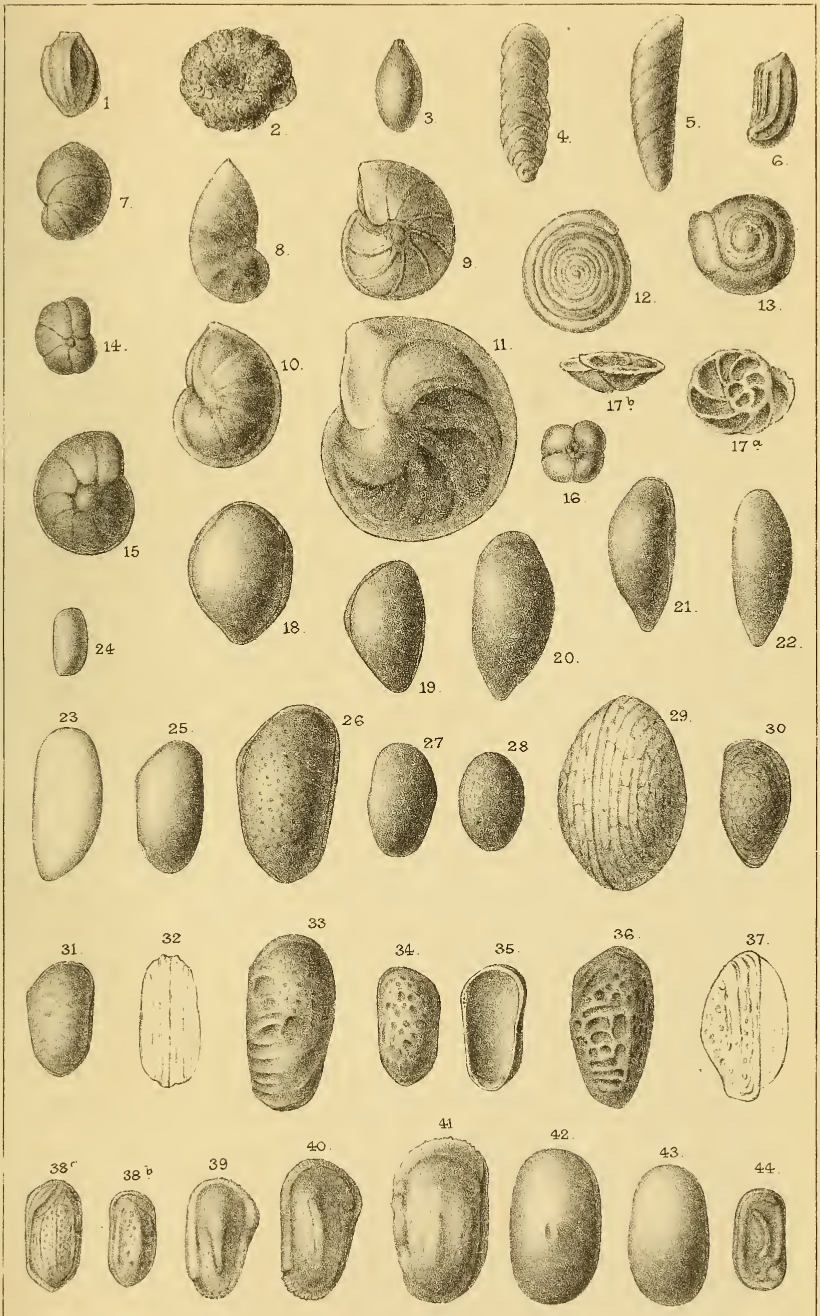
Prof. Prestwich said that in the Boulonnais an Oolite of the same age as at Richmond rested directly on Palæozoic beds.

Mr. Clarke Hawkshaw said the red-rock specimens were exactly like those of the Trias in the Severn Tunnel.

Mr. A. R. Binnie asked a question about the quality of the water.

Mr. Homersham said the water from the Oolite contained 72 grains of solid matter per gallon, but was not therefore unfit for domestic use; there were 26 grains of chloride of sodium and other mineral matter. The quality of the water would probably improve when a large quantity had been pumped from the bore-hole.

Prof. Judd said, with regard to the age of the red beds, that Prof. Prestwich and he were agreed as to the difference between the Crossness and Kentish Town strata and those at Richmond, the latter being much more like Trias. But what weighed most with him was this—at Meux's Brewery and at Turnford there were thoroughly characteristic *Devonian* beds; and, he asked, Were *Old Red Sandstone* beds likely to occur so near to those places as at Richmond? As regarded Prof. Hughes's speculative difficulty, Why should not Oolitic beds rest unconformably on Trias? at first he himself had thought the beds might be Old Red, but he had gradually arrived at the opinion which he now held. As regards the Neocomian in Meux's well, he had only come to the conclusion of their non-existence after very careful examination. Oolitic limestones occurred quite at the top of the series; and only 5 ft. below the Gault, he had obtained *Trigonia costata*, var. *pullus*. He was himself convinced that no Neocomian species had occurred in the well. He thought no argument could be based on the boulder of coal found at Dover, as it was probably carried by an iceberg, possibly from a great distance.



Geo. West & Sons del. lith. et imp.

MICROZOA *from the* RICHMOND BORING.

49. Notes *on the* Foraminifera *and* Ostracoda *from the* Deep Boring *at* Richmond. By T. Rupert Jones, Esq., F.R.S., F.G.S. (Read June 25, 1884.)

[Plate XXXIV.]

§ I. Specimens 1–8 came from 1145′ 9″ to 1146′ 6″.
§ II. Specimens 11–19 came from 1151′ to 1151′ 6″.
§ III. Specimens 21–57 came from 1205′.

They have all been carefully mounted, and will be deposited in the British Museum and elsewhere. The numbers here indicated are the numbers of the specimens as mounted and preserved, and have no reference to the order of the species as described in this paper.

§ I. *Depth of* 1145 feet 9 inches *to* 1146 feet 6 inches.

From the bed, 9 inches thick, at the depth above mentioned, there were obtained seven specimens of Foraminifera, and several Entomostracan valves.

1. Foraminifera.

These comprise six specimens of *Cristellaria* and one *Lituola*. The latter may be regarded as *L. nautiloidea*, var., and is small, discoidal, depressed (slightly biconcave), with blunt or rounded edge. It belongs to the *Haplophragmium* division, is much like the recent *H. emaciatum*, H. B. Brady, 'Report on the Foraminifera obtained during the Voyage of the "Challenger,"' p. 305, pl. 33. f. 27, and is not far removed from *H. nanum*, H. B. B., and *H. acutidorsatum*, Hantken; but the last is involute, instead of evolute, in its growth.

The specimen before us may be termed *Lituola nautiloidea*, Lam., var. (*Haplophragmium*) *depressa*, nov., or, for convenience, *L. depressa*. It looks so smooth and worn that it is possibly a *derived fossil*. Pl. XXXIV. fig. 2.

Of the *Cristellariæ*, which are all of small size, and some minute, there are the following species or varieties :—

(1) *Cristellaria rotulata* (Lamarck), thin-edged, with convex umbilicus, and raised septal lines; the chambers are rather small, very oblique and subfalcate, about nine in the last whorl (Pl. XXXIV. fig. 9). There is also a very small, ill-grown *C. rotulata*, with the posterior angle of some of the chambers projecting from the circular edge; not an uncommon condition.

(2) *Cristellaria cultrata* (Montfort), with keel, central boss, thick and raised septa, and about 7 chambers in the last whorl, Pl. XXXIV. fig. 11.

(3) A less circular (more elliptical) variety of the last-mentioned form, with 6 chambers visible, the last of which projects slightly forwards, Pl. XXXIV. fig. 10.

(4) *Cristellaria rotulata* (Lamarck). A somewhat Marginuline

Cristellaria, in which the chambers are few and ventricose, increasing rapidly in size. The last chamber is set on nearly straight, not in a spiral direction. The septal lines are depressed. Pl. XXXIV. fig. 7. This matches some varieties allied to *Marginulina simplex*, D'Orb., *Cristellaria mirabilis*, Reuss, &c.

In this limited group of Foraminifera (§ I.), there is nothing especially characteristic. These forms range through the Secondary and Tertiary formations to the Recent Period. Indeed *Cristellaria** is of Silurian occurrence, and *Haplophragmium* is known in the Carboniferous rocks.

2. Entomostraca (Ostracoda).

1. Macrocypris Bradiana, sp. nov. (Pl. XXXIV. fig. 23.)

Smooth, subelliptical, with an obliquely tapering posterior end, and the dorsal edge more convex than the other. Two specimens, one larger than the other; the former shows the outside (fig. 23), and the other the inside of a valve.

In shape this is near to, but more oblong than, *M. tumida*, G. S. Brady, 'Report on the Ostracoda of the "Challenger" Expedition,' p. 43, pl. 6. fig. 2.

2. Cythere Schwageriana, sp. nov. (Pl. XXXIV. fig. 27.)

One valve. Smooth, subovate, somewhat of the peach-stone shape; more convex on the dorsal than on the ventral border, the hinge-joint being slightly prominent. The ventral region is convex, slightly bulging over its border.

The name of Dr. Conrad Schwager, who has described many Jurassic Microzoa, is associated with this species.

3. Cythere juglandica, sp. nov. (Pl. XXXIV. figs. 36, 37.)

Three specimens. In shape somewhat like a long peach-stone; coarsely reticulate, and rough like a walnut-shell; the meshes more elongate on the ventral region.

The kind of reticulation here seen is met with in *Cytheræ* of different shapes, fossil and recent. In the specimens under notice, and among others from other parts of the deep boring at Richmond, there is considerable variation in the strength or depth of the coarsely sculptured network ornament of the valves.

4. Cythere (Cythereis) quadrilatera, Römer. (Pl. XXXIV. figs. 39, 40, 41.)

One valve (fig. 39), irregularly oblong in outline, the anterior hinge-joint standing out on the dorsal margin. Bordered all round with a raised smooth rim of varying thickness, thickest at the antero-dorsal margin. Ridged medially, from the anterior third

* *C. rotulata* has been figured by Mr. E. O. Ulrich from the Lower Silurian of Cincinnati (Journ. Cincinn. Soc. Nat. Hist. vol. v. (1882?), p. 119, pl. 5, figs. 1, 1 *a*), and M. O. Terquem has noticed a *Cristellaria* from the Devonian of Paffrath (Bullet. Soc. Geol. Fr. 3, viii. p. 414, &c., 1880).

backwards, with a smooth thickening of the test, beginning with an irregular boss just behind the front hinge-joint. Posterior margin narrowed, depressed, bordered with a very slight, tubercled rim. Some specimens from other depths in the boring (figs. 40, 41) are larger and show variation in the intensity of the tubercles.

This is the *Cythere* (*Cythereis*) *quadrilatera*, Römer, 'Monogr. Cretaceous Entom. England,' Pal. Soc. p. 18, pl. 3. fig. 10; pl. 4. fig. 10. It occurs also in the Portland Oolite of Dorset.

5. Two obscure specimens suggest the possibility of their having been—one a *Cythereis* and the other a *Cythere*, but they are undeterminable.

The above-described Ostracoda from § I. belong to common types, and offer nothing specially characteristic of any particular formation; similar forms ranging through Secondary and Tertiary into Recent times. *C. quadrilatera* is well known in the Chalk and Gault; and it accompanies other "Cretaceous" forms in the soft, white, chalky Portland Oolite at Ridgeway, Upway, Dorset. See Quart. Journ. Geol. Soc. xxxvi. p. 236.

§ II. *From the Stratum at* 1151 feet *to* 1151 feet 6 inches.

1. Foraminifera.

1. Cristellaria rotulata (Lamarck).

Small; with nine triangular chambers in the last whorl; and with a subtranslucent convex umbilicus, a flush surface, sharp edge, and nearly straight septal lines.

2. Cristellaria italica (Defrance).

Small, short, thick; a well-known triangular (arrested?) form of *Cristellaria*.

3. Cristellaria, sp. indet.

A small broken specimen, probably *derived*; white and rather rough. It looks like the butt-end (early chambers) of an elongate or Marginuline *Cristellaria*.

2. Ostracoda.

1. Bairdia Juddiana, sp. nov. (Pl. XXXIV. fig. 18.)

Very broad (that is, the valve is very high if placed in its natural position), subovate, smooth, delicately pitted.

Prof. J. W. Judd's name is associated with this species, found by his careful researches in the deep strata at Richmond.

2. Bairdia trigonalis, sp. nov. (Pl. XXXIV. fig. 19.)

Narrower than the foregoing, but broad and almost triangular; smooth and delicately pitted.

3. Cytheridea subperforata, sp. nov. (Pl. XXXIV. figs. 25, 26.)

Two specimens (fig. 25, and a broken valve). Smooth; subovate but rather long; obliquely rounded in front, the antero-dorsal border sloping; rounded posteriorly; dorsal border subangular at the front joint; hinge-line oblique, but straight; ventral border nearly straight. Closely allied to *C. perforata* (Römer), which is a Cretaceous species.

4. Cythere subconcentrica, sp. nov. (Pl. XXXIV. figs. 28, 29.)

Six or seven specimens. Small and plump; of the peach-stone pattern; smaller and rather smoother than *C. concentrica*, Reuss, which is not rare in the Chalk. It is faintly marked with a linear subconcentric reticulation, or shallow elongate pittings, particularly on the ventral region. It reminds us of the species just mentioned, and, at first sight, of its smooth variety *virginea*. See Monogr. Cret. Entom. Pal. Soc. 1849, p. 11, pl. 1. fig. 2; and Geol. Mag. vol. vii. p. 74. One specimen shows minute spots, like the bases of prickles.

5. Cythere juglandica, see above, p. 766. (Pl. XXXIV. figs. 36, 37.)

Two specimens of this well-defined *Cythere* of the peach-stone type; convex, suboblong or subquadrate, and rugose, being coarsely reticulate like a walnut-shell, with the meshes more elongate on the ventral region.

6. Cytherella symmetrica, sp. nov. (Pl. XXXIV. fig. 42.)

Symmetrically oblong-oval, or oblong with rounded ends; edge-view subcuneiform; delicately pitted; subcentral sunken spot present.

There are many oblong *Cytherellæ*, and some of them closely approach this form. *C. fraterna* (Reuss), from the Trias, is the nearest, but is not so perfectly symmetrical in outline; so also the recent *C. scotica*, G. S. Brady; but this is rather contracted medially. Among the many published figures of the Cretaceous *C. Muensteri* (Römer), some nearly match our specimen. *C. parallela*, Reuss, is symmetrical, but too narrow. For a list of the published *Cytherellæ*, and for a classification of the species, see the 'Monograph of the Carboniferous Cypridinidæ and their Allies' (Palæontographical Society), 1884 (now in the press).

The *Cytherella* under notice may well be named *C. symmetrica*.

7. A small *Cythere* (?) or short *Bairdia* (?), obscure; and a broken solid carapace of a *Cytherella*?

Of the Foraminifera and Ostracoda from 1151′ to 1151′ 6″ (§ II.), the former are *Cristellariæ*, of no special geological horizon; and some of the latter have a Cretaceous aspect, but these are associated with less marked species.

Miscellanea of § II.

A rolled, bilobed granule, and another, obscure.

Two small solid spirals (Gasteropodous ?).

Small, curved, tapering, solid body, pentagonal in section; smooth, shining, and cross-marked with very delicate striæ (comp. Blake, 'Lias,' pl. 17, f. 20, "spicule").

§ III. *From the Stratum at* 1205 *feet.*

1. Foraminifera.

1. Miliola (Quinqueloculina), sp. (Pl. XXXIV. fig. 1.)

Small; edges of chambers narrow and projecting.

Such little sharp-edged *Miliolæ* are not wanting in some of the Mesozoic strata.

2. Lagena lævis, Walker and Jacob. (Pl. XXXIV. fig. 3.)

Small, neat, simple, smooth, flask-shaped; not different from the recent form. This kind of *Lagena* occurs all through the Jurassic formations; and is known even in Silurian strata.

3. Frondicularia oolithica, Terquem, var. *regularis*. (Pl. XXXIV. fig. 4.)

Two Linguline *Frondiculariæ*, belonging to the group described and illustrated by M. O. Terquem in his 'Troisième Mém. sur les Foram. du Système Oolithique, &c.,' Metz, 1870, pl. 22, and comprising his *F. oolithica*, *spissa*, *spatulata*, &c. from the Lower Oolite. It is also a Liassic form. Our specimens begin with the usual little round knob of earliest chambers, and take on about 9 chevron-like, nearly equal chambers, limited in lateral extension, and varying somewhat in that development. Surface plain, nearly flush, and roughish.

4. Vaginulina legumen * (Linné), var. lævigata (Römer). (Pl. XXXIV. fig. 5.)

Two specimens, small and neat; one with a slight curvature of growth (fig. 5), the other straight. These belong to the *lævigata* variety of the type, which, in one form or other, is widely spread and has a long range in time, occurring certainly in the Lias and Oolites.

5. Marginulina raphanus (Linné). (Pl. XXXIV. fig. 6.)

Two specimens; very small, but typical. It is known in the Lias and the Lower Oolite. Compare Schwager's short, ribbed *Cristellaria oolithica* in Benecke's 'Geogn.-paläont. Beitr.' 1867, p. 657, pl. 34. fig. 10; also *Marginulina picta*, Terquem, in the 'Yorkshire Lias,' p. 462, pl. 19. fig. 6 *b*.

* See 'Monogr. Foram. Crag,' Pal. Soc. 1866, p. 64 &c.

6. Cristellaria crepidula (Fichtel & Moll.) (Pl. XXXIV. fig. 8.)

A small elongate Cristellarian form, with smooth surface, not limbate. Certainly as old as the Lias, frequent in the Oolites, and living now.

7. Cristellaria rotulata (Lamarck). See above, p. 765.

Several specimens. 1. One smooth, flush-surfaced, thin-edged. 2. Some, both small and largish, of ordinary character; occasionally limbate. 3. One small, flush, subtranslucent.

8. Cristellaria cultrata (Montfort). See above, p. 765.

Several; largish and small; one with a jagged keel. (? = *C. calcar*, or broken.)

9. Spirillina helvetica, Kübler & Zwingli, 'Mikrosk. Bild. Urw. Schweiz.' 1867, p. 12, pl. 2. fig. 8. (Pl. XXXIV. fig. 12.)

One specimen: small, translucent, with nine whorls, increasing very slowly in size. We need not separate our specimen from those of the Swiss Jura. *Sp. Helvetica*, from the Opalinus-clay, was again described and figured by Zwingli and Kübler in 1870 (Foram. Schweiz. Jura), but as a *Cornuspira* (p. 13, pl. 2, i. fig. 3), together with *C. eichbergensis* from the Parkinsoni-clay, p. 17, pl. 2, iv. fig. 2; but they seem to belong to the same species; and both are "colourless and glass-clear" (one is "translucent"), so they cannot be *Cornuspiræ*.

10. Spirillina crassa (Zwingli & Kübler), 'Foram. Schw. Jura,' 1870, p. 19, pl. 2, iv. fig. 2. (Pl. XXXIV. fig. 13.)

This specimen has about four whorls; the last is by far the widest. Subtranslucent, rather convex. The Swiss form (from the Callovian beds), which seems to be equivalent, was described as a *Cornuspira*, but it is "colourless and glass-clear." The specific name is not quite appropriate, unless the breadth of the whorl is taken as thickness; but we need not add to the catalogue of names.

11 & 12. Planorbulina Haidingeri (D'Orb.), and varieties (Pl. XXXIV. figs. 14, 15); and Planorbulina farcta (F. & M.), var. (Pl. XXXIV. fig. 16).

These small *Planorbulinæ* are present as seven or more specimens, varying much in size and aspect; some are broken or otherwise obscure. Two of the most definite are figured here (figs. 14, 15) as belonging to the *Pl. Haidingeri* type; and one (fig. 16) as being nearer to *Pl.* (*Truncatulina*) *lobatula*, W. & Jacob. Analogous representatives of the Planorbuline group have been described and figured by Zwingli and Kübler from the Jurassic strata of Switzerland (Foram. Schw. Jura, 1870) under various names—as *Nonionina badensis* (p. 37) from the Corallian, *Nonionina birmentorfensis* (p. 29) and *Rotalina badensis* (p. 35) from the Oxfordian, and *Nonionina oblonga* (p. 21) from the Callovian beds.

13. Pulvinulina elegans, D'Orb., var. tenella, nov. (Pl. XXXIV. figs. 17 *a*, 17 *b*.)

Only one specimen; small, depressed; deeply excavated on the upper face with the sunken tops of ten chambers; or, in other words, bearing their raised limbate coil and septa, which are not so symmetrical as in other varieties. The opposite face is subconical and smooth. This kind of *Pulvinulina* is abundant in the blue clay obtained at second-hand from the gypsum-pits at Chellaston, near Derby, and described in the Quart. Journ. Geol. Soc. vol. xvi. p. 452. Prof. Reuss long ago pointed out that these Chellaston Foraminifera had a Liassic aspect; and they were specially collated by Jones and Parker with those of the Lias and Oolites, at p. 456. As doubts were expressed about the geological stage whence the clay was derived, a search for the clay in place was made some time after, but without any good result, and the evidence is still what was stated at p. 452. *P. elegans* is described and figured, *op. cit.* 1860, p. 455, pl. 20. fig. 46, as *Rotalia elegans*; but its true relationships were pointed out in the Phil. Trans. 1865, pp. 393, 396, &c. *Pulvinulinæ* belonging to this type occur in the Trias (St.-Cassian beds), Lower Oolites, &c., and abound in the Gault. *P. caracolla* (Römer *) and *P. reticulata* (Reuss †), from the Hils Clay, are the nearest to our specimen, but they are too thick and symmetrical.

14. A small *Miliola*?, obscure; and a small, white, sandy (?), convex disk—*Webbina*?

2. Entomostraca *at* 1205 *feet.*

1–4. Bairdiæ. (Pl. XXXIV. figs. 20, 21, 22.)

Several specimens occured here, and of various outlines and shape.

Bairdia Hilda, sp. nov. (fig. 20), is longer than either fig. 18 or fig. 19 (see p. 767) in proportion, and more oblong in shape, but rounded anteriorly and acute behind (downwards in the figure).

Bairdia jurassica, sp. nov. (fig. 21), is a carapace with narrow valves, relatively long, and with outdrawn, but rather blunt, posterior angle.

B. jurassica, var. *tenuis*, nov. (fig. 22), shows the left valve (largest) of a very narrow thin *Bairdia*; but perhaps it need not be separated from fig. 21, except as a variety.

It is difficult to correlate these *Bairdiæ* with known species. The differences in outline are often of trifling amount, but yet possibly essential, as may be seen also with the Carboniferous *Bairdiæ*, in the Q. J. G. S. vol. xxxv. p. 565 &c., pls. 28 to 32; and in G. S. Brady's 'Report on the Ostracoda collected in the "Challenger" Expedition,' pls. 7 to 11; without referring to the many other published figures of *Bairdiæ* from all formations, even from the Silurian upwards.

* Verst. Norddeutsch. Kreideb. 1841, pl. 15. fig. 22.
† Sitzungsb. k. Akad. Wiss. Wien, vol. xlvi. 1863, pl. 10. f. 4.

5. Cytheridea subperforata, sp. nov., see above, p. 768. (Pl. XXXIV. figs. 25, 26.)

Two specimens (represented here by the best, fig. 26). Triangular-ovate. Right valve the smallest, overlapped by the other nearly all round, especially on the dorsal and ventral edges. Surface smooth and shining, but pitted; in one specimen the pitting is delicate, in the other (fig. 26) coarse.

6. Cythere ? tenella, sp. nov. (Pl. XXXIV. fig. 24.)

One specimen; very small and delicate; translucent; oblong, slightly oblique, with rounded ends.

7. Cythere Guembeliana, sp. nov. (Pl. XXXIV. figs. 31, 32, 33.)

Several specimens, differing much in development. Generally ovate-oblong, somewhat oblique, or subquadrate. Convex, with surface shining, but impressed with a coarse reticulation, in some cases faint. The cross meshes make faint or strong wrinklings; and the longitudinal ridges often get strong on the ventral region. Oblique transverse imprints are more or less marked on the dorsal region (see especially fig. 33), with a central roughish round pit-like mark. The two extremes are figured. This species is named after Dr. C. W. Gümbel, F.M.G.S., of Munich, who has discovered and described many Jurassic microzoa.

8. Cythere drupacea, sp. nov. (Pl. XXXIV. fig. 30.)

A specimen of the peach-stone form; convex, with full ventral region, arched back, tapering posterior and obliquely rounded anterior border. It has a coarse but faint wrinkling, with an inclination to strengthen some of the longitudinal lines. The wrinkles are oblique on the ventral region.

9. Cythere (Cythereis) quadrilatera, Römer (see above, p. 766). (Pl. XXXIV. figs. 39, 40, 41.)

Two specimens (figs. 40, 41). Smooth, glossy, with scattered spots, like the bases of small prickles; end-borders slightly denticulate; and the ridges, medial and marginal, more or less tuberculate, especially in these older (larger) individuals.

10. Cythere Blakeana, sp. nov. (Pl. XXXIV. figs. 34, 35.)

Two valves; suboblong, obliquely rounded in front, narrower and rounded behind; anterior hinge-joint rather prominent; surface coarsely reticulate, meshes stronger and straighter on the ventral region. This approaches the young forms of *Cythere dictyon*, G. S. Brady, 'Challenger Report,' p. 99, pl. 24. Our specimens are named after the Rev. Prof. J. F. Blake, F.G.S., who has elucidated many Ostracoda of the Lias.

11. Cythere Bradiana, sp. nov. (Pl. XXXIV. figs. 38 *a*, 38 *b*.)

Seven valves of a suboblong form, reticulate and costated; reticulation sometimes finer (fig. 38 *a*). The longitudinal meshes are developed into three or more subparallel ribs or ridges, joining at the ends more or less completely, with considerable difference in their mode of convergence. Sometimes they meet at the ends of the valves, but in some cases run separately to one or the other end-margin.

Cythere bermudæ, G. S. B., 'Challenger Report,' p. 90, pl. 21. fig. 2, is one of the species having the same kind of sculpture. We name this fossil species after our friend Dr. G. S. Brady, F.R.S., whose careful and successful researches are well known.

12. Cytherella subovata, sp. nov. (Pl. XXXIV. fig. 43.)

Ovate-oblong carapace; smooth, glossy, convex at posterior third; broader (higher) behind than before. This is near the Cretaceous *C. ovata* (Römer).

13. Cytherella jugosa, sp. nov. (Pl. XXXIV. fig. 44.).

Valve depressed; faintly ridged near the margin and almost all round, with an interval and a knob at the postero-ventral region; also bearing a low curved ridge and a little tubercle on the flat medial area of the valve. There are approximations to this in Jurassic * and other *Cytherellæ*, but nothing exactly the same. *C. Williamsoniana*, Jones, from the Chalk (Cret. Entom. 1842, pl. 7. fig. 26 *f*) has something like the pattern of *C. jugosa*.

14. A broken *Cythere*?, and a little peach-stone *Cythere*?; both obscure.

Miscellanea of § III.

Small, tuberculate, claviform Echinoderm spine.

A subcylindrical and a cylindrical rolled granule, obscure.

Of the Microzoa from the lowest stratum (§ III.) searched, namely at 1205 feet, some of the Foraminifera (Nodosarians—*Frondicularia*, *Vaginulina*, *Marginulina*, *Cristellaria*) are small, and look like those of the Lias, but are not peculiar to it, being found in the Lower Oolite and elsewhere. Both these and the other Foraminifera are of very wide range in time and space; but one only (*Cristellaria rotulata*) is actually present in each of the little portions of strata from the three particular depths noticed in the boring; but its close ally, *C. cultrata*, has turned up in two of them, § I. and § III.

Ten out of the eleven Ostracoda are apparently hitherto unknown forms; but they belong to well-known groups, and differ from others mostly in slight details. *Cytheridea subperforata* comes also in § II., and *Cythereis quadrilatera* in § I. The *Bairdiæ* of § III. are different from those of § II.

In a general view of the Foraminifera and Ostracoda obtained by Prof. Judd from the three special depths (§ I. 1145′ 9″ to 1146′ 6″; § II. 1151′ to 1151′ 6″; and § III. 1205′) in the deep boring at Richmond, they do not present any very special characteristics recognizable as belonging to particular horizons. The Foraminifera

* For instance, *Cytherella ulmensis*, Gümbel, Sitzungsb. Akad. München, 1871, p. 71, pl. 1. fig. 22.

comprise several common forms or varieties of *Cristellaria*, *C. rotulata* occurring in each of the depths alluded to. Small Nodosarinæ occur in the lowest stratum of the three; also *Spirillina*, *Pulvinulina* (of the *elegans* type), several small individuals of *Planorbulina Haidingeri*, and vars., and one small *Miliola*. Some of the Foraminifera are readily comparable with known Jurassic forms.

Of the Ostracoda there are several forms not previously published; and, for the most part, they differ in the three stages alluded to; but one *Cythere* occurs in § I. and § II.; one in § I. and § III.; and a *Cytheridea* in § II. and § III. Some have alliances with known Upper Mesozoic species.

Excepting a general Upper Mesozoic aspect, these limited groups, so far as yet examined, offer no special characteristic.

Genera and Species.	Pages.	Pl. XXXIV. & figs.	Stages.
FORAMINIFERA.			
Quinqueloculina. sp. indet	769	1	§ III.
Lituola depressa, nov.	765	2	§ I.
Lagena lævis, *W. & J.*	769	3	§ III.
Frondicularis oolithica, *Terquem.*	769	4	§ III.
Vaginulina lævigata, *Römer*	769	5	§ III.
Marginulina raphanus, *Linné.*	769	6	§ III.
Cristellaria, sp. indet.	765	7	§ I.
—— sp. indet.	767	—	§ II.
—— italica, *Defrance.*	767	—	§ II.
—— crepidula, *F. & M.*	770	8	§ III.
—— rotulata, *Lam.*	765, 767, 770	9	§ I., § II., § III.
—— cultrata, *Montf.*	765, 770	10, 11	§ I., § III.
Spirillina helvetica, *K. & Z.*	770	12	§ III.
—— crassa, *Z. & K.*	770	13	§ III.
Planorbulina Haidingeri, *d'Orb.*, var.	770	14, 15	§ III.
—— farcta, *F. & M.*, var.	770	16	§ III.
Pulvinulina elegans, *d'Orb.* var. tenella, nov.	771	17*a*, 17*b*	§ III.
OSTRACODA.			
Bairdia Juddiana, nov.	767	18	§ II.
—— trigonalis, nov.	767	19	§ II.
—— Hilda, nov.	771	20	§ III.
—— jurassica, nov.	771	21	§ III.
—— ——, var. tenuis	771	22	§ III.
Macrocypris Bradiana, nov.	766	23	§ I.
Cytheridea subperforata, nov.	768, 772	25, 26	§ II., III.
Cythere tenella, nov.	772	24	§ III.
—— Schwageriana. nov.	766	27	§ I.
—— drupacea, nov.	772	30	§ III.
—— subconcentrica, nov.	768	28, 29	§ II.
—— Blakeana, nov.	772	34, 35	§ III.
—— Guembeliana, nov.	772	31, 32, 33	§ III.
—— Bradiana, nov.	772	38*a*, 38*b*	§ III.
—— juglandica, nov.	766, 768	36, 37	§ I., § II.
—— (Cythereis) quadrilatera, *Römer.*	766, 772	39, 40, 41	§ I., § III.
Cytherella symmetrica, nov.	768	42	§ II.
—— subovata, nov.	773	43	§ III.
—— jugosa, nov.	773	44	§ III.

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1843. A. d'ARCHIAC. Mémoires Soc. Géol. France, vol. v. mém. no. 3, pl. 25, pp. 369, 70.

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1858. F. A. QUENSTEDT. Der Jura, p. 580, t. 73.

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1866? C. SCHWAGER. Beitrag zur Kenntniss der mikroskopischen Fauna jurassischer Schichten. Separatabdruck, Württemb. naturwiss. Jahreshefte, 21ster Jahrgang (1865), Heft i. pp. 92–142 (? others), plates ii.–vii.

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Foraminifera by Conrad Schwager, pp. 654–665; Lower Oolite of Württemberg. [pp. 148–159] (Waagen's part) pl. 34 (11), ff. 3–20.

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1869. O. TERQUEM. Deuxième Mém. du Fuller's-earth, &c., pp. 139–194, pl. 11 to 20. Published by the Author.

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1871. C. W. GÜMBEL. "Die geognostischen Verhältnisse des Ulmer Cementmergels," &c. Sitzungsb. Akad. Wissensch. math.-phys. Classe, München, 1871.

1871. T. R. JONES and W. K. PARKER. "On Terquem's Researches on the Foraminifera of the Lias and Oolites," Ann. & Mag. Nat. Hist. ser. 4, vol. viii. pp. 361–365.

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EXPLANATION OF PLATE XXXIV.

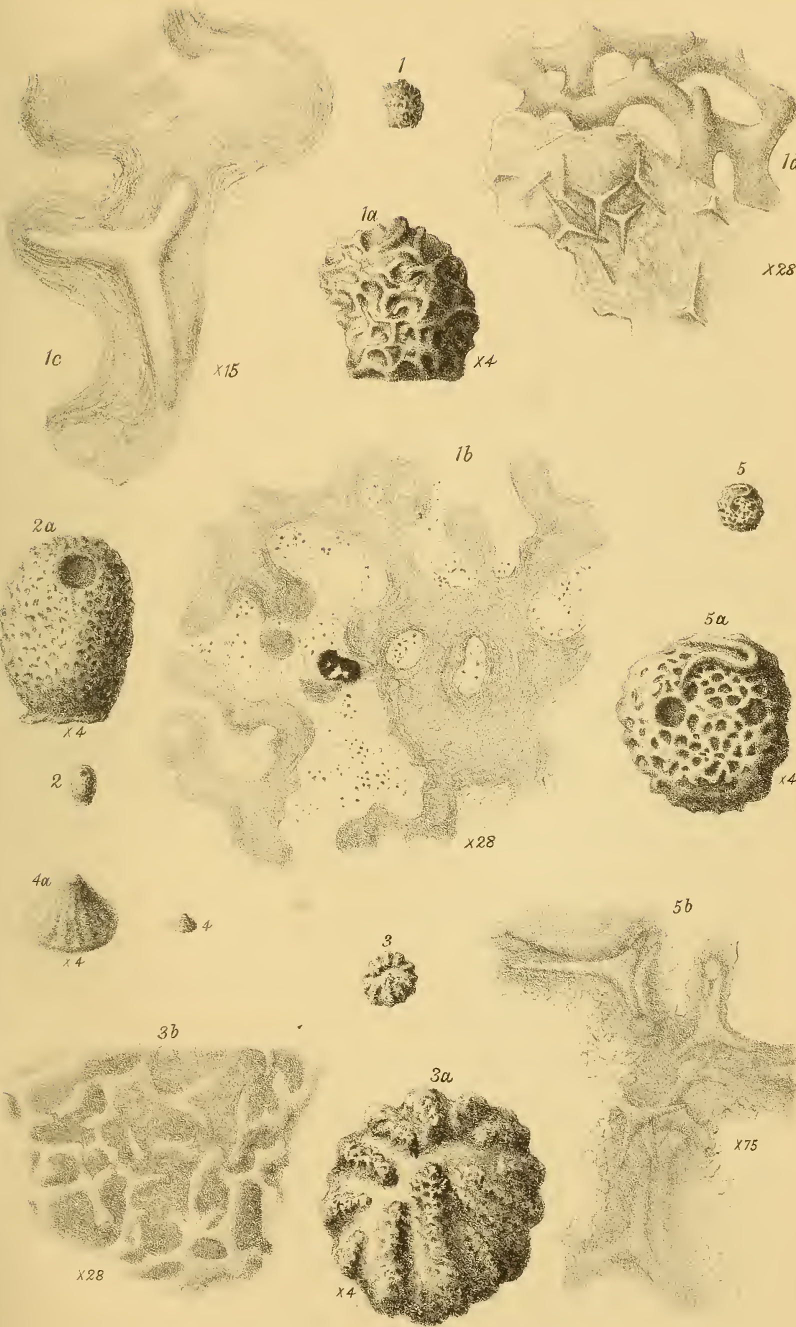
Fig. 1. *Miliola* (*Quinqueloculina*), sp. × 40 diam.
2. *Lituola nautiloidea*, Lam., var. (*Haplophragmium*) *depressa*, nov. × 25 diam.
3. *Lagena lævis*, W. & J. × 40 diam.
4. *Frondicularia oolithica*, Terquem, var. *regularis*, nov. × 25 diam.
5. *Vaginulina legumen* (Linn.), var. *lævigata*, Römer. × 25 diam.
6. *Marginulina raphanus* (Linn.). × 40 diam.
7. *Cristellaria* (Marginuline var.). × 25 diam.
8. —— *crepidula*, F. & M. × 25 diam.
9. —— *rotulata*, Lam. × 25 diam.
10. —— *cultrata*, Montf. × 25 diam.
11. —— —— ——. × 25 diam.
12. *Spirillina helvetica*, K. & Z. × 50 diam.
13. —— *crassa*, Z. & K. × 50 diam.
14. *Planorbulina Haidingeri*, d'Orb., var. × 50 diam.
15. —— —— ——, var. × 25 diam.
16. —— *farcta*, F. & M., var. × 50 diam.
17*a*. *Pulvinulina elegans*, d'Orb., var. *tenella*, nov. Upper face. 17*b*. Edge view. × 25 diam.
18. *Bairdia Juddiana*, nov. Carapace, with right valve upward. × 25 diam.
19. —— *trigonalis*, nov. Carapace with right valve upward. × 25 diam.
20. —— *Hilda*, nov. Left valve. × 25 diam.
21. —— *jurassica*, nov. Carapace showing right valve. × 25 diam.
22. —— ——, var. *tenuis*, nov. Left valve. × 25 diam.
23. *Macrocypris Bradiana*, nov. Left valve. × 25 diam.
24. *Cythere? tenella*, nov. Carapace showing left valve. × 25 diam.
25. *Cytheridea subperforata*, nov. Right valve. × 25 diam.
26. —— —— ——. Carapace showing right valve. × 25 diam.
27. *Cythere Schwageriana*, nov. Right valve. × 25 diam.
28. —— *subconcentrica*, nov. Right valve. × 25 diam.
29. —— —— ——. Edge of carapace. × 50 diam.
30. —— *drupacea*, nov. Left valve. × 35 diam.
31. —— *Guembeliana*, nov. Carapace showing right valve. Small form. × 25 diam.
32. —— —— ——. Carapace, edge view. × 25 diam.
33. —— —— ——. Right valve. × 25 diam.
34. *Cythere Blakeana*, nov. Left valve. × 25 diam.
35. —— —— ——. Left valve, inside. × 25 diam.
36. —— *juglandica*, nov. Right valve. × 25 diam.
37. —— —— ——. Right valve, ventral edge, with outline of carapace. × 25 diam.
38*a*. —— *Bradiana*, nov. Right valve. × 25 diam.
38*b*. —— —— ——. Left valve. × 25 diam.
39. *Cythere* (*Cythereis*) *quadrilatera*, Römer. Left valve. × 25 diam. 40. Left valve. × 25 diam. 41. Right valve. × 25 diam.
42. *Cytherella symmetrica*, nov. Carapace, left valve upwards. × 25 diam.
43. —— *subovata*, nov. Carapace, left valve upwards. × 25 diam.
44. —— *jugosa*, nov. Right valve. × 25 diam.

50. *On some* Fossil Calcisponges *from the* Well-boring *at* Richmond, Surrey. By George Jennings Hinde, Ph.D., F.G.S. (Read June 25, 1884.)

[Plate XXXV.]

Subsequent to bringing before the Society the description of the strata penetrated in the Richmond well-boring, Professor Judd submitted to me for examination some small fossils of dubious character which had been met with in one of the bands of calcareous shale intervening between the beds of oolitic limestone at a depth of 1205 feet beneath the surface. These fossils were associated with remains of Brachiopods, Polyzoa, and other small organisms, and presented a similar aspect of fossilization, being throughout calcareous in composition. The exterior surface of these bodies exhibits a network of delicate fibres with minute interspaces resembling that of calcisponges of Zittel's family Pharetrones. In several specimens the basal portion was covered with a delicate, more or less wrinkled membrane, and on close observation with a strong hand-lens minute three-rayed spicules could be seen here and there on the surface of this membrane. This fact, at once conclusive as to the real Sponge-character of these forms, was further supplemented by the microscopic examination of transparent sections of the fibres, in which a spicular structure can be readily detected. In all, about 45 examples of these bodies were found in the shale examined; and an idea may be formed of their small dimensions from the fact that the entire number can well be contained in a tea-spoon. The smallest specimen measures only 2·5 millim. in diameter, and the largest 10 millim., or about two fifths of an inch. In respect to size they more nearly resemble their existing analogues than the Calcisponges hitherto discovered in Jurassic and Cretaceous strata; indeed the relatively larger dimensions of these latter forms was brought forward as an argument against their calcareous origin by those who regarded them as altered siliceous sponges. But it is very probable that if the fossiliferous beds of Jurassic and Cretaceous strata were subjected to a similar careful scrutiny to that which has been given to the small quantity of material from this well-boring, they would be more frequently met with. As a fact, these small sponges have so unattractive an appearance that by the majority of collectors they would be passed over as small broken-up fragments of larger fossils. I do not think, however, that though so much smaller than the majority of Jurassic Calcisponges, these forms are either immature or imperfect. They show no evidence of having been transported to their present position, as the fibres are smooth and even, and the dermal layer unworn.

For the determination of the minute structure thin sections of the different forms were prepared; and though in some instances only a single example of a species could be spared for this purpose,



M. Suft del. et lith.

Hanhart imp.

CALCISPONGIÆ from the RICHMOND BORING.

yet traces of the spicular composition of the fibres were recognizable in all, though not always sufficiently clear to allow of their being figured.

Order CALCISPONGIÆ.

Family PHARETRONES.

INOBOLIA MICULA, Hinde, n. sp. Plate XXXV. figs. 1, 1 *a–d*.

Sponges small, apparently free, round or irregular in outline; varying from 2·5 to 10 millim. in diameter. The outer surface presents, as a rule, only the smooth naked fibres, which are arranged so as to leave interspaces of an irregular form. In some examples the base and a portion of the lateral surface show traces of a smooth dermal layer. There are no indications of distinct canals, so that the circulation must have been wholly carried on in the interspaces between the fibres.

The fibres are of a somewhat coarse character; measured in a thin section, they vary from ·14 to ·25 millim. in thickness. They are composed of relatively large, three- and perhaps four-rayed spicules in the central and subcentral portions, with filiform slender spicules bordering the exterior of the fibre. The complete form of these border spicules cannot definitely be ascertained; in one instance the spicule appears to possess three rays, but it is possible that uniaxial forms may be present as well. The rays of the large axial spicules reach a length of ·29 millim. by ·05 millim. in thickness. The dermal layer is compact in character and apparently composed of three-rayed spicules of various dimensions; the rays of these spicules overlap each other in an irregular manner. In one specimen the spicular rays are sufficiently clear to permit of measurement, and the largest seen is ·21 millim. in length, thus corresponding in size to the axial spicules of the fibre itself.

The examples of this species are by far the most numerous of any met with in the boring. They are very fragmentary in appearance, but the outer dermal layer shows that some of them at least are entire sponges. On the outer surface of the specimens the fibres are clearly shown free from matrix, but in thin sections they are see to be imbedded in a matrix of clear granular calcite, in which they appear as labyrinthic bands of a cloudy aspect. In these bands more or less clearly defined lines indicate the outlines of the spicules in the fibre; but it is rare to find even an entire spicular ray in the plane of the section. Portions of two and, more rarely, of the three rays can be detected; but in no instance can more than three rays be seen, though it is quite possible that some of these spicules may have possessed a fourth ray at right angles to the other three. The condition of the specimens also prevents any accurate determination of the proportionate length of the spicular rays; but the transverse sections are circular. The rays may be either straight or curved, and they taper in some instances very gradually, in others rapidly, from the central junction of the spicules to the acute extremity. The form of the smaller filiform spicules in which the axial spicules are, as it were, imbedded is uncertain; they appear in the microscopic sections as thread-like lines running parallel with the directions of the fibres. Judging from the characters shown in other fossil sponges with fibres of a similar composition, but in a better condition of preservation, it seems probable that these filiform spicules are three-rayed, and that the rays are sinuous and unequal in length. Irregular spicules of this character have been described by Häckel in recent calcareous sponges. The complicated appearance which these marginal spicules exhibit in thin sections may be readily imagined if we suppose that their component rays are very closely interlaced together, which would render it nearly impossible to detect the individual spicules in a thin section through the mass. The dermal layer, which is only partially preserved in a few specimens, seems to have formed a delicate, thin, compact covering over the fibres of the basal and, in part, of the lateral portions of the sponge as well. As a rule, this layer has a smooth homogeneous aspect and bears a general resemblance to the so-called epitheca of fossil corals. It is a very rare circumstance that its spicular structure is preserved: in fact it is only within the last two years that its characters have been recognized, and it is therefore remarkable that on some of these insignificant sponges its true structure should be clearly revealed.

The absence of a cloacal tube and distinct canals brings this species under the genus *Inobolia*, which is founded on the characters of a sponge from the pea-grit beds of the Inferior Oolite at Cheltenham. In the typical species, however, only the relatively large axial spicules of the fibre can be recognized, the rest of the fibre being crystalline, whilst in the present species the marginal spicules of the fibre have also been preserved. This species differs from *I. inclusa* in form and in its much smaller dimensions.

Distribution, Jurassic: Richmond, Surrey, 1205 feet beneath the surface.

PERONELLA NANA, Hinde, n. sp. Plate XXXV. figs. 2, 2*a*.

Sponges small, simple, subcylindrical or inverted conical in form, probably attached by the basal extremity, the outer surface partially enveloped in a compact dermal layer. The type specimen is 5·2 millim. in length by 3·5 millim. in width, and the well-defined cloacal aperture at the summit is 1 millim. wide.

The fibres, as seen in a transverse microscopic section, are relatively narrow, varying from ·072 to ·107 millim. in width; the spicular structure is not clearly exposed in the section examined, but traces of three-rayed spicules can be detected. On the surface of the dermal layer three-rayed spicules are faintly shown.

Only two examples of this diminutive species were met with, and one of these was used in preparing a thin section. Judging by the similarity in size of these two individuals, it seems probable that they had attained their normal dimensions. The fibres, as shown in the thin section, are so crystalline that the spicular structure is largely obliterated, but it appears to be of a similar character to that of the Jurassic species *Peronella mamillifera*, Lamx., sp., and *P. tenuis*, Hinde. By its simple form and small size this species is distinguished from others of this genus.

Distribution. Jurassic: Richmond, Surrey, 1205 feet beneath the surface.

Blastinia cristata, Hinde, n. sp. Plate XXXV. figs. 3, 3 *a*, *b*.

Sponges small, sessile, hemispherical or conical in form, the convex upper surface furnished with a series of ridges or crests, some of which extend from the central portion of the summit to the basal margin, whilst smaller and shorter ridges are intercalated between the larger; the base is usually concave and is formed of a compact wrinkled dermal layer with sharply defined margins. The largest specimen measures 6·5 millim. in height by 4 millim. in width, and a small individual is only 3 millim. in height and the same in width.

No central aperture or canals are present, and the upper surface only exhibits minute irregular apertures bounded by the fibres. In a horizontal transparent section the fibres appear as narrow labyrinthine bands, from ·05 to ·12 millim. in thickness, mainly composed of three-rayed spicules, the rays of which, in some cases, are nearly as wide as the fibre itself. Owing to the crystallization of the fibres, no trace of the smaller spicules, which probably surrounded the larger, can be distinguished; on the dermal layer of the basal portion indications of three-rayed spicules can be seen with a favourable light.

Four examples of this species were met with in the collection. In the largest and best-preserved the surface-ridges project strongly and sharply, so as to present a superficial resemblance to the septa of a coral, and the object itself calls to mind the small-ridged Polyzoa of the genus *Defrancia*, Bronn. In the smaller examples the surface-ridges are less regular and not so definite as in the larger form.

This species is much smaller than *Blastinia costata*, Goldf., sp., and is further distinguished by the less regular arrangement of the surface-ridges and the concave form of the base. I have not had an opportunity of examining the minute structure of Goldfuss's species, and cannot therefore make a comparison of this feature. It is interesting to note that the type of *Blastinia costata* is from the middle beds of the Jura-Kalk at Streitberg.

Distribution. Jurassic: Richmond, Surrey, 1205 feet beneath the surface.

Blastinia pygmæa, Hinde, n. sp. Plate XXXV. figs. 4, 4 *a*.

Sponges minute, sessile, depressed-conical in form, the upper surface smooth or with incipient ridges, the base concave, covered with a compact dermal layer. An average specimen is 3·5 millim. in width by 2·7 millim. in height. The upper surface exhibits circular and irregular apertures bounded by the fibres.

In a transparent section the fibres appear as closely arranged sinuous bands from ·06 to ·125 millim. in width; the spicular structure is but obscurely shown, but it appears to correspond with that of the preceding species.

This form mainly differs from *B. cristata* in having the upper surface either smooth or showing mere traces of projecting ridges; the fibres also appear to be somewhat more closely arranged. Only a single specimen of this minute species was available for a thin section, and consequently but a very small surface of the fibre is shown; but although the structure is largely obliterated, spicular rays can be distinctly seen. The matrix in the specimen examined is partially composed of iron pyrites.

Distribution. Jurassic: Richmond, Surrey, 1205 feet beneath the surface.

OCULOSPONGIA MINUTA, Hinde, n. sp. Plate XXXV. figs. 5, 5 *a*, *b*.

Sponges small, irregular in outline, apparently free. The upper surface is convex and exhibits an open mesh-work of fibres with sparsely scattered circular apertures of oscules, about ·75 millim. in width. The base is concave and covered with a compact wrinkled dermal layer. An average specimen measures 7 millim. in width by 5 in height.

In a microscopic section the fibres appear as loosely disposed sinuous bands from ·08 to 1·6 millim. in thickness, composed for the most part of three-rayed spicules with their rays in the axial part of the fibre. Only fragments of the larger spicules are recognizable, but it is probable that these were surrounded by smaller spicules, as in *Sestrostomella*. Faint markings of spicules can be seen in the dermal layer.

The minute dimensions of the sponge itself and of the oscular canals characterize this species.

Distribution. Jurassic: Richmond, Surrey, 1205 feet beneath the surface.

Although from the fact that all the forms discovered represent new species, no decisive conclusion can be drawn as to the correlative age of the stratum in which they occur, yet the general facies of these sponges approximates closer to Jurassic than to Cretaceous forms. Of the four genera represented, *Blastinia* and *Inobolia* are exclusively Jurassic, whilst the other two, *Peronella* and *Oculospongia*, are partly Jurassic and partly Cretaceous. It is true that no great importance can be attached to the evidence of these sponges as to the relative position of the stratum in which they occur, but from the fact that *Blastinia cristata* is closely allied to a sponge from the middle Jura-Kalk of Streitberg, and that *Inobolia micula* is referred to a genus hitherto only known from the Inferior Oolite of this country, it is probable that they belong rather to the middle or lower portions of the Oolitic series than to the upper.

The presence of calcareous sponges may be taken, as a rule, to indicate that the beds in which they occur have been deposited in comparatively shallow water. That this rule, however, is not without exception, is shown by the fact that many of the calcareous sponges discovered by the Challenger Expedition are from depths of 100 to 150 fathoms, and one species occurred at a depth of 450 fathoms.

EXPLANATION OF PLATE XXXV.

Figs. 1, 1 *a–d*. *Inobolia micula*, Hinde.

1. An average specimen, natural size.

1 *a*. The same, enlarged four times, showing the disposition of the fibres on the surface.

1 *b*. A portion of the interior fibre, enlarged twenty-eight times, showing traces of the component spicules. The fibres are imbedded in a matrix of crystalline calcite, in which are grains of iron-pyrites. Drawn from a transparent microscopic section.

1 *c*. A small portion of the interior fibre, enlarged seventy-five times, showing a large three-rayed axial spicule, and the minute filiform spicules surrounding it.

1 *d*. A portion of the dermal layer, showing some of its component spicules, enlarged twenty-eight times. A portion of the surface-fibre is shown in the upper part of the figure. Drawn by reflected light.

2, 2 *a*. *Peronella nana*, Hinde. Natural size and enlarged four times.

3, 3 *a*. *Blastinia cristata*, Hinde. Natural size and enlarged four times.

3 *b*. *The same*. A portion of the interior fibre, enlarged twenty-eight times. Drawn from a transparent microscopic section.

4, 4 *a*. *Blastinia pygmæa*, Hinde. Natural size and enlarged four times.

5, 5 *a*. *Oculospongia minuta*, Hinde. Natural size and enlarged four times. Showing the disposition of the fibres and the oscules. A small Serpula is attached to the surface of the specimen.

5 *b*. *The same*. A portion of the interior fibre showing the component spicules. Enlarged seventy-five times.

The specimens are all from Jurassic strata penetrated in the well-boring at Richmond, Surrey, at 1205 feet beneath the surface.

51. POLYZOA (BRYOZOA) *found in the* BORING *at* RICHMOND, SURREY *referred to by* PROF. JUDD, F.R.S. By GEORGE ROBERT VINE, Esq. Communicated by Prof. JUDD, F.R.S., Sec. G.S. (Read June 25, 1884.)

THE following notes are essentially the same as those originally supplied to Prof. Judd under the circumstances mentioned in his paper. With his permission I have extended my remarks, not for the purpose of correcting previous identifications, but because fresh materials have been placed at my disposal. These, I found, merited a closer comparative study than I had given to the series, and in preparing my observations for publication it was necessary to bring the results of my investigations up to the level, as far as was possible, of the palæontological work of the present day.

Many of the forms may be considered identical with those described by Jules Haime * and Prof. Brauns †; and I was inclined to place certain species under the names, and to accept the synonyms, of these authors. A reference, however, to the writings of Haime and Braun compelled me to reconsider my vaguely formed intention, after which I reworked the whole of the species and varieties found in the Richmond series—one of the most important local series that has ever been brought under my notice. Of course, in my mode of working I may appear to differ from Jules Haime in appreciation of certain forms. This is not the fact; for I feel convinced that this careful palæontologist must have had many mental forebodings before he arrived at some of his conclusions. This is especially apparent in his dealing with the *Spiropora* group, and also with the genus *Terebellaria*. In working up these groups—and here the value of the boring-washing is immediately apparent—I have endeavoured to settle, or at least simplify, many moot points. If any doubt about this should exist in the mind of the palæontologist after reading these notes, I refer him to the paper of F. D. Longe, F.G.S., "On the Relation of the Escharoid Forms of Oolitic Polyzoa to the Cheilostomata and Cyclostomata" ‡. In this special paper he will find, in spite of a splendid collection of Polyzoa from the Lower Oolite of Cheltenham, how difficult the specific study of forms has been to a really painstaking student. The reason is plain. In the whole of the Jurassic formation we have varieties of forms related, but not closely so, to forms now placed with the Chilostomatous Polyzoa. These, however, are not members of that group, though they may be considered in the light of relationship if external cell-structure is the only consideration on the part of the student. There are, however, strong reasons for believing that the "evolutionary beginnings" (if I may be allowed to express myself

* "Bryozoaires foss. de la formation Jurassique" in Mém. Soc. Géol. France, sér. 2, tome v. pp. 157–218 (1854).

† "Die Bryozoen des mittleren Jura der Gegend von Metz," in Zeitschr. d. deutsch. geol. Ges. Bd. xxxi. pp. 308–338 (1879).

‡ Geol. Magazine, Jan. 1881.

thus) of the Chilostomata originated in early Jurassic times. The Richmond series of Prof. Judd, and the less remarkable series procured from the boring for water in connexion with Meux's Brewery, referred to by Mr. C. Moore, of Bath *, have enabled me to study and compare the Polyzoa from two horizons, both of which are Jurassic. Mr. Moore's collection of specific forms, however, is not so well preserved as the Richmond series, but still I have been able to arrive at a partial conclusion respecting their age; although I do not consider my evidence on this point so conclusive or satisfactory as on the Richmond forms. Mr. Moore believed that his material was derived from Neocomian rocks. I cannot accept this opinion, judging from the Polyzoa alone. The *Stomatopora dichotoma* (1/34) is the same as the form described in this paper; the *Diastopora diluviana* (1/36) is the same as the Great-Oolite form; so also is the *D. microstoma* (1/27); the *Idmonea triquetra* (slide 1/27) is more robust, but it is not related to any Neocomian *Idmonea* known to me; and the *Entalophora* (1/31) is closely related to some of the more delicate forms of *E. richmondiensis* of this paper, while *Terebellaria ? increscens* and *Lichenopora* (in bottle 1/36) are the same as species found in the Bradford Clay and Cornbrash. There is, however, one fragment (1/33) in Mr. Moore's collection that I have never, as yet, met with elsewhere. This appears to be a minute portion of one of the bundles of *Fasciculipora Waltoni*, Haime. The apical cell-openings are large, circular, and surrounded by peristomial ridges. These are separated from neighbouring cells by a very delicate interspace. This species Haime gives, on the authority of Mr. Walton, from the Great Oolite, Hampton Cliff. There are a few forms (*Heteropora*, sp.) which seem to be related to Neocomian species.

This closer study of *Lepralia*- and *Eschara*-like forms which Mr. Longe compares with the old *Eschara foliacea* of authors, has proved to me how insufficient mere growth and outline are in deciding the question as to the zoological position of a group. It may be that the *Terebellaria increscens* now described belongs rather to the Chilostomatous than to the Cyclostomatous group, but the peculiar shape of the oœcia of this species seems to point in the opposite direction†. It is impossible to dogmatize on moot points of structure like this. It belongs to us to lay the foundation in good honest work; it remains for future systematists to say where or how groups shall be placed.

* I am indebted to Prof. Judd for obtaining for me an examination of this series. The specimens are the property of the Bath Museum.

† One of my principal reasons for refusing to believe that these *Eschara*- and *Lepralia*-like cells are "closely" related to the Chilostomata is this:—Whenever I make a section of a cell of any of the forms from the Jurassic rocks, I invariably find that the cell is tubular, in spite of its peculiar external shape. Whenever we are dealing with a true Chilostomatous type, whether from the Cretaceous or Cainozoic rocks, or recent, no indication of a tube is present, at least so far as I am acquainted with sections. There is, however, in the Jurassic *Terebellaria increscens* a large development of the distal part of the cell at the expense of the proximal, and the thinner the incrustation the broader will be the superficial area of the cell.

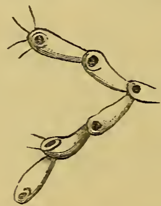
		Richmond slides.	Meux.	Known Horizon.
	STOMATOPORA, *Bronn.*			
1.	dichotoma, *Lamx.*	1	1/34	Bradford Clay &c.
2.	Waltoni, *Haime*.........	2		Bradford Clay &c.
	DIASTOPORA, *Milne-Edw.*			
3.	diluviana, *Lamx.*	3	1/36 1/27	Great Oolite &c.
4.	microstoma, *Mich.*......	4	1/27	Great Oolite &c.
5.	var. connectens, *Vine*	4 *		
6.	Lamourouxii, *Haime*...	5		Great Oolite &c.
	IDMONEA, *Lamx.*			
7.	triquetra, *Lamx.*	6	1/27	
	ENTALOPHORA, *Lamx.*			
8.	straminea, *Phill.*	*?		Great Oolite.
9.	richmondiensis, *Vine*...	8	1/31 ?	Allied to Forest [Marble species.
10.	——, var. pustulopora, *V.*	9		
	TEREBELLARIA (restricted)			
11.	increscens, *Vine*.........	10	*?	Allied to Cornbrash [sp.
	LICHENOPORA ?			
12.	Phillipsii, *J. H.*	11		Great Oolite.
	HETEROPORA, *Blainv.*		?	
13.	conifera, *Lamx.*	12		Inferior and Great [Oolite.
	? FASCICULIPORA, *D'Orb.*			
14.	Waltoni, *Haime*.........		*	Great Oolite.

1. STOMATOPORA DICHOTOMA, Lamx. Fig. 1.

Alecto dichotoma, Lamx. Exp. méth. des Pol. 1821, tab. 81. figs. 12, 13, 14.

Aulopora dichotoma, Goldf. Petr. Germ. p. 218, pl. 65. fig. 2; Jules Haime and authors generally. See Haime's Jurassic Bryozoa, for synonyms &c.

Fig. 1.—Zoœcia of *Stomatopora dichotoma*, Lamx., typical form. Enlarged.



This beautifully delicate species is present in the Richmond material, but very rare. It will be seen that the linear cells, as figured by Goldfuss, are characteristically simple. One specimen adherent to a piece of shell is well preserved, though fragmentary. In Mr. Charles Moore's specimens from Meux's Brewery boring (1/34) a fragment of three cells shows the delicately punctured surface.

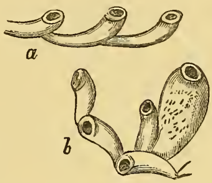
Richmond series, Prof. Judd, slide 1; C. Moore's series, No. 1/34, Bath Museum.

Horizon and locality. Great Oolite, Caen, on *Terebratula*; Bath (*William Walton*); also at Hampton Cliff; and Bradford Clay (*J. Haime*).

2. Stomatopora Waltoni, J. Haime. Fig. 2 *a*, *b*.

Stomatopora Waltoni, Haime, Bryoz. Foss. Form. Juras. 1854, pl. vi. f. 2; Vine, Brit. Assoc. Rep. Foss. Polyzoa, 1882, p. 251.

Fig. 2.—Cells of *Stomatopora Waltoni*, J. Haime. Enlarged.



a. Normal arrangement of cells. *b*. Basal colonial growth with oœcium.

This is a very variable species, and I was tempted to give some of the forms, at least, the varietal name "*producta*," on account of the cells being much produced at the distal extremities (fig. 2, *a*). In some of the specimens this feature is very prominent (slide 2 *a*); but as it is characteristic of the Bradford-Clay *Stomatoporæ* generally, I think that it would be unwise to increase the already too abundant difficulties of the palæontologist. It may be well, therefore, to give the following diagnosis, worked up from a fine series of specimens.

Zoarium irregular, branches free, and sometimes anastomosing. *Zoœcia* elongate, produced at the distal extremity of the cell; orifice circular; peristome thick and slightly contracted, giving to the cell a bulgy appearance in some specimens just below the orifice; tubes finely punctured. *Oœcia* a distended cell, very bulgy in the middle, sometimes single, occasionally in clusters.

Richmond series, Prof. Judd, slides 2 *a*, *b*, *c*. Not represented among Mr. Moore's specimens.

Horizon and locality. Great Oolite, Kidlington, *S. dichotomoides* type. Intermediate between the Inferior- and Great-Oolite species. *S. Waltoni* (typical), Bradford Clay and Cornbrash. Mr. Walford quotes Forest Marble (local work).

3. Diastopora diluviana, Lamx.

Berenicea diluviana, Jules Haime, Bryoz. Foss. Form. Juras. pl. vii. f. 2, 2 *a*.

? *Diastopora diluviana*, Vine, Brit. Assoc. Rep. Foss. Pol. 1882, p. 256.

I have not given in the above the several synonyms or references which Haime places under the name. In my own Report the form referred to, as peculiar to or characteristic of the Inferior-Oolite series, may be referred to again as *D. pellucida*. The present forms are characteristic of the Great-Oolite series, and are well shown in figures in Haime's Monograph. The following diagnosis of the Bradford-Clay species is drawn up from some very fine specimens.

Zoarium incrusting, very irregular. *Zoœcia* partially immersed, closely compacted, covering large spaces on shell and stone; orifice of cell circular, slightly raised; lip prominent, but not what may be called protruded; tubes finely punctured. *Oœcia* consisting of a distended cell or of several cells, but not so characteristic as in *D. ventricosa*, Vine. Colony originating with a primary cell, assuming a flabellate, and ultimately an irregular, outline. Rarely discoid in its matured or nearly matured growth.

Richmond series, Prof. Judd, slides 3 *a*, *b*, *c*. C. Moore's (Meux Brewery), 1/36; slides M. 1/27 &c., 1/29 *a*, *b*.

Horizon and locality. Great Oolite, environs of Caen (*Ranville*); Bradford; Ardennes (*J. H.*); "Bath Oolite."

From the latter locality I had a large specimen, incrusting shell (Mr. Shrubsole's cabinet); but the cells of these are less robust than in the Richmond and Bradford-Clay forms. The only locality I had was "Bath Oolite—from the neighbourhood of Bath." Mr. Moore's specimens are more closely allied to this form than to those from Richmond.

In some of the specimens from the Richmond horizon there is a slight departure from the normal type, caused by peculiarities of habit; but as I cannot detect any departure from the characteristic cell-features, I have preferred not to give any new names to these. The slides are marked 3 *d* and 3 *e*.

4. Diastopora microstoma, Michelin.

Berenicea microstoma, Haime, *op. cit.* pl. vii. figs. 3 *a–d*.

D. microstoma, Vine, Brit. As. Rep. 1882, p. 256; Haime gives as synonyms *D. undulata*, of both Michelin and D'Orbigny.

The five slides that I have mounted of this form show, I think, the characteristic features of this species. That marked 4 *a* may very well serve as a type of *D. undulata*, but this conception of character would be erroneous. As in *D. ventricosa*, Vine, and some specimens of *D. diluviana*, Lamx., there are several oœcia in the colony, and the bulgy appearance of these causes the undulations noticed by the respective authors. Another point of interest is that the general habit of the species is a proliferous one, one colony overlapping another, or striking off from the marginal rim of some bulky specimen, and then helping to cover the parent colony. The separation of the cells, too, in this species is very distinct, appearing as mere extensions of the peristome, while the remaining parts of the tubes are undistinguishable or nearly so. It is this species—or an ally of this species, for it may be wise at some future time to separate them—that forms incrustations on the stems of *Entalophora*, producing that peculiar spiral character which is generally regarded by authors as *Terebellaria*. I have traced the form through a series of spirals, beginning as a mere point, and then increasing in size until very bulky zoaria are produced; and I have noticed the same features in a species on *Entalophora* from the Greensand of Haldon Hill.

Richmond series, Prof. Judd, slides 4 *a*, *b*, *c*, *d*, *e*. C. Moore's (Meux Brewery), slide M. 1/27; poor specimen.

Locality and horizon. Ranville; Great Oolite, Hampton Cliff; my own cabinet, from Bradford Clay.

5. Diastopora microstoma, Michelin, var. *connectens* (n. var.).

Zoarium irregular and occasionally proliferous. *Zoœcia* varying in character, sometimes only the peristome visible above the surface, at other times slightly decumbent, separated by interspaces, roughened by lines which appear to connect the peristomes of cell and cell; mouth circular, lip (normal) thick; cell bulging immediately below the mouth; proximal part of the tube rarely visible.

Richmond series, Prof. Judd, slide 4**a*: type.

On account of the peculiar way in which the cells of *D. microstoma* are separated in the zoarium, I prefer to place this form as a variety of that species rather than any other.

6. Diastopora Lamourouxi, J. Haime.

Diastopora Lamourouxi, Haime, *op. cit.* pl. viii. figs. 1 *a–b*.
D. foliacea (pars), Bronn; Blainville.

There are in the Richmond washings a great number of specimens of *Diastopora* having a very robust habit. I do not think that these can be placed under any of the species of *Berenicea* given by Haime in his Monograph of the Jurassic Bryozoa. There are, however, in his Group of Diastopores simples two species, one *D. Lamourouxi* and the other *D. Waltoni*, the latter from the Inferior Oolite of Cheltenham. The Richmond species is closely allied to *D. Lamourouxi*, if not identical with it.

If I am right in identifying this robust form, I can only say that I have not previously met with it as a British fossil. The specimen figured by Haime has the cells long and tubular, with a circular mouth, and the peristome slightly raised. These are the characteristic features of the specimens under consideration.

The synonymy of *Diastopora foliacea*, of Lamouroux, Bronn, and Blainville, has been well discussed by Prof. Brauns in his able paper on the Bryozoa of the Middle Jurassic of Metz, 1879, and he justifies the separation of *D. Lamourouxi* on the ground of its simple habit, and also on account of the circular peristome. *Elea foliacea* is a distinct operculate form, from the Inferior Oolite.

Richmond series, Prof. Judd, slides 5, 5 *a*. Not present in C. Moore's series.

Horizon and locality. Great Oolite, Ranville (*Eudes Deslongchamps*).

Idmonea, Lamouroux.

Reptotubigera (pars), D'Orbigny.

When writing my Brit. Assoc. Report Foss. Polyzoa, Jurassic species (1882), I was not acquainted with the Jurassic *Idmonea triquetra*, Lamx. In these Richmond washings, and also in Mr. Moore's collection, fragments are present, though not common. Before, however, I pass on to describe the Richmond form, it may be well to make a few remarks upon the genus.

I have not been able to refer to Lamouroux, Exposition Méthodique, 1821, in which this genus is described; I will therefore accept the description given by Mr. Busk, Crag Polyzoa, p. 104. In this diagnosis Mr. Busk says—"Mouths of cells disposed in parallel, transverse, or oblique, usually alternate, rows on each side of the front of the branches, which is angular or carinate in the middle." There can be no objection to this description of a well-marked type of structure. When, however, we compare the Jurassic *I. triquetra* with some of the more tubular *Idmoneæ* of the Cretaceous epoch, a very marked difference is observable; and it is because of these peculiarities that I wish, now that I have the opportunity, to direct special attention to Jurassic forms.

In Miss E. C. Jelly's collection from the Inferior Oolite (no locality given) there is an adherent specimen, having all the characters of *Idmonea* as given by Busk (and presumably by Lamouroux), except that it is "adherent" instead of "ramose." I believe that if students would direct their attention to specimens of this Inferior-Oolite form, it would be found that from the decumbent branches upright ramose branches are formed. However this may be, it seems to be a fair conjecture that from this Inferior-Oolite species the Richmond form is developed. The peculiar character of the cell is not unique on branches of this species, for in some of the *Entalophoræ*, from both the Inferior Oolite and the Great Oolite, a similar form of cell is found. I have no desire under present circumstances to speculate as to the origin of distinct groups, otherwise than to remark upon the apparently characteristic "facies" of species of Polyzoa from the various horizons of the Jurassic rocks. In this paper I have been careful in describing the Richmond series for this special purpose.

7. Idmonea triquetra, Lamouroux.

Idmonea triquetra, Lamx. Expos. Méth. p. 80, 1821 (Busk).

Zoarium (decumbent?) or ramose; branches triangular, having an inferior side (back) rather broad and free from cells, and two other sides which rise from the inferior, forming an apparently, rather than really, carinated front. *Zoœcia* forming obliquely linear or transverse rows; mouth circular; peristome thick and slightly protruded; tubes densely punctate. *Oœcia* formed by the clustering of certain cells, over some of which there is a closure-like operculum.

Richmond series, Prof. Judd, slides 6 *a*, *b*, *c*. C. Moore's series (Meux Brewery), slide 1/27 &c. The specimens on this slide are much more bulky than those in the Richmond series.

In comparing *I. fenestrata*, Busk (Crag Polyzoa, p. 105), Mr. Busk makes certain remarks which seemed sufficient to guide him in the separation of his species from the Jurassic *I. triquetra*.

There is a difference between the two forms; and I am glad that they are kept distinct.

8. Entalophora straminea, Phillips.

Millepora straminea, Phill. Geol. of Yorksh. (ed. 1829), p. 149, pl. ix. fig. 1.

Spiropora straminea, Haime, *op. cit.* pl. ix. fig. 6.

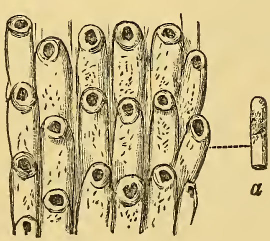
Entalophora straminea, Brauns, Bry. mittl. Jur. Metz.

Spiropora straminea, Vine, Brit. Assoc. Rep. 1882, p. 12 of Rep.

Phillips gives the horizon of his species as "Bath Oolite," and quotes several localities in which it is found.

As the individual specimens that I placed under the above name are the most abundant of the Jurassic forms from Richmond, and as there seems to be great confusion among authors respecting Phillips's type-species, I think it far wiser to separate and limit the various forms. And I do this for two reasons:—1. In my notes on the specimens sent to me by Prof. Judd, and under the circumstances mentioned, I gave, after a careful examination, three names—*E. straminea*, Phill., *E. bajocensis*, D'Orb., and *E. cæspitosa*, Lamx. Judging by cell-character, all three of these species are present in the material obtained from Richmond; but the three cell-characters are as often on a single specimen as on several; and for this reason alone a confusion must always follow careful work, if the old names be persistently retained. 2. Then, again, my friend Mr. Walford identifies a Forest-Marble species with *Spiropora cæspitosa*, Lamx. Now this Forest-Marble form is identical, or as nearly so as possible, with the Richmond forms, only much more bulky in zoarial growth. Then both *E. straminea*, Phill., and *E. cæspitosa*, Lamx., are assigned to two horizons—Inferior and Great Oolite.

Fig. 3.—Portion of the zoarium of *Entalophora richmondiensis*, showing the typical arrangement of the cells. Enlarged.



a. Natural size.

9. Entalophora richmondiensis (n. sp.). Fig. 3.

Zoarium ramose, bifurcating, rarely, if ever, anastomosing;

branches varying in size from $\frac{1}{32}$ to $\frac{1}{24}$ inch in thickness, bulging at the nodes immediately beneath the bifurcation, where the measurement in breadth is about three quarters of a line. *Zoœcia* disposed all round the branch in obliquely linear or transverse series, occasionally irregularly placed on the branch; about seven cells to the line in a longitudinal, and ten cells to the line in the direction of the zoœcia, whether oblique or transverse; mouth circular; peristome distinct, slightly tufted or raised above the general surface of the branch; cells tubular, punctate, and bounded by their own walls, occasionally produced on the margins of the branch. *Oœcia* a clustering of certain cells, some of which are covered by a solid opercular lid.

Richmond series, Prof. Judd, slides 8 *a–d*. Not represented in C. Moore's series, but 1/31 is closely allied.

I regard as allies of this species the British Great-Oolite form of *Spiropora straminea*, Phill. (Haime, op. cit. pl. ix. fig. 1; Phill. Geology of Yorkshire), the *S. cæspitosa*, Lamx., from the Bradford Clay and Forest Marble, and the Hampton Cliff specimens of *S. bajocensis*. The *S. bajocensis* from the Inferior Oolite is related to this group; but it differs in certain peculiarities of structure from the forms indicated above.

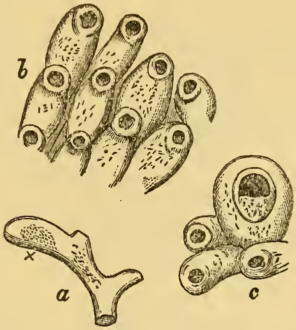
It may be well now to direct attention to some specimens or forms of incrustation called by authors *Terebellaria*, which cover with a thin layer of growth colonies of *Entalophora richmondiensis*, and mimic the various outlines of its surface. This form, which will be presently considered, has a very different cell from that of the *Entalophora* described above; and I cannot help expressing my opinion that the character of *Diastopora ramosissima* (Haime, pl. ix. figs. 3 *a*, *b*) has been drawn up from a specimen of *Entalophora* obscured by a colonial growth of *T. increscens*, Vine, and that the species itself has been much misunderstood by authors who have not entered so minutely into details as I have been compelled to do with these Richmond fossils. I have in my cabinet specimens of the species described by Haime from the Forest Marble and also from the Bradford Clay and Cornbrash series, and upon the study of these I found the opinion now expressed. It is quite possible, too, that some of the specimens included under *T. increscens* may be regarded by other authors as *Diastopora ramosissima*, D'Orb.

10. Entalophora richmondiensis, Vine, var. *pustulopora*.

It may be well to note the peculiar characters of colonial growth in this series, and to distinguish the forms by a varietal name. I regard these as the early stages of *E. richmondiensis*; but the habit somewhat approaches that of *Pustulopora clavata*, Busk (Crag Pol. p. 107, pl. xvii. fig. 1).

Richmond series, Prof. Judd, slides 9 *a*, *b*, *c*. Early and advanced stages of growth.

Fig. 4.—*Terebellaria* (?) *increscens*, Vine.



a. Branch of *Entalophora* incrusted with *Terebellaria? increscens* in two patches; Bradford-Clay specimen.
b. Portion of colony at *x* enlarged.
c. Portion of colony with oœcium enlarged. From Cornbrash specimen.

11. Terebellaria (?) increscens, Vine. Fig. 4.

T. ramosissima, Vine, Brit. Assoc. Rep. on Foss. Polyzoa, 1882, p. 254.
? *Diastopora ramosissima*, Haime (pars), Juras. Bry. pl. ix. figs. 3*a*, *b*.

Zoarium a thin ribbon-like layer of cells growing upon foreign bodies, or coiling itself upon its own previously formed zoaria, ultimately assuming a spiral, ramose, dendroid, or massive form. *Zoœcia* slightly elongated (or distended), sometimes disposed in spiral lines, but rather more distended at the distal than at the proximal part of the cell; orifice circular, occasionally semicircular; peristome thick; front of cell finely punctured. *Oœcium* an enlarged globose cell, having beneath the orifice a semicircular cluster of punctures definitely arranged.

The above diagnosis, with but very slight alterations, was drawn up from a series of forms from different horizons: Bradford Clay, Forest Marble, and Cornbrash. There are some features, such as the oœcia, that I have not found as yet in the Richmond forms, otherwise the rest of the diagnosis has been checked off as descriptive of specimens in the present series. It appears to me that it would be advantageous to science if the name *Terebellaria* were suppressed, but, seeing that the whole of the typical features have been found growing upon what passes for *Terebellaria* of authors, especially from the horizons given, I have thought that it would answer my purpose if I just placed a [?] between brackets after the generic name.

Richmond series, Prof. Judd, slides 10 *a*, *b*. C. Moore's series: one poor specimen.

Range of this peculiar cell-structure: Inferior Oolite, Mr. Longe's collection; Bradford Clay, Forest Marble, Cornbrash. My own cabinet.

This species is an incrusting one, and as such it has no special form otherwise than that given to it by the shape of branches &c. upon which it grows.

12. Lichenopora Phillipsii (?), Haime, op. cit. pl. x. fig. 10.

One fragment only, which I place doubtfully in this genus, and as but one form of it is known in the Great Oolite, as a representative of this species. It may, however, belong to the genus which Haime retains as *Apseudesia*, Lamx.

Richmond series, Prof. Judd, slide 11.

13. Heteropora conifera, Lamouroux.

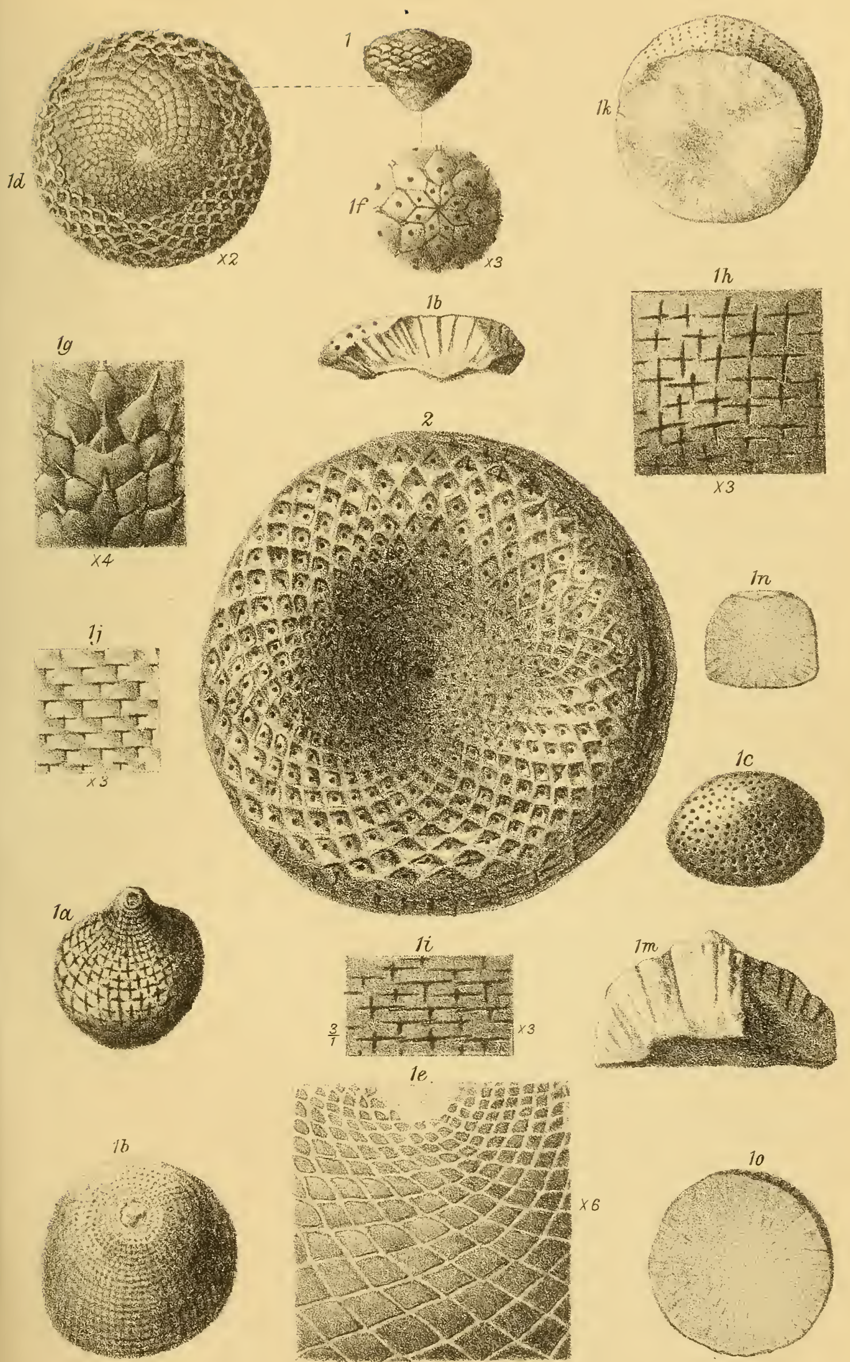
H. conifera, Lamx., Haime, op. cit. pl. xi. fig. 1 *a–c*.

It is useless to give the variety of synonyms of this species as given by Prof. Brauns. It will be necessary to have sections of the forms before any details of structure are supplied. The student of this peculiar species will find ample references to typical structures on reference to Prof. Nicholson's palæontological works; but no definite conclusion respecting its classificatory position has as yet been arrived at.

Richmond series, Prof. Judd, slide 12 *a, b, c*. C. Moore's collection.

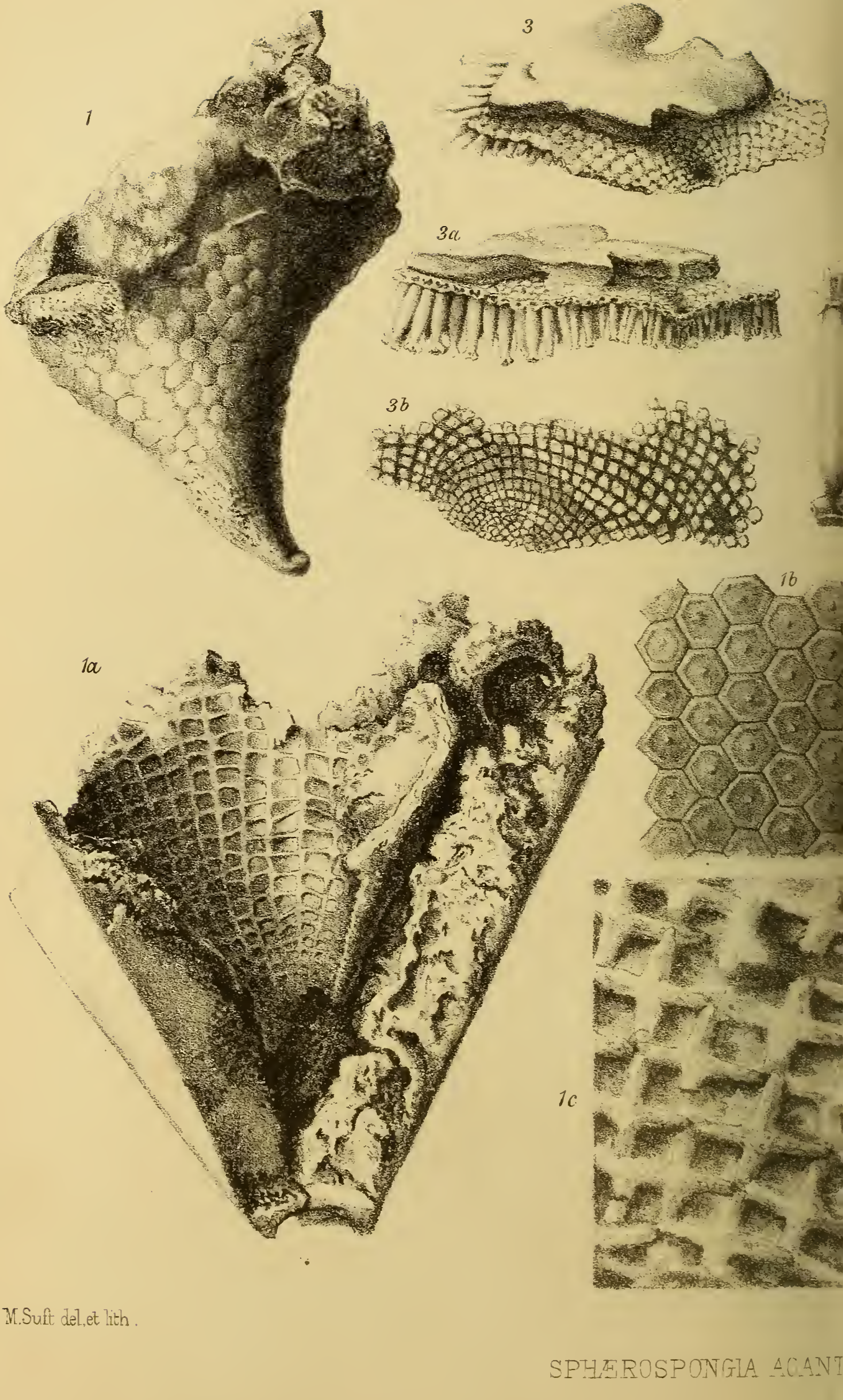
Horizon and locality. Haime gives Inferior and Great Oolite.

1 a–c Ischadites Koenigi
2 " Lindstromi



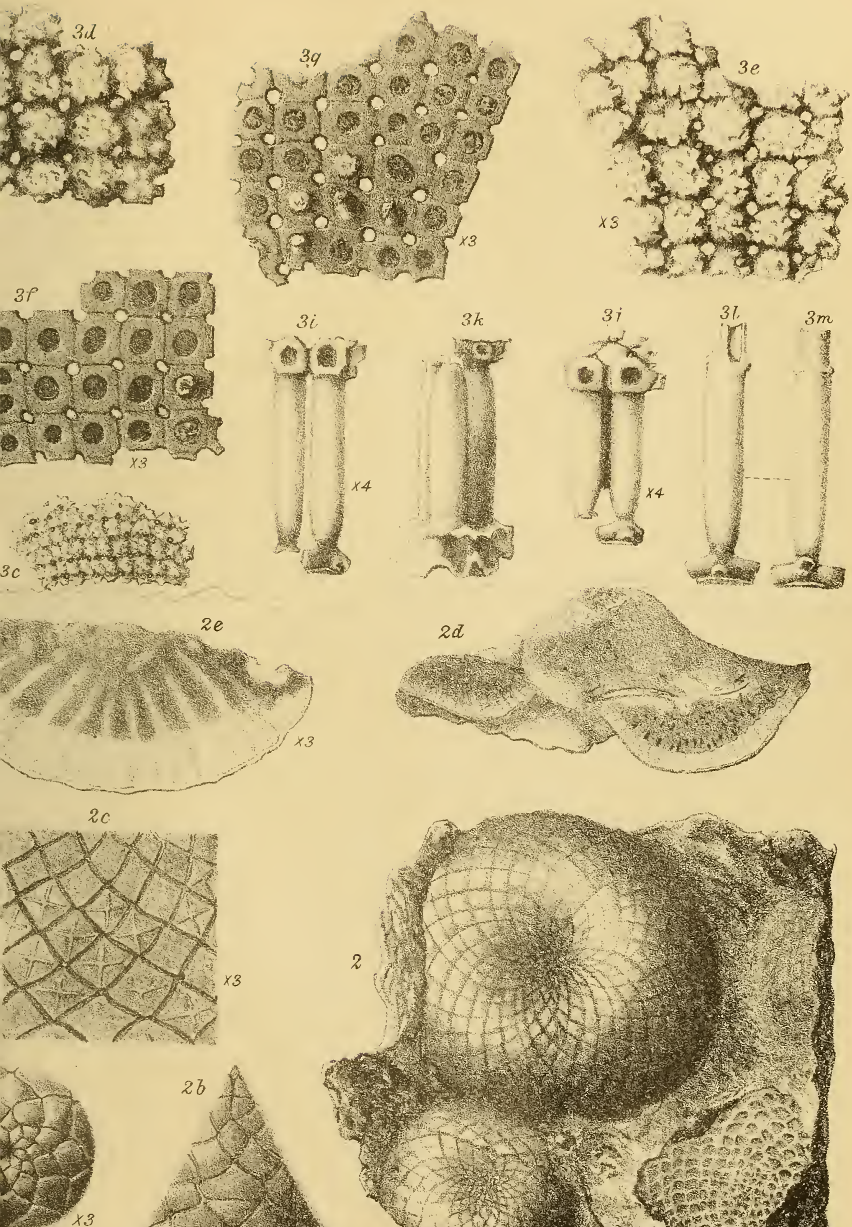
M. Suft del. et lith. Hanhart imp.

ISCHADITES.



M.Suft del,et lith.

SPHÆROSPONGIA ACANT



Hanhart imp.

AND RECEPTACULITES.

M. Suft del. et lith. Hanhart imp.

SPHÆROSPONGIA, ACANTHOCHONIA AND RECEPTACULITES.

52. *On the* Structure *and* Affinities *of the* Family *of the* Receptaculitidæ, *including therein the Genera* Ischadites, *Murchison* (=Tetragonis, *Eichwald*); Sphærospongia, *Pengelly*; Acanthochonia, *gen. nov.*; *and* Receptaculites, *Defrance*. By George Jennings Hinde, Ph.D., F.G.S. (Read June 25, 1884.)

[Plates XXXVI., XXXVII.]

Contents.

I. Introduction.

Amongst the Palæozoic fossils whose characters differ to such an extent from those of existing organisms that great differences of opinion as to their affinities have been expressed by the various palæontologists who have studied them, the above-named genera occupy a prominent position. They have been assigned in turn to pine-cones, Foraminifera, Sponges, Corals, Cystideans, and Tunicate Mollusca; but after all that has been written on them, such competent authorities as Ferdinand Römer * and Zittel † agree in stating that they form an altogether uncertain group of organisms, which, though ranged provisionally amongst the Foraminifera, have hardly a single typical character in common with them. Under these circumstances a fresh attempt to interpret their structure will not be inappropriate; and though the new facts which I have to bring forward do not make any very important additions to those ascertained by previous students of the group, they at least furnish, in my opinion, striking evidence in favour of the affinity of these forms to Sponges. This relationship has already been strongly advocated by the late Mr. Billings ‡; and though the basis of comparison which he instituted between the structure of *Receptaculites* and the gemmulæ of freshwater sponges cannot now be maintained, yet in regarding the former as a sponge, Mr. Billings showed, in my opinion, a clearer insight into its systematic position and structure than later authorities, such as Prof. Gümbel and Dr. Dames, who have ranged it with Foraminifera.

The materials which have served as the foundation for the following observations have been derived from several sources. First, the collection in the British Museum of Natural History, of which a list will be found in the 'Catalogue of the fossil Forami-

* Lethæa Pal. 1 Th. p. 285. † Handb. der Pal. 1 Bd. 1880, p. 727.
‡ Pal. Fossils of Canada, vol. i. 1865, p. 388.

nifera' by Prof. Rupert Jones. It includes several species of *Receptaculites* from the Silurian strata of the Baltic, Canada, the United States, and the Arctic regions, also from the Devonian of Belgium; *Ischadites Kœnigii*, from the West of England and Gotland; *Sphærospongia tessellata*, from Devonshire; and specimens of a new genus, *Acanthochonia*, from the Silurian of Bohemia. For the opportunity afforded me of studying this collection, I beg to express my thanks to the Keeper of the Geological Department, Dr. Henry Woodward, F.R.S. Next, a splendid collection of nearly 150 specimens of *Ischadites*, from the Silurian strata of Gotland, which have been freely placed at my disposal for examination by Prof. G. Lindström of Stockholm, to whom I feel under great obligations for thus enabling me to study specimens in excellent preservation. Further, Prof. F. Römer generously sent me from Breslau a small collection, including figured types of *Receptaculites* from Devonian strata at Ober-Kunzendorf in Silesia. My thanks are also due to Prof. McKenny Hughes for the opportunity of studying the collection in the Woodwardian Museum at Cambridge; to Mr. J. F. Whiteaves, F.G.S., for specimens of *Receptaculites* from Canada; and to Mr. A. Champernowne, F.G.S., for an example of the same genus from Devonshire. In the Museum of the Society I have studied the type specimen of *Ischadites Kœnigii*, Murch.; and in the Museum at Jermyn Street, I have, through the kind permission of the Director-General of the Geological Survey, examined numerous examples of *Ischadites* and the type specimen of *Sphærospongia tessellata*, Phill. Lastly, I have made use of specimens collected by myself from Silurian and Devonian strata of Canada.

A short historical sketch of the principal notices which have appeared respecting this group of fossils will be of interest, as showing the various opinions brought forward about their nature and affinities.

The first account of a member of this group is by Defrance, in the 'Dictionnaire des Sciences Naturelles,' 1827, tom. 45, p. 5, Atlas, pl. 68, who describes and figures two specimens from Devonian strata in the neighbourhood of Chimay, Belgium, to which he gave the name of *Receptaculites Neptuni*. These specimens, the types of the genus, show very imperfectly the real characters of the organism. The original structures have either been replaced by iron-peroxide, or the spaces which they occupied are now vacant. Defrance gives a very clear account of the characters exhibited, and compares the regular arrangement of the rhomboidal plates of the outer surface to the disposition of the scales on the cone of a pine-tree. The connecting pillars are, in these specimens, merely hollow cells. The author expresses doubts whether the fossils are marine organisms, but finally concludes that they may belong to the order of Polyps.

Goldfuss, in the 'Petrefacta Germaniæ' (1826–33) p. 31, t. 9, f. 18, 19, describes and figures under the names of *Coscinopora placenta* and *C. sulcata* two fragments of the same species already made known by Defrance. The first-named species is stated to be from the Uebergangs-Kalk (Devonian) of the Eifel, and the latter, evidently erroneously, from the Jura-Kalk, probably from Switzerland. The condition of these specimens appears to have been similar to that of Defrance's types in having the places occupied by the connecting pillars vacant; and this fact apparently led Goldfuss to compare the tubes to the canals in the siliceous sponge *Coscinopora infundibuliformis*, Goldf.

Murchison, in the 'Silurian System' (1839), p. 697, pl. xxvi. f. 11, under the name of *Ischadites Kœnigii*, figures a group of fossils on the surface of a slab of shaly limestone from Lower Ludlow rocks at Ludlow. Though the specimens have all been compressed, and the original structure entirely removed, leaving merely impressions of its former presence, yet the originally ovate or subspherical form and the tessellation of the surface can be clearly recognized. Murchison, without expressing an opinion as to the affinities of these fossils, referred them to Mr. König, who thought that they might belong to the family of Ascidiæ. No suspicion of any relationship between these ovate bodies and the cup- and disk-shaped specimens of *Receptaculites* appears to have been entertained.

Professor Phillips, in the 'Palæozoic Fossils of Devon and Cornwall' (1841), p. 135, t. 59, f. 49, first named the type of another genus of this group, *Sphœronites tessellatus*. The type specimen had, indeed, been already figured nine years previously, in connexion with a paper by De la Beche "On the Geology of Tor and Babbicombe Bays, Devonshire"*, though it had not been named; but Mr. W. J. Broderip, to whom it had been referred, stated that the fossil may have belonged to the Tunicata. The specimen is pear-shaped, partially imbedded in a hard limestone, and showing a surface of hexagonal plates. Phillips regarded it as a Cystidean, allied to the genus *Echinosphœrites*, Wahlenberg, and he placed it in the Cystidean genus *Sphœronites*, Hisinger.

In 1840, Eichwald, in 'Die Urwelt Russlands,' p. 81, t. 3, f. 18, proposed the genus *Tetragonis* for a fossil of uncertain origin, which he thought might probably belong to the same family as the problematical *Ischadites*, Murch. Curiously enough, Eichwald's type specimen was brought to London by Murchison to show to W. Lonsdale; but that palæontologist does not appear to have recognized any relationship between it and *Ischadites*, though, as we shall see later on, it is undoubtedly congeneric with this latter genus. The specimen is pear-shaped, and the outer surface is divided by vertical and transverse lines into oblong areas, with small perforations at the alternate angles. Oblique lines regularly winding round the fossil are also mentioned. I shall show further on that the appearances presented by the type of *Tetragonis* are similar to those of *Ischadites*, when the rhomboidal surface plates are removed and the horizontal spicular rays beneath are exposed. This being the case, Eichwald's name *Tetragonis* will have to give place to Murchison's name *Ischadites*, which has the priority. Eichwald ranks *Tetragonis* with corals, and in this order he also places another example of *Ischadites* which is named *Receptaculites Bronnii*.

* Trans. Geol. Soc. ser. 2, vol. iii. p. 164, t. 20. figs. 1, 2.

In the 'Palæontology of New York,' vol. i. (1847) p. 68, t. 24, f. 3, Prof. J. Hall refers, with a query, to *Receptaculites Neptuni*, Defr., some fragmentary specimens from the Trenton limestone of Carlisle, Pennsylvania.

In the 'Geological Survey of Wisconsin, Iowa, and Minnesota' (1852), p. 586, t. 2B, f. 13, D. Dale Owen refers another example of this group, from Lower Silurian limestones in Iowa, to a new genus of Foraminifera, under the name of *Selenoides iowensis.* Only the concave base of the specimen is figured; but as the upper portion is described as dome-shaped, it probably belongs to the genus *Ischadites.* According to Miller's 'Catalogue of American Fossils,' the same author, D. Dale Owen, had previously described, in 1840 and 1844, three other species of *Receptaculites*, which bear the names of *R. dactioloides*, *R. reticulatus*, and *R. sulcatus*; but the works containing the descriptions are not accessible to me.

In 1859, J. W. Salter gives descriptions and figures in 'Canadian Organic Remains,' Dec. i. p. 43, t. 10, of two disk-shaped specimens of *Receptaculites*; one, *R. occidentalis*, from Trenton limestone at Pauquette's Rapids, on the Ottawa, the other, *R. australis*, from Upper Silurian strata of New South Wales. Salter regarded these bodies as allied to the Foraminiferal genus *Orbitolites*, and stated that the rhomboidal plates and the columns, which in these specimens are of silex, represented the spaces formerly occupied by the animal sarcode. Salter figures and refers to four connecting processes or stolons given off from the columns, and also indicates the perforations in the plate of the inner or upper surface.

D'Eichwald in 'Lethæa Rossica' (1860), p. 427, brings under the family of the Receptaculitidæ the following genera, *Receptaculites*, *Tetragonis*, *Mastopora*, *Escharipora*, and *Ischadites.* The family is regarded as belonging to the Anthozoa, and its structure is stated to consist of very regularly arranged cells or tubes which appear to be covered by a corneous operculum. In addition to the species mentioned by the author in the 'Urwelt Russlands,' there are here further enumerated, *R. orbis* (=*Escharites forniculosus*, Schlot.), from the *Orthoceras*-Kalk of Baltischport; *Tetragonis sulcata* and *T. parvipora,* which, judging from the figures, do not belong to the family at all, and *Ischadites Eichwaldi*, O. Schmidt, and *I. altaicus*, Eichw. *Sphæronites tessellatus*, Phill., is stated to approach near to *Ischadites.* The genera *Mastopora*, Eichw., and *Escharipora*, Hall, do not appear to me to be in any way allied to the Receptaculitidæ.

Mr. W. Pengelly, in the 'Geologist' (1861), vol. iv. p. 340, t. 5, figures a specimen of *Sphæronites tessellatus*, Phill., showing the inner surface divided into a network of quadrilateral meshes by the interlacing of what may be termed vertical and horizontal ribs. Pengelly regards the form as a sponge, and applies to it the generic name *Sphærospongia.*

In the same year in which Pengelly employed the term *Sphærospongia* for the *Sphæronites tessellatus*, Phill., J. W. Salter, referring to the same form ('Memoirs of the Geological Survey of Great Britain; the Geology of the neighbourhood of Edinburgh,' 1861,

p. 136), states that it is a sponge, and that he proposed the term *Sphærospongia* for the Devonian species. At the same time he mentions a Caradoc fossil (without adding any further description) as of the same genus, in which, as will be shown, he was mistaken. Whether, however, we regard Pengelly or Salter as the author of the term, there is no doubt that it was first applied to the Devonian species *Sphæronites tessellatus*, Phill., and this form will thus remain as the type, and the genus will not be invalidated by the circumstance that Salter ranged under it, several years later, other forms which have no relationship whatever with the type species. Salter further states, in the same memoir, that *Ischadites* is a regularly formed sponge, with vertical and transverse bundles of fibres, and that he now regarded *Receptaculites* also as a very regular cup-shaped sponge, with a skeleton arranged precisely after the pattern of the soft parts in *Orbitolites*.

According to Miller's 'Catalogue of American Palæozoic Fossils' Prof. Hall has described in the 'Report of the Superintendent of the Geological Survey of Wisconsin, 1861,' five species of *Receptaculites* from strata of Trenton and Niagara age. I have in vain sought for a copy of the pamphlet containing this Report in the libraries of the scientific societies of London, and cannot therefore express an opinion as to the character of these species.

Mr. E. Billings, in the 'Palæozoic Fossils of Canada' (1865), vol. i. p. 378, gave an elaborate description of the structure of *Receptaculites*, based principally on the characters of *R. occidentalis*, Salt. He described the genus as consisting of discoid, cylindrical, ovate, or globular-shaped bodies, hollow within, and usually, if not always, with an aperture in the upper side. He supposed that even the large flattened examples of *R. occidentalis* were but the basal portions of conical hollow individuals, of which the upper portions had fallen to pieces after the death of the animal. The body-wall, according to Billings, consisted of three parts, an external integument, the ectorhin, and an internal, the endorhin, composed of rhomboidal plates, between which are cylindrical hollow tubes or spicules, which extend between plates of the outer and inner surface. The outer extremity of each spicule carries four small slender stolons extending to the four corners of the plate which covers them, and Billings states that they seem to form a connexion with the stolons of adjacent spicules. The plates of the endorhin are said to possess four small canals which radiate from the centre of each plate (where they communicate with the vertical spicule) to each of its sides; and further a circular orifice is present at the angles of the plates. Billings's description is supplemented by diagrammatic representations of a vertical section of a subconical species and of the structure of the body-wall. It ought not to be forgotten that these figures are merely diagrammatical, and I do not think any *conical* form has ever been discovered with an interior plate like that figured by Billings, though it fairly represents the structure of the open cup-shaped examples of *Receptaculites*. Billings recognized the affinity between *Receptaculites* and the genera *Tetra-*

gonis and *Ischadites*, and states that *Tetragonis* appears to be merely *Receptaculites* with the ectorhin removed. He institutes a comparison between the structure of the wall of *Receptaculites* and that of the gemmulæ or resting-spores of the fresh-water siliceous sponges of the genus *Spongilla*, and regards the small birotulate spicules, or amphidisks, and the enveloping coriaceous membrane of the gemmules of *Spongilla* as analogous to the spicules of *Receptaculites*.

In the same volume, Billings also describes as new species *Receptaculites calciferus* and *R. elegantulus* from the Calciferous formation, *R. canadensis* and *R.* ? *insularis* from the Silurian of Anticosti, and *R. Jonesi* from Lower Helderberg strata at Gaspé.

Mr. J. W. Salter, in the 'Palæontology of Niti in the Northern Himalaya' (1865), p. 47, t. 5, gives a definition of *Sphærospongia* as a *new* genus, in which he includes a sponge from the Caradoc rocks of Britain (without giving either the name or the description of the form), and two species, *S. melliflua* and *S. inosculans*, from the Himalaya. The generic definition by no means corresponds with the characters of *Sphærospongia tessellata*, Phill., sp., the real type, and Salter seems to have included therein the characters of two or three heterogeneous fossils. Of the species enumerated from the Himalaya, only one, *S. inosculans*, probably belongs to the present group, and this, as Salter remarks, much resembles *Ischadites* and may provisionally be included in that genus.

Dr. W. Dames, in a memoir on the Devonian deposits in the vicinity of Freiburg, in Lower Silesia (Zeitschrift der deutschen geologischen Gesellschaft, Bd. xx. 1868, p. 483, t. 10. f. 1), gives a detailed account of the structure of *Receptaculites Neptuni*, Defr., as shown in examples of this species from Ober-Kunzendorf, which agrees in the main points with that of Billings, though Dames failed to perceive, in the so-called endorhinal plates of this species, the apertures and the interior canals described by Billings in the inner plate of *R. occidentalis*; but he states that there are certainly more than four canals in the ectorhinal plates. Dames denies that any real similarity exists between *Receptaculites* and the gemmulæ of *Spongilla*, on the grounds that there is no evidence of the originally coriaceous character which Billings attributes to some of the integumentary plates of *Receptaculites*, and that the spicules of the fossil genus are much larger at the periphery than near the nucleus; whereas the amphidisks of *Spongilla* are of uniform dimensions throughout. In conclusion, Dames places *Receptaculites* with the Foraminifera, in proximity to the family of the Orbitolitidæ, and proposes to form for it, with *Tetragonis* and *Ischadites*, the family of the Receptaculitidæ. This author further mentions the occurrence of *Receptaculites* in shales of Carboniferous age at Rothwaltersdorf.

Messrs. Meek and Worthen, in the 'Geology of Illinois,' vol. iii. (1878), described, and figured for the first time, two species of *Receptaculites*, *R. globularis* and *R. Oweni*, from the Galena strata of Illinois. They also figure, as a doubtfully new species, a specimen which, from the figure, appears to be identical with the form placed under *R. globularis*, which, it may be stated, really belongs to the genus *Ischadites*. The authors express no opinion on the characters of these fossils, and refer to the hollow casts of the spicules as cells.

J. W. Salter, in the 'Catalogue of the Cambrian and Silurian fossils in the Geological Museum of the University of Cambridge' (1873), gives a figure of *Ischadites Kœnigii*, Murch., from Dudley, representing it with a short cylindrical stem and diverging rootlets, and states that it is one of the regular sponges, like *Sphærospongia*, and that it possesses a root and a foramen at the top, after the manner of *Grantia*. I may here remark that the stem and root represented as belonging to this specimen are probably imaginary, since neither in the Museum at Cambridge nor in the Jermyn Street or British Museum is there a single example showing traces of any basal stem, nor is such an appendage presented in the numerous and perfectly preserved examples of this species which occur in the isle of Gotland.

In 1875 an important treatise on the organization and systematic position of *Receptaculites* *, by Dr. C. W. Gümbel, appeared in the 'Abhandlungen der k. bayer. Akademie der Wissenschaften.' The author's observations were based on examples of *R. Neptuni*, Defr., from Devonian strata in Belgium and Silesia, and he considers the original form of these bodies to have been open cup-shaped as they are now found, and not conical with a small central aperture, as supposed by Billings. By making sections through specimens, Gümbel was enabled to ascertain more thoroughly their interior characters, and to add further particulars of their structure to those made known by Billings. Both the outer and inner surfaces of the organism are stated to possess a very thin layer, now of a carbonaceous material, but originally probably of a leathery or horny consistency. The contact margins of the plates of the outer surface are stated to be uneven, and provided with minute sinuosities, which probably indicate the presence of small canals, thus allowing communication between the interior of the organism and the outer medium. The surface-plates are said to consist of three distinct layers—(1) a thin coaly surface-layer; (2) an upper layer of calcite; and (3) an under-layer of the same substance. This under-layer, if I understand correctly Gümbel's explanations, consists of the four radiating arms at the ends of the pillars, with canals in the centres of each, which are termed the epistyle. The radiating arms of the epistyle are stated not to connect directly with those of adjoining epistyles, but to rest side by side. The inner termination of the pillars, according to Gümbel, is not furnished, like the outer, with an epistyle of four arms, but they possess a greater number of thick irregular branches with subdivisions. These are never intergrown with the main plates of the inner integument, which are said to be strongly folded in the interior. Further, the plates of the inner surface of this species are said not to possess the circular canals described by Billings in *R. occidentalis*, but are covered with small warty elevations indicating the presence of cells. Gümbel agrees with Billings that the interspaces between the

* Beiträge zur Kenntniss der Organisation und systematischen Stellung von *Receptaculites*; Abhandl. k. bayer. Akad. Wiss. Band xii. Abth. i. pp. 170–215, Pl. A.

columns of the interior of the organism, now uniformly filled with matrix, were, in the lifetime of the animal, occupied by sarcode. He further believes that the original material of the skeleton was a finely fibrous crystalline aragonite, and that this structure was entirely opposed to the probability of its alliance to sponges. On the other hand, the inner organization agrees very well with that of the Foraminifera, with which order *Receptaculites* may unquestionably be placed, though its relationships are not with the Orbitolitidæ, as Salter first, and Dames afterwards, supposed, but with the family of the Dactyloporidæ. As the result of an examination of specimens of *Ischadites Kœnigii* from the Silurian of the isle of Gotland, Gümbel concludes that its organization does not in the least differ from that of *Receptaculites*, so that there is no ground for constituting it a distinct species; and *Tetragonis* only differs in the accidental absence, through weathering, of the plates of the outer surface. Still further, Gümbel finds a relationship between *Protospongia fenestrata*, Salt., and *Receptaculites*.

In 1878, Mr. R. Etheridge, F.R.S., described, in the Quart. Journ. Geol. Soc. vol. xxxiv. p. 575, from Silurian strata in the Arctic Regions, two species of *Receptaculites*, one of which is referred to *R. occidentalis*, and the other, which is the largest species yet known, is named *R. arcticus*.

Quenstedt, in the 'Petrefactenkunde Deutschlands,' Bd. 5 (1878), p. 586, states that though the characters of *Receptaculites* are not yet well understood, it may nevertheless belong to the corals. The author figures, as a new species, *R. scyphioides*, a cup-shaped specimen from Devonian strata at Ober-Kunzendorf in Silesia, without, however, indicating any characters which could distinguish it from *R. Neptuni*. Other species of *Receptaculites* are figured, and the characters of *Ischadites* and *Tetragonis* are referred to, without, however, adding anything of importance respecting these genera.

Ferd. Römer, in the 'Lethæa Palæozoica,' 1 Th. (1880), p. 285, proposes to include in the family of the Receptaculitidæ the genera *Receptaculites*, *Cyclocrinus*, *Pasceolus*, *Tetragonis*, *Polygonosphærites*, and *Archæocyathus*, and places the family provisionally with the Foraminifera, although there is no satisfactory ground for a comparison with that group. He adopts the description of the structure of *Receptaculites* given by Gümbel, and agrees with this author that there are no apertures in the plates of the inner surface as described by Billings; but he does not think that there is any communication between the margins of the plates as surmised by Gümbel. Römer further adds a description and figure of a new species, *Receptaculites carbonarius*, from the Carboniferous Limestone of Silesia. With respect to *Ischadites*, Römer thinks that this genus, if not identical with *Receptaculites*, stands very near to it. Bohemian specimens usually referred to *I. Kœnigii*, are, according to Römer, distinct from this species, probably belonging to a different genus. The term *Polygonosphærites* is employed instead of *Sphærospongia*, Pengelly, as the author thinks that this latter term should be rejected, since it implies a connexion with sponges. Römer regards the relationship between *Sphærospongia tessellata*, Phill., sp., and *Receptaculites* as hardly doubtful. As regards *Tetragonis*, the author remarks that our knowledge of it is as incomplete as its position is uncertain, and that the presence of surface-plates has not been decisively determined any more than the existence of perforations at the angles of the squares into which the surface of the fossil is divided as described by Eichwald. In addition to the type species *T. Murchisonii*, Eichw., the author includes in *Tetragonis, T. Danbyi*, McCoy, and *T. eifeliensis*, Röm., which, however, do not properly belong to the genus. As the essential characters of the other genera placed by Römer in the Receptaculitidæ, namely *Cyclocrinus*, Eichw., *Pasceolus*, Bill., and *Archæocyathus*, Bill., do not in my opinion agree in the least with those of *Receptaculites* and its allied genera, it is not worth while to notice his statements respecting them.

In the first part of the first volume of the 'Handbuch der Paläontologie' (1876), p. 83, Prof. Zittel places *Receptaculites* in the family of the Dactyloporidæ; but in a supplement at the end of the volume (p. 727) *Receptaculites* and its allied genera are stated to form an altogether doubtful group; and as they have hardly a single typical feature in common with Foraminifera, and as the Dactyloporidæ, with which they were placed by Gümbel, are now known to be calcareous Algæ, and not Foraminifera, they should be removed from this Order. In addition to the various genera included in this family by Römer, Zittel further adds *Goniolina*, D'Orb., *Archæocyathellus*, Ford, and *Protocyathus*, Ford.

Lastly, in the 'Catalogue of the Fossil Foraminifera in the British Museum' (1882), Prof. T. Rupert Jones gives a list of the species of *Receptaculites* and its allies under the heading of "Rhizopoda of uncertain alliance." In a note on the Receptaculitidæ (p. 83) the author adopts Gümbel's reference of the leading genus to Foraminifera on the ground of the similarity of its structure to *Dactylopora*.

Terminology employed.

In conformity with the opinion which I shall endeavour to establish, that the systematic position of the Receptaculitidæ is with Sponges, it seems desirable to employ other terms for the component parts of the organism than those which have been used by Gümbel, Dames, and other writers, who have regarded these organisms as Foraminifera. I propose therefore to adopt the term "spicules" for the component parts of these fossils. The different parts of each separate spicule may be designated as follows:—(1) "Head- or summit-plate" of the spicule, for the rhomboidal or hexagonal-plates of the outer surface, which are the equivalents of the rhomboidal-plates of the ectorhin, Billings; rhomboidische Tafeln, Dames; rhombische Plättchen, Gümbel. (2) For the four horizontally extended arms or rays immediately beneath the head-plate (the Stolons, Bill.; Kanäle, Dames; Epistyle, Stützarme, Gümb.), I propose the term "horizontal rays" of the spicule. (3) For the tapering or subcylindrical arm or ray extending at right angles to the horizontal rays towards the interior of the organism, and in *Receptaculites* reaching to the inner plate (the cylindrical tubes or hollow spicula, Bill.;

cylindrische Röhre, Dames; Säulchen, Gümbel; cells, Hall, Meek, and other American palæontologists; trous ronds, Defrance), the name "vertical ray" may be used. As regards the relative position in the organism of the spicular plates and rays, that angle of the summit-plate and the horizontal ray beneath it which point towards the basal nucleus or commencement of growth of the organism (one of the radial stolons, Bill.; radial-centripetaler Ast, Gümb.) may be termed the "proximal angle and ray;" whilst the angle and ray pointing in the opposite direction, that is, towards the periphery of the organism in the flattened examples, or towards the summit in the conical forms (radial-centrifugaler Ast, Gümb.), will be the "distal angle and ray." The other two angles of the summit-plate and the corresponding rays (= cyclical stolons, Bill.; concentrische Aestchen, Gümb.) may be named "lateral angles and rays." Thus in those specimens in which the head-plates of the spicules have been removed, and the surface below them appears as if divided into small rectangular spaces, the lines radiating from the nucleus to the periphery, or to the summit in conical examples, are formed by the distal and proximal rays of the spicules, whilst the lines crossing the former at right angles, and producing concentric circles, are formed by the lateral rays.

For the inner or upper integument in the genus *Receptaculites* (=Endorhin, Bill.; innere Hülle, Gümb.) I propose merely to use the term "inner layer."

II. Mineral Structure and Aspect under different Conditions of Preservation.

One of the first considerations in relation to the true nature of these fossils, and one to which little attention appears to have been directed by those who have hitherto studied them, is that of their original mineral constitution. The generally accepted conclusion of the Foraminiferal nature of *Receptaculites* appears to have lulled any suspicion that might have been entertained as to the originally calcareous constitution of its skeleton; and even in the solitary instance in which a serious attempt has been made by Mr. Billings to compare its structure with that of spicules of siliceous sponges, there is no evidence brought forward to show the probability that its skeleton may have been also originally siliceous. Though, in the majority of examples, the skeleton is now of carbonate of lime, yet, so far as I am aware, not a single specimen has been found in which this mineral is otherwise than in a crystalline condition, and cannot therefore be regarded as the original structure of the organism. This circumstance alone is sufficient to show that there is a *prima facie* ground for questioning whether some other mineral than calcite may have formed the hard parts of the organism. The extraordinary diversity of appearance which *Receptaculites* and its allies exhibit, according to the different conditions in which the skeleton is preserved, stands also in intimate connexion with the question of its original nature, and renders it of importance to ascertain this point by a comparison of the different condition of these fossils from strata of different lithological constitution, and also of the present nature of other fossils which are associated with them, and whose normal mineral structure is known.

The different states in which the fossils now occur may be enumerated as follows:—

(1) That in which the skeleton has been entirely removed, leaving only impressions and hollow casts to indicate its former presence.

(2) That in which the skeleton is now in the condition of crystalline calcite.

(3) That in which the skeleton consists of iron peroxide and iron pyrites.

(4) That in which the skeleton is of silica.

Though, as a rule, individual specimens are exclusively in one or another of these mineral conditions, it not unfrequently happens that the same specimen may be composed of two or more different minerals, thus, for example, part may be of crystalline calcite and part of iron peroxide, and these two substances may even be intermingled in different proportions; in another specimen the skeleton may be partly of calcite and partly of silica; whilst, again, the structure of another may partly consist of iron peroxide and partly of empty moulds.

(1) Considering the condition in which the solid parts of the skeleton have disappeared, leaving empty moulds, we find that this principally occurs in specimens preserved in calcareous shales and mudstones and in dolomites. Instances are met with in the Devonian mudstones of Belgium; and the typical forms of *Receptaculites,* described by Defrance, were partly in this condition, since he mentions ‘trous ronds’ which appear to have been partly empty and partly filled with iron peroxide and calcite. In the calcareous shales and mudstones of the Wenlock and Ludlow strata of the West of England, the specimens of *Ischadites Kœnigii* occur, with rare exceptions, as compressed casts, which rarely show more than the impressions of the summit-plates of the spicules and of the horizontal rays beneath. The other calcareous fossils in these beds with *Ischadites*, such as corals, brachiopods, lamellibranchs, trilobites, &c., have well-preserved calcareous skeletons. In the Galena beds or dolomites of Trenton age, in the States of Illinois, Iowa, and Wisconsin, the large flattened examples of *Receptaculites occidentalis*, Salt., generally known as the “sunflower coral” or “lead fossil,” are entirely in the condition of casts. In these beds, also, even the shells of the brachiopods (with the exception of *Lingula*) and gastropods have disappeared, leaving only casts. It is a significant fact, however, particularly when we recollect the association of flint nodules and casts of siliceous sponges in the Upper Chalk of this country, that in the Galena beds of Illinois, where the casts of *Receptaculites* are so abundant, certain portions of the limestone are marked by an abundance of flints arranged in parallel layers*.

* Geol. of Illinois, vol. i. p. 171.

The aspect of the casts of *Receptaculites* and *Ischadites* differs so much from that of the same fossils when the structures themselves are present that one can readily understand the origin of the erroneous opinion held by several palæontologists that these fossils consisted of series of hollow cylindrical cells. In the examples from the Galena limestones of Illinois, the surface of the fossil is divided into shallow lozenge-shaped areas by the crossing of comparatively thick curved ridges of yellowish coarsely-granular dolomite. At the bottom of these areas are the hollow cylindrical tubes, the casts of the vertical spicular rays, which extend quite through to the horizontal plate above. The tube-walls, or rather the interspaces between the tubes, for there are no definite walls, consist of the same dolomitic material as the matrix. When the under surface is worn down or broken away only the cylindrical tubes are exposed. The only indications in these specimens of the horizontal rays of the spicules are four small horizontal projections, which extend from the cell-walls immediately beneath the cast of the summit-plate. These projecting processes fill the interspaces originally existing between the horizontal rays. The coarse-grained character of the dolomitic matrix of these fossils is ill-adapted for retaining their finer structural markings.

The casts of *Ischadites* from the finer calcareous mud of the Wenlock and Ludlow strata vary considerably in appearance from those of the fossils just referred to. In the best-preserved specimens, which, however, are more or less distorted and flattened by compression, the surface is marked by distinct ridges which cross each other diagonally, leaving between them small lozenge-shaped or rhomboidal depressions. The ridges are usually even, though sometimes they exhibit minute sinuosities. Occasionally the depressions are crossed by two other series of lines, less distinctly marked than the diagonal ridges, which divide each rhomboidal area into four triangles. At the intersection of these lines, in the centre of each area, are small circular apertures, not always shown however, which are the casts of the vertical spicular rays. The diagonal ridges represent the minute linear interspaces between the margins of the head-plates of the spicules; and the vertical and concentric lines, which are more clearly shown when the diagonal ridges are worn down, indicate the horizontal rays.

(2) In which the skeleton consists of crystalline calcite. This is the common condition in which these fossils occur, and it is found in specimens from different formations and localities. Thus calcite is present in *Ischadites* from Gotland and in some forms of the same genus from Dudley and Malvern; it forms the skeleton of *Sphærospongia* from Devonian strata in Devonshire, also of *Acanthochonia* from the Silurian rocks of Bohemia, and of *Receptaculites* from the Trenton limestone in Canada, from the Silurian strata of the Baltic and the Arctic regions, and from the Devonian of Silesia and Belgium. The matrix enclosing these crystalline calcite specimens is usually an organic limestone in which the remains of other kinds of fossils are abundant, and these, for the most part, retain the calcite in an amorphous condition; in other cases the matrix is a calcareous

shale or mudstone. In no instance, so far as I am aware, has any member of this group been discovered in arenaceous strata.

In examples of *Ischadites* from Djupvik in Gotland, as also in some forms of *Sphærospongia* and *Acanthochonia*, the head-plates of the spicules are exceptionally well preserved, and exhibit a smooth shining horny lustre so as to give an impression that they are formed of amorphous calcite. This smooth appearance is, however, merely confined to the outer surface of the plates, for in transverse sections the material immediately beneath the surface is decidedly crystalline. As a general rule the outer surface of the spicules, when laid bare by weathering, is slightly rough and uneven, and the internal aspect in polished sections or fractured surfaces is more or less coarsely crystalline. The interspace between the outer and inner surface is usually filled with a matrix of a similar character to that of the enveloping limestone rock, and in this the vertical spicular rays, as seen in sections, show well-defined outlines, but no special wall-substance is apparent between the matrix and the crystalline substance of the rays. In some instances the summit-plates and the horizontal rays are amalgamated into a continuous mass of crystalline calcite in which neither canals nor the separate horizontal rays can be distinguished. In these cases it would seem as if the original material had been first completely removed by solution and the moulds afterwards filled with the crystalline calcite. In none of the Silesian specimens of *Receptaculites* which I have seen is there any indication of the finely fibrous crystalline structure which Gümbel regards as the original character of the skeleton, though in some of the weathered examples of *Acanthochonia* from Bohemia, the crystalline calcite is fibrous and the crystals radiate from centres in a somewhat similar manner to that figured by Gümbel. The calcite in weathered-out specimens of *Sphærospongia* from Devonshire is mostly of a granular crystalline character, and the surface of the spicular plates and rays is peculiarly rough and uneven.

(3) In which the skeleton consists of iron peroxide and iron pyrites. The former material is of very common occurrence in specimens of *Receptaculites* from Belgium, Silesia, and Canada, and of *Ischadites* from Gotland. The matrix of these fossils is either limestone or calcareous shale. The instances in which the skeleton consists of iron pyrites are rare. Not unfrequently the iron peroxide is partly intermingled with calcite. It is sometimes of a dark brown, but more usually of a rusty tint. As a rule the head-plates are not clearly shown in specimens of this material, and when the outer surface is preserved, it appears as a thin continuous dark or rusty crust. When this is slightly weathered, the outlines of the plates are indicated by delicate lines of the fine-grained matrix; further weathering exposes the horizontal rays of the spicules, forming, in the examples of *Ischadites*, clearly marked dark lines running from the base to the summit crossed by other lines tracing concentric circles. When more closely examined, the lines are seen not to be in all cases continuous, as the spicular ray sometimes do not meet,

though very frequently they overlap each other. In specimens still further worn, by weathering or other causes, the horizontal rays disappear, and the surface is covered with circular apertures, infilled with the iron peroxide, disposed in straight lines running from the nucleus to the summit or the periphery of the fossil. The rusty infilling is frequently removed by the weather, and the holes themselves become considerably enlarged. Though the horizontal and vertical spicular rays are very clearly shown in these iron-peroxide specimens, yet I have not detected in them any traces of the interior canals, nor, in fact, could these structures be expected to be preserved in such soft incoherent material.

(4) In which the skeleton is of silica. The only examples in which, to my knowledge, this mineral constitutes the skeleton are specimens of *Receptaculites* from Trenton limestone at Pauquettes rapids, on the Ottawa River. The matrix enclosing these specimens is a compact blue limestone filled with the remains of corals and mollusca, some of which at least are replaced by silica in the form of Beekite. The silica in *Receptaculites* is evidently in a secondary condition, as it appears, after the matrix has been removed by dilute acid, in a minutely granular state on the exterior surface of the plates and rays, giving them a rough aspect under the lens, and in the form of delicate plates and radiating crystalline fibres in their interior. It happens even here that the specimens are not invariably of silica, but part of an individual may be of crystalline calcite and part of silica; and it is a notable circumstance, as tending to throw some light on the original material of these bodies, that whilst in the siliceous portion of the specimens the interior canals are clearly shown in the spicular rays, no traces of them appear in those parts which have been replaced by crystalline calcite.

From the above it is evident that the question of the original mineral nature of *Receptaculites* and its allies is a complex one, and that it is doubtful if a single specimen has yet been discovered in which the original structure has been preserved. It will I think be generally conceded that crystalline calcite, of which the skeleton is now most frequently composed, does not constitute its primary structure, which must either have been another form of carbonate of lime, such as aragonite, or silica. Gümbel * maintains that in certain specimens from Silesia the original structure of *Receptaculites* exists in the form of a finely fibrous crystalline material which may be taken to be aragonite, but he does not mention the characters by which it may be distinguished from calcite. The proof brought forward by Gümbel that this material forms the original structural element of the skeleton is that the constant oblique direction in which the crystalline fibres radiate from the central axis of the vertical spicular rays never appears in purely crystalline structures, and also that there are numerous parallel lines within the fibrous material which cannot be attributed either to aragonite or to fibrous calcite, but to organic structure; this material, in thin microscopic sections, has a great resemblance to the prismatic layer (Kalkstäbchenschicht) in the

* Beitr. p. 26 (sep. copy).

shells of certain mollusca. The facts brought forward by Gümbel do not, however, appear to me to be sufficient to prove the organic nature of this fibrous crystalline structure. The constant direction of the radiation of the fibres may be attributed to the fact that the vertical axis of the spicular ray is the centre from which the rays diverge to the surface of the spicule. That the faint concentric and parallel lines, noted by Gümbel in vertical and transverse sections of the spicules, may indicate their mode of growth by the addition of concentric layers seems extremely probable, but such markings might yet be shown even on the supposition that calcite had replaced silica, and so far from being directly opposed to the supposed relationship to Sponges, as Gümbel asserts, they are, in fact, strong evidences in favour thereof, since the spicules alike of calcareous and siliceous sponges are built up of concentric layers deposited round a central axial canal.

If we now take into consideration the supposition that silica has been the original mineral constituent of the Receptaculitidæ, we are confronted by the fact that the instances are comparatively few in which this mineral now forms the skeleton, and even then it is, like the crystalline calcite, in a secondary condition. But from the experiences obtained of the changes which the organic silica of sponges undergoes in the fossil condition, there are reasonable grounds for believing that the skeleton of *Receptaculites* may have been of a siliceous and not of a calcareous character. Nothing is more common than to find the spicular mesh-work of undoubted siliceous sponges in the Jurassic limestones of Germany and elsewhere wholly replaced by crystalline calcite, but so that the perfect form is retained, and in some instances even the central axial canal can be detected. Equally familiar too is the fact that in the Upper Chalk of this country the siliceous skeleton of the sponges has been wholly removed by solution, and the cavities are now either empty or replaced by iron peroxide. And this solution and replacement are so general that in the sponge-beds of certain Jurassic areas it is very rare to find a single individual sponge in which the original siliceous skeleton is intact; whilst in the Upper Chalk of this country we must resort to the sponges enclosed in flint nodules to find a specimen in which the spicules are of silica, and even then the silica is in a secondary condition. The examples of undoubted siliceous sponges from Palæozoic rocks are not very numerous, but in many of them the skeletons have been either removed, leaving empty casts, or replaced by crystalline calcite, iron peroxide, and iron pyrites. The siliceous sponges of the genera *Aulocopium* and *Astylospongia*, from Silurian strata of the Baltic basin and in West Tennessee, are, indeed, often in a siliceous matrix; but it happens that the minute structure of the sponges themselves, when it is preserved at all, is generally a compound of iron or merely represented by empty moulds, and these sponges may be considered somewhat in the light of siliceous nodules in which the silica liberated from their own skeletons and those of other sponges has been aggregated. Other siliceous sponges of the genus *Astræospongia*, from the Silurian of Tennessee are now partly of calcite and partly of silica, and spicules of this genus even occur detached in the condition of calcite in the same strata in Gotland from which the calcite specimens of *Ischadites* have been procured. Evidence in favour of the siliceous constitution of the Receptaculitidæ is also furnished by the circumstance, already alluded to, that the interior canals in the spicules of the siliceous examples of *Receptaculites* from the Trenton limestone are distinctly shown, whilst these structures have been entirely obliterated in portions of the same specimens which have been replaced by calcite. That some of the molluscan shells in the same rock have suffered a change from calcite to silica can be explained on the supposition that this silica has been derived from the solution of the portions of *Receptaculites* which have been replaced by calcite. The silica of the layers of flints in the Galena limestone of Illinois may also have originated from a similar source, as the numerous specimens of *Receptaculites* in these rocks are invariably in the form of hollow casts.

In conclusion it may be stated that on comparing the present condition of the skeleton of the Receptaculitidæ with that of undoubted siliceous sponges from both Palæozoic * and Mesozoic strata, we find that there is a great similarity in their mineral structure and that it is now very frequently in the form of crystalline calcite, iron peroxide, iron pyrites, silica in a secondary condition as well as empty cavities, and there are therefore good grounds for believing that if the Receptaculitidæ are allied to Sponges, the proof for which must be sought from other considerations, their spicular skeleton was originally composed of silica.

III. Characters of the different Genera.

Though the genera which I have included in the family of the Receptaculitidæ all possess similar essential structural features, yet in some forms these are of a simpler character and are better preserved than in others, and as these simpler forms furnish a key towards understanding the structure and character of the more complex, it seems desirable to consider them first. I therefore propose to commence with the genus *Ischadites* or *Tetragonis*, leaving *Receptaculites* to the last, since this genus possesses in certain respects a more complicated and variable structure than any of the others.

Genus Ischadites, Murchison, 1839, Siluria, p. 697.

Tetragonis, Eichwald †, *Receptaculites*, pars auct.

The type forms of this genus consist of a group of flattened bodies, with circular or ovate outlines, from 25 to 40 millim. in diameter, preserved on the surface of a slab of hard bluish calcareous shale.

* Since this paper was in type, specimens of *Ischadites Kœnigii* have been discovered in the Silurian of the Pentland Hills, which closely resemble in their condition of preservation the examples of *Amphispongia* from the same locality.

† Urwelt Russlands, Heft 2, 1842, p. 81.

The specimens are now only in the condition of casts, that is, of impressions in the shale of the structures of the organisms, which have entirely disappeared; and it is evident that they have been greatly compressed, and that they were originally subspherical or ovate in form. The details of the form in these specimens can only partially be ascertained; the basal extremity appears to have been obtusely conical without either stem or roots; the body gradually increased in diameter for about half the distance between the base and summit, and then gradually contracted to the summit, at which there was a small circular aperture, which originally opened into the inner cavity. The surface of these bodies is covered with delicate oblique ridges, crossing each other with the greatest regularity, and dividing the surface into small rhomboidal depressed areas, disposed in quincunx. These areas are small near the base, widest in the central zone, and again minute towards the summit. Within the rhomboidal areas, and only occasionally shown, are two sets of lines, one set running straight from the base to the summit, and the other crossing the first at right angles, so that each rhomboidal area is divided into four parts by the lines which intersect in the centres of the areas and extend to each of their angles. These lines in the type specimen are only faintly and rarely seen, though in Murchison's figures, which are partially restorations and not accurate representations of the originals, they are clearly delineated.

The above is all that can be learned from an examination of Murchison's type specimen of *Ischadites Kœnigii*, which is now in the Museum of the Society. It seemed desirable to refer to the type form before passing to a description of the structural details of the genus, as shown in examples of the same species from Silurian strata of the isle of Gotland, in which the component parts of the organism are beautifully preserved in calcite or iron peroxide.

Outer form.—This is to a certain extent variable even in the same species from the same locality. The prevalent forms are ovate or biconvex, or more or less depressed conical; some are subspherical, and others pyriform. The central zone in some specimens is bulged out conspicuously (Pl. XXXVI. fig. 1), but generally there is an evenly rounded contour from the base to the summit. The base may be either obtusely conical, flattened, or very frequently concave. The summit is usually obtusely conical; rarely there is a small central elevation (Pl. XXXVI. fig. 1 *a*). A small circular perforation is present in the centre of the summit which opens into the originally hollow cavity of the body; this is now invariably filled with the matrix of shale or mudstone.

Structure.—This entirely consists of spicules of various dimensions, regularly arranged in vertical and oblique rows, and held in position by the interlocking of their summit-plates and horizontal rays. We will first consider the plates which form the summits or heads of the spicules. These are apparently delicate structures with smooth flattened upper or outer surfaces, thickest in the central portion where they connect with the horizontal rays, and gradually diminishing towards the margins, which are very thin. They have a generally rhomboidal outline, but in some parts of the specimen two of the sides of the rhomboids are not uniformly straight, but have a slight curve, which gives the plates the form of a sector of a circle. Another modification is frequently, if not invariably, present in the spicular plates of the basal portion, which have their distal angles, or those directed away from the basal nucleus, either truncate or with a slight notch, from which one of the horizontal rays projects and extends, as will be shown, nearly to the centre of the plate immediately in front (Pl. XXXVI. fig. 1*g*). The plates forming the basal nucleus are also more elongated than any others (Pl. XXXVI. fig. 1*f*). At the intercalation of fresh rows of spicules, there is a modified summit-plate of a pentagonal form and larger size; in front of this is a triangular plate, which is succeeded by plates of normal shape. The plates near the nucleus, as well as those of the nucleus itself, are relatively small, but they quickly increase in size towards the zonal area, where they attain their greatest dimensions (2 to 4 millim.); they then gradually diminish in size towards the summit, and the smallest plates surrounding the summit-aperture are scarcely distinguishable without a lens, measuring from ·25 to ·4 millim. in width, or about one-tenth the diameter of the zonal plates. In none of the examples of this genus have I detected any minute structure in the head-plates of the spicules; they are now throughout of crystalline calcite, and in some cases sufficiently thin and translucent to allow the horizontal rays to be seen through them.

The manner in which the spicular plates are arranged on the surface of the organism forms its most conspicuous feature. They are disposed in regular spiral curves which, starting in opposite directions from the basal nucleus and extending to the summit, give to the surface the exact appearance of the engine-turned case of a watch. This arrangement has been compared to that of the plates of a ganoid fish, and the scales of the cone of a pine tree. Each rhomboidal plate is so arranged that one of its angles points to the basal nucleus, and its opposite angle to the summit of the specimen, whilst the other angles are lateral, so that the distal angle of one plate is in contact with the proximal angle of the plate immediately in front of it. Thus vertical lines extending from the base to the summit would pass through the proximal and distal angles of the plates, whilst concentric lines would pass through the lateral angles. At the nucleus, or centre of the base, there is a series of 8 minute spicules with diamond-shaped head-plates, which are so arranged as to form a star-shaped figure, the distal angles of each plate representing one of the rays of the star, and a line connecting the lateral angles would trace a small circle, with the proximal angles of the plates for its centre (Pl. XXXVI. fig. 1*f*).

As a rule, the margins of the plates appear to fit closely and evenly to each other, so as not to leave any interspace between their edges, but in some cases the upper or front margins seem to be slightly elevated as if they imbricated over the lower or hind margins of the spicular plates immediately in front, and left a small intermediate space, now filled with the matrix. That the plates, or at least those of the lower portion of the organism, did not fit so closely as to exclude the passage of water from the exterior to the interior cavity of the organism, is shown by the fact that one of the horizontal spicular rays projects from underneath the distal angle of each of the plates and extends over the outer surface of the plate in front, thus clearly preventing a close-fitting union at the margins, and, further, the ridges, which characterize the outer surface of the casts of specimens, are produced by the infilling of the matrix in the interspaces between the margins of the plates. Though the spicular plates in some of the Gotland examples appear as if cemented together at their margins, yet a very slight degree of weathering is sufficient to show that there was originally a distinct, though minute, linear interval between them; and their apparent union is probably caused by the calcitic replacement of the originally separate structures which gives the appearance of their having been fused together into one mass.

These summit- or head-plates appear to have been connected by a somewhat narrow neck to the horizontal rays of the spicules at the central point of junction with these and the vertical rays, as the horizontal rays appear to be independent except at their central junction. As a rule, the head-plates are seldom preserved *in situ*. Thus in the large majority of the specimens from Gotland, they have quite disappeared, but in a few from a single locality, Djupvik, they are still retained. That they were present in all originally is made clear by faint traces of their marginal outlines which can generally be detected, and their absence is to be attributed to the facilities which their extended surfaces offer to weathering influences.

It has been already mentioned that the surface of the fossil immediately beneath the rhomboidal spicular plates is divided into minute oblong rectangular areas by vertical and concentric lines. These lines are formed by the apposition of the horizontal spicular arms or rays. The spicules, in addition to the head-plate, consist of five rays; four extended in a horizontal direction, at right angles to each other, whilst the fifth extends from the junction of the four with the summit-plate towards the interior of the organism and thus at right angles to the horizontal rays. The spicular rays are circular in transverse section, thickest at their central point of junction with each other and the head-plate, and they gradually taper to bluntly-pointed extremities. Only in one specimen have I been able to detect the presence of canals in the interior of the rays. The vertical or entering ray appears to be the longest, the lateral rays are subequal, whilst the distal ray, or that pointing to the summit of the specimen, seems to be longer than the opposite or proximal ray.

The four horizontal rays are so arranged that each ray extends towards one of the angles of the head-plate of the spicule. Thus one ray, the proximal, points to the basal nucleus, and its opposite, the distal, to the summit. This distal ray in the basal portion of the organism frequently projects beyond the margin of the spicular head, and overlies the head-plate of the spicule immediately in front or above it (Pl. XXXVI. fig. 1 *g*). There is, of course, a correspondence in size between the head-plates and the horizontal and vertical rays of the spicules of which they form parts, that is, the largest plates are attached to the longest and stoutest rays, but the horizontal rays are not limited in length to the areas of the summit-plates, as they most frequently extend beyond and overlap the rays from adjoining spicules. As a general rule the horizontal rays vary in length from one half the diameter to the entire diameter of the summit-plate. Very frequently in specimens in which the spicular plates have been weathered away, either the proximal or distal ray of the horizontal rays is absent, and this probably arises from the missing ray having been in close contact with the under or inner surface of the head-plate, and thus becoming destroyed with the plate; the lateral rays on the other hand are usually intact (Pl. XXXVI. fig. 1 *i*). The rays of the eight spicules of the nucleus appear to be of the same character, though smaller than those succeeding them.

The effect of the arrangement of the horizontal rays of the spicules above described is to produce vertical and transverse lines which form by their intersection oblong areas, the angles of which correspond to the angles and the centres of the head-plates. It will be seen that every alternate angle corresponds with the centre of one of the head-plates, and with the vertical ray of each spicule.

The vertical rays of the spicules, which extend at right angles to the summit-plates and the horizontal rays, are only seen when the interior of the specimens is exposed by fracture or by section. They are never so clearly shown as the horizontal rays, many have apparently disappeared, and their characters can only be known by comparing different specimens in which a few are yet preserved. They appear as delicate, gradually tapering shafts, the extremities of which are pointed, and reach about half way to the centre of the interior cavity, where they terminate freely (Pl. XXXVI. figs. 1 *k*–*o*). In numerous specimens which I have examined, whether fractured irregularly or cut so as to show even vertical and transverse sections, I have been unable to discover any traces of an interior plate or integument corresponding to that in *Receptaculites*, though the pointed ends of the rays were readily discernible: and the fact of the gradual tapering of the spicules, and the distance to which they extend in the interior cavity, appear to me strongly presumptive that in this genus an inner layer is not developed. This distinctive feature of the genus as contrasted with *Receptaculites*, is not only apparent in specimens from Gotland, but also in one example at least from Wenlock strata at Dudley. Billings has also shown a similarly free termination of the vertical spicular rays in an example of the genus from the Lower Helderberg group at Gaspé, Quebec, which he has named *Receptaculites Jonesi* *. He makes no mention however, of the absence of an inner layer, and the dark shaded space in the figure is inserted to show where it is supposed to exist.

* Pal. Fossils of Can. vol. i. p. 385, fig. 363.

In a similar manner, Gümbel has figured a vertical section of an *Ischadites* * from Gotland, in which a dark shading is intended to indicate the outline of an inner layer, but, from the form and extension of the spicular rays, the figure is evidently diagrammatical, and I have no doubt that, as in the Gotland specimens which I have examined, the spicular rays terminate freely.

Not unfrequently examples of *Ischadites* occur, in which, through weathering, both the spicular head-plates and the horizontal rays have disappeared, and only the basal ends of the vertical rays are shown on the surface as small rounded nodes, disposed in vertical lines (Pl. XXXVI. fig. 1 *c*). I have also noticed, in some specimens in which the walls have been crushed in, spicules completely detached and removed from their original positions, thus showing clearly their independence.

From the characters of *Ischadites* as given above, there can be no doubt that the genus *Tetragonis*, Eichwald †, is congeneric therewith. From the descriptions and figures of the type species, *T. Murchisoni*, Eichw., it is evident that it is a specimen in which the spicular head-plates have entirely disappeared, and the surface exhibits the small oblong areas formed by the horizontal rays, together with the apertures of the vertical rays at their angles. Eichwald himself recognized a relationship to *Ischadites*, and entrusted his type specimen to Murchison for comparison with this latter genus; but in the 'Lethæa Rossica' ‡, he makes no further mention of this, although he therein describes some forms of *Ischadites*, and also includes under *Tetragonis* two new species, *T. sulcata* and *T. parvipora*, which, however, belong to an entirely different group than the type species. By most later writers the generic identity of *Tetragonis* and *Ischadites* has been freely acknowledged; Ferd. Römer §, however, expresses doubts as to the former existence of plates and of the apertures at the angles in the type specimen, but this mistake has probably arisen from regarding as examples of the genus, other forms which have no close relation to it.

As the term *Ischadites*, Murch., has the priority of publication the name *Tetragonis*, Eichw., becomes obsolete.

The genus *Ischadites* itself has, by several writers, been regarded as identical with *Receptaculites*, but though similar in its main structural features to this latter genus, it is sufficiently characterized by its conical or ovate form, inclosing a central cavity, with a small summit-aperture, and by the absence of an inner layer. From *Sphærospongia*, Pengelly, it is distinguished by the rhomboidal form of the spicular plates, and the development of vertical spicular rays; and from *Acanthochonia*, gen. nov., by its conical ovate form and central cavity.

* Beitr. Taf. A. f. 29.
† Urwelt Russlands, Heft 2 (1842), p. 81, t. 3. f. 18.
‡ Vol. i. pt. 1, p. 430. § Lethæa Pal. Th. i. p. 303.

Genus Sphærospongia, Pengelly, 1861, Geologist, vol. iv. p. 340.

1841. *Sphæronites*, Phillips (non Hisinger), Pal. Fossils of Devon and Cornwall, p. 135.

1861. *Sphærospongia*, Salter, pars, Memoirs of the Geological Survey of Great Britain. The Geology of the Neighbourhood of Edinburgh, p. 136.

1875. *Pasceolus*, Kayser (non Billings), Zeitschr. d. deutsch. geol. Gesellsch. Bd. xxvii. p. 776.

1880. *Polygonosphærites*, F. Römer, Lethæa Palæozoica, Th. i. p. 296.

The typical example of this genus, on which Phillips bestowed the name *Sphæronites tessellatus*, is now preserved in the Jermyn-Street Museum, and from this, and other examples of the same species from Devonshire, the characters described below have been ascertained. The form of the original specimen is incomplete; it appears to have been pear-shaped, but as only a portion of the dome-shaped summit is preserved, it is difficult to determine whether it possessed an entire roof, or whether there was a central aperture, as in *Ischadites*. Other specimens are open, cup- or funnel-shaped, gradually curving towards the base, which terminates in a small bluntly-rounded extremity with no appearance of stem or roots, so that these fossils were clearly free and unattached. The funnel-shaped specimens are frequently hollow, the peculiar granular crystalline matrix not having penetrated into the interior cavity, but their upper surfaces are invariably obscured by the matrix, so that I have been unable to ascertain whether these organisms had a complete dome-shaped roof or not.

The outer surface is composed of an apparently close-fitting covering of spicular head-plates of hexagonal form (Pl. XXXVII. figs. 1, 1 *b*); but though the margins seem to be in intimate contact, narrow linear spaces filled with the matrix are occasionally visible between them, and these interspaces are very generally shown in the granular crystalline examples. The spicular plates are somewhat smaller in the basal portion, but in the middle and upper portions of the organism they are tolerably uniform in size, and, for the most part, regular hexagons in figure. The plates in the type specimen are smooth on their upper surface, nearly flat, and with a small central rounded elevation, which is only seen in the best-preserved specimens; in the majority of examples no trace of it is shown. They also exhibit numerous fine concentric lines, resembling lines of growth, and occasionally their margins are slightly elevated, sufficiently in some cases to cause a slight depression between the margin and the central protuberance. No structure can be seen in these head-plates, and their thickness appears to be inconsiderable. They are arranged in an extremely regular quincunx.

In the hollow specimens (Pl. XXXVII. fig. 1 *a*) the interior surface immediately beneath the summit-plates, is divided into oblong and quadrate spaces by vertical and transverse ridges. The vertical ridges run from the base to the upper portion of the specimen, generally parallel with each other, and fresh ridges are intercalated as the width of the specimen increases; the transverse ridges are generally less regular than the vertical, and are frequently curved and discontinuous. On closer inspection these ridges are seen to be composed of horizontal spicular rays, and the hexagonal plates above form the summits of the spicules (Pl. XXXVII. fig. 1 *c*). The horizontal rays are thickest at their central junction with the summit-plates, and they gradually taper to their extremities, where they are bluntly pointed. They are not altogether equal in length, and they usually overlap at their ends. The lateral rays are also not unfrequently curved and thus give an irregular appearance to the transverse ridges. Central axial canals are clearly seen in the rays exposed in a polished transverse section of the type specimen. In the character of the horizontal rays, and in their disposition with respect to each other and to the head plates, there is the closest agreement with *Ischadites*. It is doubtful, however, whether the spicules of *Sphærospongia* were furnished with vertical rays like those of *Ischadites*. No clear evidence on this point is afforded by the specimens which I have examined, and their present mineral condition is unfavourable for the preservation of minute details. The only evidence of the existence of a vertical fifth spicular ray is shown by a small knob-like point, projecting towards the interior cavity from the central junction of the four horizontal rays, and this may represent either an aborted ray or the fractured stump of a vertical shaft. There are, as may be supposed from the absence of the vertical rays, no traces of an inner layer, and scarcely a doubt can be entertained that, in this genus, as in *Ischadites*, no inner layer existed.

This genus is characterized by its form and by the regular hexagonal figure of the spicular plates, as well as by the presence of a small central knob in each, and also by the absence of vertical spicular rays.

The first reference to this genus is by Mr. W. J. Broderip in a note to a paper by De la Beche on the Geology of Tor and Babbacombe Bays, Devonshire *. Very good figures are given of the type specimen—which, however, only shows the character of the outer surface—and from these Broderip thinks that it may have belonged to the Tunicata. He did not, however, propose for it any generic or specific name. Some years later J. Phillips copied the figures given in De la Beche's paper, and stated his belief that the fossil was a Cystidean allied to the genus *Echinosphærites*, Wahl. (*Sphæronites*, Hisinger), and he named it *Sphæronites tessellatus*. In 1855 an imperfect example of the same species was figured in the 'Geology of Russia' † under the name of *Echinosphærites tessellatus*. In the same year, also, the late Dr. Bowerbank ‡ instituted a somewhat fanciful comparison between *S. tessellatus*, Phill., and the small calcareous sponge *Dunstervillia elegans*; and T. Austin §, referring to

* Trans. Geol. Soc. (1832), ser. 2, vol. iii. pl. xx. f. 1, 2.

† By Murchison, Verneuil, and Keyserling, p. 381, t. 27. f. 7.

‡ Ann. & Mag. Nat. Hist. 1845, vol. xv. p. 299. § Id. p. 406.

Dr. Bowerbank's paper, states that there can be no doubt that *S. tessellatus* is the calcareous skeleton of a spongiform body, and that *Ischadites* is of similar origin. In 1850–56 the brothers Sandberger * figured two specimens from Vilmar and referred them to the proboscis of a crinoid.

Hitherto only the characters of the outer surface of the fossil had been known; but in 1861 † Mr. W. Pengelly described the interior of a cup-shaped specimen as "divided into a network of quadrilateral meshes by the interlacing of what may be termed horizontal ribs, the primary extending from the bottom to the top of the cup, and secondary springing from various heights in the sides or wall." Though Mr. Pengelly did not recognize the spicular character of the ridges or ribs, he believed the organism to be a sponge, and gave it the name of *Sphærospongia tessellata*. In the same year (1861) the late Mr. J. W. Salter ‡, in the course of some remarks on *Amphispongia*, referred to the great *Sphæronites pomum* (=*S. tessellatus*, Phill.) from the Devonian rocks, as a sponge allied to *Grantia*, and he also proposed the term *Sphærospongia* for the Devonian species. He adds that the Caradoc fossil is of the same genus. No further reference to or description of this Caradoc fossil, thus stated to be congeneric with *S. tessellatus*, Phill., is given, nor need I further refer to it here beyond stating that it appears to be a fossil which has been named later *Sphærospongia hospitalis*, Salt., and that it has neither generic nor family characters in common with the species, which, alike by Salter and Pengelly, is put forward as the type of the genus. In order to determine, if possible, the question of priority, as both the references to the name were published in the same year, I inquired of Mr. Pengelly, who informed me that he could not be certain after such a long interval of time, but he thought it probable that the name was suggested to him by his friend Mr. Salter. As, however, the interior characters of the fossil were first described and figured by Mr. Pengelly, and the generic name definitely applied to this species, it seems to me only just, in the absence of decisive evidence as to the priority of publication, that he should be regarded as its author, even though Mr. Salter may have suggested the appellation to him, and this course is further to be recommended on the ground that Salter does not appear to have had any clear ideas of the structure of the type species, since he afterwards included in the genus *Sphærospongia* a variety of forms which have no relation whatever with the type species. Whether, however, Pengelly or Salter be regarded as the author of the term, there is no doubt of the fact that *S. tessellatus*, Phill., is the typical species, and therefore the doubtful forms afterwards placed in the genus by Salter and other authors have no claim to remain in it.

Kayser § refers the *S. tessellatus*, Phill., to Billings's genus *Pasceolus*,

* Die Versteinerungen des rheinischen Schichtensystems in Nassau, pp. 384, 385.

† Geologist, vol. iv. p. 340, pl. v.

‡ Mem. Geol. Survey, "Geol. of Edinburgh," p. 136.

§ Zeitschr. d. deutsch. geol. Gesellsch. 1875, p. 780, t. 20.

with which, however, it has, in my opinion, no relationship. His specimens only show the exterior surface, and from this he judges that the organism must be a "Foraminifer like *Receptaculites*."

Ferd. Römer * states that the relationship of *S. tessellatus*, Phill., to *Receptaculites* cannot be doubted after Pengelly's observations on its interior structure. He states, moreover, that Pengelly discovered in the interior of this form a *canal*-system consisting of horizontal and vertical tubes, thus regarding the ribs mentioned by Pengelly as canals. F. Römer rejects the term *Sphærospongia* on the grounds that even if the fossil could be shown to belong really to Salter's genus, yet, as the name indicates a relationship to Sponges, it is inappropriate; he therefore proposed to substitute the term *Polygonosphærites* instead. As, however, the type form seems to me to be a sponge, Römer's objection to its name loses its force.

Genus Acanthochonia, Hinde, gen. nov.

I propose this genus to include some shallow cup-shaped specimens from the Silurian strata of Bubowitz near Prague in Bohemia, where they occur in beds of the Étage E of Barrande. Though apparently very abundant, several specimens being oftentimes present in a single hand specimen of rock, only the outer surface is exposed to view; but, judging from the exceptionally favourable state of preservation of the surface of these cup-shaped examples, and the invariable absence of any traces of summit structures, there seems good reason for supposing that they retain their original and complete form. I have not, however, been able clearly to make out the natural margins of the cup, which are always enclosed by the matrix, and only indistinctly shown, even in vertical sections through the specimens. The base is either evenly rounded or with a shallow concavity in the centre; there is no trace of any attachment, and the forms were evidently free (Pl. XXXVII. fig. 2).

The outer surface is composed of spicular plates, usually rhomboidal in form, though in some cases the proximal and distal angles of the rhomboids are slightly truncate and the plate becomes approximately hexagonal. The outer or upper surfaces of the plates are flat, smooth, and exhibit the same horny-lustre as in the Djupvik examples of *Ischadites*. Concentric lines of growth are also apparent, though not so clearly marked as in *Sphærospongia*; and occasionally there are traces of a central knob-like elevation in the plates, as in this latter genus. At the nucleus or centre of the base there is a small circle of eight spicular plates arranged in a star-like form. The mode of arrangement of the plates in spiral curves, as well as the insertion of fresh rows, is precisely similar to what has been already described in *Ischadites*. The spicular plates fit at their margins, but not so closely as to preclude the possibility that a narrow channel may have existed between them originally, and this

* Leth. Pal. Th. i. p. 297, fig. 54.

is also indicated by the delicate concave casts of the outer surface, in which the individual plates are marked out by thin raised ridges, which are the filled-up spaces which existed originally between them. The slightest degree of weathering also is sufficient to clearly expose the intermarginal channels and tenuity of the edges of the plates. In this form, too, the distal spicular rays, that is, those which point to the margins of the cup, project in some instances beyond the distal angles of the summit-plates, and extend to nearly the centre of the plates immediately in front. Owing, however, to the calcitic replacement which has taken place, both the rays and the plates over which they extend appear as if welded into one continuous mass.

The horizontal rays beneath the summit-plates are but seldom exposed in the specimens of this genus, but in a few instances in which the plates have been weathered, they exhibit the same character and arrangement as in *Ischadites*. In vertical sections, passing through the centre of the base of the specimens, there is shown, immediately beneath the outer surface, a continuous layer, from 1 to 3 millim. in thickness, of crystalline calcite, in which no structure whatever can be seen; projecting beyond this mass, however, there are numerous straight or slightly curved tapering shafts or rays which terminate acutely. These rays are smallest in the basal portion, and reach their maximum size about halfway between the base and the margins of the cup. They project at right angles to the summit-plates from beneath which they originate. These rays are completely surrounded by the hard matrix of greenish grains and fragmentary organisms, and the natural terminations of several can be distinctly seen. As in *Ischadites*, they end quite free in the concavity of the cup, without being attached to an inner layer as in *Receptaculites* (Pl. XXXVII. fig. 2 *e*). The thick band of crystalline calcite surrounding the interior of the cup appears to have been produced by the amalgamation into an undistinguishable mass of the summit-plates, the horizontal rays, and the basal portion of the vertical rays.

The distinguishing character of this genus is an open cup-like form into which the vertical spicular rays project. It resembles *Ischadites* in structural details, but differs therefrom in the absence of a covered-in summit, enclosing a central cavity. From *Sphærospongia* it is distinguished by the generally rhomboidal form of the spicular plates, and the well-developed vertical rays. The absence of an inner layer marks this genus off from *Receptaculites*. For the type species, which appears hitherto to have passed under the name of *Ischadites Kœnigii*, I propose the specific name *Barrandei*. The specimens from which the above description is taken are in the British Museum of Natural History.

The only previous notice of this form, of which I am aware, is by Ferd. Römer *, who remarks that it differs specifically, if not generically, from *Ischadites Kœnigii*, to which it had usually been referred.

* Leth. Pal. Th. i. p. 292.

Genus RECEPTACULITES, Defrance, 1827.

Receptaculites, Defrance, Dictionnaire des Sciences Naturelles, t. 45, Atlas, pl. 68.

The typical examples of this species to which the author gave the name of *R. Neptuni* were from Devonian strata at Chimay in Belgium, and consisted, judging from the figures, of two individuals, one cup-shaped and the other a flat disk-shaped specimen. The characters of these specimens were evidently very imperfectly preserved, and the author merely refers to an outer surface of rough markings and protuberances arranged in regular curved lines, and an upper surface exhibiting round shallow holes. Succeeding writers, with the exception of Salter and Billings, have based their descriptions of the genus upon specimens of the same species from Belgium and Silesia, whilst these latter authors have referred more particularly to species from a lower geological horizon in Canada and Australia, which, in some structural details, differ from the Devonian forms described by Dames, Gümbel, and others; but it is doubtful if these differences really exist or are merely owing to the imperfect preservation of the specimens. The following description is from the study of specimens from Devonian strata in Belgium, Silesia, and Canada, and from Silurian strata in the United States, Canada, the Arctic regions, and the Baltic.

In outer form the examples of this genus are open cup-shaped or flattened expansions with a circular outline and sometimes with slightly incurved margins. Numerous gradations occur between cup- and platter-shaped examples of the same species. In some specimens there appears to be no tendency to an incurvature at the margins, even in very large forms, such as those of *R. occidentalis*; while in others there is a short upward curvature, so that when complete they must have resembled a wide, shallow, dish. The nucleus, or starting-point of growth, is usually a small obtusely conical projection, which in no wise served as a point of attachment, and the organism is invariably free. Whether the margins of the cup were open or covered in any way is uncertain, as in no case is the structure of the upper edge clearly shown. There seems no evidence in favour of the supposition of Mr. Billings that the complete specimens of this genus possessed dome-shaped or conical summits similar to those of *Ischadites*, for though platter- and cup-shaped examples are abundant in certain strata, and apparently perfect as regards their outer form, yet in no single instance has an upper portion been discovered in connection with them; and if we take into consideration the numerous instances in which the smaller and more delicate forms of *Ischadites* still retain their complete form and conical summits, the conclusion appears justifiable, as Gümbel has already remarked, that the specimens of *Receptaculites* were originally of the form in which they are now found as fossils. No specimen has yet been found to correspond with the diagrammatic representation which Mr. Billings * has given of a supposed complete example of the genus.

* Pal. Foss. vol. i. p. 378, f. 353.

Taking first into consideration the structure of the outer or under surface of the fossil, we find that it consists of a layer of rhomboidal spicular plates of the same character and disposed in precisely the same manner as those in *Ischadites* and *Acanthochonia*. I have not been able to ascertain definitely the precise form of the nucleus or commencement of growth of the spicules, but it is probably similar to that of the genera already described; the plates in the centre are the smallest, whilst those in the central and peripheral portions of the organism are the largest. The outer surface of the spicular plates is flat, and their margins are very thin and delicate; the central portion was firmly united to the rest of the spicule immediately above the horizontal rays. There appear in this genus also delicate linear interspaces between the margins of the plates, which are particularly conspicuous in silicified specimens which have been freed from the calcitic matrix; the interspaces, however, in these forms may be partly owing to the destruction by the acid of the delicate edges of the plates. No structure is visible in the summit-plates; when silicified they are apparently compact, whilst in the calcareous forms, when the surface is gently rubbed and polished, radiating fibrous crystals of calcite, oftentimes intermingled with iron-peroxide, are exposed.

According to Gümbel *, the spicular plates (Kalkplättchen) of *Receptaculites* consist of three distinct layers—(1) of a thin carbonaceous layer, (2) of an upper layer of crystalline calcite, and (3) of an under layer of the same material; and there seems therefore a notable discrepancy between his observations and my own that the plates are composed of a single, relatively thin, structureless layer. This discrepancy is, however, more apparent than real, since the spicular plates as I have defined them correspond to only the second or upper calcareous layer of Gümbel. The carbonaceous surface-layer, which Gümbel describes as extending completely over both the outer and inner surfaces of the organism, appears from his description to be of a very dubious character. From what I have seen of the Ober-Kunzendorf specimens in which it is said to occur, I should judge that it would arise from a slight mineral deposit incrusting the surface of the fossil; but if, as Gümbel asserts, one or two layers of cellular structure are shown in thin sections of this surface-layer, they would, to me, rather indicate the presence of an incrusting coral or polyzoan than, as Gümbel supposes, an original outer covering of a coriaceous or keratose consistency. No mention of this carbonaceous layer has been made by any other independent observer, or in any examples from other localities than Ober-Kunzendorf, and Gümbel himself does not attach any particular importance to it. In the upper calcite layer of Gümbel, which is the equivalent of my summit-plates and the ectorhin of Billings, this author does not appear to have observed more than radiating fibrous grooves, probably of mineral origin. The lower calcitic layer of Gümbel's *Kalkplättchen* comprises the horizontal spicular rays, and I agree with Billings in regarding these structures, which

* Beitr. p. 21.

are only united with the summit-plate at the common centre of the spicule, as distinct from the summit-plate itself.

The horizontal rays, the equivalents of the stolons of Billings, the Stützarme or Epistyle of Gümbel, are only seen when the summit-plates of the spicules have been partially or entirely removed by natural or artificial means, and they then appear as four short rays radiating from a common centre, which also coincides with the centre of the head plate. Their arrangement is precisely similar to that in *Ischadites*, but they are very much smaller and slenderer in proportion to the dimensions of the vertical ray of the spicule, than in this latter genus, and consequently less resemble normal hexactinellid spicules. The horizontal rays of each spicule, as in *Ischadites*, are distinctly free from the rays of adjoining spicules, and very frequently they overlap each other and rest side by side. This fact is clearly recognized by Gümbel*; but Billings† supposed that they were connected with the rays of adjoining spicules, though they are shown in his diagram as meeting each other, but not in contact.

In the silicified specimens of *R. occidentalis* from which Billings's description was taken, the extremities of the spicular rays appear to be invariably incomplete after treatment with acid, so that he had himself no opportunity of observing their natural termination. In the same specimens, the peculiar fact is shown that the horizontal spicular rays are not all strictly in the same plane, or at right angles to the vertical ray, for while this is the case with the lateral rays, the distal and proximal rays are slightly oblique, so that the proximal ray, or that pointing to the nucleus, projects slightly upwards, while the distal or opposite ray extends slightly downwards (Pl. XXXVII. figs. 3 *l*, *m*). The four horizontal rays are traversed by axial canals, which unite with each other and with the canal of the vertical ray at the central point of junction of the spicule. I have not been able to detect more than four horizontal rays with their corresponding canals in any of the specimens of *R. occidentalis*, and Gümbel refers to four only in the specimens which he examined; but in the cast of a specimen from Ober-Kunzendorf figured by Dames‡, and which through the kindness of Prof. F. Römer I have had an opportunity of seeing, there are, in addition to four well-marked horizontal rays, small subordinate rays apparently radiating from the central point of junction of the spicule, in a similar manner to those of certain spicules of *Holasterella conferta* §, Carter.

It will not be necessary to again describe the different aspects of the surface of the organism in different conditions of fossilization, since the subject is referred to in treating of *Ischadites*, and there is no difference in the aspect of *Receptaculites* under similar conditions; but whilst no silicified examples of the former genus are known, they are not uncommon in one species of *Receptaculites*

* Beitr. p. 29, t. A. fig. 4 *b*. † Pal. Foss. vol. i. p. 380.
‡ Zeitsch. d. deutsch. geol. Gesellsch. Bd. xx. p. 484, t. 10. f. 1.
§ See Cat. Foss. Sponges, Brit. Mus. p. 152, t. 32, f. 2.

and exhibit the structure more clearly than any of the calcitic specimens.

The vertical spicular ray in *Receptaculites* (the cylindrical tube or hollow spicula of Billings; the Säulchen of Gümbel) is usually straight, and nearly cylindrical for the greater part of its length, but near its junction with the horizontal rays it somewhat suddenly contracts to form a short neck, and above this it expands and gives off the four horizontal rays already described, which are capped by the summit-plate. At its opposite extremity, the vertical ray is modified to form the substance of the inner layer. In most, if not all, of the species of *Receptaculites*, the vertical ray exhibits the same peculiar neck-like contraction. In none of the silicified specimens which I have examined are there any traces of the so-called "intermediate small connecting stolons along the columns" mentioned by Salter *, which probably arise from chance fragments of silica in the interspaces between the columns. The surface of the vertical ray appears to have been smooth, although in some cases the mould exhibits slight transverse furrows, but whether these markings arise from the fossilization, or indicate constrictions in the rays, I am unable to determine. The vertical ray is also penetrated by an axial canal which connects with the canals of the horizontal rays above and with the horizontal canals of the inner layer below. The rays are, in conformity with the thickness of the specimen, relatively short near its nucleus, and of greater and nearly equal length in its central and peripheral portions. As seen in sections of decalcified specimens, the vertical rays appear as so many curved rows of vertical pillars, each of which is separated from those surrounding it by an interspace of about half its own thickness, and each spicule composed of the vertical and horizontal rays and the summit-plate is entirely independent except at its basal end, where, as already stated, it is united to and forms part of the inner layer.

The structure of the inner or upper layer of *Receptaculites* (endorhin of Billings; innere Hülle, Gümbel) has not been ascertained so definitely as that of the exterior portion of the organism, owing to the rare cases in which it is preserved. The descriptions given of it by Dames and Gümbel, which have been taken from thin sections or etched surfaces of *R. Neptuni*, do not agree with those of Billings, which are based on the study of silicified specimens of *R. occidentalis*. In specimens of *R. Neptuni* from Belgium which I have seen, this inner layer is only shown in vertical sections as a thin delicate line of iron peroxide in which no structure whatever is visible; but in a Canadian example of apparently the same species, the inner layer, though only consisting of iron peroxide, exhibits well-marked perforations, the same as in *R. occidentalis*. Again, in another specimen of this species from Devonshire, the inner ends of the vertical rays appear to pass into circular or rhomboidal plates, but I cannot determine if these are united together to form a continuous layer.

In *R. occidentalis*, the inner or upper layer appears to be funda-

* Canad. Org. Rem. dec. 1, p. 45, t. 10. f. 4*a*, *b*.

mentally composed of modified extensions of the basal ends of the vertical rays of the spicules. Instead of tapering to a pointed extremity as in *Ischadites* and *Acanthochonia*, the vertical rays, in this species of *Receptaculites*, continue cylindrical to near their basal extremities, and then abruptly expand into horizontal plates. These plates have four straight sides, but at each of the corners there is a semicircular or semielliptical vertical hollow. Each plate appears also to be traversed by four horizontal canals, which radiate from the centre, where they are in connection with the canal of the vertical ray. The inner surface of the plate is flat; the upper surface, or that which is exposed in the cup or disk, is oftentimes convex and deeply ridged and furrowed (Pl. XXXVII. figs. 3 *c–g*). These plates are intimately united together so as to form a continuous inner or upper layer. The delimitations of the separate plates in this layer are not always preserved; in many specimens they appear to have been completely obliterated, and the layer resembles a continuous plate with numerous cylindrical or elliptical canals which penetrate through it at right angles. These canals are formed by the apposition of the vertical hollows in the corners of the plates of which it is primarily built up. On the inner side of the plate, facing the interior cavity, the canal-apertures are evenly circular or elliptical, but on the outer surface they frequently enlarge and extend into irregular open channels, which run between the canals and across the intermediate surface. The horizontal canals in the substance of each plate also appear, when the plates are amalgamated together in one layer, to intercommunicate together. This inner layer, though primarily formed of plates developed from the basal ends of the spicules, appears, when complete, to form an independent membrane, and to be distinct from the vertical rays, which readily break off at their junction with its inner surface. It is thus entirely different from the spicular plates which compose the outer or under surface of the organism, which are clearly distinct from each other and form the head of each separate spicule. The inner surface of a silicified example, when freed from the matrix, shows indeed, at a superficial glance, an apparent division into component plates, but when closely examined this effect is seen to be produced by the regular lines of perforations and the deep furrows connecting them.

It will be seen that my observations of the structure of the inner layer or endorhin of *R. occidentalis* agree with those of Mr. Billings. The diagram* which this author has given of the body-wall of *Receptaculites*, conveys an erroneous idea of the structure of the inner wall on account of the greatly exaggerated distances between the columns or vertical rays. In reality these are only about one half their own diameter apart; and if, in the limited interspaces between them, room is allowed for the vertical canals, it will be seen that the horizontal canals are necessarily very short.

Gümbel's † description of the inner layer of *R. Neptuni* varies

* Pal. Foss. Can. p. 382, fig. 357.
† Beitr. pp. 30, 31.

considerably from that of *R. occidentalis.* He states that the vertical spicular rays (Säulchen) increase in thickness towards the inner integument, near to which they contract and again expand to form a support to the calcareous plate proper of the inner layer. The expansion however is not decidedly four-armed, but a greater number of thicker irregular branches, with apparently lateral branchlets, radiate from the pillar. These are not united by growth with the main plate. Small canals also run through the plates, though they are only recognizable with difficulty. Thus the plates of the inner integument consist of a principal calcareous layer and a radiating under layer extending from the pillars. There is also a very thin surface layer of daık carbonaceous material resembling that of the outer integument, but with a distinctly marked granular surface. Gümbel further states that, after repeated careful observations, he is firmly convinced that there does not exist any perforations in the angles of the plates of the inner integument of *R. Neptuni*, and that these perforations cannot be considered as one of the characters of the genus. He thinks, however, that communication with the exterior took place by means of small channels between the sutures of the plates, into which also the branching canals from the pillars certainly extended.

Notwithstanding the apparently fundamental differences in the structure of the inner layer of *R. occidentalis* and that of *R. Neptuni*, I am still of opinion that the characters shown in the silicified examples of the former species probably represent with greater accuracy those of the genus than those which Gümbel has described in *R. Neptuni*. It is quite possible that in the replaced calcified specimens, which can only be seen in sections or etched surfaces, the real characters of the inner layer may be so concealed or altered as not to be recognizable, and that therefore greater dependence should be placed on the silicified examples, in which all the other characters of the organism are better preserved than in the examples with skeletons of crystalline calcite.

The characters of the genus *Receptaculites* may be briefly summed up as follows:—Cup- or platter-shaped bodies of considerable size, with walls of definitely arranged spicules. The outer surface is formed by the rhomboidal head-plates of the spicules; beneath these are the horizontal rays, and robust subcylindrical vertical rays, which are connected with an inner layer or perforated plate. Communication with the exterior was carried on between the margins of the summit-plates of the spicules on the outer surface, and through the cylindrical canals of the inner surface layer, or, according to Gümbel, through intermarginal canals.

From all the other genera of the family, *Receptaculites* is distinguished by the possession of an inner layer.

It seems unnecessary to give a detailed history of the genus, since this has been sufficiently shown in the previous part of the paper. By the earlier authors, Defrance and Eichwald, the hollow casts of the vertical spicular rays were regarded as polyp-cells and the form was placed amongst the Corals; it was next placed by

Salter amongst the Foraminifera, as allied to the family of the Orbitolitidæ; Billings placed it with Sponges on account of a supposed resemblance to the gemmulæ of *Spongilla*; it was again relegated to the Foraminifera by Dames, who placed it as the type of a family near the Orbitolitidæ; and later Gümbel retained it in the same order, but included it in the family of the Dactyloporidæ. But since the typical forms of that family have been proved to be calcareous Algæ, the systematic position of *Receptaculites* has been regarded as very doubtful, though F. Römer still retains it provisionally amongst the Foraminifera, as also does such an authority on this order as Rupert Jones. Zittel, however, rejects it from the Foraminifera, and leaves its position uncertain.

IV. The Affinities and Systematic Position of the Receptaculitidæ.

The different genera of this family have been variously referred, by those who have studied their structures, to such widely diverse divisions of the animal kingdom as Foraminifera, Sponges, Corals, Cystideans, and Ascidians, and they have also been supposed to belong to the vegetable kingdom and referred to fossil cones. It is not necessary to dwell on their supposed relationship to the three last-mentioned groups of animals, since it is now generally recognized to have been based on an entire misconception of the true structure of these fossils. The resemblance to Corals originated in the idea that the hollow cylindrical cells, which are really only the casts of the vertical spicules, were in fact the cells inhabited by the polyps; and their supposed likeness to Cystideans and Ascidians arose from a fancied similarity in the character of the spicular plates of the outer surface to those constituting the external skeleton of these animals. Later writers have either referred them to Foraminifera or Sponges. The prevalent opinion of palæontologists to within a recent period has been in favour of their alliance to the first of these two orders; but since the particular division of the Foraminifera in which Gümbel placed them has been shown to be of plant and not of animal origin, the opinion has been expressed that this family should be considered as an extinct group without any recognizable near affinities to any other division of the animal kingdom. It seems difficult to understand the reasons for ranging any of the genera of this family under Foraminifera, since in no single important feature is there any resemblance to typical examples of this group; neither in form, size, nor internal structure is there any correspondence with either fossil or recent Foraminifera, and only on the supposition of Salter * that the now solid parts of the organism were originally filled with living sarcode, whilst the intermediate spaces were occupied by the calcareous skeleton, could a strained resemblance be found between *Receptaculites* and the family of the Orbitolitidæ. Salter † himself,

* Canad. Org. Rem. dec. 1, p. 46.
† Mem. Geol. Survey, 1861, p. 136.

however, afterwards relinquished this comparison, and ranged this genus under Sponges. Even accepting Gümbel's own definition, that the skeleton in this genus consists of outer and inner walls composed of individual plates supported by pillars extending between them and enclosing the sarcode, there does not appear to be any feature distinctively resembling foraminiferal structure, for no undoubted Foraminifer possesses walls of individual plates and a relatively enormous interior cavity without any partition into chambers. If, however, in *Receptaculites* no resemblance to Foraminifera is manifest, still less support for this comparison is afforded by the structure of the other genera of the family, in which, as we have seen, there is no skeletal inner wall.

It cannot be said, however, that those who advocated the relationship of this family to Sponges brought forward any satisfactory proofs of the alliance. Thus, for example, *Sphærospongia tessellata*, Phill. sp., was regarded by Dr. Bowerbank and Mr. Austin as a calcareous sponge, on the ground that the spicular plates of the outer surface were similar in structure and arrangement to those of *Dunstervillia* (*Sycandra*, Häck.) *elegans*, though there is no reason for supposing that the plates of *Sphærospongia*, like those of *Dunstervillia*, were made up of a multitude of microscopic acerate spicules; and further, whilst in the former genus there are large spicular rays beneath the plates, in the latter there are cylindrical or conical tubes bounded by spicules; nor can any definite homology be shown between the structure of *Receptaculites* and its allies and that of the gemmulæ of fresh-water sponges, with which it was compared by Mr. Billings. Independently of the enormous disproportion in size, in no case do the minute birotulate spicules of these latter bodies assume the regular form of the spicules in the Receptaculitidæ, that is of a summit-plate, with four horizontal rays beneath, and an elongated vertical ray either terminating freely or connected with a continuous inner plate. It is only in the genus *Ischadites*, moreover, that there is an approximation in outer form to the gemmulæ of *Spongilla*, for we have seen that in *Acanthochonia*, *Receptaculites*, and probably also in *Sphærospongia*, the outer form is either cup- or platter-shaped.

But though Mr. Billings's comparison of *Receptaculites* to these minute gemmulæ cannot be entertained, yet to him is due the merit of having recognized a resemblance between what he termed the cylindrical shaft and stolons of this genus and the spicules of sponges. He states * that "each tube, with its cylindrical shaft and plate at each extremity, resembles not remotely a birotulate spiculum, or it might perhaps with more probability be described as consisting of two spicula united at their points. Thus the ectorhinal plate with the four stolons may be a peculiar form of the foliato-peltate spicule. The cylindrical shaft may be a spiculum approaching the acuate or acerate varieties, with its point inserted into the nucleus of the foliato-peltate spiculum."

The knowledge that has been gained in the last few years of the

* Pal. Foss. Can. p. 387.

structure of recent and fossil siliceous sponges, makes it easier now to institute a comparison between them and the Receptaculitidæ than at the time when Mr. Billings wrote, and I now propose to show the extent of the resemblance.

First as regards the outer form. Though this is such a variable feature in sponges that but little importance can be attached thereto, yet the fact that in outer form the various members of the Receptaculitidæ are either platter- or cup-shaped, or conical, enclosing a central cavity with a summit aperture, is not without its significance when we consider that these are the commonest forms assumed by both recent and fossil sponges. Another feature too in which the Receptaculitidæ show a resemblance to undoubted Palæozoic sponges is the uniform absence of any point of attachment, so that the organism was perfectly free; thus contrasting with the usually attached Mesozoic and recent sponges. Ferd. Römer * has called particular attention to this fact in connection with the Palæozoic genera *Astylospongia*, *Aulocopium*, and *Astræospongia*, and also to the further circumstance, that the Palæozoic sponges do not form united colonies, but are distinct individuals, and this is the case also with all the members of the Receptaculitidæ.

The only structural elements of the skeleton of the Receptaculitidæ (if we except the inner layer of the genus *Receptaculites* itself) consist of the spicules, and these appear to me to be distinctly homologous with the spicules of hexactinellid sponges. The similarity between the four horizontal rays and the vertical rays of the spicules of this family and the same elements of the spicules of ordinary hexactinellid sponges is so close that it cannot fail to be recognized. The rays radiate at right angles to each other from a common centre; they gradually taper from the centre to their extremities (with the exception of the vertical ray in *Receptaculites*, which connects with the interior plate); and each ray is traversed by an axial canal which unites with the canals from the other rays in the central junction of the spicule. A resemblance (though not to hexactinellid spicules) is also presented by the peculiar neck-like contraction of the vertical spicular ray immediately beneath the horizontal rays in *Receptaculites*, to the spicules of Cretaceous examples of *Geodia*, such as *Geodia clavata*, Hinde †, and *G. coronata*, Hinde, in which there is a similar contraction immediately beneath the head-rays. In *Ischadites* and *Acanthochonia*, five rays of the normal hexactinellid spicule are well developed and terminate freely in obtusely pointed extremities, whilst in *Sphærospongia* and *Receptaculites* only four rays are normal, the fifth or vertical ray in the former genus being apparently represented only by a short blunted process, whilst this ray in the latter genus is not free at its basal extremity, but organically attached to an inner plate.

But though the analogy between the horizontal and vertical rays of the spicules and those of recognized hexactinellid sponges is readily apparent, yet this is not the case with the summit-plate or

* Leth. Pal. Th. i. p. 306.

† Fossil Sponge-spicules from the Upper Chalk, pl. ii.

head of the spicules, which in all the Receptaculitidæ is either rhomboidal or hexagonal in figure, very thin at its margins, but thicker at the central junction of the spicule, where it unites with the other rays. By those who have written on the group, this spicular plate has been regarded as a distinct integral portion of the organism, independent of the rays beneath, whereas it appears to me to have formed a constituent part of the spicule with which it was connected at the central point of junction with the horizontal and vertical rays. If the plate were separate from the rest of the spicule and formed by itself a dermal plate or surface-covering over the organism, it is difficult to explain how it would have been retained in its position ; in the instances in which it is absent, this arises from weathering or the effects of fossilization, which have similarly affected the rays beneath.

In no other hexactinellid sponge, so far as I am aware, are there any spicules with similarly constituted head-plates ; in many, however, no sixth or summit-ray is developed; but in some of the abnormal spicules of the Carboniferous sponge, *Hyalostelia Smithii**, Young and Young, sp., the sixth ray is in the form of a rounded knob. We have only to consider that the sixth ray in the spicules of the Receptaculitidæ, instead of being contracted to a knob merely, as in the Carboniferous sponge, has been developed in a horizontal direction, and by additions to its margins has assumed the regular rhomboidal or hexagonal figure by which it is adapted to fit in with the adjoining spicular plates to form an exterior layer to the organism. Strong confirmatory evidence of the theory that the summit-plates of the spicules are modifications of the sixth ray in the ordinary hexactinellid spicule, is afforded by the small blunted knob which projects in the centre of these summit-plates in the best-preserved examples of *Sphærospongia*, and traces of which are also present in *Acanthochonia*. In these forms we find the commencement of the sixth or summit-ray in the small central knob, from which, as a centre, the plate is developed horizontally by successive marginal additions.

But though, in regular hexactinellid sponges, spicules with horizontal summit-plates are unknown, yet in certain lithistid sponges there are spicules with specially modified summit-plates, adapted for the outer surface of the sponge, which may, though in a somewhat distant degree, be compared with the spicular plates in the Receptaculitidæ. Thus, in the Cretaceous genera *Plinthosella*, Zitt.†, *Ragadinia*, Zitt. ‡, and *Pholidocladia*, Hinde, and in the existent genus *Discodermia*, Bocage §, the outer surface of the sponge is covered with a layer of minute flat scale-like spicules, some with entire, others with lobate margins. In some a small shaft projects at right angles from the centre of the underside of the spicule, whilst

* See Cat. Foss. Sponges Brit. Mus. pl. 32. f. 1.

† See Hinde, Foss. Sponge-spicules, t. 4. f. 35–46; and Cat. Foss. Sponges, pl. 20. f. 4 *a*.

‡ Cat. Foss. Sponges, pl. 20. f. 5 *b*.

§ See Carter, Ann. & Mag. Nat. Hist. ser. 5, vol. vi. pl. 8.

in others it is absent, and only the plate remains. Now these scale-like spicules are, in reality, modifications of three of the four divergent rays of the normal lithistid spicule, and they vary as much from the usual development of these rays as do the summit-plates in *Receptaculites* from the normal sixth ray of the hexactinellid spicule. These lithistid surface-spicules show at least the possibility that under special conditions the normal cylindrical rays may develop into horizontal plates; and if this is the case in lithistid sponges, there is reason to supose that a similar change might take place in hexactinellids as well. But though it may be conceded that no close resemblance exists between the summit spicular plates of the Receptaculitidæ, and the modified sixth ray of the normal hexactinellids, yet this difference is insufficient in my opinion to outweigh the close similarity which occurs in other rays of the spicules.

In addition to similarity of form, the disposition of the spicules in the Receptaculitidæ closely resembles that in some normal hexactinellid sponges. This is most strikingly shown by a comparison with the Cretaceous genus *Cincliderma*, Hinde *, in which there is a surface-layer of five-rayed spicules; four of the rays are so arranged horizontally that their extremities overlap each other, and form definite rectangular interspaces, of a similar character to those which are produced by the horizontal rays in *Ischadites*; whilst the fifth ray projects invariably in the same manner as the vertical spicular ray in the latter genus. In the Silurian hexactinellid genus *Plectoderma*, Hinde†, there is also a surface-layer composed of spicules with four horizontal rays and entering vertical ray, but there is not the definite quadrate arrangement present in *Ischadites*. In the Cambrian hexactinellid genus *Protospongia*, Salt. ‡, the surface-squares are formed also by the four horizontal rays, and in this genus the fifth ray of the spicule is not developed, thus resembling *Sphærospongia*. The resemblance of the surface of this sponge to that of *Receptaculites* induced Gümbel to place it in the same group with the latter. The Devonian genus *Dictyophyton*, Hall, has also the same regular arrangement of the surface into quadrate interspaces, and though the spicules in this genus have not yet been discovered, there can hardly be a doubt that they were similar to those of *Protospongia* and *Plectoderma*. It is not without significance that, both by McCoy and by Ferdinand Römer, examples of *Dictyophyton* have been placed in the genus *Tetragonis*, Eichwald, which, as we have seen, is synonymous with *Ischadites*, Murch.

With respect to the relative dimensions of the spicules of the Receptaculitidæ, and those of recognized hexactinellid sponges, it may be stated that though in some of the species of *Receptaculites* itself, the individual spicules are considerably larger than in any known sponge, yet there is not so great a disproportion as to render a comparison fanciful or extravagant. Thus, in *R. arcticus*, Etheridge, the largest form of the family known, the spicules are from 10 to 18 millim. in length, and about 3 millim. in thickness;

* Cat. Foss. Sp. pl. 28. f. 1 *a–d*.
† Id. t. 31. f. 1. ‡ Id. pl. 28. f. 2.

whereas in hexactinellid sponges of the genera *Hyalostelia*, Zitt., and *Holasterella*, Cart., the spicules reach a maximum length of 9 millim., and a thickness of ·5 to ·9 millim. But, on the other hand, in the genus *Ischadites*, the spicules are not at all larger, and many of them are in fact much smaller than the surface-spicules of Palæozoic and Jurassic hexactinellid sponges.

The only other structural feature which remains for comparison is the inner or upper surface-layer which, as we have seen, is only developed in the genus *Receptaculites*. As already mentioned, the structure of this plate in the typical example of the genus, *R. Neptuni*, is not definitely known, but in the allied species, *R. occidentalis*, it consists of a continuous layer or plate, perforated vertically by canals giving access to the interior of the specimen, and also with short horizontal canals crossing each other at right angles, penetrating its substance, and communicating at their points of intersection with the canals in the vertical rays of the spicules. In its complete form this inner plate appears to me to be analogous to that which forms the inner or upper wall of the Jurassic hexactinellid genus *Porocypellia*, Pomel*.

The circulation of water through the organism in the Receptaculitidæ appears to have followed a similar course to that occurring in sponges generally. It seems to have found admission through the narrow linear apertures beween the margins of the spicular plates of the outer surface, and after passing through the interspaces between the spicules, which in the living state were lined by the sarcode, to have found its exit through the aperture in the summit of *Ischadites*, or through the perforated inner layer in *Receptaculites*, or freely into the open cups of *Acanthochonia* and *Sphærospongia*.

The resemblances referred to above appear to me to justify the conclusion that the Receptaculitidæ constitute a family of siliceous Hexactinellid Sponges. The body-walls are composed of spicules of the hexactinellid type, but modified by the development of regular rhomboidal or hexagonal plates in place of the head-ray of the normal spicule. The spicules are arranged in definite order, so that the summit-plates form oblique, curved, or spiral rows, whilst the four horizontal rays mark radial and concentric lines. In one genus the body-wall is bounded by a perforated inner layer.

The character and position of the spicules ally the family to the Palæozoic genera *Protospongia*, *Dictyophyton*, and *Plectoderma*. As, however, the component spicules of the skeleton do not appear to have been connected together, otherwise than by the sarcode (save in the genus *Receptaculites*), the family would be ranked in Zittel's suborder Lyssakina.

If in some structural features the Receptaculitidæ stand apart from fossil sponges of a more recent geological horizon, other undoubted Palæozoic sponges also exhibit abnormal characters. Thus it is only in the genera *Protospongia*, Salt., and *Dictyophyton*, Hall, that there exists a surface-structure of definite larger and smaller quadrate areas; in *Astylospongia*, F. Röm., the canal and spicular struc-

* See Zittel, Neues Jahrb. 1877, p. 364, t. 5. f. 1 *a*.

tures are of such a character as to render it doubtful whether the genus should be ranked under Hexactinellids or Lithistids; in *Astrœospongia*, F. Röm., the form and disposition of the spicules differ so much from those of any other genus, that, though ranged under the Hexactinellidæ, it would be better placed as the type of a distinct order; and, finally, in the genera *Hyalostelia*, Zitt., and *Holasterella*, Carter, there is an extraordinary diversity in the form and size of the spicules. These facts clearly show that the structure of the principal genera of Palæozoic sponges varies widely from that of more recent types of the class, and materially lessen the weight of any objections which may be urged against the inclusion with them of the Receptaculitidæ.

V. Geological Distribution.

The earliest known member of the group has been described by Billings from the Calciferous (Ordovian or Lower Silurian) of the Mingan Islands, Lower St. Lawrence. In the Trenton limestone of Canada, and its equivalent, the Magnesian or Galena limestones of Illinois and Wisconsin, examples of *Receptaculites* are abundant, and the genus *Ischadites* makes its appearance here, and in Lower Llandeilo beds in Wales. *Receptaculites* also occurs in the Orthoceratite limestone of Esthonia and in Lower ? Silurian of the Arctic regions.

In the higher division of the Silurian proper, the genus *Ischadites* is the most abundant. It is present in Wenlock and Ludlow strata in North Wales; in the Dudley and Malvern areas; in the island of Gotland and the Russian Baltic provinces; in the Niagara group of Ohio, Wisconsin, and Illinois, and at a slightly higher horizon at Gaspé, Gulf of St. Lawrence. *Receptaculites* is present in the Upper Silurian of Australia, and doubtfully also in Canada. The genus *Acanthochonia* occurs in the Silurian proper, Etage E. of Barraude, in Bohemia.

In the Devonian formation the genus *Receptaculites* is present in the middle division; in Mudstone Bay, Devonshire; in Belgium, the Eifel district, and also in the Rhenish province on the right side of the Rhine; at Ober-Kunzendorf in Silesia, and in Canada. The genus *Sphœrospongia* occurs in Devonian limestones near Plymouth, also in Nassau and the Eifel, in Germany, and in the Urals, in Russia. *Ischadites* has not yet been found in the Devonian.

From Carboniferous strata only a single species of *Receptaculites* ? from Silesia has been recorded by F. Römer, and no member of the group appears at any higher horizon.

All the examples of this family occur in limestone or in fine calcareous shales or mudstones, which probably indicate a habitat of deep or moderately deep water. It is evident, also, from the perfect manner in which the lightly attached spicules are preserved in their respective positions that the organism must have lived and been interred at undisturbed depths.

VI. Genera not belonging to the Group, but usually included therein.

A notice of the family would be incomplete without referring to certain other genera which have been, by various palæontologists, included in it, and indicating the reasons for their omission. Beginning first with Eichwald*, we find that, in addition to the genera herein recognized as proper to the family, he has included two others, *Mastopora* and *Escharipora*, Hall. The former genus is undoubtedly congeneric, if not identical, with *Nidulites favus*, Salt., and will presently be mentioned in connexion with *Cyclocrinus*; the latter name is applied by Hall to a Polyzoon, but the form which Eichwald regarded as identical with Hall's type species has certainly no relation to it, nor to the Receptaculitidæ, though I am unable to judge from the figure and description to what group it may belong.

F. Römer† has embraced in the Receptaculitidæ, besides the recognized genera, the following: *Cyclocrinus*, Eichwald (=*Nidulites*, Salt.), *Pasceolus*, Bill., and *Archæocyathus*, Bill., though he acknowledges that these forms stand in very various degrees of relationship to the typical genera of the group. To these Zittel‡ has further added *Goniolina*, D'Orb., *Archæocyathellus*, Ford, and *Protocyathus*, Ford.

From an examination of specimens of *Cyclocrinus Spaskii*, Eichw., from the Silurian at Anticosti, and of *Nidulites favus*, Salt., from Lower Llandovery strata at Haverfordwest, and from Mullock Hill, Ayrshire, I am unable to see any structural resemblance in them to any of the Receptaculitidæ. The type of *Cyclocrinus* is a spherical body whose outer surface is covered with regularly arranged cup-like depressions, rounded below, with a small central circular aperture which opens into the central hollow body-cavity, and with pentagonal or hexagonal margins. Fitting into these small cup-like depressions are short, hollow, prismatic cells with rounded bases, which, like the cups, are perforated. I have not seen in the cups any traces of the short rays figured by Eichwald §; their absence, however, may be owing to the fossilization of the specimens. There is no feature in these fossils analogous to the spicules of the Receptaculitidæ; the structures which F. Römer compares to the vertical spicular rays in *Ischadites* appear to me to be prismatic cells, or short tubes with open surface-apertures. Though convinced that *Cyclocrinus* and its equivalent, *Nidulites*, have no connexion with *Ischadites* and its allies, I am not prepared to offer any suggestion as to their real characters.

The genus *Pasceolus*||, Billings, is just as enigmatical as *Cyclocrinus*. It has been compared with *Sphærospongia*, Pengelly; but

* Lethæa Rossica, vol. i. pp. 434, 435.

† Lethæa Pal. Th. i. p. 286.

‡ Handb. der Pal. vol. i. p. 728.

§ Leth. Rossica, vol. i. p. 638, Atlas, t. 32. f. 21 *b*.

|| Can. Geol. Surv. Rept. 1856, p. 342; Pal. Foss. Can. vol. i. p. 390, f. 366; Cat. Silur. Foss. Anticosti, p. 69.

after studying very carefully examples of Billings's type species, *P. Halli*, which I collected myself from Silurian strata at Anticosti, I can positively assert that there is nothing in common between the structure of this species and that of *Sphærospongia*. I am also able to affirm the correctness of Billings's latest description of this form, that its surface consists of small convex elevations, composed of a very thin minutely wrinkled layer, which is sometimes translucent. There is no evidence that this surface-layer was divided into distinct plates, or that the elevations were perforated. Certainly, in *Pasceolus* there is nothing to correspond with the spicules of the Receptaculitidæ, and no analogy appears to me to exist between these forms. I may also here mention that two forms placed by Salter in the genus *Sphærospongia*, *S. hospitalis* * and *S. melliflua* †, have no affinity with the type of this genus, *S. tessellatus*, Phill. sp., but are probably related to *Pasceolus*, Bill. No reliance can be placed on Salter's figure of *S. hospitalis* which is evidently diagrammatical only.

F. Römer has ranked *Archæocyathus* ‡, Bill., in the Receptaculitidæ from its possessing an outer and inner wall connected by vertical lamellæ which are thought to correspond with the connecting pillars, or vertical spicular rays of *Receptaculites*. There is, however, no real analogy between these structures, and it seems to me probable that, if a sponge at all, *Archæocyathus* will be found to be composed of minute spicules similar to those figured by Billings in *A. minganensis*. *Archæocyathellus* §, Ford, and *Protocyathus* ||, Ford, appear to be closely allied to *Archæocyathus*.

I am unable to express any opinion as to the resemblance of the genus *Goniolina*, D'Orbigny ¶, to members of this group, since the description given of it by that author is limited to the surface-characters of the fossil.

VII. Revision of the Species.

In the absence of any satisfactory generic definitions, the same forms have been placed by different authors sometimes in one and sometimes in another genus. I have below endeavoured to arrange them in accordance with the characters which I have assigned to the different genera. It will be seen that in several instances I have comprehended in a single species forms which have hitherto been placed under several; but the numerous gradational differences in minute details of outer form and size in the large suite of specimens which I have examined, clearly show that these variations are not of the specific value which has been placed on them.

* Cat. of Cambr. & Silur. Foss. Univ. Cam. p. 40.
† Pal. Niti, p. 48, t. 5. f. 4, 5, 6.
‡ Pal. Foss. Canada, vol. i. p. 354, figs. 342–344.
§ Amer. Journ. Sci. 1873, vol. v. p. 211.
|| Id. 1878, vol. xv. p. 124. ¶ Prodr. de Pal. vol. ii. p. 41.

Genus Ischadites, Murch.

Ischadites Kœnigii, Murch. (Pl. XXXVI. figs. 1, 1 *a–o*.)

1839. *Ischadites Kœnigii*, Murch. Silurian System, p. 697, t. 26. f. 11.
1842. *Receptaculites Bronnii*, Eichw. Urwelt Russlands, 2 Heft, p. 80, t. 1. f. 9.
1852. *Selenoides iowensis*, D. Dale Owen, Geol. Survey of Wisconsin, &c., p. 587, t. 2 B. f. 13.
1858. *Receptaculites Eichwaldi*, Schmidt, Die silur. Formation von Ehstland, &c., p. 232.
1860. *Receptaculites Bronnii*, Eichw. Lethæa Rossica, vol. i. p. 429, t. 27. f. 2 *a*, *b*.
1860. *Ischadites Eichwaldi*, Eichw. id. p. 436, t. 27. f. 3 *a*, *b*, *c*.
1865. *Receptaculites Jonesi*, Bill. Pal. Foss. Can. vol. i. p. 385, f. 363, & p. 389, f. 365.
1865. *Receptaculites iowensis*, Bill. id. p. 385, f. 364.
1866. *Ischadites antiquus*, Salt. Mem. Geol. Surv. Gt. Brit. p. 282, f. 4.
1867. *Ischadites tessellatus*, Salt. MS. (see Siluria), 5th ed. p. 509.
1868. *Receptaculites globularis*, Meek & Worth. Geol. Surv. Illinois, vol. iii. p. 301, t. 2. f. 2 *a*, *b*,
1868. *Receptaculites* —— sp.?, Meek & Worth. id. p. 301, t. 2. f. 1 *a*, *b*.
1873. *Ischadites Kœnigii*, Salt. Cat. Sil. & Cambr. Fossils, Cambridge, p. 100.
1875. *Receptaculites ohioensis*, Hall & Whitf. Geol. Surv. Ohio, Pal. vol. ii. p. 123, t. 6. f. 1.
1875. *Receptaculites subturbinatus*, Hall, 27th Annual Report State Museum, t. 3. f. 1, 2, 3.
1875. *Ischadites Kœnigii*, Gümb. Beitr. p. 43, t. A. f. 28, 29, 30.
1878. *Ischadites Kœnigii*, Nich. & Ether. Silur. Foss. Girvan, p. 20.
1878. *Ischadites Kœnigii*, Quenst. Petref. Deutsch. Bd. v. p. 592.
1880. *Ischadites Kœnigii*, Zitt. Handb. der Pal. vol. i. p. 728.
1880. *Ischadites Kœnigii*, F. Römer, Leth. Pal. Th. 1, p. 291.
1882. *Ischadites Kœnigii*, Jones, Cat. Foss. Foram. Brit. Mus. p. 2.

Sponges either ovate, or more or less depressed, conical; small individuals measuring 4 millim. in height by 6·5 millim. in width, and large, 40 millim. by 45 millim., with numerous gradations between these extremes. The base is either conical with an obtuse termination, flattened, or concave. In the examples with flattened or concave bases, the greatest width is attained near the base itself; whilst in the forms with a conical base the specimen is widest about midway between the base and the summit. The summit is generally slightly truncate or evenly rounded; occasionally there is a short elevated neck. The summit-aperture varies from 2 to 5 millim. in width. The summit-plates of the spicules vary from 2 to 4 millim.

in width in the zonal region, where they are largest, to from ·25 to ·4 millim. in the vicinity of the summit-aperture. The character and position of the spicules are referred to in the generic description. The longest of the vertical spicular rays which I have seen vary from 7 to 10 millim.

This species varies considerably in size and in details of outer form; but in the large collection which Prof. Lindström sent me from the isle of Gotland there are numerous transitional forms between the extremes, so that it is impossible to regard them as more than a single species, and in this gradational series there are specimens closely corresponding, not only to Murchison's type, but also to the forms which by Eichwald, Salter, D. Dale Owen, Meek, Billings, and Hall have been described as distinct species. The diversity of synonyms given to this single species can be further explained by the extraordinary difference of aspect which it presents under different conditions of preservation.

Eichwald recognizes the similarity of *R. Bronnii* to *I. Kœnigii*, but places it as a different species because it is not compressed, and the surface-markings are absent. The figure of *Selenoides iowensis*, D. Dale Owen, represents the concave basal surface of an individual. *R. Jonesi*, Bill., is a very similar form to Owen's *iowensis*; the figure of its vertical section clearly shows the free termination of the vertical rays of the spicules. *T. antiquus*, Salt., which is in the Jermyn Street Museum, is simply the impression of a portion of the outer surface of an individual which shows no character to distinguish it from *I. Kœnigii*. The MS. name of *S. tessellatus*, Salt., appears to have been given to a specimen which is also in the Jermyn Street Museum, and which cannot be distinguished from Murchison's type. Even if this had been a valid species, the specific name would require to be changed, since it had been previously employed by Winchell and Marcy for an example of this genus.

The specimens figured under *Receptaculites globularis*, and *R.*——? by Meek and Worthen, represent the concave bases and the lateral areas of two individuals. These authors appear to have followed Hall in regarding the base as the summit of the specimen, whilst they describe the summit, which, as shown by the figures, is obscured by matrix, as a broad base of attachment. The *R. ohioensis* of Hall and Whitfield is merely an imperfect cast of an individual of this species. The base of *R. subturbinatus*, Hall, is represented as the summit of the specimen.

Distribution. Lower Llandeilo: Garn Arenig, Wales. Woolhope beds Malvern: near Buildwas. Wenlock shales and limestone: Dudley, Usk, Malvern, Walsall; Balcletchie and Penkill, Ayrshire. Lower and Upper Ludlow: Ledbury and near Ludlow: Pentland Hills. Orthoceratite limestone: Reval. Lowest beds of the Silurian, at Visby, Westergarn, near Klintehamn, Djupvik, in the isle of Gotland. Galena Division of Lower Silurian at Scale's Mound, Illinois, and in Iowa. Niagara group at Waldron, Indiana; Yellow Springs, Ohio. Lower Helderberg Group at Gaspé, province Quebec.

Ischadites Murchisonii, Eichwald, sp.

1842. *Tettragonis Murchisonii*, Eichw. Urwelt Russlands, Heft 2, p. 81, t. 3. f. 18.

1842. *Zamia rossica*, Kutorga, Verhandl. d. min. Gesellsch. St. Petersb. p. 7, t. 2. f. 3 *a–c*.

1860. *Tetragonis Murchisoni*, Eichw. Leth. Rossica, p. 431.

1860. *Ischadites altaicus*, Eichw. id. p. 437, t. 27. f. 4.

1875. *Tetragonis Murchisonii*, Gümb. Beitr. p. 40, 45.

1878. *Tetragonis Murchisonii*, Quenst. Petref. Deutsch. Bd. 5, p. 592.

1880. *Tetragonis Murchisonii*, F. Römer, Leth. Pal. Th. 1, p. 303.

The typical example of this species is elongated pear-shaped; it measures 100 millim. in length, by 58 millim. in width. The base is stated to have a short stem, but this is probably incorrect, as none is shown in the figure, which is slightly concave below; and as the author also says that the basal portion is broken off there seems to be no proof of his asserted stem. The specimen is widest at its lower third, and gradually tapers to the summit, which is curved. The typical example only shows the vertical and concentric lines formed by the horizontal spicular rays, and the perforations of the vertical rays.

Zamia rossica, Kutorga (*Ischadites altaicus*, Eichw.), appears to me from the figures and description of the author to be not improbably a specimen of *I. Murchisonii*, in which the summit-plates of the spicules have been preserved. The specimens figured do not show the characters either of the base or summit. The spicular plates are rhomboidal in the figure, though some are stated to be hexagonal; they vary from 3·5 to 7 millim. in width, and clearly show concentric lines of growth. In a section of a small individual there are vertical spicular rays 10 millim. in length. By Kutorga the form was referred to a pine-cone.

Distribution. Orthoceratite limestone: Reval, Wesenberg, Baltic Provinces of Russia.

Tetragonis sulcata et parvipora, Eichw. Lethæa Rossica, pp. 432, 433, Atlas, t. 27. f. 5, 6.

These two species are, as already remarked by F. Römer, of an altogether different character from the type of the genus, and do not belong to the family.

Tetragonis Danbyi, McCoy, Brit. Pal. Foss. p. 62, t. 1 d. f. 7, 8.

Tetragonis eifeliensis, F. Römer, Leth. Pal. Th. 1, p. 304, f. 5, 6.

These species are also of a different character from *Ischadites Murchisonii*, and belong to the genus *Dictyophyton*, Hall.

ISCHADITES LINDSTRŒMI, Hinde, n. sp. (Pl. XXXVI. fig. 2.)

Cf. *Ischadites Grindrodi*? Salter, MS. (see Bigsby's Thesaurus Siluricus, p. 4).

Sponges with wide bases, markedly concave in the centre, and with apparently low conical summits. The specimens vary from 50 to 100 millim. in diameter. The spicular surface-plates vary from 3·5 to 5 millim. in greatest width. No summit has been preserved.

This species differs from *I. Kœnigii* in its considerably larger dimensions and the larger size of the summit-plates. I cannot say whether it is the same as the *I. Grindrodi*, Salter, MS., since there is no description or figure of this species. Some specimens of this species in the Jermyn Street Museum are labelled, but not by Salter, *I. Grindrodi,* whilst others precisely similar bear the label of *I. Kœnigii.* It seems best therefore, in the absence of definite knowledge of the type of *I. Grindrodi*, to adopt another name, and I propose to name it after Prof. G. Lindström of Stockholm, to whom I am indebted for the loan of the specimens.

Distribution.—Wenlock shale: Malvern, Lower Ludlow, Ledbury; lowest beds of the Silurian: Petesvik, Hablingbo, isle of Gotland.

ISCHADITES TESSELLATUS, Winchell and Marcy *.

1866. *Ischadites tessellatus*, Winch. and Marcy, Mem. Bost. Soc. Nat. Hist. vol. i. pt. 1, p. 85, t. 2. fig. 3.

Non *I. tessellatus*, Salt. MS., Siluria, 4 ed. 1867, p. 509.

1870. *Receptaculites formosus*, Meek and Worthen, Proc. Ac. Nat. Sc. Phil. p. 23.

1875. *Receptaculites formosus*, Meek and Worthen, Pal. Illinois, Vol. vi. p. 500, t. 24. fig. 1.

1875. *Ischadites tessellatus*, Gümbel, Beitr. p. 40.

The specimen figured is the cast of the lower portion of an apparently pear-shaped individual with a conical base. The rhomboidal spicular plates are from 2·5 to 5·5 millim. in width. According to the author some examples are 62 millim. in height by 43 in width, and thus considerably larger than *I. Kœnigii*, whilst the general form distinguishes the species from *I. Lindstrœmi.*

Meek and Worthen figure a perfect example of this species under the name of *R. formosus.* Its correspondence in form and the fact of its being derived from the same geological horizon and locality place its identity with this species beyond doubt.

Distribution.—Silurian: Niagara limestone, near Chicago, Illinois.

* According to Miller's 'Catalogue of American Palæozoic Fossils' (1877), p. 43, this species is a synonym of *Receptaculites infundibulus*, Hall, Geol. Report Wisconsin, 1861. I have been unable to obtain a copy of Hall's paper either in the library of the Geological Society or in that of the British Museum. I may say that in the absence of figures, mere verbal description, like Hall's, of the fossils of this group, is quite insufficient for the recognition of species, more particularly when the character of the fossil is so little understood by the author that he regards the base of the fossil as its summit, and *vice versâ.* Meek and Worthen (Geol. Illinois, vol. iii. p. 302) similarly express their inability to recognize Hall's species of this genus in the absence of figures, and there are therefore sufficient grounds for rejecting the species described in this paper unless subsequently verified and figured by the author or other writers.

Ischadites? inosculans, Salter.

Sphærospongia inosculans, Salt. Pal. of Niti, p. 49, t. 5. figs. 7, 8, 9.

This species is based on a small compressed fragment, 18 millim. long by 13 millim. wide, of an apparently conical individual. The outer surface consists of slightly convex elliptical plates? with small irregular digital projections which interlock with each other. The plates show no structure, nor are there any indications of spicular rays beneath them. Possibly the form may belong to a new genus, but as the only specimen known (now in the British Museum) is insufficient to furnish generic characters, it seems preferable to allow it to remain provisionally under *Ischadites*, which, as Salter remarks, it much resembles.

Distribution.—Silurian: Niti Pass, Northern Himalaya.

Genus Sphærospongia, Pengelly.

Sphærospongia tessellata, Phill. sp. (Pl. XXXVII. figs. 1, 1 *a–c.*)

1841. *Sphæronites tessellatus*, Phill. Pal. Foss. Devon, &c., p. 135, t. 59. f. 49.

1832. *Tunicate fossil*, Broderip, Trans. Geol. Soc. ser. 2, vol. iii. p. 164, t. 20. f. 1, 2.

1844. *Sphæronites tessellatus*, F. Röm. Rhein. Uebergangsgeb. p. 64.

1845. *Echinosphærites tessellatus*, Murch. Keyserl. Vern. Geology of Russia, p. 381, t. 27. f. 7.

1845. *Sphæronites tessellatus*, Bowerb. Ann. & Mag. Nat. Hist. vol. xv. p. 299.

1845. *Sphæronites tessellatus*, Austin, id. p. 406.

1850–56. *Proboscis of crinoid*, G. & F. Sandberger, Verstein. des Rhein. Schicht.-Sys. pp. 384, 385.

1861. *Sphærospongia tessellata*, Pengelly, Geologist, vol. iv. p. 340, t. 5.

1875. *Pasceolus tessellatus* et *Rathi*, Kayser, Zeitschr. d. deutsch. Geol. Gesellsch. p. 780, t. 20.

1880. *Polygonosphærites tessellatus*, F. Römer, Leth. Pal. Th. 1, p. 297, f. 54.

1880. *Polygonosphærites tessellatus*, Zitt. Handb. der Pal. vol. i. p. 728.

The characters of the type species have been fully referred to in the description of the genus. The specimens vary greatly in dimensions; the typical form, though imperfect, is 85 millim. in height and 115 in width near the summit. The spicular head-plates are from ·5 to 7·5 millim. in width. The average dimensions of a number of specimens in the British Museum are 60 millim. in height and the same in width, and the surface-plates are from 2·5 to 5 millim. wide.

Ferd. Römer places the form described in the 'Geology of Russia' as distinct from this species, but judging from the figure given of it, there does not appear sufficient reason for separating it from *S. tes-*

sellata. Kayser has also constituted a new species *S. Rathi*, which, however, appears to me not to differ from Phillips's species.

Distribution.—Devonian: Newton Bushell, Devonshire; Vilmar, Nassau; Eifel, Germany; River Jolva, near Bogoslofsk, Ural, Russia.

Genus Acanthochonia, Hinde.

Acanthochonia Barrandei, Hinde, sp. n. (Pl. XXXVII. figs. 2, 2 *a–e*.)

The characters of this species have been given with those of the genus. The specimens vary from 20 to 50 millim. in greatest width, and from 7 to 15 millim. in height. The spicular plates are only 1 millim. in width near the centre of the base, whilst those near the margins of the cup measure 5 millim. across. The summit-plates themselves appear to be thin, though their real thickness cannot be determined from vertical sections as they are fused into a crystalline mass with the horizontal rays and the basal portion of the vertical rays. The vertical rays are about ·5 millim. in thickness and 8 millim. in length, in the lateral portions of the cup, and smaller near the base.

Distribution.—Silurian. Etage E of Barrande, Bubowitz, near Prague, Bohemia.

Genus Receptaculites, Defrance.

Receptaculites neptuni, Defrance.

1827. *Receptaculites Neptuni*, Defr. Dict. des Sci. Nat. t. 45, p. 5, atlas t. 68. f. 1*a*, 1*b*, 1*c*, 1*d*.

1826–33. *Coscinopora placenta* et *sulcata*, Goldf. Petref. Th. 1, p. 31, t. 19. f. 18, 19.

1842. *Receptaculites Neptuni*, Archiac & Verneuil, Trans. Geol. Soc. ser. 2, pt. 2, p. 407.

1844. *Receptaculites Neptuni*, F. Römer, Rhein. Uebergangsgeb. p. 59.

1868. *Receptaculites Neptuni*, Dames, Zeitsch. d. deutsch. geol. Gesellsch. Bd. xx. p. 483, t. 10. f. 1.

1875. *Receptaculites Neptuni*, Gümbel, Beiträge, Abhandl. d. k. bay. Akad. der Wiss. II. Cl. Bd. xii. 1 Ab. p. 169, t. A.

1878. *Receptaculites Neptuni*, Quenstedt, Petref. Bd. v. p. 596, t. 142. f. 20.

1878. *Receptaculites scyphioides*, Quenst. id. p. 586, t. 142. f. 15, 16.

1879. *Receptaculites Neptuni*, Nich. Man. Pal. vol. i. p. 127, f. 29.

1876–80. *Receptaculites Neptuni*, Zitt. Handb. d. Pal. p. 84, f. 20.

1880. *Receptaculites Neptuni*, F. Römer, Leth. Pal. vol. i. p. 290. tlas, t. 35. f. 7*a*, *b*, *c*.

1882. *Receptaculites Neptuni*, T. R. Jones, Cat. Foss. Foram. Brit. Mus. p. 4.

Sponges either shallow cup- or disk-shaped, varying in diameter from 65 to 180 millim. The base in its centre forms a slight conical, sometimes curved, projection. The thickness of the walls varies from 3 millim. near the nucleus to 10, 15, and in one unusually thick example 20 millim. near the margins of the cup or disk. The rhomboidal spicular plates are from 4 to 5·5 millim in extension; they are usually flattened above, though occasionally through pressure they become concave. The horizontal rays are from 1 to 1·5 millim. in thickness; the distal ray not unfrequently projects from beneath its own plate to the centre of the plate in front of it. The vertical rays or pillars vary from 1 to 2·5 millim. in thickness; they are usually contracted immediately beneath the horizontal rays and then again expand and maintain a uniform thickness to their contact with the inner or upper layer of the wall. The characters of the inner wall in this species are somewhat doubtful. According to Gümbel and Dames it resembles the plates of the outer wall. Its structure is not shown in examples which I have seen from Belgium and Ober-Kunzendorf, but in a Canadian example of the species there are regular rows of perforations as in *R. occidentalis.*

There is a considerable variation in the size of specimens of this species from different localities. Thus the walls and spicules in the Belgian specimens are much less robust than in those from Ober-Kunzendorf.

Quenstedt has placed some examples of this species under the name of *R. scyphioides*, solely on account of a superficial resemblance to the sponge *Tremadictyon* (*Spongites*) *reticulatus,* Quenst. sp.

Mr. Champernowne has lately discovered an example of this species in hardened mudstones in Devonshire. It is much compressed and exhibits partially the inner surface.

Distribution.—Middle Devonian: Mudstone Bay, Devonshire. Chimay, Couvin and elsewhere in Belgium; Eifel, Germany; Ober Kunzendorf, Silesia; near Widder, Ontario, Canada.

RECEPTACULITES OCCIDENTALIS, Salter. (Pl. XXXVII. figs. 3, 3 *a–m.*)

1859. *Receptaculites occidentalis*, Salt. Can. Org. Rem. dec. i. p. 45, t. 10. f. 1–7.

1845. *Coscinopora sulcata*, D. Dale Owen (non Goldfuss), Geol. Report, Iowa, &c. p. 25 pl. vii. fig. 5.

1862. *Receptaculites Oweni*, Hall, Rep. Geol. Surv. Wisc. vol. i. p. 46, fig. 2, and p. 429.

1865. *Receptaculites occidentalis*, Bill. Pal. Foss. Can. vol. i. p. 381, figs. 354–356.

1868. *Receptaculites Oweni*, Meek and Worthen, Pal. Illinois, vol. iii. p. 302, t. 2. f. 3.

1875. *Receptaculites occidentalis*, Gümbel, Beitr. p. 7.

1878. *Receptaculites occidentalis,* R. Etheridge, Quart. Journ. Geol. Soc. vol. xxxiv. p. 577.

1878. *Receptaculites iowensis*, Quenst. Petref. Bd. v. p. 589, t. 142. f. 17.

1880. *Receptaculites occidentalis*, F. Römer, Leth. Pal. vol. i. p. 289.

1882. *Receptaculites occidentalis,* T. R. Jones, Cat. Foss. Foram. Brit. Mus. p. 3.

1882. *Receptaculites Neptuni?* T. R. Jones, id. p. 3.

This well-known species grows in flattened disk-like expansions, which, when entire, are from 100 to 200 millim. in diameter. The nucleus or commencement of growth is a small conical projection on the under surface and forms a small pit on the upper. The walls vary in thickness from 4 millim. in the centre to 12 millim. at the periphery of the organism. The spicular plates of the outer surface, with the exception of those immediately round the nucleus, vary from 3 to 5 millim. in width, and the horizontal rays are somewhat more than half the width of the plates. The vertical rays vary from 1 to 2 millim. in thickness. The inner or upper plate is about 1 millim. in thickness; the vertical canals by which it is perforated are about 1 millim. in width. The upper or outer surface of this plate is frequently irregularly furrowed by open canals.

In the massive limestones at Pauquettes Rapids on the Ottawa, the species is very abundant and is partly composed of silica and partly in the state of crystalline calcite. When freed from the matrix by dilute acid, the structure is more clearly shown than in any other example of the genus. The specimens from Illinois, &c., are generally in the condition of casts. This species was referred by D. Dale Owen to *Coscinopora sulcata*, Goldf. $=$*R. neptuni*, and Hall, in 1861, proposed to change the name to *R. Oweni*. Previously to this, however, Salter described and figured the species and gave it the name which it now bears. Salter suggested that *R. Neptuni*? Hall,* from the Trenton limestone of Carlisle, Pennsylvania, might also belong to the same species, but from Hall's figures it appears to be distinct, and it is moreover stated to be suborbicular or hemispherical. The examples from Illinois and other Western States are usually of somewhat greater diameter than those from the same horizon in Canada, but from a comparison of specimens from these different places I am unable to detect any differences which would justify regarding them as distinct species. Their external aspect is, however, strikingly dissimilar owing to their different states of fossilization.

Distribution.—Lower beds of the Trenton limestone: Pauquettes Rapids, Ottawa River, Canada. Galena limestone: Galena, Dixon, Illinois; various localities in Wisconsin and Iowa. Lower Silurian: Cape Louis Napoleon; Igloolik, Arctic regions.

RECEPTACULITES ORBIS, Eichwald.

1860. *Receptaculites orbis*, Eichw. Leth. Ross. vol. i. p. 428, t. 27. f. 1; cf. *Escharites forniculosus*, Schloth. Petrefactenkunde, 1820, p. 343.

1858. *Receptaculites orbis*, Fr. Schmidt, Silur. Form. von Ehstland, &c., p. 232.

1875. *Receptaculites orbis*, Gümb. Beitr. pp. 39, 41.

1880. *Receptaculites orbis*, F. Römer, Leth. Pal. Th. 1, p. 289.

1882. *Receptaculites orbis*, T. R. Jones, Cat. Foss. Foram. Brit. Mus. p. 2.

Flattened disks from 80 to 150 millim. in diameter. The walls

* Pal. New York, vol. i. p. 68, t. 24. f. 3.

near the margins are about 5 millim. in thickness; the spicular plates are from 2·5 to 3 millim. in width. According to Gümbel the inner layer of this species is perforated by canals in a similar manner to that of *R. occidentalis*. I have only seen a single example of this species. It approaches closely to *R. occidentalis*, but the spicular plates and rays appear smaller. Eichwald's figures 1 *b*, *c*, though stated to be of the natural size, are evidently enlarged.

Eichwald states that *Escharites forniculosus*, Schlot., is a synonym of his species; but as Schlotheim's description is altogether insufficient to recognize the form, and is, moreover, not accompanied by any figure, it seems preferable to retain Eichwald's name and authority for it.

Distribution.—Orthoceratite limestone: Odinsholm, Reval, Baltischport, Esthonia.

RECEPTACULITES AUSTRALIS, Salter.

1859. *Receptaculites australis*, Salt. Canad. Org. Rem. dec. i. p. 47, t. 10. f. 8–10.

1878. *Receptaculites australis*, R. Etheridge, jun., Cat. Austr. Foss. p. 3.

1880. *Receptaculites australis*, F. Römer, Leth. Pal. Th. 1, p. 290.

According to Salter this species is mainly distinguished from *R. occidentalis*, Salt., by the imperfectly lobed surface of the spicular plates. Apparently the specimens, like those of *R. occidentalis*, are siliceous, and it is doubtful whether the so-called lobed surfaces of the plates may not be due to irregular accretions of this mineral.

Distribution.—Upper Silurian: Yarradong, New South Wales.

RECEPTACULITES ? CANADENSIS, Billings.

1863. *Ischadites canadensis*, Bill. Geol. Canada, p. 309, f. 313, and p. 327.

1865. *Receptaculites canadensis*, Bill. Pal. Foss. Canada, vol. i. p. 384, f. 362.

1880. *Receptaculites canadensis*, F. Römer, Leth. Pal. Th. 1, p. 289.

The specimen thus named consists of only a compressed fragment of an individual, from which it is impracticable to determine if it forms part of a *Receptaculites* or *Ischadites*, and it is quite insufficient to furnish satisfactory specific characters. No description of it is given in the 'Geology of Canada,' where it is first figured, and the only apparent reference to it, on p. 327, states that it is an *Ischadites* allied to *I. Kœnigii*, the first instance of the genus on the continent. In the "Palæozoic Fossils," Billings notes the differences between this form and *R. Oweni*=*R. occidentalis*, which, however, arise from its different state of preservation.

Distribution.—Niagara limestone: Township of Esquesing, Ontario, Canada.

RECEPTACULITES CALCIFERUS, Billings.

1865. *Receptaculites calciferus*, Bill. Pal. Foss. Canada, vol. i. p. 359, f. 346.

The species is founded on a mere fragment, which shows the crossing ridges formed by the horizontal spicular rays. If Billings's figure is correct, the rays and the spicular plates above them must be considerably larger than in *R. occidentalis.*

Distribution.—Calciferous formation: Mingan Islands, Lower St. Lawrence.

RECEPTACULITES ARCTICUS, Etheridge.

1878. *Receptaculites arcticus*, Eth. Quart. Journ. Geol. Soc. vol. xxiv. p. 576.

1882. *Receptaculites arcticus*, T. R. Jones, Cat. Foss. Foram. Brit. Mus. p. 3.

The fragments of this species indicate flattened, platter-shaped individuals with slightly incurved margins. They were evidently of considerable size. The total thickness between the outer and inner walls varies from 10 to 20 millim. The summit-plates reach to 7 millim. in width. No trace of the horizontal spicular rays can be seen; these and the head-plates are merged together into a layer of crystalline calcite 2·5 millim. in thickness. The vertical rays, like those of *R. occidentalis,* are contracted immediately beneath the horizontal rays and then expand again and continue of an even thickness to their junction with the inner or upper plate. The rays are from 2·5 to 3·5 millim. in thickness, and their length corresponds to the thickness between the walls. The characters of the inner layer are not shown. The structure is now entirely replaced by coarsely crystalline calcite.

The large proportions of the form itself and of the spicular plates and rays distinguish this species from all others of the genus.

Distribution.—Lower Silurian: Cape Louis Napoleon, Cape Frazer, Arctic regions (type specimens in British Museum).

RECEPTACULITES? CARBONARIUS, F. Römer.

1871. *Receptaculites carbonarius*, F. Römer, Jahresber. Schles. Gesellsch. p. 42.

1880. *Receptaculites carbonarius*, F. Römer, Leth. Pal. 1 Th. p. 291, f. 53.

The imperfect example of this species is insufficient to determine its originally complete form; the author suggests that the relatively deep cup-shaped body may have been contracted above to a narrow aperture, in which case it would resemble an *Ischadites.* As, however, its interior characters are not known, its generic position remains doubtful.

Distribution.—Carboniferous Limestone: Rothwaltersdorf, Silesia.

RECEPTACULITES? RHOMBIFER, F. A. Römer.

1850. *Receptaculites* } *rhombifer*, F. A. Römer, Palæontographica,
Sphæronites } Bd. iii. p. 30, t. 4. f. 21.

1880. *Polygonosphærites rhombifer*, F. Römer, Leth. Pal. 1 Th. p. 298.

The figured type is a deep cup-shaped specimen, probably imperfect. The spicular plates are for the most part rhomboidal, and this feature would exclude it from *Sphærospongia*. The generic position must remain uncertain until its interior characters have been ascertained.

Distribution.—Upper Devonian: Harz, Germany.

Species which have been erroneously referred to Receptaculites.

Receptaculites? *elegantulus*, Billings, Pal. Foss. Can. vol. i. p. 359, f. 347. The only characters shown are faint ridges arranged in quincunx, marking out small rhomboidal pits. The small proportions and uniform size of these interspaces appear to me to indicate that it does not belong to the present group.

Receptaculites? *insularis*, Billings, Cat. Silurian Fossils of Anticosti, p. 29. Billings recognizes that the characters of this species are altogether distinct from those of the genus under which he has placed it with a query, and he suggests that it is congeneric with *Tetragonis sulcata*, Eichw. Leth. Rossica, p. 432, t. 27. f. 5 *a*, *b*. But this latter species is not a true *Tetragonis*, and probably belongs to a quite distinct group.

Note.—S. A. Miller, in Cat. American Pal. Fossils (1877), refers to *Receptaculites*, *Lunulites dactioloides*, Owen, 1840, and *Orbituloides reticulata*, Owen, 1840, 'Report on Mineral Lands, Niagara Group.' I have been unable to find this work in the libraries of the scientific societies in London, nor does it appear to be quoted in the 'Bibliography of North American Invertebrate Palæontology,' White and Nicholson. F. Römer, in Leth. Pal. 1 Th. p. 289, 290, refers the above species to Miller himself!

In the supplement to the Catalogue (1883) Miller further refers to *Receptaculites sacculus*, Hall, 'Descriptions of new Species of Fossils from Waldron, Indiana,' 1879, and *Receptaculites devonicus*, Whitfield, 'Descriptions of new Species of Fossils from Ohio,' 1882. Neither of the papers containing these descriptions is obtainable in London, nor can I ascertain where they have been published.

EXPLANATION OF PLATES XXXVI. & XXXVII.

Plate XXXVI.

Figures 1, 1 *a*–*o*. *Ischadites Kœnigii*, Murchison.

Figs. 1, 1*a*–*c*. Specimens showing differences in form and conditions of preservation. All natural size.

1. A small form, showing a prominently developed central zone, and with the summit-plates of the spicules preserved.

1 *a*. A specimen with an elevated summit, and clearly showing the horizontal rays of the spicules, the summit-plates which originally covered the surface having disappeared.

Fig. 1 *b*. A specimen with a flattened base and depressed summit, showing faint vertical and concentric lines formed by the horizontal spicular rays.

1 *c*. A specimen showing sections of the vertical rays of the spicules, both the spicular plates and the horizontal rays having disappeared.

The specimens are from the lowest beds of Silurian age in the isle of Gotland; fig. 1 is from Djupvik, and the others from the vicinity of Visby. With the exception of fig. 1 *c*, they have been lent by Prof. G. Lindström from the Royal Museum at Stockholm.

1 *d–g*. Showing the characters of the summit-plates of the spicules.

1 *d*. The upper portion of fig. 1, enlarged twice, showing the regular disposition of the spicular plates and the slightly elevated distal angles of those of the zonal region.

1 *e*. Shows the arrangement of the minute spicular plates at the summit of a small specimen, surrounding the central aperture. Enlarged six times.

1 *f*. The base of fig. 1, enlarged three times, showing the eight diamond-shaped spicular plates of the nucleus and the plates succeeding them, each having a clearly marked central spot, indicating the centre of the spicule.

1 *g* is a portion of the lateral surface of a specimen, enlarged four times, showing the extension of one of the horizontal rays of each spicule, from beneath the distal angle of its corresponding summit-plate, over the summit-plate of the spicule in front of it. In the centre of the figure are the modified summit-plates developed at the intercalation of a fresh row of spicules.

1 *h–j*. Showing the characters of the horizontal spicular rays.

1 *h*, 1 *i*, are portions of the lateral areas of two specimens in which the surface summit-plates have disappeared, showing the four horizontal rays of independent spicules. The rays are often incomplete, and they frequently overlap each other. Enlarged three times.

1 *j*. The surface of the upper portion of a specimen in which only three of the four horizontal spicular rays are preserved; the fourth, or distal ray, having disappeared with the summit-plate. Enlarged three times.

1 *k–o*. Showing the characters of the vertical spicular rays.

1 *k*, *l*, *m* are fractured specimens, showing the tapering extension and the free termination of the vertical rays in the interior of the central cavity, now filled with matrix. Natural size.

1 *n* is a smooth vertical section, and 1 *o* a transverse section, similarly showing the extension of the vertical rays.

Fig. 2. *Ischadites Lindstrœmi*, Hinde.

The base of a specimen showing the ridges formed by the matrix between the margins of the spicular summit-plates, which have disappeared; the dark spot in the centre of each rhomboidal area indicates the vertical rays of the spicules; some traces of the horizontal rays are also shown. From Silurian strata at Petesvik, isle of Gotland.

Plate XXXVII.

Figures 1, 1 *a–c*. *Sphærospongia tessellata*, Phillips, sp.

Fig. 1. A specimen, imperfect at the summit, showing the hexagonal spicular summit-plates of the surface. Natural size. From Middle Devonian strata at Newton Bushell, near Torquay, Devonshire. In the collection of the British Natural History Museum.

Fig. 1 *a*. Another specimen from the same locality, also imperfect, showing the interior surface. The vertical and transverse ribs are formed by the horizontal spicular rays, which are now partially amalgamated together. Natural size.

1 *b*. A portion of the outer surface of the typical example of the genus, now in the Jermyn-Street Museum, showing the slightly elevated knob in the centre of each of the spicular summit-plates. Natural size.

1 *c*. A portion of the inner surface of a fragmentary specimen, enlarged three times, showing clearly the horizontal rays and the independence of the spicules.

Figures 2, 2 *a–e*. *Acanthochonia Barrandei*, Hinde.

2. Two nearly entire individuals and portions of two others, partially imbedded in a fractured piece of rock. The bases and outer surface of the specimens are shown. Natural size. These and the following examples are from Silurian strata, Etage E. of Barrande, at Bubowitz, near Prague. They were obtained for the British Natural History Museum from Barrande himself.

2 *a*. The basal portion of an individual, enlarged three times, showing the eight spicular plates forming the nucleus, and the disposition of the summit-plates succeeding them.

2 *b*. A portion of the outer surface of another specimen, enlarged three times, showing the arrangement of the spicular summit-plates, from the nucleus, at the apex of the figure, to nearly halfway to the margin of the cup. In the centre of the figure are shown the two modified spicular plates, one pentagonal and the other triangular, which are developed at the intercalation of a fresh row of spicules.

2 *c*. A portion of the outer surface of a specimen in which the summit-plates are partially destroyed, showing the horizontal spicular rays beneath. Enlarged three times.

2 *d*. A vertical section of two specimens imbedded in the rocky matrix. Natural size.

2 *e*. A vertical section, passing nearly through the centre of a specimen, enlarged three times, showing the extension and the free termination of the vertical rays of the spicules. The spicular plates and the horizontal spicular rays are undistinguishably merged together in a thick outer layer of crystalline calcite (shown white in the figure), and the free vertical rays are now of the same material.

Figures 3, 3 *a–m*. *Receptaculites occidentalis*, Salter.

3, 3 *a*, 3 *b*. Different views of a fragment of a platter-shaped specimen, partially freed by acid from the calcitic matrix. Natural size.

3. Shows the perforated inner or upper layer.

3 *a*. The spicules connected with the inner layer.

3 *b*. The summit-plates of the spicules of the outer or under surface.

Collected by the author from the lower beds of the Trenton limestone at Pauquettes Rapids, Ottawa River, Canada.

3 *c–g*. Different views of fragments of the inner or upper layer.

3 *c*. The upper or exposed surface. Natural size.

3 *d*, *e*. The same surface, enlarged three times, showing its rough channelled character.

3 *f*, *g*. The reverse or inner side of the same fragments. The smaller circular or elliptical apertures are the canals which extend through the inner layer, and the larger shaded circles in figs. 3 *f*, *g* show the places of attachment of the vertical spicular rays to the inner surface of the layer; in some places the broken ends of the rays yet remain.

The delimitation of the plates, originally composing the inner layer, is shown in 3*f*, whilst in 3*g* it has partially disappeared.

Fig. 3*h–m*. Different views of partially detached spicules, enlarged four times.

3*h*. Two spicules in their natural position, showing at their bases the summit-plates, the broken truncated ends and the canals of the horizontal rays, and the neck-like constriction of the vertical rays; whilst at the top the vertical rays are connected with portions of the inner layer which unites them together.

3*i, j*. Spicules showing hollow canals in the inner layer at their summits.

3*k*. Spicules in a reversed position, showing in one the thin summit-plate immediately above the truncated horizontal rays.

3*l, m*. Two views of the same spicule, showing the different direction of two opposite horizontal rays; that in 3*l* pointing downwards, and its opposite, as seen in 3*m*, directed upwards; in both the rays ar broken, and only their hollow bases remain. At the summit of the spicule is shown the interior of one of the canals which penetrate the inner layer.

53. *Notes on some* Cretaceous Lichenoporidæ. By G. R. Vine, Esq. (Communicated by Prof. P. Martin Duncan, F.R.S., F.G.S.) (Read June 25, 1884.)

In his classification of British Marine Polyzoa (1880, vol i. p. 471) Mr. Hincks established the family Lichenoporidæ for the inclusion of a very peculiar group of recent Polyzoa. In this family two genera are admitted and defined, *Lichenopora*, Defrance, and *Domopora*, d'Orbigny. In the synonymy appended to these genera no fewer than twenty-one obsolete names are given, and others could have been added to the catalogue. In his remarks on the genus *Lichenopora* (*op. cit.* p. 472) Mr. Hincks observes:—" D'Orbigny has constructed a large number of genera, which are merely arbitrary groups based on very trivial modifications of this well-marked type." One of the suppressed genera of the Lichenoporidæ is *Radiopora*, d'Orb.; and as species belonging to the genus are occasionally met with in our own Neocomian rocks, I have thought it better to direct attention to one species at least, before describing a form altogether new.

The genus *Radiopora* is accepted and described by Mr. Busk, in his British-Museum Catalogue of Marine Polyzoa (Pt. iii. Cyclostomata, p. 34), as follows:—

"Family DISCOPORELLIDÆ, Busk.

(3) Radiopora, d'Orb.

D'Orb., 1874, Pal. Franç. p. 992.

" Zoarium adnate, crustaceous, spreading irregularly, and composed of confluent disks like those of *Discoporella*: surface reticulate or cancellous; cells disposed in serial lines radiating from the centres of the constituent disks." Brit. Mus. Cat. pt. iii. p. 34.

In the British Marine Polyzoa (p. 473), Mr. Hincks begins his description of the species of *Lichenopora* thus:—" 1. Colony simple; or composed of many confluent disks. (*Radiopora*, d'Orbigny.)"

The type species of *Lichenopora* is *L. hispida*, Flem., and one of the varieties of this well-known form is given by Mr. Hincks (p. 473) as " Var. *a* (*meandrina*, Peach)." This is a composite variety with a well-marked character; and if we accept the type and the variety as *Lichenoporæ*, why then I can see no justifiable reason for keeping the two genera for recent and fossil species, when both may be included in one. As, however, there are peculiarities of structure in the Neocomian fossil, altogether unlike the structure of recent *Discoporellæ*, it will be best to redescribe the Cretaceous form. I cannot say whether we are right in assigning to d'Orbigny the following species; but as the fossil came into my possession as named below, and as I have used the name in my British-Association Report on Fossil Polyzoa, iv. 1883, I will let it stand for the present.

RADIOPORA PUSTULOSA, d'Orb.

=*R. pustulosa*, Vine, B. A. Rep. 1883,=? *R. bulbosa*, d'Orb. Pal. Franç. Terr. Cret. Tome v. p. 996.

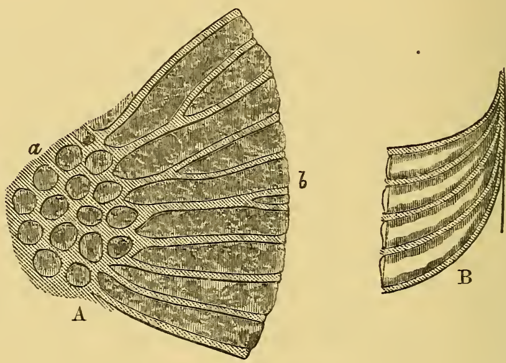
1. *Superficial Zoaria.*—If we examine any ordinary specimen of *R. pustulosa*, which I believe is rather common in the Lower Greensand of Faringdon, we shall find that the exposed surface is composed of a series of undulating or mamilliform prominences which are very characteristic. A mere superficial examination of these mamillæ will show that they are slightly rayed, and that the interspace between one mamilla and another is filled in by an apparently loose cancellous texture. If the apices of these prominences are slightly rubbed down and then examined under a low power of the microscope, the rayed character of the series of cells is distinctly visible. A better process, however, is to break from the fossil small fragments and then prepare and mount them as transparent objects. In these sections the structure of this species may be advantageously studied, and it is from specimens thus prepared that the following observations are made.

2. *Massive Colonial Growth.*—The massive growth of *R. pustulosa* is peculiar. The multiform zoaria are built up of a series of apparently laminated layers, of varying thickness; but on the average four of these layers measure about half a line. There is, however, a longitudinal as well as a superficial section which must be studied if the details of the building-up of massive forms of the fossil Polyzoa are to be mastered. In the longitudinal section of *R. pustulosa* before me there are about thirty of these layers. Towards the base of the fossil the disks, which will be described presently, are few in number, probably three or four; but of the primary disk I cannot speak. This simple layer, which may be conveniently spoken of as the originating layer, is composed of confluent disks, which appear to have had a limited range superficially.

The upward building of colonial growths began at the edges of the originating layer, whence fresh or newer zoaria gradually spread and consolidated over the first-formed as well as over successive layers; but the disks did not always anastomose at the edges, like the disks of var. α (*meandrina*, Peach), previously referred to. Many of them remained free, while others were connected, in part, by what appears to be cancellous tissue. This, however, I believe to be a deceptive feature; for in all probability what we suppose to be cancelli are only the broken edges of the tubular extensions of disk and disk. In some sections of the fossil a peculiar overlapping may be seen, and even the beginning of a new disk which will become proliferous on its near neighbour. This "overlapping," too, gives rise to a peculiar structure of the longitudinal section. In the general building up of the zoaria of this species it may be noted that the mamillæ in each succeeding layer are immediately above the mamillæ below, and not covering up interspaces or previously formed zoaria discrimininately. I cannot tell the why or the wherefore of this;

but the fact being known, the study of a single colony or disk will be less puzzling to future students.

Fig. 1.—*Sections of the zoarium of* Radiopora pustulosa, *d'Orb.* Enlarged.



A. Transverse section of the disk; *a.* Celluliferous centre; *b.* Tubular cells cut at different angles, sloping upwards towards the margin of the disk.
B. Longitudinal section of some of the marginal cells.

3. *Zoarial Disks.*—It is almost impossible to break off from the fossil a fragment too small to show a single disk at least. Generally speaking two or three may be secured. I have drawn, with the aid of the *camera lucida*, a transverse section of one of these disks (fig. 1, A). In the central part (*a*) there is a kind of cancellous structure, which appears to me to be nothing more than the cut ends of the tubular cells. These are contiguous, many-shaped, but more frequently circular or hexagonal, and the wall of each is distinct.

In the outer region of the disk (*b*) the circle is composed of long, tubular zoœcia which radiate from the axis. The zoœcia are also contiguous by their walls, but in some places these are separated by slight division; but I have no evidence of cancellous interspaces, as in some of the *Discoporellæ*, or even as in *Radiopora simplex*, Busk (Brit. Mus. Cat. pl. xxxiv. fig. 2). Mr. A. W. Waters, however, has identified one of his Bay-of-Naples Polyzoa as *R. pustulosa*, d'Orb. (Ann. & Mag. Nat. Hist. April 1879, p. 277); and as he speaks of "cancelli-tubes which in the lower half are divided across the axis by septa* [tabulæ ?], giving this part a somewhat cellular appearance," it seems to me to be pretty evident that our own Lower-Greensand species may be looked upon as distinct from the recent Bay-of-Naples

* Since the above was written, I find that Mr. S. O. Ridley (Ann. & Mag. Nat. Hist. June 1881, p. 452) has drawn special attention to the "septal structures in *Lichenopora*," in his paper on the Polyzoa of Franz-Josef-Land. Assuming that his view may possibly be a correct one (*op. cit.* p. 453), the "septa," or "tabulæ" of Polyzoan species may ultimately merit special study.

R. pustulosa, d'Orb.; but whether it is distinct from the Upper-Greensand form * described by d'Orbigny, I cannot say.

In longitudinal section of the layers of *R. pustulosa*, and only in certain places favourable for observation, some of the zoœcia are seen to be small horn-like tubes (fig. 1, B), wide at the top and thinning towards the proximal end. The ends of these tubes are attached apparently to a laminar layer, but in no sense identical with that which is generally represented surrounding the zoarium of species of *Discoporella*. The use of the word "laminar" then must be regarded as a convenient term, rather than as a structurally correct one, whenever it may be applied in descriptions of Palæozoic or Mesozoic Polyzoa.

In describing *Lichenopora hispida*, Mr. Hincks says (*op. cit.* p. 474), "The composite form seems to owe its origin to successive buddings from the margin, the cluster of distinct disks thus produced gradually coalescing so as to constitute a massive zoarium with a mamillated surface."

It will be seen from the above remarks, and from the figures supplied, that the structure of the Lower Greensand *R. pustulosa* differs in many ways from that of *Lichenopora hispida*, Flem., *R. pustulosa*, Waters, and the variety of *L. hispida* (var. *a meandrina*, Peach); but the mode of zoarial aggregation seems to be the same in all the fossil and recent forms of the Lichenoporidæ. In the identification of species, however, it is necessary to state whether the forms described as *Lichenopora* are allied to the more ancient, or to the more recent forms.

The species which I am about to describe is unlike any recent *Lichenopora* known to me, and also unlike any described form found in either the Cainozoic or Mesozoic rocks; I am obliged, therefore, to describe it as new.

LICHENOPORA PAUCIPORA, n. sp.

Fig. 2.—Lichenopora paucipora, *Vine*, *zoarium from above.* Enlarged 20 diameters.

Zoarium stipitate, with a disk-like capitulum slightly cupped; stipitate column coarsely ribbed, arising from a contracted cellular base, having a diameter of about one sixteenth of an inch, height of

* See Waters, *op. cit.* p. 278.

column about half a line; breadth of capitulum, so far as at present known, varying from three quarters of a line to a line. Basal attachment or early mode of growth unknown. *Zoœcia* arranged in serial rays; but the cells rarely exceed two in each ray, depressed in the central portion of the zoarium, slightly exserted towards the margin, orifices oval or circular, peristome thick. *Oœcia* unknown. No cancellous centre or interspaces.

Horizon: Neocomian.

Locality unknown.

The specimens of *L. paucipora* which I have here described have been handed over to me by Mr. George Busk, F.L.S. He informs me that they were discovered by Prof. P. Martin Duncan, F.R.S., amongst other fossils from the Greensand of some unknown locality.

It appears to me to be pretty evident, from the peculiarities of the marginal cells in the full-sized capitulum already figured, that the zoarium of this species may yet be found to grow much larger than in the specimens submitted to me for examination. The transverse section of the capitulum, and also the longitudinal section of the column, are unique in character, and in all probability we have here the colonial beginning of some unknown type of Mesozoic Polyzoa, rather than a matured species; nevertheless it will be better to allow the form to bear the name given to it.

54. OBSERVATIONS *on certain* TERTIARY FORMATIONS *at the south base of the* ALPS, *in* NORTH ITALY. By Lt.-Colonel H. H. GODWIN-AUSTEN, F.R.S., F.G.S., &c. (Read June 25, 1884.)

HAVING last spring paid a visit to the south side of the Alps, my principal object being to see and examine the magnificent moraines of Ivrea, and the Val d'Aosta, which supplied the materials of which they are composed, I was led into the examination of certain Tertiary formations which this great mass of moraine material generally conceals. These Tertiary beds, exposed at a few points near Ivrea, have long since been noticed by the Italian geologists who have studied and written about this part of the country.

My interest thus aroused, I afterwards proceeded to visit similar patches at Boca and Maggiora, east of the Sesia river; but it was not until I got to the Lago d'Orta, and was walking over the moraines at its southern end, that I came on the most interesting section containing the best-preserved fossils. These latter have been examined and named by Dr. Gwyn Jeffreys, and the appended list greatly increases the interest and value of this communication. I shall begin therefore by giving a detailed account of this section, referred to casually in my Address to the Geographical Section of the British Association at Southport in 1883, and I shall afterwards refer to other localities in their turn.

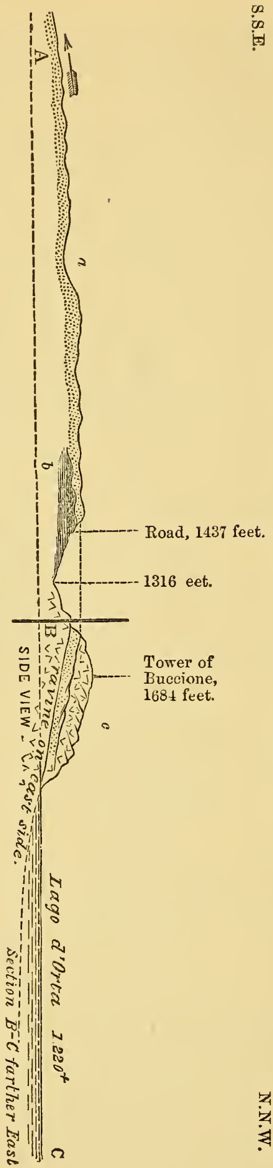
SECTION AT BUCCIONE.

Those who know the Lago d'Orta will remember the old tower that stands so conspicuously on a steep point at the southern end of that lovely little lake, which, though very small when compared with its neighbour the Lago Maggiore, possesses many striking points of difference and interesting physical features. The level of its surface is far higher—by 580 feet. Like Maggiore, it lies in a north-and-south valley, but its drainage is diametrically opposite, viz. from south to north; this was not, I think, the original direction in preglacial times. During those conditions the moraine matter was swept south against the present drainage-lines, converting Monte Motterone and its spurs into a gigantic isolated mass, like an island in a sea of ice, precisely similar to those isolated masses of rock that are often seen in existing glaciers on a smaller scale. The principal point of interest relating to the section is its position so well within the mountain-zone; other points will be shown as the section is described.

Proceeding from Orta southward, along the main road on the east margin of the lake (see Map, fig. 1), we come at last to a little bay under and to the north of the commanding point on which the old tower of Buccione stands; and a little ravine here runs up the east side of the porphyry spur (fig. 2). Works connected with the new railway extension from Borgomanero were in progress, so that good fresh sections were exposed at the head of this ravine.

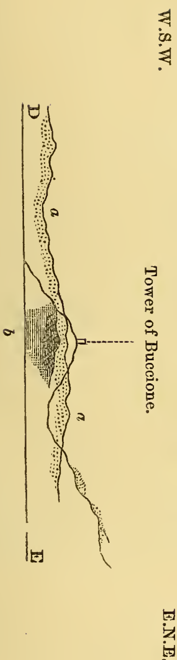
Fig. 1.—*Map of the Southern end of the Lago d'Orta.*

Fig. 2—*Section in line* A, B, C *of Map, fig.* 1.



a. Moraines. *b.* Pliocene, with marine shells. *c.* Porphyry.

Fig. 3.—*Section in line* D, E *of Map, fig.* 1.



The moraine débris has been deposited with the general slope of its layers northward towards the lake; great crushing of the same was apparent, in consequence of its being impeded by the mass of porphyry; it had been forced up and over this gorge, and it contained some enormous blocks. The hill-slopes to the east are all of the same porphyritic rock, capped by moraine matter up to a considerable height. On reaching the new railway bridge and the top of the ascent, I emerged upon a plateau draining and stretching southward, with long regular lines of parallel moraines rising from it and trending in the same direction. Turning to the right, the road descends towards Villa Luzzara, having on the right side a small ravine running down to the lake; south-west of the tower, and rising on the left side, is the scarp of the moraines. A short distance further, at a point nearly due south-south-east of the tower (figs. 1 & 2), I came on a low scarp (exposed in cutting the road) of well-stratified beds, horizontal from west to east, facing the road, consisting of blue-tinted micaceous sands with some purple-coloured beds. A very brief examination showed them to be fossiliferous and marine; and in one bed, about 4 feet thick, the fossils were well preserved but not numerous. I got out as many as I could, although the pouring rain prevented me from making as much use of the time as I could have wished; the number of species is therefore not great. From the level of the road I traced these beds up a little ravine to a height of about 65 feet above it, their upper surface being there distinctly worn off and rounded smooth by ice-action. At the top the beds appeared to dip slightly northwards; but this I am inclined to think was due probably to the pressure they have been subjected to, or to a slight slip, rather than to any displacement of level or contortion; for the lower beds close to the road did not appear to partake of this dip. Above, these deposits are capped by the moraines I have before alluded to, and marine talus from the same conceals them elsewhere to the right and left.

Descending gradually towards the entrance-gate of the Villa Luzzara, and with a clear view to the north up the lake, the higher moraines are left behind, and nothing but glacial deposit is seen on the surface. This gateway is situated on the water-parting at the extreme southern end of the Lago d'Orta. The marine beds have here been removed, and if any occur below the transported material, they must be a far lower set of beds of this series.

I found none below the road near the section, where a steep grass-field leads down into the ravine, and extends to the porphyritic scarp of the Buccione promontory.

Standing on the higher level of these marine beds, here 1500 feet above the sea and 217 feet above the level of the lake (and it must be remembered that many feet of the upper beds have been swept away), I looked away northward over the lake, and my horizon cut the lofty spurs north of Cuzzago and Vogogna on the Toce river, at a level of 850 feet above the Lago Maggiore, into which it flows. It appeared to me that the marine beds had once had a far greater extension to the northward, far down the valley towards the Toce, before the great alteration of level which placed this longitudinal valley relatively so much above that of Maggiore. That this depression of the Lago d'Orta was once an arm of that Tertiary sea, I think there is little doubt. We have a southern extension of highly fossiliferous Pliocene strata, thirteen miles due south and to the west of Borgomanero, as I shall presently describe. These marine beds must also have extended east and west across the valley, possibly much above this level of about 700 feet above the present bottom, taking 500 feet as the maximum depth of the lake*, and this long previous to the commencement of the glacial epoch, during which they were removed, and that so completely that only these remnants now exist. If we examine the position of the remnant of Buccione, we can easily see how it has been preserved.

Directly north, and only about 500 yards distant, stands the promontory of Buccione, a mass of rock rising 250 feet higher, which has withstood the whole period of glacial action, and here impeded that force southward. These marine beds were thus at an early period defended from the direct destructive glacial action, and in this sheltered position have been preserved. Directly you pass to the west of the Buccione hill and obtain a clear view north down the valley, as I have shown above, the Tertiary beds disappear. Two other similar examples of this accidental preservation of once extensive deposits, due to their topographical position during the great movement of the former gigantic glaciers and their moraine débris down the flanks of these mountains towards the plains, came under my notice.

List of the Fossils named by Dr. J. Gwyn Jeffreys.

Arca antiquata, *Linné.*
Diplodonta rotundata, *Montagu.*
Corbula gibba, *Olivi.*
Natica catena, *Da Costa.*
Cassidaria echinophora, *L.* Miocene and Pliocene.
Nassa costulata, *Brocchi.* Miocene and Pliocene.
—— turbinellus, *Brocchi.*
Bulla utriculus, *Brocchi.*
—— ovulata, *Brocchi.*
Ringicula buccinea, *Brocchi.*

He adds:—"In all 10 species. I consider them older Pliocene or Plioceno inferiore of the Italian palæontologists."

Section at Boca.

In the bed of the Strona stream, east of Boca, at 1172 feet above sea-level, just above the bridge, four feet of rich ochry sandy clay, and thick-bedded red clays, with a bed of conglomerate (having its upper surface undulating, as if denuded), are seen in the low bank, dipping 35° south-west. The conglomerate is composed of boulders, from 2 to 4 inches in diameter, of the adjacent porphyry, with schists and granite from the mountains to the north, showing that in early Pliocene times their waste was considerable, and that it came from the Orta valley.

* The greatest depth (140 metres, or 459 feet), I am informed by Mr. G. Ronchetti of Orta, is between the point of Crabia and the cascade of Acqualba.

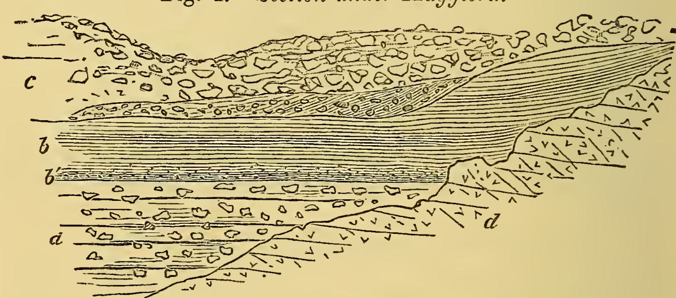
These boulders, although retaining their form and colour, are so completely disintegrated and softened that they can be sliced off in mass easily with the edge of the hammer.

Higher up the winding ravine the dip changes to south, at a lower angle, and the beds rest against the porphyry, the lowest beds being gritty, with quartz pebbles and red ochraceous beds above. The Tertiary beds can be traced here and there below the bridge, but are there of a grey marly character, and only showing in the low banks as far as the high road from Boca towards the plains beyond. The village stands on the same formation, which here rises to about 250 feet, west of the stream. I could find no fossils.

SECTION AT MAGGIORA.

The next section of the Tertiary beds occurs at Maggiora, about a mile to the east, on the road to Borgomanero; and, owing to the formation of a new road descending towards the Sizzone river, good fresh sections were exposed in the Pliocene.

Fig. 4.—*Section under Maggiora.*



a. } Tertiary.
b. }
b′. } Shell bed.

c. Glacial deposit.
d. Porphyry?

Just after leaving the village the descent commences, and at 1188 feet by aneroid, the beds are seen resting on the original sloping surface of the porphyry (fig. 4), at what must have been at one period of their deposition the sea-margin; for a bed $3\frac{1}{2}$ feet thick, of a rusty-coloured muddy sand (*b′*), rests on broken angular débris of the adjacent porphyry, buried in a similar sand (*a*), with no admixture of other rocks.

The base of this bed (*b′*) for a few inches is crowded with marine shells, a small *Pecten* being common; but they are not in a sufficiently good state of preservation to carry away, or to collect hurriedly, and I had no time to do so in a methodical manner. These deposits are horizontal, and extend to the level of the river below, 1089 feet above sea-level, so that about 100 feet or more of these beds are here exposed, blue-grey beds among them (and I noticed them low down in the next ravine to the east, the Vallanzana). They have all the appearance of having been deposited in a sinking area against a steep and originally rocky coast-line. This is an exceedingly instructive section. These beds are capped, as shown in figure 4, by moraine débris (*c*); and it is interesting to note that this moraine matter is the western limit of the great right lateral moraine which was thrown out from the Val d'Orta. On passing to the westward of Maggiora no more of such drift is seen; the low porphyry hills at the back of Boca are free from it. Here, again, we find the soft Tertiary formation coming in where glacial action has been in a less degree exerted, on the margin of the great glacier which extended from this point 18 miles without a break, to the left lateral moraine on the flank of Monte Grande, near Gavirate, on the Lago Varese. This Tertiary remnant has here also, as at the Lago d'Orta, been protected by the steep scarp of the porphyry against which it rests. If these beds, as well as those at Boca, be proved to belong to the *Newer* Pliocene, like those at Monte Grande and at Strambinello, near Ivrea, then this was somewhere near the limit of the coast-line of that later Pliocene sea. Maggiora is more than 500 feet above the level of Lago Maggiore, only eight miles to the east, so that if during *later* Pliocene times the sea did not extend to the Orta valley, there is every reason for supposing that it did extend far up the depression of Maggiore, and its two great branches the Toce and Ticino, of which I shall give some further proof. The Inferior, or *Older*, Pliocene of Orta first described, may have had even a wider extension northward, further within the mountains than the *Newer*.

The Neighbourhood of Ivrea.

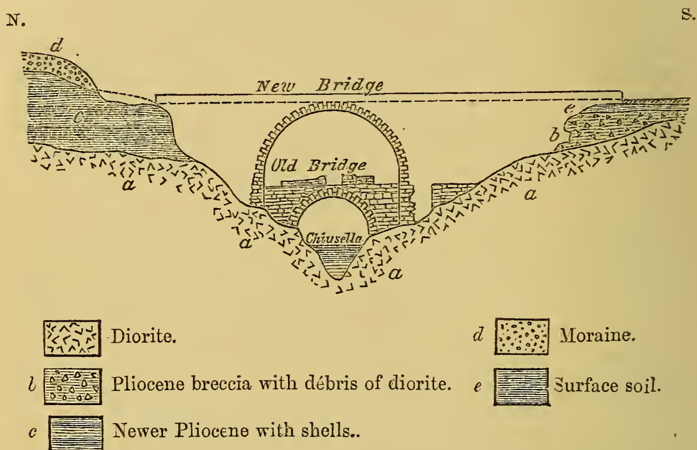
The next and last sections I shall refer to are those I saw first in the neighbourhood of Ivrea, especially that at Strambinello, referred to by Gastaldi. I am indebted to the kindness of Signor Luigi Bruno, a land-surveyor of Ivrea, for calling my attention to the section; it was he who recommended me to visit the place, as well as several others of geological interest in the neighbourhood; and he also showed me his plans and sections. My best thanks are also due to him for his section, which I now produce (fig. 5), made in 1870, drawn by him, and subsequently forwarded to me.

Any one visiting this old town should go to Strambinello; for not only is it interesting to the geologist, but the scenery of the Chiusella valley is very beautiful. As the section may not be commonly known to English geologists, and as it is most instructive and bears on the previous sections treated of, I give a description of it.

At the bridge spanning the Chiusella beyond Strambinello, at 1059 feet above the sea, the base of the Pliocene with marine shells is seen, resting horizontally on the diorite rock, through which the river has since cut its way some feet below. The difference of denudation and its action on the rock is very well displayed here, when, first, it was subjected to ice-action and water combined, and, secondly, to water-action only, as at the present day.

On the south bank the Pliocene is broken up and mixed with diorite detritus, showing that their destruction was due to their more exposed position, further from the steep slope of the hill behind an against which they were deposited.

Fig. 5.—*Section across the Chiusella at the Ponte dei Preti near Strambinello.*



In the Museum at Ivrea I was shown a collection of marine shells found in the Newer Pliocene beds of this gorge, *Pecten jacobæus* being common. Not far distant, beyond St. Giovanni, in the Borriana ravine, the Pliocene beds are again met with; but only a few feet of them are visible in the bed of the ravine. I could find no marine shells; and Signor Luigi Bruno, who knows the country and its geology well, told me that here they are very rare indeed. At the lowest exposed level was a bed of pale bluish sandy loam, which contained fragments of long pieces of fossil wood a good deal carbonized. The great massive moraine-deposits rest upon and surround this remnant or outlier of the Pliocene formation, which no doubt in a similar way underlies the terminal moraine as far as those exposed on and near the Lago di Candia. At first the higher beds were destroyed by the advancing ice, and were broken up and contorted, portions only being finally protected from further denudation by the moraine matter being piled up above them.

When we survey this country from some central and commanding point, such as the Castiglia hill in Ivrea, the position of these Pliocene beds in the east-to-west gorge of the Chiusella is better understood. They are seen lying close under the steep slope of the diorite ridge which extends from Brosso to Vistorio, and which is capped by the great right lateral moraine of the old Dora Baltea glacier; this, when entire, swept over the gorge, then filled with ice, and was united in one continuous moraine with that on the south at Bairo &c. The ice and these accumulations moving at right angles to the narrow gorge, its force was considerably diminished just under the lee of the diorite face of the hill above Strambinello, and the moraine profonde covered up, protected, and preserved the small remnants of the marine beds which remain to tell so much of past conditions here.

Again, ascending to the top of La Serra, the grand left lateral moraine, and crossing its great breadth of four miles to Monte Grando on the Biella road, directly we pass off the area where glacial action has been excessive, the Pliocene formation is again met with in this more sheltered corner.

It is difficult to say to what thickness the Pliocene had attained before the final elevation to its present altitude, and it may once have been higher; it had a great horizontal extension at the south base of the Alps, and there has been an enormous destruction of these beds, chiefly during the Glacial period. I believe that the Pliocene sea extended far up the main valleys in fiord-like arms; and it is not surprising that all deposits of this age have been so completely and cleanly swept out of these valleys, so that, with the exception of the remnant on the Lago d'Orta, not a vestige remains. Within the valleys glacial denudation, when at its maximum, must have been more rapid and complete than on the southern face of the mountains; and yet even here for miles there is no trace of these deposits.

I trust that in bringing these sections to your notice I have been able to show how the existing portions have been preserved, and what is their relative position to the present valleys and lake-basins.

At Arona, where I spent some days exploring the country on both sides the Lago Maggiore, I was fortunate enough to find, near the village of Dormiletto, traces of marine conditions. This village, situated on the south-west extremity of the lake, stands on a plateau about 100 feet above it (112 feet by aneroid), and close under the moraine which rises immediately to the west. This moraine is much intersected by narrow ravines, showing on their sides fine sections of the moraine profonde, and the surface moraine on the top.

In the bed of such a ravine close to Dormiletto fossils were found in a patch of fine white gritty marl, showing up through the subangular débris. Its position *in situ* I never determined quite to my satisfaction, so small a portion being uncovered; and I had no means of excavating for any distance and removing the gravel and blocks of stone which covered it. It was in the very lowest and narrowest part of the ravine, just where it opened on to the plateau, so that nothing below this level can be seen in any direction. If this is a large detached block buried in the ravine, then it must either have been derived from the cliffs at the head or on the side of the ravine, or it has been washed out of the moraine material.

After very close search, I could discover no bed similar to it in the ravine above, nor any blocks of similar material in the glacial sands and clays. In either case it is interesting; if it is *in situ*, we have proof of marine conditions here; if transported, it must be a portion of beds not far distant, situated at a higher level to the north, whence all the moraine débris has travelled. I am inclined to think it is *in situ*, because on removing as much as I could of the sand and stones I did not reach the bottom of the mass; also because the present level of the bottom of the ravine, as well as that of the plateau in front, may be assumed to be due to the impermeable nature of this clay, of which a small portion only is now exposed to view.

I have thought the presence of this fossiliferous clay worth recording, as it may be still more exposed in another year or two here or in some of the adjacent ravines, and others may be led to visit and examine the section*.

* The fossils are mostly casts of Mollusca, Echinoderms, &c.; but the marl is full of organisms of various kinds, which I hope to get examined.

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

[The fossils referred to are described; and those of which the names are printed in italics are also figured.]

END OF VOL. XL.

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PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1883–84.

November 7, 1883.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

James Diggle, Esq., Assoc. M. Inst. C.E., The Hollies, Heywood, Manchester; Charles Anderson Ferrier, Esq., F.L.S., 54 Free Grove Road, N.; and Prof. W. Stephens, M.A., University of Sydney, New South Wales, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Geology of the South Devon Coast from Tor Cross to Hope Cove." By Prof. T. G. Bonney, M.A., F.R.S., Sec. G.S.

2. "Notes on Brocchi's collection of Subapennine Shells." By J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.G.S.

3. "British Cretaceous Nuculidæ." By John Starkie Gardner, Esq., F.G.S.

Rock-specimens and microscopic sections were exhibited by Prof. T. G. Bonney, in illustration of his paper.

November 21, 1883.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Skull and Dentition of a Triassic Mammal (*Tritylodon longævus*, Ow.) from South Africa." By Sir R. Owen, K.C.B., F.R.S., F.G.S.

2. "Cranial and Vertebral Characters of the Crocodilian genus *Plesiosuchus*, Owen." By Sir R. Owen, K.C.B., F.R.S., F.G.S.

3. "On some tracks of Terrestrial and Freshwater Animals." By Prof. T. McKenny Hughes, M.A., F.G.S.

The following objects were exhibited:—

Specimens exhibited by Sir R. Owen and Prof. Hughes in illustration of their papers.

Two large photographs of Kimberley Diamond Mine; also a new Geological Map of a part of the Orange Free State, by the late G. W. Stow, F.G.S., exhibited by Prof. T. Rupert Jones, F.R.S., F.G.S.

Recent tracks on mud from near Mundesley, exhibited by E. T. Newton, Esq., F.G.S.

December 5, 1883.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

George Jonathan Binns, Esq., Government Inspector of Mines, Dunedin, New Zealand; Horace T. Brown, Esq., 47 High Street, Burton-on-Trent; James Dairon, Esq., 4 Garden Street, Glasgow; Rodolph De Salis, Esq., B.A., Portnall Park, Ascot, Berks; Hugh Exton, M.D., J.P., Hon. Curator of the National Museum, Bloemfontein, Orange Free State, South Africa; John Forrest, Esq., C.M.G., Perth, Western Australia; Prof. Bernard J. Harrington, B.A., Ph.D., McGill College, Montreal; James Patrick Howley, Esq., Assistant Geologist of Newfoundland, St. John's, N.F.; John Sylvester Hughes, Esq., M. Inst. C.E., Portmadoc, North Wales; Prof. George T. Kennedy, M.A., B.A.Sc., King's College, Windsor, Nova Scotia; Rev. Arthur Noel Malan, M.A., Eagle House, Wimbledon; Robert Sydney Milles, Esq., Hobart, Tasmania; Edwin Radford, Esq., 160 Coningham Road, Uxbridge Road, W.; Edward Pierson Ramsay, Esq., F.L.S., Commissioner of N. S. Wales Fisheries and Curator of the Australian Museum, Sydney, N. S. Wales; William Henry Rands, Esq., Assoc. R.S.M., Geological Survey of Queensland, Brisbane; Thomas Roberts, Esq., B.A., St. John's College, Cambridge; Joseph Ridgway, Esq., 32 Shaw Road, Dudley, Worcestershire; and Harry Page Woodward, Esq., Geological Survey of South Australia, Adelaide, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Cambrian Conglomerates resting upon and in the vicinity of some Pre-Cambrian Rocks (the so-called intrusive masses) in Anglesey and Caernarvonshire." By Henry Hicks, M.D., F.G.S.

2. "On some Rock-specimens collected by Dr. Hicks in Anglesey and N.W. Caernarvonshire." By Prof. T. G. Bonney, D.Sc., F.R.S., Sec. G.S.

3. "On some Post-glacial Ravines in the Chalk-Wolds of Lincolnshire." By A. J. Jukes-Browne, Esq., F.G.S.

The following specimens were exhibited:—

Rock-specimens, exhibited by Dr. Hicks, in illustration of his paper.

A Stick made from wood from the Buried Forest discovered in excavating the Prince's Dock, Bombay, the circumstances of which are described by Mr. Medlicott in the Records of the Geological Survey of India, exhibited by Capt. A. W. Stiffe, I.N., F.G.S.

December 19, 1883.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

Rev. W. R. Andrews, M.A., Teffont Rectory, Salisbury; Robert James Frecheville, Esq., Truro; and Rev. Philip R. Sleeman, 65 Pembroke Road, Clifton, Bristol, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following Donations to the Museum were announced:—

Specimens of the so-called Miocene fossils from South Australia and Victoria, presented by Prof. Ralph Tate, F.G.S., and a Stick made from wood from the Buried Forest discovered in excavating the Prince's Dock, Bombay, presented by Capt. A. W. Stiffe, I.N., F.G.S.

The Secretary read the following note from Capt. Stiffe in reference to the latter specimen:—

"I wish to offer the Society a piece of wood from the buried forest discovered on excavating the Prince's Dock, Bombay. The circumstances are described in a paper in the 'Geological Survey Records of India' by Mr. Medlicott. The lowest part of the forest was about 16 feet below low-water springs, and the trunks of trees were found *in situ* and imbedded in a blue clay lying beneath 4 or 5 feet of recent marine mud. The thickness of the blue clay does not appear to be given.

"It is curious that a log which was considered to have been charred by fire was found associated with the trees of the buried forest; other wood was found which apparently had drifted into the same area.

"The area excavated for the dock was 30 acres, but similar wood has been dredged up beyond those limits while deepening the approaches. The unaltered state of the wood is noteworthy.

"Arthur W. Stiffe, F.G.S."

The following communications were read:—

1. "On some Remains of Fossil Fishes from the Yoredale Series at Leyburn in Wensleydale." By James W. Davis, Esq., F.G.S.

2. "Petrological Notes on some North-of-England Dykes." By J. J. H. Teall, Esq., M.A., F.G.S.

3. "The Droitwich Brine Springs and Saliferous Marls." By C. Parkinson, Esq., F.G.S.

The following specimens were exhibited :—

Rock-sections and specimens, exhibited by J. J. H. Teall, Esq., F.G.S., in illustration of his paper.

A large mass of Tellurium from Turkey, exhibited on behalf of F. Claudet, Esq., by John Arthur Phillips, Esq., F.R.S., F.G.S.

January 9, 1884.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

Patrick Doyle, Esq., Madras; Alfred Harker, Esq., B.A., St. John's College, Cambridge; Rev. Frederick Hastings, 7 Euston Square, London, N.W.; Rev. John Milne-Curran, Dubbo, New South Wales; and William Ford Stanley, Esq., Cumberlow, South Norwood, were elected Fellows, Prof. G. Capellini, of Bologna, a Foreign Member, and M. Alphonse Briart, of Mons, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. "On the Volcanic Group of St. David's." By the Rev. Prof. J. F. Blake, M.A., F.G.S.

2. "On further Discoveries of Vertebrate Remains in the Triassic Strata of the South Coast of Devonshire, between Budleigh Salterton and Sidmouth." By A. T. Metcalfe, Esq., F.G.S.

Rock-specimens and microscopic rock-sections were exhibited by Prof. Blake in illustration of his paper.

January 23, 1884.

R. Etheridge, Esq., F.R.S., Vice-President, in the Chair.

George Henry Nelson, Esq., M.A., Middle Schools, Canterbury, and John Philip Spencer, Esq., Assoc. M. Inst. C.E., 7 Dean Street, Newcastle-on-Tyne, were elected Fellows of the Society.

The following name of a Fellow of the Society was read out for the second time from the Chair in conformity with the Bye-laws, Sec. VI. B, Art. 6, in consequence of the non-payment of the arrears of his contribution:—T. R. Mellor, Esq.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Serpentine and associated Rocks of Porthalla Cove." By J. H. Collins, Esq., F.G.S.

2. "Outline of the Geology of Arabia." By C. M. Doughty, Esq. Communicated by Prof. T. G. Bonney, D.Sc., F.R.S., F.G.S.*

The following objects were exhibited:—

Rock-specimens, exhibited by J. H. Collins, Esq., F.G.S., in illustration of his paper.

Flint implements, from the gravel of Arabia Petræa, exhibited by C. M. Doughty, Esq., in illustration of his paper.

* This paper has been withdrawn by the author by permission of the Council.

February 6, 1884.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

Edward John Dunn, Esq., Oaklands, Claremont, near Cape Town, was elected a Fellow, and Dr. Joseph Szabó, of Buda-Pest, a Foreign Member of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "A Delta in Miniature.—Twenty-seven years' work." By T. Mellard Reade, Esq., F.G.S.

2. "On the Nature and Relations of the Jurassic Deposits which underlie London." By Prof. John W. Judd, F.R.S., Sec.G.S. With an Introductory Note on a Deep Boring at Richmond, Surrey, by Collett Homersham, Esq., Assoc. M. Inst. C.E., F.G.S.

Prof. Bonney called attention to a rock-specimen exhibited by Mr. R. N. Worth, F.G.S., and by him named Trowlesworthite. It consisted chiefly of reddish orthoclase, purple fluor, and black schorl, in intimate association with quartz, and was found by Mr. Worth as a loose block on Trowlesworthy Tor. The rock appeared to be the result of a peculiar alteration of the granite of the district, in which black mica had been altered into tourmaline, some of the felspar had been replaced by schorl and quartz, and the original quartz constituents by fluor spar. Professor Bonney, who had examined the rock microscopically for Mr. Worth, stated the reasons which led him to believe that the last-named unusual change had taken place.

The following specimens were exhibited:—

Specimens, exhibited by Prof. J. W. Judd, F.R.S., Sec.G.S., and C. Homersham, Esq., F.G.S., in illustration of their paper.

A specimen of Trowlesworthite, exhibited by R. N. Worth, Esq., F.G.S.

A specimen of the highest rock, about 19,000 feet, on Chimborazo (20,703 feet), and one from the summit of Cotopaxi, 19,498 feet, collected by E. Whymper, Esq., exhibited by Prof. T. G. Bonney, D.Sc., F.R.S.

A specimen from the bottom of the Gayton boring, exhibited by R. Etheridge, Esq., F.R.S.

Specimens of cores from well-borings at Kentish Town, Meux's Brewery, and H.M. Dockyard, Chatham, and of coal from the Chalk near Dover, exhibited by W. Topley, Esq., F.G.S., on behalf of the Director-General of the Geological Survey.

ANNUAL GENERAL MEETING,

February 15, 1884.

J. W. Hulke, Esq., F.R.S., President, in the Chair.

Report of the Council for 1883.

In presenting their Report for the year 1883, the Council of the Geological Society think that they may fairly congratulate the Fellows upon a decided improvement in the state of the Society's affairs, when compared with that shown in their last year's Report. The Income of the Society was greater, and the Expenditure less in 1883 than in 1882; and there was a marked increase in the number of Fellows elected, and especially in the number of contributing Fellows.

The number of Fellows elected during the year is 60, of whom 50 paid their fees before the end of the year, making, with 7 previously elected Fellows who paid their fees in 1883, a total accession during the year of 57 Fellows. Against this we have to set the loss by death of 28 Fellows, and by resignation of 12 Fellows, while 8 Fellows were removed from the list for non-payment of contributions, making a total loss of 48 Fellows. This would give an increase upon the year of 9 Fellows, but in April last the attention of the Council was called to the number of names which had been standing for years, without any addresses, upon the List of Fellows, and after due consideration it was resolved that the names of all those Fellows whose addresses were unknown, and whose election dated back before the Incorporation of the Society in 1826, should be removed from the list of Fellows. In accordance with this resolution the names of 12 Fellows were removed from the list, producing an apparent decrease of 3 in the number of Fellows. The names of 3 Honorary Members, whose election dates from the years 1808 and 1809, were also removed. Of the 28 Fellows deceased 2 were compounders, and 13 non-contributing Fellows, while 3 non-contributing Fellows became resident; and thus the number of contributing Fellows is actually increased by 22, being now 822.

The total number of Fellows and Foreign Members and Correspondents was 1441 at the end of the year 1882, and 1434 at the end of 1883.

At the end of the year 1882 there was 1 vacancy in the list of Foreign Members; and during 1883 intelligence was received of the death of 4 Foreign Members. Two of these vacancies in the list of Foreign Members were filled up by election during the year, and a third by the reinstatement of the name of a Foreign Member whose death had been erroneously reported. In the list of Foreign Correspondents there was 1 vacancy at the end of 1882; intelligence was received of the death of 1 Foreign Correspondent in 1883; and these losses, with the filling-up of the above-mentioned vacancies in the list of Foreign Members, produced 4 vacancies in the list of Foreign Correspondents, 3 of which were filled up during the year. Thus at the close of 1883 there were 2 vacancies in the list of Foreign Members, and 1 in that of the Foreign Correspondents.

The total Receipts on account of Income for the year 1883 were £2675 10*s.* 8*d.*, being £68 1*s.* 9*d.* more than the estimated Income for the year. The total Expenditure, on the other hand, amounted to £2413 4*s.* 4*d.*, or £165 11*s.* 5*d.* less than the estimated Expenditure of the year. The excess of Income over Expenditure was therefore £262 6*s.* 4*d.*

The Council have to announce the publication during the past year of Mr. Ormerod's Second Supplement to his Classified Index to the publications of the Society.

The Council have also to announce the completion of Vol. XXXIX. and the commencement of Vol. XL. of the Society's Quarterly Journal.

The Council have awarded the Wollaston Medal to Professor Albert Gaudry, F.M.G.S., in recognition of the value of his Palæontological researches, and the important scientific generalizations which he has founded upon his careful and laborious observations.

The Murchison Medal, with the sum of Ten Guineas from the proceeds of the Fund, has been awarded to Dr. Henry Woodward, F.R.S., F.G.S., in testimony of appreciation of his valuable researches into the structure and classification of the Fossil Crustacea, especially the Merostomata and Trilobita, and of his services to the progress of Geology in Great Britain by conducting the Geological Magazine for nearly twenty years.

The Lyell Medal, with a sum of Twenty-five Pounds from the proceeds of the Fund, has been awarded to Dr. Joseph Leidy, F.M.G.S., in recognition of his valuable contributions to Palæontology, especially his investigations upon the Fossil Mammalia of Nebraska and the Fossil Sauria of the United States of North America.

The balance of the proceeds of the Wollaston Donation Fund has been awarded to Edwin Tulley Newton, Esq., F.G.S., in testimony of appreciation of his researches among the Pleistocene Mammalia of Great Britain, and to assist him in the prosecution of further investigations of a like kind.

The balance of the proceeds of the Murchison Geological Fund has been awarded to Martin Simpson, Esq., in recognition of the value of his researches among the Jurassic rocks of Yorkshire, and especially upon the classification and distribution of the Ammonitidæ, and to aid him in carrying out further investigations of a similar nature.

The balance of the proceeds of the Lyell Geological Fund has been awarded to Professor C. Lapworth, F.G.S., in recognition of the value of his researches into the Palæontology and Physical Structure of the older rocks of Great Britain, carried on frequently under unfavourable circumstances and to the injury of his health, and to aid him in the prosecution of similar investigations.

A sum of Twenty Pounds from the proceeds of the Barlow-Jameson Fund, has been awarded to Professor Leo Lesquereux, F.C.G.S., in testimony of appreciation of his researches into the Palæobotany of North America ; and a like sum from the same source to Dr. James Croll, F.R.S., in recognition of the value of his investigations into the later physical history of the earth ; and to aid them in further researches of a similar kind.

Report of the Library and Museum Committee.

Library.

Since the last Anniversary Meeting a great number of valuable additions have been made to the Library, both by donation and by purchase.

As Donations the Library has received about 105 volumes of separately published works and Survey Reports, and about 234 Pamphlets and separate impressions of Memoirs ; also about 138 volumes and 135 detached parts of the publications of various Societies, and 15 volumes of independent Periodicals presented chiefly by their respective Editors, besides 16 volumes of Newspapers of various kinds. This will constitute a total addition to the Society's Library, by donation, of about 297 volumes and 234 pamphlets.

A considerable number of Maps, Plans, and Sections have been added to the Society's collections by presentation, chiefly from various Geological Surveys, from the Ordnance Survey of Great Britain, and from the French Dépôt de la Marine. They amount all together to 356 sheets, and include 296 sheets, large and small, from the Ordnance Survey, and 28 sheets from the Dépôt de la Marine; the remainder being for the most part the Maps of the Geological Surveys of Belgium, New Jersey, Norway, Saxony, Sweden, and Switzerland.

The Books and Maps above referred to have been received from 120 personal Donors, the Editors or Publishers of 15 Periodicals, and 148 Societies, Surveys, and other Public Bodies, making in all 283 Donors.

By Purchase, on the recommendation of the Standing Library Committee, the Library has received the addition of 88 volumes of Books, and of 91 parts (making about 30 volumes) of various Periodicals, besides 49 parts of certain works published serially.

Of the Geological Survey Map of France 8 sheets have been obtained by purchase; and the Society has also purchased a copy of the 'Geologische Karte von Central-Europa' by Dr. H. Bach.

The cost of Books, Periodicals, and Maps purchased during the year 1883 was £94 4*s*. 1*d*., and of Binding £61 15*s*., making a total of £155 19*s*. 1*d*. Two new Bookcases were added to the Library in 1883, at a cost of £30 17*s*.

Museum.

The Collections in the Museum remain in much the same condition as at the date of the last Report of the Committee.

During the year 1883 several interesting Donations were made to the Museum. These include:—A round boulder from a pothole in the Yuba River, and rock-specimens from the Sierra Buttes Mine, California, presented by F. Tendron, Esq., F.G.S.; a collection of 30 Microscopic slides of Placer Gold from California, presented by the State Mineralogist, H. G. Hanks, Esq.; Fossil Plants from the Cape-Breton Coal-measures, presented by C. Barrington Brown, Esq., F.G.S.; a series of Rocks and Fossils from Japan, presented by Prof. John Morris, M.A., F.G.S.; Rock-specimens from William's Cañon, Colorado, presented by H. Bauerman, Esq., F.G.S.; a waterworn pebble of Galena from Minera, Wrexham, presented by Dr. C. Le Neve Foster, F.G.S.; specimens of the so-called Miocene Fossils from Southern Australia, presented by Prof. Ralph Tate, F.G.S.; and a specimen of wood from a buried forest at Bombay, presented by Capt. A. W. Stiffe, I.N., F.G.S.

Comparative Statement of the Number of the Society at the close of the years 1882 and 1883.

	Dec. 31, 1882.		Dec. 31, 1883.
Compounders	312	......	313
Contributing Fellows	800	......	822
Non-contributing Fellows	248	......	222
	1360		1357
Honorary Members	3	......	0
Foreign Members	39	......	38
Foreign Correspondents	39	......	39
	1441		1434

General Statement explanatory of the Alterations in the Number of Fellows, Honorary Members, &c. at the close of the years 1882 *and* 1883.

Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1882			1360
Add Fellows elected during former year and paid in 1883			7
Add Fellows elected and paid in 1883			50
			1417
Deduct Compounders deceased		2	
Contributing Fellows deceased		13	
Non-contributing Fellows deceased		13	
Contributing Fellows resigned		12	
Contributing Fellows removed		8	
Compounders taken off List of Fellows *		2	
Non-contributing Fellows taken off List of Fellows *		10	
		—	60
			1357
Number of Honorary Members, Foreign Members, and Foreign Correspondents, December 31, 1882		81	
Deduct Foreign Members deceased	4		
Foreign Correspondent deceased	1		
Foreign Correspondents elected Foreign Members	2		
Honorary Members taken off List of Fellows *	3		
	—	10	
		71	
Add Foreign Members elected	2		
Foreign Member, name restored to List of Fellows	1		
Foreign Correspondents elected	3		
	—	6	
		—	77
			1434

* See Report of the Council, p. 9.

Deceased Fellows.

Compounders (2).

Harcourt, E. V. V., Esq.
Overstone, Lord.

Resident and other Contributing Fellows (13).

Bolam, H. G., Esq.
Cowlishaw, J., Esq.
Drew, Dr. J.
Forbes, W. A., Esq.
Greaves, C., Esq.
Hale, R. B., Esq.
Herbert, W. H., Esq.
Hudson, R., Esq.
Kennedy, M., Esq.
Pickup, P., Esq.
Robert des Ruffières, C., Esq.
Rumble, T. W., Esq.
Young, L. H. G., Esq.

Non-contributing Fellows (13).

Babington, W., Esq.
Boase, Dr. H. S.
Brown, T., Esq.
Chambers, Dr. W.
Grindrod, Dr. R. B.
Jauncey, W., Esq.
Lynde, J. G., Esq.
McClelland, J., Esq.
Minton, S., Esq.
Mitchell, J., Esq.
Talbot de Malahide, Lord.
Taylor, W., Esq.
Wrey, W. L., Esq.

Foreign Members (4).

Barrande, M. Joachim.
Heer, Prof. Oswald.
Merian, Prof. P.
Nilsson, Prof. S.

Foreign Correspondent.

Coquand, M. Henri.

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*Names taken off the List of Fellows by order of the Council** (15).

Bowles, W., Esq.
Copland, A., Esq.
Evans, Rev. R.
Eaton, J., Esq.
Harris, W., Esq.
Hartwell, F., Esq.
Lefevre, H. F. S., Esq.
Mackenzie, C., Esq.
Meyer, Dr. C.
Picquot, A., Esq.
Skene, J., Esq.
Walker, J., Esq.
Wilkinson, J. B., Esq.
Wilson, J., Esq.
Wilson, J., Esq.

* See Report of the Council, p. 9.

Fellows Resigned (12).

Abbay, Rev. R.
Devincenzi, Il Comm. G.
Dixon, J., Esq.
Flight, Dr. W.
Gledhill, J., Esq.
Grenfell, Rev. A. S.
Irvine, D. R., Esq.
Murphy, J. J., Esq.
Oldfield, R. C., Esq.
Rathbone, E. P., Esq.
Rolleston, J. F. L., Esq.
Snell, J., Esq.

Fellows Removed (8).

Crompton, Rev. J.
Dawes, J. T., Esq.
Dorrington, James, Esq.
Harte, J., Esq.
Plant, R., Esq.
Rhys, L., Esq.
Smyth, S. R., Esq.
Swete, Dr. E. H. W.

The following Personages were elected from the List of Foreign Correspondents to fill the vacancies in the List of Foreign Members during the year 1883.

Professor J. S. Newberry of New York.
Professor O. M. Torell of Stockholm.

The following Personages were elected Foreign Correspondents during the year 1883.

M. François L. Cornet of Mons.
Baron F. von Richthofen of Leipzig.
Professor Karl A. Zittel of Munich.

After the Reports had been read, it was resolved:—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and distributed among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to J. W. Hulke, Esq., retiring from the office of President.

That the thanks of the Society be given to Professor P. M. Duncan, R. Etheridge, Esq., and Dr. J. Gwyn Jeffreys, retiring from the office of Vice-President.

That the thanks of the Society be given to Professor T. G. Bonney, retiring from the office of Secretary.

That the thanks of the Society be given to Professor P. M. Duncan, R. Etheridge, Esq., Dr. A. Geikie, S. R. Pattison, Esq., and Professor H. G. Seeley, retiring from the Council.

After the Balloting-glasses had been duly closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year:—

OFFICERS.

PRESIDENT.

Prof. T. G. Bonney, D.Sc., F.R.S.

VICE-PRESIDENTS.

W. Carruthers, Esq., F.R.S.
John Evans, D.C.L., LL.D., F.R.S.
J. A. Phillips, Esq., F.R.S.
Prof. J. Prestwich, M.A., F.R.S.

SECRETARIES.

W. T. Blanford, Esq., F.R.S.
Prof. J. W. Judd, F.R.S.

FOREIGN SECRETARY.

W. W. Smyth, Esq., M.A., F.R.S.

TREASURER.

Prof. T. Wiltshire, M.A., F.L.S.

COUNCIL.

H. Bauerman, Esq.
W. T. Blanford, Esq., F.R.S.
Prof. T. G. Bonney, D.Sc., F.R.S.
W. Carruthers, Esq., F.R.S.
John Evans, D.C.L., LL.D., F.R.S.
Col. H. H. Godwin-Austen, F.R.S.
H. Hicks, M.D.
Rev. Edwin Hill, M.A.
G. J. Hinde, Ph.D.
J. Hopkinson, Esq.
Prof. T. McKenny Hughes, M.A.
J. W. Hulke, Esq., F.R.S.
J. Gwyn Jeffreys, LL.D., F.R.S.
Prof. T. Rupert Jones, F.R.S.
Prof. J. W. Judd, F.R.S.
J. A. Phillips, Esq., F.R.S.
Prof. J. Prestwich, M.A., F.R.S.
F. W. Rudler, Esq.
W. W. Smyth, Esq., M.A., F.R.S.
J. J. H. Teall, Esq., M.A.
W. Topley, Esq.
Prof. T. Wiltshire, M.A., F.L.S.
H. Woodward, LL.D., F.R.S.

LIST OF
THE FOREIGN MEMBERS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1883.

Date of Election.

1827. Dr. H. von Dechen, *Bonn.*
1848. James Hall, Esq., *Albany, State of New York.*
1850. Professor Bernhard Studer, *Berne.*
1851. Professor James D. Dana, *New Haven, Connecticut.*
1851. General G. von Helmersen, *St. Petersburg.*
1853. Count Alexander von Keyserling, *Raykül, Russia.*
1853. Professor L. G. de Koninck, *Liége.*
1854. M. Joachim Barrande, *Prague.* (*Deceased.*)
1856. Professor Robert Bunsen, For. Mem. R.S., *Heidelberg.*
1857. Professor H. R. Göppert, *Breslau.*
1857. Professor H. B. Geinitz, *Dresden.*
1857. Dr. Hermann Abich, *Vienna.*
1859. Dr. Ferdinand Römer, *Breslau.*
1860. Dr. H. Milne-Edwards, For. Mem. R.S., *Paris.*
1862. Professor Pierre Merian, *Basle.* (*Deceased.*)
1864. M. Jules Desnoyers, *Paris.*
1866. Dr. Joseph Leidy, *Philadelphia.*
1867. Professor A. Daubrée, For. Mem. R.S., *Paris.*
1870. Professor Oswald Heer, *Zurich.* (*Deceased.*)
1871. Dr. Sven Nilsson, *Lund.* (*Deceased.*)
1871. Dr. Franz Ritter von Hauer, *Vienna.*
1874. Professor Alphonse Favre, *Geneva.*
1874. Professor E. Hébert, *Paris.*
1874. Professor Albert Gaudry, *Paris.*
1875. Professor Fridolin Sandberger, *Würzburg.*
1875. Professor Theodor Kjerulf, *Christiania.*
1875. Professor F. August Quenstedt, *Tübingen.*
1876. Professor E. Beyrich, *Berlin.*
1877. Dr. Carl Wilhelm Gümbel, *Munich.*
1877. Dr. Eduard Suess, *Vienna.*
1879. Dr. F. V. Hayden, *Washington.*
1879. Major-General N. von Kokscharow, *St. Petersburg.*
1879. M. Jules Marcou, *Cambridge, U. S.*
1879. Dr. J. J. S. Steenstrup, For. Mem. R.S., *Copenhagen.*
1880. Professor Gustave Dewalque, *Liége.*
1880. Baron Adolf Erik Nordenskiöld, *Stockholm.*
1880. Professor Ferdinand Zirkel, *Leipzig.*
1881. Il Commendatore Quintino Sella, *Rome.*
1882. Professor Sven Lovén, *Stockholm.*
1882. Professor Ludwig Rütimeyer, *Basle.*
1883. Professor J. S. Newberry, *New York.*
1883. Professor Otto Martin Torell, *Stockholm.*

LIST OF
THE FOREIGN CORRESPONDENTS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1883.

Date of Election.

1863. Dr. G. F. Jäger, *Stuttgart.*
1863. Count A. G. Marschall, *Vienna.*
1863. Professor G. Meneghini, *Pisa.*
1863. Professor Giuseppe Ponzi, *Rome.*
1863. Dr. F. Senft, *Eisenach.*
1864. Dr. Charles Martins, *Montpellier.*
1866. Professor J. P. Lesley, *Philadelphia.*
1866. Professor Victor Raulin, *Bordeaux.*
1866. Baron Achille de Zigno, *Padua.*
1870. Professor Joseph Szabó, *Pesth.*
1871. M. Henri Coquand, *Marseilles.* (*Deceased.*)
1871. Professor Giovanni Capellini, *Bologna.*
1872. Herr Dionys Stur, *Vienna.*
1872. Professor J. D. Whitney, *Cambridge, U. S.*
1874. Professor Igino Cocchi, *Florence.*
1874. M. Gustave H. Cotteau, *Auxerre.*
1874. Professor G. Seguenza, *Messina.*
1874. Dr. T. C. Winkler, *Haarlem.*
1875. Professor Gustav Tschermak, *Vienna.*
1876. Professor Jules Gosselet, *Lille.*
1877. Professor George J. Brush, *New Haven.*
1877. Professor A. L. O. Des Cloizeaux, For. Mem. R.S., *Paris.*
1877. Professor E. Renevier, *Lausanne.*
1877. Count Gaston de Saporta, *Aix-en-Provence.*
1879. Professor Pierre J. van Beneden, For. Mem. R.S., *Louvain.*
1879. M. Édouard Dupont, *Brussels.*
1879. Professor Guglielmo Guiscardi, *Naples.*
1879. Professor Gerhard Vom Rath, *Bonn.*
1879. Dr. Émile Sauvage, *Paris.*
1880. Professor Luigi Bellardi, *Turin.*
1880. Dr. Ferdinand von Hochstetter, *Vienna.*
1880. Professor Leo Lesquereux, *Columbus.*
1880. Dr. Melchior Neumayr, *Vienna.*
1880. M. Alphonse Renard, *Brussels.*
1881. Professor E. D. Cope, *Philadelphia.*
1882. Professor Louis Lartet, *Toulouse.*
1882. Professor Alphonse Milne-Edwards, *Paris.*
1883. M. François Leopold Cornet, *Mons.*
1883. Baron Ferdinand von Richthofen, *Leipzig.*
1883. Professor Karl Alfred Zittel, *Munich.*

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE "DONATION FUND"

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., &c.

"To promote researches concerning the mineral structure of the earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,"—"such individual not being a Member of the Council."

1831. Mr. William Smith.
1835. Dr. G. A. Mantell.
1836. M. L. Agassiz.
1837. { Capt. T. P. Cautley. / Dr. H. Falconer.
1838. Sir Richard Owen.
1839. Professor C. G. Ehrenberg.
1840. Professor A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron L. von Buch.
1843. { M. Elie de Beaumont. / M. P. A. Dufrénoy.
1844. Rev. W. D. Conybeare.
1845. Professor John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. Rev. Dr. W. Buckland.
1849. Professor Joseph Prestwich.
1850. Mr. William Hopkins.
1851. Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. { M. le Vicomte A. d'Archiac. / M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir H. T. De la Beche.
1856. Sir W. E. Logan.
1857. M. Joachim Barrande.
1858. { Herr Hermann von Meyer. / Mr. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Professor Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Professor Gustav Bischof.
1864. Sir R. I. Murchison.
1865. Dr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Professor Carl F. Naumann.
1869. Dr. H. C. Sorby.
1870. Professor G. P. Deshayes.
1871. Sir A. C. Ramsay.
1872. Professor J. D. Dana.
1873. Sir P. de M. Grey-Egerton.
1874. Professor Oswald Heer.
1875. Professor L. G. de Koninck.
1876. Professor T. H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Professor Bernhard Studer.
1880. Professor Auguste Daubrée.
1881. Professor P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.
1883. Mr. W. T. Blanford
1884. Professor A. Gaudry.

AWARDS
OF THE
BALANCE OF THE PROCEEDS OF THE WOLLASTON "DONATION-FUND."

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. G. A. Mantell.
1836. Professor G. P. Deshayes.
1838. Sir Richard Owen.
1839. Professor C. G. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Professor Edward Forbes.
1842. Professor John Morris.
1843. Professor John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. { Cape-of-Good-Hope Fossils. / M. Alcide d'Orbigny.
1849. Mr. William Lonsdale.
1850. Professor John Morris.
1851. M. Joachim Barrande.
1852. Professor John Morris.
1853. Professor L. G. de Koninck.
1854. Dr. S. P. Woodward.
1855. Drs. G. and F. Sandberger.
1856. Professor G. P. Deshayes.
1857. Dr. S. P. Woodward.
1858. Mr. James Hall.
1859. Mr. Charles Peach.
1860. { Professor T. Rupert Jones. / Mr. W. K. Parker.
1861. Professor A. Daubrée.
1862. Professor Oswald Heer.
1863. Professor Ferdinand Senft.
1864. Professor G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Mr. W. Carruthers.
1870. M. Marie Rouault.
1871. Mr. R. Etheridge.
1872. Dr. James Croll.
1873. Professor J. W. Judd.
1874. Dr. Henri Nyst.
1875. Mr. L. C. Miall.
1876. Professor Giuseppe Seguenza.
1877. Mr. R. Etheridge, Jun.
1878. Professor W. J. Sollas.
1879. Mr. S. Allport.
1880. Mr. Thomas Davies.
1881. Dr. R. H. Traquair.
1882. Dr. G. J. Hinde.
1883. Mr. John Milne.
1884. Mr. E. T. Newton.

AWARDS OF THE MURCHISON MEDAL
AND OF THE
PROCEEDS OF "THE MURCHISON GEOLOGICAL FUND,"
ESTABLISHED UNDER THE WILL OF THE LATE
SIR RODERICK IMPEY MURCHISON, Bart., F.R.S., F.G.S.

"To be applied in every consecutive year in such manner as the Council of the Society may deem most useful in advancing geological science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any inquiries bearing upon the science of geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of geological science."

1873. Mr. William Davies. *Medal.*
1873. Professor Oswald Heer.
1874. Dr. J. J. Bigsby. *Medal.*
1874. Mr. Alfred Bell.
1874. Professor Ralph Tate.
1875. Mr. W. J. Henwood. *Medal.*
1875. Professor H. G. Seeley.
1876. Mr. A. R. C. Selwyn. *Medal.*
1876. Dr. James Croll.
1877. Rev. W. B. Clarke. *Medal.*
1877. Professor J. F. Blake.
1878. Dr. H. B. Geinitz. *Medal.*
1878. Professor C. Lapworth.
1879. Professor F. M'Coy. *Medal.*
1879. Mr. J. W. Kirkby.
1880. Mr. R. Etheridge. *Medal.*
1881. Professor A. Geikie. *Medal.*
1881. Mr. F. Rutley.
1882. Professor J. Gosselet. *Medal.*
1882. Professor T. Rupert Jones.
1883. Professor H. R. Göppert. *Medal.*
1883. Mr. John Young.
1884. Dr. H. Woodward. *Medal.*
1884. Mr. M. Simpson.

AWARDS OF THE LYELL MEDAL

AND OF THE

PROCEEDS OF THE "LYELL GEOLOGICAL FUND,"

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE

SIR CHARLES LYELL, BART., F.R.S., F.G.S.

The Medal "to be given annually" (or from time to time) "as a mark of honorary distinction as an expression on the part of the governing body of the Society that the Medallist has deserved well of the Science,"—"not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions at the discretion of the Council for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced."

1876. Professor John Morris. *Medal.*
1877. Dr. James Hector. *Medal.*
1877. Mr. W. Pengelly.
1878. Mr. G. Busk. *Medal.*
1878. Dr. W. Waagen.
1879. Professor Edmond Hébert. *Medal.*
1879. Professor H. A. Nicholson.
1879. Dr. Henry Woodward.
1880. Mr. John Evans. *Medal.*
1880. Professor F. Quenstedt.
1881. Principal J. W. Dawson. *Medal.*
1881. Dr. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. Dr. J. Lycett. *Medal.*
1882. Rev. Norman Glass.
1882. Professor C. Lapworth.
1883. Dr. W. B. Carpenter. *Medal.*
1883. Mr. P. H. Carpenter.
1883. M. E. Rigaux.
1884. Dr. Joseph Leidy. *Medal.*
1884. Professor C. Lapworth.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially "as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much."

1877. Professor O. C. Marsh.
1879. Professor E. D. Cope.
1881. Dr. C. Barrois.
1883. Dr. Henry Hicks.

AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

"The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science."

1880. Purchase of microscope.
1881. Purchase of microscope lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Professor Leo Lesquereux.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Due for Subscriptions for Quarterly Journal ..	2	16	2			
Due for Arrears of Annual Contributions	180	0	0			
Due for Arrears of Admission-fees	56	14	0			
				239	10	2
Estimated Ordinary Income for 1884:—						
Annual Contributions from Resident Fellows, and Non-residents of 1859 to 1861				1460	0	0
Admission-fees				280	0	0
Compositions				136	10	0
Annual Contributions in advance				21	0	0
Dividends on Consols and Reduced 3 per Cents.				233	0	11
Advertisements in Quarterly Journal....................				6	10	0
Sale of Transactions, Library-catalogue, Ormerod's Index, Hochstetter's New Zealand, and List of Fellows	8	0	0			
Sale of Quarterly Journal, including Longman's account	210	0	0			
Sale of Geological Map, including Stanford's account	20	0	0			
				238	0	0
				£2614	11	1

THOMAS WILTSHIRE, TREAS.

6 *Feb.* 1884.

the Year 1884.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes and Insurance	31	2	6			
Gas	26	0	0			
Fuel	34	0	0			
Furniture	20	0	0			
House-repairs and Maintenance	20	0	0			
Annual Cleaning	20	0	0			
Washing and sundry small Expenses	35	0	0			
Tea at Meetings	16	0	0			
				202	2	6
Salaries and Wages:						
Assistant Secretary	350	0	0			
Clerk	160	0	0			
Assistant in Library and Museum	130	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	41	12	0			
Charwoman and Occasional Assistance	30	0	0			
Attendants at Meetings	8	0	0			
Accountants	10	10	0			
				875	2	0
Official Expenditure:						
Stationery	25	0	0			
Miscellaneous Printing	25	0	0			
Postages and other Expenses	62	0	0			
				112	0	0
Library				150	0	0
Publications:						
Geological Map	20	0	0			
Quarterly Journal	1000	0	0			
,, ,, Commission, Postage, and Addressing	90	0	0			
List of Fellows	34	0	0			
Abstracts, including Postage	107	0	0			
				1251	0	0
Balance in favour of the Society				24	6	7
				£2614	11	1

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, 1 January 1883.	98	11	7			
Balance in Clerk's hands, 1 January 1883.	1	5	7			
				99	17	2
Compositions				136	10	0
Arrears of Admission-fees..............	44	2	0			
Admission-fees, 1883	315	0	0			
				359	2	0
Arrears of Annual Contributions				181	16	0
Annual Contributions for 1883, viz.:						
Resident Fellows	1432	4	0			
Non-Resident Fellows ...	20	9	6			
				1452	13	6
Annual Contributions in advance				64	11	6
Dividends on Consols	201	8	1			
,, Reduced 3 per Cents.	30	6	10			
				231	14	11
Taylor & Francis: Advertisements in Journal, Vol. 38..				6	10	6
Journal Subscriptions in Advance..................				0	16	4
Publications:						
Sale of Journal, Vols. 1–38	118	6	2			
,, Vol. 39 *	87	14	9			
Sale of Library Catalogue	5	1	0			
Sale of Geological Map	27	8	9			
Sale of Ormerod's Index.......................	2	7	3			
Sale of Hochstetter's New Zealand	0	18	0			
				241	15	11
*Due from Messrs. Longman, in addition to the above, on Journal, Vol. 39, &c......................	65	14	3			
Due from Stanford on account of Geological Map	9	10	4			
	75	4	7			
				£2775	7	10

We have compared this statement with the Books and Accounts presented to us, and find them to agree.

(Signed) J. ARTHUR PHILLIPS, F. G. HILTON PRICE, } *Auditors.*

4 *Feb.* 1884.

Year ending 31 *December,* 1883.

EXPENDITURE.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes	24	3	9			
Fire-insurance	12	0	0			
Gas	26	3	4			
Fuel	33	3	0			
Furniture	46	0	3			
House-repairs	8	10	2			
Annual Cleaning	19	13	0			
Washing and Sundries	34	5	8			
Tea at Meetings	16	0	0			
				219	19	2
Salaries and Wages:						
Assistant Secretary	350	0	0			
Clerk	160	0	0			
Assistant in Library and Museum	110	0	0			
House Steward	105	0	0			
Housemaid	40	0	0			
Errand Boy	41	12	0			
Charwoman and Occasional Assistance	28	13	0			
Attendants at Meetings	8	0	0			
Accountants	10	10	0			
				853	15	0
Official Expenditure:						
Stationery	21	7	10			
Miscellaneous Printing	30	17	5			
Postages and other Expenses	62	17	0			
				115	2	3
Library				155	19	1
Publications:						
Geological Map	8	16	9			
Journal, Vols. 1–38	12	16	11			
,, Vol. 39 ... 794 6 10						
,, ,, Commission, Postage, and Addressing . 80 18 2						
	875	5	0			
Ormerod's Index	30	13	9			
List of Fellows	33	12	6			
Abstracts, including Postage	107	3	11			
				1068	8	10
Balance in Bankers' hands, 31 Dec. 1883	346	0	1			
Balance in Clerk's hands, 31 Dec. 1883	16	3	5			
				362	3	6
				£2775	7	10

"Wollaston Donation Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1883	31	14	10	Cost of striking Gold Medal awarded to Mr. W. T. Blanford	10	10	0
Dividends on the Fund invested in Reduced 3 per Cents.	31	14	11	Award to Professor J. Milne	18	1	10
				Part cost of New Dies (third instalment)	3	3	0
				Balance at Bankers', 31 December 1883	31	14	11
	£63	9	9		£63	9	9

"Murchison Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1883	19	11	8	Award to Professor H. R. Göppert, with Medal	10	10	0
Dividends on the Fund invested in London and North-Western Railway 4 per cent. Debenture Stock	38	18	4	" Mr. John Young	28	9	7
				Balance at Bankers', 31 December 1883	19	10	5
	£58	10	0		£58	10	0

"Lyell Geological Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1883	51	9	1	Award to Dr. W. B. Carpenter, with Medal	25	0	0
Dividends on the Fund invested in Metropolitan 3½ per cent. Stock	68	13	6	" Mr. P. H. Carpenter	21	15	8
				" Mons. E. Rigaux	21	15	8
				Balance at Bankers', 31 December 1883	51	11	3
	£120	2	7		£120	2	7

"Barlow-Jameson Fund." Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1883	22	10	6	Balance at Bankers', 31 December 1883	37	2	4
Dividends on the Fund invested in Consols	14	11	10				
	£37	2	4		£37	2	4

"BIGSBY FUND." TRUST ACCOUNT.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', 1 January 1883	12	5	4	Cost of striking Gold Medal awarded to Dr. H. Hicks	12	5	4
Dividends on the Fund invested in New 3 per Cents	6	2	7	Balance at Bankers', 31 December 1883	6	2	7
	£18	7	11		£18	7	11

VALUATION OF THE SOCIETY'S PROPERTY; 31 December, 1883.

Property.	£	s.	d.	£	s.	d.	Debts.	£	s.	d.
Due from Longman & Co., on account of Journal, vol. xxxix. &c.				65	14	3	Balance in favour of the Society	8692	18	1
Due from Stanford on account of Map				9	10	4				
Due from Subscribers to Journal (considered good)				2	16	2				
Balance in Bankers' hands, 31 Dec. 1883				346	0	1				
Balance in Clerk's hands, 31 Dec. 1883				16	3	5				
Funded Property:—										
Consols, at 101	6900	7	2	6969	7	2				
Reduced 3 per Cents. at 101	1036	5	5	1046	12	8				
Arrears of Admission-fees (considered good)				56	14	0				
Arrears of Annual Contributions (considered good)				180	0	0				
				£8692	18	1		£8692	18	1

d [*N.B. The above does not include the value of the Collections, Library, Furniture, and stock of unsold Publications.*]

THOMAS WILTSHIRE, *Treas.*

6 *Feb.* 1884.

Award of the Wollaston Medal.

In presenting the Wollaston Gold Medal to Prof. A. Gaudry, F.M.G.S., the President addressed him as follows:—

Professor Gaudry,—

The Council of the Geological Society has awarded you the Wollaston Medal in recognition of the value of your palæontological researches and the important scientific generalizations you have deduced from long and laborious observations. The numerous papers on topographical geology and on palæontology you have contributed during the past 30 years, your important 'Recherches Scientifiques en Orient entreprises par les ordres du Gouvernement pendant les années 1853–1854,' your 'Animaux fossiles et géologie de l'Attique,' and, lastly, your work 'Les Enchaînements du monde animal dans les temps géologiques,' have made your name so familiar, wherever our branch of natural science is cultivated, that in receiving you, we feel we are not receiving a stranger, but a scientific brother, and one who, by his labours and singleness of aim, has achieved a position as a palæontologist such as few can hope to attain. Personally, it affords me great and sincere pleasure that it has fallen to my lot to hand you this Medal, which, by the consent of all, has never been more worthily bestowed.

Professor Gaudry, in reply, said:—

Mr. President,—

I regret much that I speak English too imperfectly to express well the sentiments which I feel in my heart. I can only say that my pleasure in receiving the Wollaston Medal is in proportion to my admiration for the labours of the illustrious Geological Society of London and to my affection for many of its Fellows. I beg the Geological Society and its distinguished President to accept my best thanks.

Award of the Wollaston Donation Fund.

The President then presented the Balance of the Proceeds of the Wollaston Donation Fund to Mr. E. Tulley Newton, F.G.S., and addressed him as follows:—

Mr. Newton,—

The Council has voted you the Balance of the proceeds of the "Wollaston Donation Fund," in recognition of the value of your researches amongst the Pleistocene Mammalia of Great Britain, and to assist you in the prosecution of further investigations.

Your Memoirs published by the Geological Survey of England and Wales "On the Vertebrata of the Forest-bed series of Norfolk and Suffolk" and on "The Chimæroid fishes of the Cretaceous Rocks" and your papers published in our Journal are considered by the Council to evince great merit; they regard them as a bright earnest of future work which they hope may be promoted by this award.

Mr. Newton, in reply, said:—

Mr. President,—

Most highly do I appreciate the honour which the Council of the Geological Society have conferred upon me to-day by awarding me the proceeds of the Wollaston Fund,—an honour wholly unexpected, and valued the more because of the kind manner in which you, Sir, have been pleased to speak of my work among the fossil vertebrata, which it has been my pleasure and, in part, my duty, to undertake.

Such work is always a source of pleasure and profit in itself; but its recognition by those who are most capable of judging of its value is certainly the greatest satisfaction and highest reward one can receive. In accepting this award, I do so with the greater pleasure because I feel that it is not only an honour to myself, but an indication of the goodwill which exists between the Geological Society and the members of the Geological Survey.

If any thing could enhance the value of the award in my estimation, it would be receiving it, as I do to-day, from the hands of one who, standing in the foremost rank of anatomists and palæontologists, is so competent to judge of such work as mine, and who by kind and gentle sympathy has not only encouraged investigation, but gained the warmest regards of all who have come within the circle of his influence.

Award of the Murchison Medal.

In presenting the Murchison Medal to Dr. Henry Woodward, F.R.S., the President said:—

Dr. Henry Woodward,—

The Council has awarded you the Murchison Medal and a grant of Ten Guineas in recognition of your valuable researches into the structure and classification of the fossil Crustacea, especially of the Merostomata and Trilobita, and your services to the progress of geology in Great Britain by your conduct of the Geological Magazine for nearly twenty years. Your Monograph on the "Merostomata," published by the Palæontographical Society, and your "Catalogue of British fossil Crustacea, with their synonyms and the range in time of each genus and order," will long continue to be works of reference indispensable to every student of these interesting life-forms. But valuable as are these written records, they discover but a small part of the services you have rendered in the advancement of our science. How much more you have done by the assistance you have so freely given to all who have sought your help at the Museum in deciphering some difficult matters in palæontology will never be fully known.

Dr. Woodward, in reply, said:—

Mr. President,—

I cannot, I fear, adequately express my thanks to the Council for the honour they have conferred upon me this day in awarding me the Murchison Medal.

This mark of their esteem is peculiarly appropriate, since its founder, Sir Roderick Murchison, was for many years one of the most active of the Trustees of the British Museum, under whom I have now had the honour to serve for the past twenty-six years. Since my election to the Geological Society, twenty years ago, I cannot but recall that the Council has upon two former occasions (in 1866 and 1879) encouraged and assisted me in my scientific work by an award. I feel, however, that the Medal now bestowed by you, Sir, is a far higher recognition of my scientific labours, and one which gives them the stamp of the approval of the Geological Society.

I thank you for alluding to the 'Geological Magazine,' now in its twentieth year, and which (saving the first year, when it was edited in conjunction with Prof. T. Rupert Jones) I have personally carried on since its commencement. I believe it has had its uses, serving not only as a sluice-gate in times of emergency to let off the overflowing productions of pent-up Fellows thirsting for publication, but also as a convenient and ready method of printing *short papers*, which might be deemed too ephemeral for admission into the Society's Journal.

Although, for the past four years, my time has been so very largely taken up with the removal of the Geological Collections from Bloomsbury, and their rearrangement in the New Museum in Cromwell Road, as to preclude almost entirely the possibility of doing original scientific work, I trust it will not always be so, but that shortly I may give some evidence of being worthy of the honour I have received this day; and those palæontologists who have visited and consulted the collections since their removal can best appreciate how those four years have been spent, and with what result, in the better display of the great collections now under my charge.

Award of the Murchison Geological Fund.

The President then handed the balance of the proceeds of the Murchison Geological Fund to Mr. R. Etheridge, F.R.S., for transmission to Mr. Martin Simpson, of Whitby, and addressed him as follows:—

Mr. Etheridge,—

The balance of the proceeds of the Murchison Donation Fund has been awarded by the Council to Mr. M. Simpson, Curator of the Whitby Museum. He has devoted much attention to the fossils of that district, and he is the author of two books descriptive of them. The Council hopes that this cheque may be of assistance to him in continuing the useful extra-official work he has long been carrying on in that locality.

Mr. Etheridge, having expressed the pleasure that it gave him to receive, on behalf of Mr. Simpson, this testimony of the Society's appreciation of the life-long labours of one who had pursued palæontological studies with so much devotion, read the following extract from a letter which he had received from Mr. Simpson:—

"Dear Sir,

"I feel deeply honoured by the kind recognition of my humble services to geological science. I feel this the more, as I have had no assistance or encouragement from my fellow-townsmen.

"In my reply to Prof. Bonney, I endeavoured to express the deep sense I felt for this honour conferred upon me, and my best thanks are due to the Council.

"In a letter recently received from Prof. Owen, he says that Whitby is much indebted to science; I hope, however, that it will not be thought egotistic on my part if I say that science is in some way indebted to Whitby, which was amongst the first to make important palæontological discoveries, and to attract to the place the distinguished geologists of the day, when our science was only in its infancy. I hope, therefore, this mark of distinction now conferred upon me will not be misplaced when awarded to the last, now living, of an enthusiastic race of palæontologists which sprang up in these parts at the very origin of the science, and contributed towards placing it on a solid foundation.

"In pursuing my own researches it has ever been my constant care to carefully and honourably preserve the labours of others, and to render them beneficial to the public.

"In this way the Whitby Museum, established in 1823, or sixty years ago, has, under very great difficulties, grown up to be something considerable, and is highly appreciated by the many literary and scientific persons who visit Whitby and its neighbourhood.

"I have done all I can, or am able to do, relative to my catalogue of our Lias species, and I shall have great pleasure and satisfaction in applying the Murchison Donation Fund towards still publishing descriptions of our local fossils."

Award of the Lyell Medal.

The President next handed the Lyell Medal to Prof. W. H. Flower, F.R.S., for transmission to Dr. Joseph Leidy, F.M.G.S., and addressed him as follows:—

Professor Flower,—

The Council has bestowed on Dr. J. Leidy the Lyell Medal, with a sum of £25, in recognition of his valuable contributions to palæontology, especially as regards his investigations on the Fossil Mammalia of Nebraska and the Sauria of the United States of America. These vast and, in comparison with our own country, but little-explored territories have for some years past yielded a harvest of fossil vertebrate remains of exceeding richness, of which we have no example here. How well this harvest is being garnered by our Transatlantic *confrères* the flood of memoirs published by them during the last quarter of a century bears witness. Amongst these scientific labourers in the palæontological harvest-field, Dr. J. Leidy has held a foremost place. Careful in observing, accurate in recording, cautious in inferring, his work has the high merit which trustworthiness always imparts. The well-nigh astounding number of papers written by him between 1845 and 1873, amounting to 187, his Reports on the 'Extinct Vertebrate Fauna of the Western Territories,' his 'Synopsis of the Extinct Mammalia of North America,' and his 'Cretaceous Reptiles of the United States,' testify to the fertility of his pen.

Professor FLOWER, in reply, said:—

Mr. PRESIDENT,—

As I have profited so deeply by Dr. Leidy's palæontological writings, and also have the pleasure of his personal friendship, I was much gratified by his request, communicated to me by telegraph a few days ago, that I would represent him on this occasion, and receive from your hands the award which the Council has so worthily bestowed. By the same means of communication, he mentions the interesting incident, that it was by Sir Charles Lyell's advice, given to him in Philadelphia about thirty years ago, that he was induced to abandon the study of medicine and take up palæontology. A letter which, I understand, Dr. Leidy has written in which he doubtless has expressed his own thanks to you, has not yet reached me; but I am quite sure that this recognition of his valuable labours in that marvellously fruitful field of discovery, the extinct vertebrate fauna of North America, will be greatly appreciated by him, and by his fellow-countrymen, by whom he is so justly esteemed.

[The following is the letter from Dr. Leidy, mentioned by Prof. Flower:—

"Philadelphia, Pa., 1302 Filbert St.
"Feb. 7th, 1884.

"My Dear Sir,

"I have this minute received your note of Jan. 25th and hasten to reply, that there may be no delay in my answer, for the Anniversary Meeting of Feb. 15th. I was equally surprised and delighted at the action of the Council of the Geological Society in awarding to me the Lyell Medal and its accompaniment. Such approbation of my services I regard as rich compensation added to the pleasure derived from my labours. I must add that I feel as if Sir Charles Lyell himself was expressing satisfaction, in consideration of my having complied with his wish, when 30 years ago, in my own home here, he said he hoped I would devote my time to Palæontology, instead of Medicine.

"Please present to the Geological Society my warmest thanks for the honour it has conferred upon me.

"I have written to Prof. W. H. Flower, asking him to receive the award on my account.

"With sincere regard,
JOSEPH LEIDY."

MR. WARINGTON W. SMYTH,
For. Sec. Geol. Soc.]

AWARD OF THE LYELL GEOLOGICAL FUND.

In presenting to Prof. C. LAPWORTH, F.G.S., the balance of the Lyell Geological Fund, the PRESIDENT said:—

Professor Lapworth,—

The Council has awarded to you the balance of the proceeds of the Lyell Donation Fund in recognition of the value of your researches into the palæontology and physical structure of the older rocks of Great Britain—carried on frequently under unfavourable circumstances and to the injury of your health—and to aid you in similar investigations. Your papers on "The Girvan Succession," "The Moffat Series," published in our Journal, and "The Graptolites," and "The Secret of the Highlands," contributed to the 'Geological Magazine,' were the outcome of an extremely laborious and detailed exploration of the districts to which they refer—an exploration in conducting which you spared no pains and shrank from no hardships. No one who desires to know the structure of these districts can safely omit a careful study of these very instructive papers.

Professor Lapworth in reply said:—

Mr. President,—

I am very grateful to the Council of the Geological Society for this proof of their continued interest in my geological work, and to yourself, Sir, for the generous and kindly manner in which you have spoken of what I have done. I am at present too little recovered to hope that I shall soon be in a position to resume my studies of the ancient British rocks and fossils; but you may rest assured that immediately my ordinary health is restored, I shall of necessity gravitate again, if I may so express myself, to the old familiar fields.

As this award has been made me from the Lyell bequest, I shall hold it both a pleasure and a duty to endeavour to devote it to working out a few fresh facts for discussion in this Society, along the linesl aid down in the 'Principles.' Whether that endeavour will ever be realized is for the future to determine. Even the most I ever hope to accomplish will be to show, vast as is the mass of geological material hitherto collected, how insignificant it actually is in comparison with that which remains for discovery, and what a mighty future awaits that great science to which we are all devoted.

Award of the Barlow-Jameson Fund.

The President then handed to Professor Bonney, D.Sc., F.R.S., for transmission to Dr. J. Croll, a portion of the proceeds of the Barlow-Jameson Fund, and said:—

Professor Bonney,—

The Council, in recognition of the value of Dr. James Croll's researches into the "Later physical History of the Earth," and to aid him in further researches of a like kind, has awarded to him the sum of £20 from the proceeds of the Barlow-Jameson Fund. Dr. Croll's work on 'Climate and Time in their Geological Relations,' and his numerous separate papers on various cognate subjects, including "The Eccentricity of the Earth's Orbit," "Date of the

Glacial Period," "The Influence of the Gulf Stream," "The Motion of Glaciers," "Ocean Currents," and "The Transport of Boulders," by their suggestiveness have deservedly attracted much attention. In forwarding to Dr. Croll this award, the Council desires you to express the hope that it may assist him in continuing these lines of research.

Professor Bonney, in reply, said:—

Mr. President,—

I have been charged by Dr. J. Croll to express to the Society his regret that his weak health and the great distance at which he resides prevent him from being present in person to-day to receive this award. He desires me to express his deep sense of the honour which is done to him in this renewed mark of the appreciation of his work, and he gives us the cheering news that though still at times suffering, he is now able to do a little work, a proof of which, in a paper on Mr. Wallace's remarks on the theory of Climate, reached me yesterday. Deeply though I regret Dr. Croll's absence, I feel honoured in representing a man who has done such original suggestive and valuable work.

In handing to Professor Seeley, F.R.S., a second portion of the proceeds of the Barlow-Jameson Fund for transmission to Professor Leo Lesquereux, F.C.G.S., the President spoke as follows:—

Professor Seeley,—

The Council has awarded to Professor Leo Lesquereux the sum of £20 from the proceeds of the Barlow-Jameson Fund, in recognition of the value of his researches into the Palæo-botany of North America, and to aid him in further investigations of a similar kind.

Professor Lesquereux's "Contributions to the Fossil Cretaceous and Tertiary Flora of the Western Territories," published in the 'Reports of the United States Geological Survey,' are works which, for their matter, typography and illustrations leave nothing to desire. In transmitting this award to Professor Lesquereux, you will convey to him the hopes of the Council that it may assist him in prosecuting further investigations in the difficult branch of research in which he has already accomplished so much.

Professor Seeley, in reply, said:—

Mr. President,—

I feel much honoured in receiving this award on behalf of Professor Lesquereux. His valuable researches not only contribute systematic descriptions of the American Secondary and Tertiary floras, but furnish almost the only data for comparing those floras with the plant life from similar strata on this side of the Atlantic. All Professor Lesquereux's work is marked by such exactness and care, that I am glad we are thus able to honour it, and offer assistance in its progress.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

J. W. Hulke, Esq., F.R.S.

Gentlemen,

A custom dating, I believe, from the foundation of the Society, imposes on me the sad yet salutary obligation of beginning my address with a reference to the losses our ranks have sustained by death during the official year now closing. Although our losses of Fellows have been numerous, I find in the obituary list one only who had ever communicated a "paper." I allude to Dr. McClelland, who, in 1827, contributed a paper "On the Natural History of Upper Assam where the Tea-plant grows wild;" and it is from the rolls of Foreign Members and Correspondents that we miss long-familiar names.

On the 27th September, at Lausanne, at the ripe age of 74 years, died Prof. Oswald Heer, whose long and zealous devotion to the study of fossil plants, pursued during the greater part of a long life under the adverse circumstances of slender means, ill health, and great physical weakness, could not fail to secure admiration and respect. His intimate personal friends tell of his extreme amiability and of his sympathetic nature. In early life he was a very successful student of entomology, in which he even in later years took a keen interest; but he will be best remembered as one of the foremost pioneers in Palæo-botany, in which difficult branch of research he acquired a wider than European reputation. The estimation in which the Society held him was testified by the award to him of the Wollaston Fund in 1862, of the Murchison Fund in 1873, and of the Murchison Medal in the following year.

In October the Society lost another of its Foreign Members, Joachim Barrande, who died on the 5th of that month at Frohsdorf, in Austria, whither he had been called some months previously by the fatal illness of his former pupil, the Comte de Chambord. Exiled from his native land, his attention was early directed to the collection and study of the Palæozoic fossils of Bohemia, his adopted country. His colossal work, the 'Système Silurien de la Bohême,' of which no fewer than 22 volumes had been published at the time of his decease, and a large number of separate papers, bear witness to his unflagging industry, his singleness of purpose, and his critical acumen, the possession of which alone made possible so great an undertaking. Barrande has left to the city of Prague his unrivalled collection of fossils, and considerable funds for its maintenance and for the completion of the 'Système.' Our Society marked its high estimation of his labours by awarding to him, in 1851, the Balance of the Wollaston Fund, the diploma of Foreign Membership in 1854, and the Wollaston Medal in 1855.

On the 30th November the Society lost one of its oldest Foreign Members, SVEN NILSSON, who on that day fell asleep, in his 96th year, at Lund, in the University of which he long held a prominent Professorship. His first publication noticed in the 'Royal Society's Catalogue of Scientific Papers,' is dated 1816, but he had published four years earlier (1812) a paper on the different methods of classifying the Mammalia. The date of his latest paper of which I find any notice is 1873. His researches, published mostly in Swedish, dealt chiefly with Zoology, Ethnology, and Antiquities. One of his palæontological papers, published in 1827 at Lund, treats of the Cretaceous Fossils of Sweden.

Another very aged Foreign Member who last year passed away to his long rest is PIERRE MERIAN, M.D., of Basle. According to the 'Royal Society's Catalogue of Scientific Papers,' his first paper was published in 1817, and by 1873 the number of memoirs and shorter papers which had then issued from his pen amounted to 98. Most of the subjects treated in these are geological. His more important works are:—'Beiträge zur Geognosie,' 1821; 'Geognostische Uebersicht des südlichen Schwarzwaldes,' 1831; and 'Ueber die in Basel wahrgenommenen Erdbeben,' 1834. He is said to have been a man of genial temperament and very hospitable, and to have been much beloved.

By the death of M. HENRI COQUAND the Society lost one of its Foreign Correspondents, elected in 1871. The place and time of his decease are both unknown to me, as is also his age; but this must have been advanced, since his first paper was published in 1835 or 1836. He was a voluminous writer: his published contributions to science, recorded in the 'Royal Society's Catalogue of Scientific Papers,' up to the end of 1873, amounted to 76. A large proportion of these, I am informed, relate to the geology of the Secondary period. Amongst his principal works are:—a 'Traité des Roches,' Paris, 1857; 'Description physique, géologique, paléontologique et minéralogique du Département de la Charente,' 8vo, Besançon, 1858; 'Géologie et Paléontologie de la Région sud de la Province de Constantine,' 8vo; Atlas, 4to, Marseilles, 1865; and 'Monographie de l'étage Aptien de l'Espagne,' 8vo, Marseilles, 1865.

Turning from these sad memories to a retrospect of the work accomplished by the Society in the past year, it is satisfactory to find that, notwithstanding the numerous losses the Society has sustained, there have not appeared any traces of "dissipation of energy" in its zeal for research in those branches of "natural knowledge," the investigation of which is the motive of its existence. The gaps in our ranks have been filled by fresh labourers; and, to judge by the number of communications received, by their matter, and by the large attendances at our meetings, the present session may fairly claim to have been one of more than average interest.

An analysis of the subjects of the papers read during the year has shown a large numerical preponderance of those treating of stratigraphical questions. In the preceding year the preponderance was on the side of Palæontology.

Of the stratigraphical papers a large proportion related to the Palæozoic and the Archæan divisions of rocks; and of these indubitably one of the most important, both in respect of its immediate subject and also on account of the bearing of the author's conclusions upon the age of homotaxious rocks in other districts, was Dr. A. Geikie's paper, entitled "On the supposed Pre-Cambrian Rocks of St. Davids." I may not claim that intimate acquaintance with the locality and with its petrology, without which it is not possible independently to form an opinion of the completeness of the proofs offered by the author that the three Pre-Cambrian groups of Dr. Hicks are, in the main, actually masses of eruptive rock of younger age than the "Lower Cambrian Conglomerates" apparently overlying them; and that they are not, as Dr. Hicks thinks, in the main, masses of metamorphosed sedimentary rocks (with subordinate additions of eruptive rocks) of greater age than the "Lower Cambrian Conglomerates." The impression left on my mind, after an attentive consideration of the paper, and of the debate upon it, is that, having regard to the importance of the question raised by Dr. A. Geikie, it is very desirable that he and Dr. Hicks might find it practicable together to revisit St. Davids, a proceeding which, as it would afford opportunities for explaining on the spot difficulties as they presented themselves, would tend greatly to remove and to reconcile discrepancies of interpretation, and might even result in an agreement upon the true order of succession and age of these rock-masses, a desideratum scarcely to be expected from a continuation of polemical papers lately promised *.

A paper, scarcely less important on account of the question it raised, was that by Dr. Callaway, on "The Age of the newer Gneissic Rocks of the Northern Highlands." These, which had usually been considered of "Lower Silurian" age, are, Dr. Callaway contended, Archæan; and he supported this opinion by a large body of evidence laboriously gathered in the field. Having visited several of the localities which furnished the sections with which Dr. Callaway's paper was illustrated, I can bear testimony to the conscientiousness of his work; yet, if I may be allowed to say it, the conviction grew upon me that, considering the very involved character of the country, no complete proof of the true sequence of its rock-masses is to be expected from any exploration less than a very detailed survey of the entire area, mapped on a large scale, and supplemented by an exhaustive petromicroscopical and chemical study.

* A preliminary accord upon petrographical nomenclature would be essential to such success. The need of this is so obvious, that it would be ridiculous even to refer to it, had it not become apparent in the course of the debate that the common name "granite" was by one party held to include rocks consisting of a binary mixture of quartz and felspar, and by the other party applied to the ternary mixture of the above two minerals with a third, usually mica, commonly so designated.

Here I may be excused for insisting that no new reading which may arise out of a revision of the work of the early explorers of the Highlands should be thought to cast any discredit upon them; they themselves would have been foremost in disclaiming its finality. I am confident that no geologist can have visited the north of Scotland without bringing away an intense admiration at the grand results attained by those pioneers who did not possess the topographical advantages and the refined methods of optical and chemical analysis we enjoy.

In a paper read on the 7th of January, "On the Volcanic Group of St. Davids," Prof. J. F. Blake gave a third reading of the geological structure of this memorable district, to the effect that Dr. Hicks's three groups or systems—Dimetian, Arvonian, and Pebidian, constitute a gradational, continuous series of volcanic rocks of earlier age than the "Lower Cambrian Conglomerates." Prof. Blake therefore is in accord with Dr. Hicks as to their age, and, in the main, in accordance with Dr. A. Geikie as to their nature. Mr. Blake's opinions being the outcome of field-work, carried on during a residence in the district, claim attention.

Two short papers by Prof. Bonney, one "On a Section recently exposed in Baron-Hill Park, near Beaumaris," the other "On the Rocks between the Quartz-felsites and the Cambrian Series in the neighbourhood of Bangor," were very valuable contributions to our knowledge of the Archæan rocks of those localities.

A communication by Dr. Hicks, "On the Cambrian Conglomerates resting upon, and in the vicinity of, some Pre-Cambrian Rocks (the so-called intrusive masses) in Anglesey and Caernarvonshire," was a rejoinder to Dr. A. Geikie's paper, the first noticed in this retrospect. The great value of Dr. Hicks's paper consisted in the evidence, apparently unimpeachable and supported by numerous rock-specimens, brought forward in proof of the composition of these conglomerates largely or mainly of pebbles derived from the granitoid rocks beneath them. The identity of the pebbles with the underlying rocks was established by Prof. Bonney, by microscopical evidence, in a supplementary note, which for perspicuity left nothing to be desired.

In a paper "On the Geology of the South-Devon Coast from Torcross to Hope Cove," Prof. Bonney discussed the problem of a transition from slaty to foliated rocks. He showed that for this district the evidence is against it, and upon clear indications that the foliated rocks had undergone much folding and crumpling after their foliation was completed, and before the great earth-movements which had affected the Palæozoic rocks, he referred the foliated rocks to the Archæan division.

Mr. J. H. Collins, in a communication "On the Serpentines and Associated Rocks of Porthalla Cove," stated his belief that an actual transition between the rocks mentioned in the title occurred, an opinion which he supported by evidence in part drawn from their chemical constitution. In the discussion which followed, the consensus of opinions appeared distinctly unfavourable to the author's views.

Leaving these remotest geological ages for later ones, the first paper that was read this session was an excellent example of the valuable kind of work which is peculiarly possible to a geologist whose long residence in a particular locality makes him thoroughly familiar with all its physical circumstances, and enables him to seize each fresh exposure of rocks; and, which constitutes a great safeguard against errors arising out of hasty observations, allows him to check first impressions by frequent visits. I allude to Mr. Walford's paper "On the Relation of the so-called Northampton Sand of North Oxfordshire to the *Clypeus*-grit." Its great value was abundantly testified in the debate which ensued on its reading, although some of the speakers did not conceal their doubts of the completeness of the demonstration attempted by the author.

A communication by Prof. Sollas "On the Estuaries of the Severn and on their Tidal Sediment and Alluvial Flats" had, in addition to its intrinsic geological interest (one element in which was the demonstration that these deposits comprise a larger amount of marine materials than had been previously supposed), a very important bearing on sanitation in connexion with the disposal of the sewage of large towns.

One of the latest stratigraphic papers, and one of very great importance on account of the additional information it contained respecting the rocks beneath the metropolis, was that read on the 6th inst. by Prof. Judd, entitled "On the Nature and Relations of the Jurassic Deposits which underlie London," with an "Introductory Note on a deep Boring at Richmond, Surrey," by Mr. Collett Homersham. Exact measurements, then first obtained, of the thickness of the members of the Chalk, evidence of the separation of these by two junction-beds indicating unconformity (as Barrois had noticed in France), the demonstration of members of the "Great Oolite," and the presence in these beds of pebbles derived from the older crystalline rocks, the occurrence of a red sandstone, referred by Prof. Judd with great probability to the Poikilitic series, and the distinct proof of the presence of anthracite in the form of derived fragments in the Oolitic series, rendered this paper the most valuable contribution which perhaps has yet been made to our knowledge of the sequence and behaviour of the rocks beneath London.

Dynamical Geology was represented by Mr. H. J. Johnston Lavis's paper "On the Geology of Monte Somma and Vesuvius, being a Study in Vulcanology;" by Mr. D. Mackintosh's communication, entitled "Results of Observations on the Positions of Boulders and the Evidence they furnish of the Recency of the Close of the Glacial Period;" by Mr. A. J. Jukes-Browne's two communications "On the relative Age of some Valleys in Lincolnshire," and "On some Post-glacial Ravines in the Chalk-Wolds of Lincolnshire," and, lastly, by a paper from Mr. T. Mellard Reade, "On a Delta in Miniature: 27 years' work."

Whatever estimate may finally be formed of the precise value of Mr. Johnston Lavis's communication in its bearings on the complex questions of vulcanology generally, no doubt can be entertained of the importance of the large number of observed facts he has gathered and very carefully recorded.

In connection with Mr. Mackintosh's paper, the observation may be allowed me (to which the author himself, I feel confident, would not make objection) that the circumstances affecting aërial waste are so variable in intensity that any calculations of time based upon such waste of boulder-pedestals must be accepted only as tentative of the solution of a problem which probably is incommensurable with our largest units of the divisions of time.

Mr. A. J. Jukes-Browne, in his two papers, described instructive examples of some of the circumstances which affect the change of direction of river-courses; and Mr. Mellard Reade's communication was a record of denudation and deposition, very instructive on account of the known average quantity of rainfall, and the known quantity of work done within a known time.

On Petrology and Mineralogy, in addition to notes appended to stratigraphical papers to which allusions have been already made, the following communications were read, viz.:—"On the Basalt-glass (Tachylyte) of the Western Isles of Scotland," by Prof. Judd and Mr. Cole; an "Additional Note on Boulders of Hornblende Picrite near the Western Coast of Anglesey," by Prof. Bonney; a note on "Cone-in-Cone Structure," by Mr. J. Young; and "Petrological Notes on some North of England Dykes," by Mr. J. J. H. Teall.

Respecting the first of these papers I will merely say that it is, I believe, the most thorough and exhaustive account which has yet appeared of this interesting rock-substance; and of the last I would venture the opinion that its subject is fully as exhaustively treated. The constancy of chemical composition and of intimate structure to which Mr. Teall called attention, strongly supports his opinion that the rock-masses constituting such dykes do not, as some have thought, consist, in any appreciable degree, of the fused substances of the sedimentary rocks through which they have been forced, but are wholly and directly of volcanic origin.

Prof. Bonney's instructive note on Picrite Boulders threw fresh light on a kind of rock but little known in this country, and respecting which, in consequence of its variability, some confusion of opinion had prevailed.

Turning to Palæontology, not one Palæo-botanical paper was received. All the communications read during the Session referred to the Animal Kingdom, and of these, reversing the occurrence of last year, the majority related to Vertebrata.

Of the papers on Invertebrata, that by Mr. R. F. Tomes "On some new or imperfectly known Madreporaria from the Coral-rag and Portland Oolite of Wiltshire, Oxfordshire, Cambridgeshire, and Yorkshire," which may be regarded as a continuation of former papers on the Corals of the Lias and Inferior Oolite, constitutes a valuable addition to our knowledge of the coral fauna of the Secondary rocks.

Our acquaintance with Australian fossil Bryozoa was largely increased by a paper by Mr. A. W. Waters, who, by adding 18 new species, brought up to 155 the number of Chilostomata discussed by him.

In a paper entitled "Notes on Brocchi's Collection of Shells," Dr. Gwyn Jeffreys placed before us a revision of the collection described by Brocchi in the 'Conchologia fossile Subapennina,' now preserved in the Museo Civico at Milan.

Dr. Jeffreys's extensive and exact knowledge of living and fossil forms gave, as one of the speakers in the debate remarked, this paper a peculiar value.

Mr. J. S. Gardner, in a paper "On the British Cretaceous Nuculidæ," embodying the results of a close study of his very extensive collection of these shells, discussed the distinctness of the Nuculidæ from the Arcidæ, and the descent of the Cretaceous from the earlier forms, and suggested the adoption of a trinomial nomenclature expressive of the relationship of species.

If I may be permitted for a few moments to digress from the Society's work, I would invite attention to Dr. G. J. Hinde's valuable 'Catalogue of Fossil Sponges' just issued by the Trustees of the British Museum. Treating principally of the sponges of the Chalk, Greensand, and Oolitic beds, it will long be the standard work of reference on the subject.

Taking the papers on Vertebrata, in the zoological order of their subjects, the first to be noticed is that communicated by Mr. J. W. Davis on 19th December, "On some Remains of Fossil Fishes from the Yoredale Series at Leybourne, in Wensleydale." A considerable series of careful descriptions of these remains, mostly teeth and spines, and diagnoses of species, several of which the author considered new, formed the chief part of this communication. The author's great experience in fossil Ichthyology is a guarantee for the skilful treatment of these difficult fossils; yet after an attentive consideration of the paper, I could not dispel the conviction that, having regard to the formal variation of the teeth in different parts of the mouth, it is evident that species founded on detached and isolated teeth should be regarded as provisional only until their validity has been established by fossils demonstrating the complete dentition—a caution which I feel confident the author himself recognizes.

I may be permitted here to congratulate Mr. Davis on the completion of his monograph on "The Fishes of the Carboniferous Limestone," recently published in the 'Transactions of the Royal Dublin Society,' chiefly based on the Florence-Court Collection, formed by the Earl of Enniskillen, and lately added to the National Collection in the Cromwell-road, which contained a large number of Agassiz's type specimens. It is certain for a long time to be the standard work of reference on this Ichthyic fauna.

Reptilia, using this designation in its widest sense, have again, as in former years, furnished the subjects of several communications. One of the first of these was that by Prof. H. G. Seeley "On the Dinosaurs from the Maastricht Beds." The remains, treated in this papers with the author's customary care and precision, are referred to two types—one Megalosaurian, the other Iguanodont. Their great interest, as the author observes, consists in their being the most recent evidences of the Dinosaurian subclass in geological time.

It would be a felicitous circumstance were the publication of this paper by directing attention to the occurrence of such fossils in the Maestricht beds to lead to the discovery of less imperfect remains which might afford fuller information respecting the above genera, and in particular regarding *Orthomerus Dolloi*, described by the author*.

Personally, it was to myself a matter of great satisfaction that the description of the Maestricht fossils should have been undertaken by Prof. Seeley. I had long since studied them with the intention of bringing them under the Society's notice, and I am glad to find that my delay in so doing has resulted in their being discussed by so able a palæontologist.

In a paper read on the 25th April by Sir R. Owen, "On the Skull of *Megalosaurus*," we have an account, worthy of that anatomist, of an imperfect premaxillary, a nearly complete maxillary, and some mandibular fragments referable to this genus. These remains, which had a short time previously been obtained from blocks of sandstone quarried for building a school near Sherborne, afford additional information respecting the structure of the Megalosaurian cranium, the orbital and occipital regions of which continue, however, unknown. The maxillary bone is the most perfect yet discovered. The author gives a reconstruction of the skull on the pattern of the *Varanus giganteus*, the largest living carnivorous Lizard. His figure bears a close general resemblance to that in Phillips's 'Geology of Oxford' (Oxford, 1871, p. 199), but differs from this in some details. A discussion of the affinities of Reptiles and Birds, expressing, as it does, the mature views of so eminent a biologist, gives to this paper a value quite distinct from that which accrues from its immediate subject.

I may add that the number of teeth in this Sherborne premaxillary, 3–3, agrees with that in a pair of Megalosaurian premaxillaries preserved in the private collection of Mr. James Parker at Oxford. These indicate the distinctness of the premaxillaries from the maxillaries, respecting which a doubt was once expressed, and also their individual separateness. They show also the presence of an outer or lateral, and an inner or mesial ascending process, points in which they resemble the premaxillaries of *Iguanodon* and *Hypsilophodon*. For the opportunity of seeing his unique collection of Megalosaurian remains some years since, and for his recent courtesy in affording me an opportunity of examining mandibles of two species of this genus with reference to the presence of a presymphysial bone, I am glad to seize this occasion to offer Mr. James Parker my warmest thanks.

In Sir R. Owen's restoration of the skull of *Megalosaurus* the orbit

* M. Dollo has very recently most obligingly forwarded to me a "Note" on Dinosaurian remains found in the Upper Chalk of Belgium.

is represented as posteriorly incomplete, and a lower temporal bar as absent. This is remarkable, since in *Iguanodon*, *Hypsilophodon*, *Scelidosaurus*, *Diclonius*, and *Diplodocus*, in short, in every known Dinosaurian skull, the orbit is separated posteriorly from the temporal fossa by the junction of processes of the jugal and post-frontal bones, and a lower temporal bar is present. In all these skulls also the quadrate is a much stouter and longer bone than that indicated in Sir R. Owen's restoration.

Here I would invite attention to a magnificent fragment of a Megalosaurian sacrum from Great Sandford in the Society's Museum. Only three examples of this segment of the vertebral column are known. Of these, one, in the British Museum at Cromwell Road, has been figured by Sir R. Owen in the 'Fossil Reptilia;' another, in the Oxford University Museum, was figured by Phillips in his 'Geology of Oxford;' and the third, our own, which I have had placed upon the table, unfigured as yet, is in some respects a very instructive specimen.

In another paper, on "The Cranial and Vertebral Characters of the Crocodilian genus *Plesiosuchus*, Owen," Sir R. Owen redescribes and renames some Crocodilian fossils obtained from the Kimmeridge Clay by Mr. J. C. Mansel (now Mr. J. C. Mansel-Pleydell), which in May and in December 1869* I had the honour of bringing under your notice, and which I referred to a *Steneosaurus*, n. sp. *S. Manseli*. I was gratified to find that Sir R. Owen's description of these remains accorded with my own, and that our only difference respecting them consisted in our different estimate of the taxical value of the variations in detail of this skull from that of Geoffroy St.-Hilaire's type of *Steneosaurus*. The chief differences pointed out by myself in 1869 are those now indicated by Sir R. Owen, viz. the greater extension of the frontal bones upon the upper surface of the snout, the prolongation of the nasals between the premaxillaries into the posterior border of the external bony nostril, and the smaller number of teeth. With a full recognition of these characteristics, it seemed to me preferable to retain the Saurian indicated by these Kimmeridgian fossils in the genus *Steneosaurus* than to originate for it a new genus; indeed this appeared the only prudent course pending the acquisition of fresh material which should afford information of the structure of the interorbital and palatal regions of the skull, then and still unknown. When I wrote my papers in 1869 I did not doubt the genuineness of Cuvier's two skulls of the Gavial, "Tête à museau plus allongé," and "Tête à museau plus court," although there were not wanting circumstances calculated to excite distrust: thus Cuvier himself relates his reconstruction of the "Tête à museau plus allongé" out of two pieces remaining in the collection originally belonging to the Abbé Bachelet, two in the cabinet of M. De Dree, two sent to him from Geneva by M. Jurine, and the muzzle out of three pieces received from M. Faujas and the Abbé Besson. Later in 1869 a copy of the 'Prodrôme des Téléosauriens

* Quart. Journ. Geol. Soc. 1869, vol. xxv. p. 390, plates xvii., xviii., and vol. xxvi. p. 167, plate ix.

du Calvados,' most courteously presented to me by its author, M. Eugène Eudes Deslongchamps, first showed me that my confidence in these two skulls had been misplaced. M. E. E. Deslongchamps, whose accurate and extensive acquaintance with the Crocodilians of the Calvados, equalled only by that of his father, then lately deceased (upon whose work the 'Prodrôme' is chiefly based), after a careful study of the type skulls, distinctly asserts that the "Tête à museau plus allongé" is compounded of the snout of *Steneosaurus Edwardsii*, Desl., of the frontal region of *Metriorhynchus* (H. v. Meyer) *superciliosus*, Desl., and of the occipital region of a smaller individual of this last species. Further, the "Tête à museau plus court" is built up of the cranial part of a *Metriorhynchus*, the middle part of the snout of a *Steneosaurus* in the Cabinet de Genève, and the end of a snout from Honfleur. From the Honfleur Gavials Cuvier separated another under the title "Crocodile de Caen." This type skull consists of the hinder part of the skull of *Teleosaurus Cadomensis* (De Blainv.) and the snout of a species of *Steneosaurus*, probably that figured later by De la Beche under the specific name of *S. oxoniensis*. It is probable that Geoffroy St.-Hilaire founded his two genera *Teleosaurus* and *Steneosaurus* on the type crania of the "Crocodile de Caen" and the "Tête à museau plus allongé," because collateral evidence makes it likely that he had not at that time studied the "Tête à museau plus court;" and he tells us respecting the origin of the name *Steneosaurus*, "de l'étroitesse singulièrement remarquable et décidément caractéristique du crâne entre les fosses temporales on déduira sans doute un jour la principale considération et le nom générique des fossiles trouvées à Honfleur"*. Now this narrowness between the temporal fossæ is very conspicuous in the Kimmeridge skull.

To the fictitious† character of the two type crania is probably referable the great confusion which has arisen in connexion with the Crocodilia of the Secondary period, in illustration of which I need only cite a few of the genera which have been constructed from their remains—*Metriorhynchus*, H. v. M.; *Cistosaurus*, H. v. M.; *Mystriosaurus*, Kaup; *Pelagosaurus*, Bronn; *Moselosaurus*, *Engyommasaurus*, B.; *Glaphyrorhynchus*, B.; *Streptospondylus*, H. v. M.; *Leptocranius*, B.; and *Macrospondylus*, H. v. M. Each of these is a member of one of Geoffroy St.-Hilaire's two original genera which, in spite of their spurious birth, have acquired in the course of years a concurrent ascription of associated anatomical characters which has preserved them from suppression. I need not now enlarge upon the differential characters which separate the Teleosaurs from the Steneosaurs, these may be found in Deslongchamps's instructive 'Prodrôme,' for it will not, I think, be contended by any that *Steneosaurus Manseli*, Hulke, belongs to the first of the two genera. If, however, each of these two genera be enlarged to the rank of a family or suborder (Teleosauria and Steneosauria), comprising several

* Mém. du Mus. tom. xii. p. 149.

† I need scarcely add that this word is not used in a disrespectful sense. My intense admiration of Cuvier would make such a meaning impossible to me.

genera, amongst which *Teleosaurus* and *Steneosaurus* are types, it may be found convenient to remove *Steneosaurus Manseli* into a separate genus or subgenus; but at present I would venture to deprecate any disturbance of the original name.

Ascending from these lower Vertebrata to Mammalia, Sir R. Owen, in a paper "On the Skull and Dentition of a Triassic Mammal, *Tritylodon longævus*, O., from South Africa," brought under our notice on 21st November a skull which, if the age of its *gisement* be established, is one of the earliest evidences yet obtained of Mammalian life. The resemblance of the crowns of the molar teeth to those of *Microlestes* and *Stereognathus* suggests an affinity with these. A doubt expressed in the debate respecting the Mammalian nature of the skull has since been dispelled by the removal of a portion of the outer alveolar wall, which has discovered the molar teeth to possess double roots.

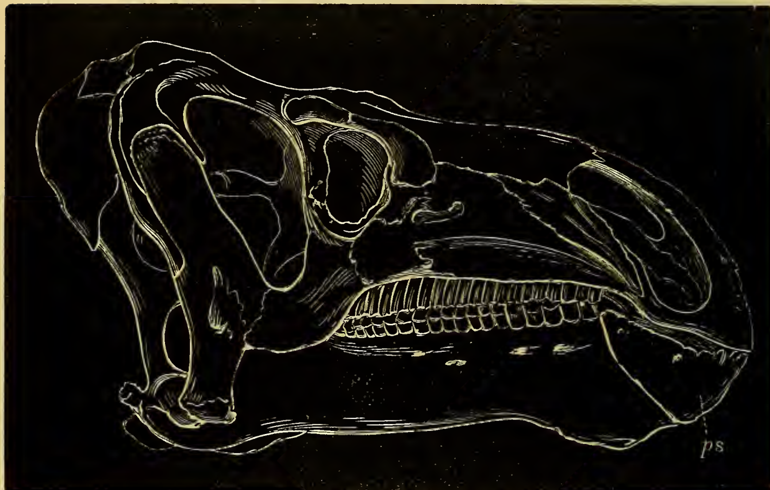
The only other mammalian paper received was one by Prof. Boyd Dawkins, "On the Alleged Existence of *Ovibos moschatus* in the Forest-bed, and its Range in Space and Time." The subject of this very interesting communication was the upper part of the skull of an adult female, fortunately in such excellent preservation as to place its identification beyond doubt. The author referred to the discoveries of remains of this animal in Britain, some of which were in post-glacial beds, and others in beds regarded by him as preglacial. In this latter category he was disposed to place the present fossil. In the debate doubts were expressed respecting the completeness of the evidence of the locality whence the skull was procured, and consequently of its geological age.

The time and scope permissible to an address will not allow me, even if I possessed the requisite knowledge for the task (and this I may not claim), to allude to, much less to offer you a review of, the progress of the several departments of geology in other countries during the past year; but I would not bring my task to a close without referring to some extremely valuable additions which have been made to our knowledge of skeletal structure in the Dinosauria, a subclass of Reptilia in which I have long been deeply interested.

The "Notes" on the anatomy of *Iguanodon*, based on the large number of remains preserved in the Musée d'Histoire Naturelle at Brussels, begun by M. Dollo last year, have been continued by him; and thanks to the labours of this discriminating and zealous palæontologist, we have now a knowledge of the skeleton of this Dinosaur so full that there remain only a few and not very important details to render it complete. M. Dollo's "Note on the pelvis and skull" is very important. I may be pardoned for remarking that to myself it was a matter of great satisfaction to find confirmed by him the identification of the skull which, in 1871, I had the honour of bringing under your notice *. Perhaps the most interesting feature in the skull is the mandibular element, aptly designated by M. Dollo "Os présymphysien" (fig. 1 *ps*), the true skeletal place of which the completeness of the Bernissart fossils has enabled him to demonstrate by the

* Quart. Journ. Geol. Soc. vol. xxvii. p. 199, pl. xi. (Hulke).

Fig. 1.—*Side view of Cranium of* Iguanodon bernissartensis, *Dollo.* (After Dollo.)



incontestable evidence ot undisturbed natural articulation. I had often myself in bygone years pondered over a detached, mutilated example in the collection of the late Rev. W. Fox, now in the British Museum, but was quite unable to identify it with any element in the vertebrate skeleton then known to me. A similarily formed detached bone bedded in a block of clay, together with a mandible of *Hypsilophodon*, has long been in my own collection; and recently Prof. E. D. Cope has figured this same element in *Diclonius*, a member of the Hadrosauridæ, the Transatlantic representatives of our Iguanodontidæ. Thus in three Dinosaurs, members of closely allied herbivorous genera, there is now known to be present in the mandible an azygos element, till lately unrecognized, and not known to exist in any other Sauria. What is this? In *Diclonius*, *D. mirabilis* (fig. 2 *ps*), Prof. Cope names it "Dentary"; but apart from the obstacles which the structure of the mandible in this Dinosaur, as described and represented by Cope, offer to the reception of this identification, the coexistence cf the "os présymphysien" together with the "Dentary" in *Iguanodon*, negatives this determination of its homology. M. Dollo, with commendable reserve, suggests that it may be the morphological equivalent of the "Mento-Meckelian" elements present in the mandible in Batrachia, termed by Prof. P. Albrecht "intermaxillaires inférieures." A. Ecker, as noticed by Dollo, figured these in 'Die Anatomie des Frosches' (fig. 22. p. 40), Braunschweig, 1864. They are well shown in several of the plates illustrating Prof. W. K. Parker's memoir "On the Structure and Development of the Skull of the Frog," Phil. Trans. 1871, and this author's later memoir "On the Structure and Development of the Skull in Batrachia," in Phil. Trans. 1881 (from which fig. 3 *m.m.*,

Fig. 2.—*Inferior view of the Extremity of the Mandible of* Diclonius mirabilis, *Cope.* (After Cope, Proc. Acad. Nat. Sci. Philad. 1883, pl. vi.)

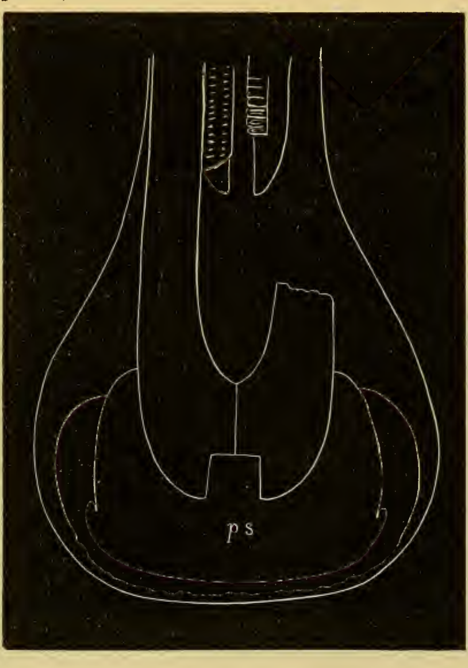
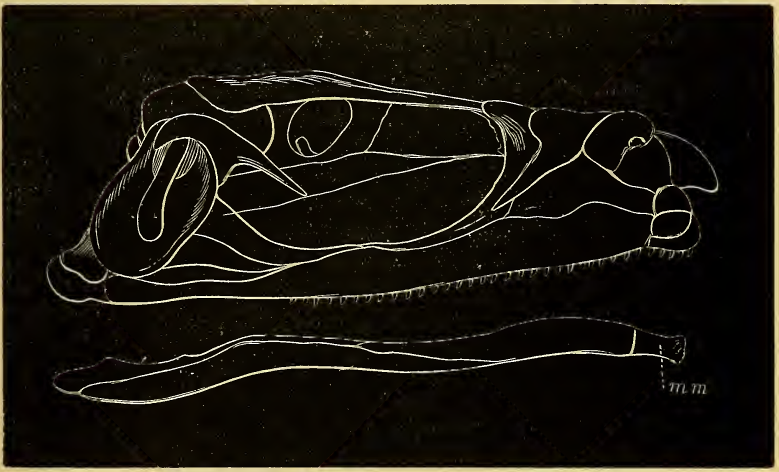


Fig. 3.—*Side view of the Cranium of* Xenophrys monticola, *Günth.* (After Parker, Phil. Trans. (1881), vol. clxxii. pl. xxiii. fig. 7.)



showing a side view of the skull and mandible of *Xenophrys monticola* is copied). The Mento-Meckelian element in the Frog is also represented and described in Parker and Bettany's 'Morphology of the Skull,' fig. 45, p. 171, London, 1877, in which it is stated to be derived in part from Meckel's "cartilage-rod," and in part from the remains of the "inferior labial" cartilage.

But the Mento-Meckelian mandibular element can be traced lower in the vertebrate scale; for Dr. A. Günther figures it in *Aspidorhynchus Fisheri* ('Introduction to the Study of Fishes,' fig. 146, p. 369), naming it here the "presymphysial bone" (as noticed by Dollo). In *Protopterus*, the Meckelian cartilage extends beyond the dentate,

Fig. 4.—*Cranium of* Aspidorhynchus Fisheri. (Original from specimen in the British Museum.)

coalescing with its fellow in the median line, to form a stout azygos plate, the free edge of which is set with small pointed processes singularly suggestive of likeness to *Iguanodon*. The Mento-Meckelian bone is recognizable also in *Sturio* and in *Amia*. Thus it is present in *Lepidosteoidei*, *Dipnoi*, *Chondrostei*, and *Amioidei*, in four therefore of the eight suborders under which Dr. A. Günther arranges the numerous genera of the once dominant order of the Ganoid fishes.

This mandibular element is, however, not restricted to the lower vertebrates, for it exists in the human embryo, in which it was discovered by A. von Kölliker, and by Callender, in whose paper in the Phil. Trans. 1869 it is figured (pl. xiii. fig. 6 *a*). In a footnote referring to this paper, W. K. Parker calls it the "inferior intermaxillary element," Phil. Trans. p. 200, vol. clxi.

This wide distribution of the Mento-Meckelian element appears to me to afford strong support to the homology of the presymphysial bone of *Iguanodon* offered by Dollo. The time at my disposal will not permit me to examine in detail the many interesting features of the skull in *Iguanodon*, discovered or confirmed by M. Dollo. I can allude to two only:—the edentulousness of the premaxillary, which alone would be sufficient to demonstrate its generic distinctness from *Hypsilophodon;* and the fixity of the quadrate, which is rendered incapable of movement by the abutment of the quadrato-jugal and the pterygoid against it, and by the closeness with which the squamosal embraces its upper end and also descends upon its surfaces, a disposition of this latter bone which has some resemblance to that obtaining in Amphibians and Ganoids.

In a short account of the vertebral column, M. Dollo states that it contains 85 vertebræ; of these 10 are cervical, 18 dorso-lumbar, 6 sacral, and 51 caudal. The forms of the articular surfaces of the centra in these several regions agree with those in *I. Prestwichii* figured by myself in our Journal; and thus M. Dollo's labours afford an additional proof of the critical acumen of those early palæontologists Drs. Melville and Mantell. M. Dollo finds that the neurapophyses of the atlas were synchondrously united superiorly, and he has not discovered any trace of preatlas or capping-piece, which some have regarded as the modified neural spinous process. Thus in *Iguanodon* the atlas appears fashioned on the Lacertilian pattern, which is noteworthy, since the other presacral vertebræ have Crocodilian rather than Lacertilian features. In the sacrum M. Dollo finds 6 vertebræ—one more, therefore, than in the type sacrum of *I. Mantelli* in the British Museum; but I am in doubt whether Dollo does not include in the sacrum the last lumbar vertebra, which in old individuals is usually united by synostosis to the first sacral, and is functionally inseparable from it. Should this be the case, Dollo's views in this matter are in accord with those of Melville and Mantell, who for this and other interpretations were once so harshly censured. An expression M. Dollo uses with respect to diapophyses, "upper transverse processes," leaves me in doubt, also, whether he considers these absent from the sacrum. A very instructive fragment of a sacrum of an immature *I. Mantelli* in my own collection, shows slender "upper transverse processes," diapophyses, outgrowth from the neurapophyses in the level of the crown of the neural arch; and massive "lower transverse processes," parapophyses, of which the original distinctness from the vertebral centrum is indicated by the still obvious suture which marks their union.

I have already noticed some interesting points of resemblance in the cranial structure of *Iguanodon* to similar ones in Amphibia and certain Ganoids, at the lower end of the vertebrate scale, and in the higher vertebrates, man included. It may be here remarked that similar resemblances are observable in respect of the vertebral column. Thus, in *Iguanodon*, the cervical vertebræ are opisthocœlous; they are so in *Salamander*, in *Pipa*, and in *Lepidosteus*; so also are they in certain cervicals in some higher Mammalia, a familiar instance of which is the horse. In *Iguanodon*, in the sacrum, the neurapophyses are intervertebrally situated; this is also their relation to the centra throughout the vertebral column in the Ganoid *Amia*.

More attractive probably to the larger number of readers than his "Quatrième Note" just cited, will be found Dollo's "Troisième Note," in which he describes the pelvic girdle and hind limbs, and gives an excellent representation of one entire skeleton, as mounted by M. De Pauw, the excellent Contrôleur des Ateliers of the Musée.

M. Dollo adopts the erect attitude of *Iguanodon*; and for this he adduces reasons which claim attentive consideration. Time will not allow me here to do justice to them, and I must refer those who are interested in this vexed question to Dollo's memoir.

The undisturbed natural association of the pelvic bones in some of the Bernissart skeletons has enabled Dollo to give an excellent side view of the pelvis in *I. bernissartensis*, Blgr. Its accuracy is unimpeachable. In its essential features it is in accord with the restoration of the pelvis of *I. Mantelli*, which, in June 1875, I submitted to the Society; but there are some details which the better preservation of the Bernissart fossils has enabled Dollo to correct. Thus the direction of the preacetabular part of the os pubis (præpubis of Marsh), which I had originally imagined to have an inward curve, Dollo shows to be curved outwards. The foramen at the point where the post-acetabular part of the pubis (post-pubis of Marsh) diverges from the body of this bone, and which I had identified with the uppermost opening in the bird's obturator foramen, and suggested that it might, in *Iguanodon*, as in the bird, transmit the tendon of the Obturator internus muscle, M. Dollo interprets differently. He shows that the ischiatic half is contributed by the ischio-pubic border of the body of the ischium, and that it is not, as I had wrongly supposed from my less perfect material, contributed by the obturator process of the shaft of the ischium.

M. Dollo believes the larger opening, marked ii. in his figure, to be the homologue of that which in the bird transmits the Internal obturator tendon, basing this belief on the identification of the process given off from the ventral border of the ischium, beyond the neck of this bone in *Iguanodon*, with that present in some birds, notably Ratitæ. The small foramen next the acetabulum, marked i., he homologizes with a depression which he observed in the chicken above that for the obturator tendon. This I have not succeeded in discovering in *Struthio* and *Rhea*, birds which I selected on account of their well-developed ischiatic obturator process, and the completeness of the upper foramen which (ii. in Dollo's figures) this process makes by its union with the postacetabular part of the os pubis.

[*Note.*—In discussing the homologies of these foramina in reptiles and birds it is needful to bear in mind that the term obturator foramen has been applied to very different apertures. Thus it has been given to the aperture by which the obturator nerve leaves the pelvis, and also to the space lying between the os pubis and the ischium; now in lizards the nerve pierces the os pubis by an opening entirely within this bone, and it does not pass through the ischio-pubic interval; in Chelonians, however, it takes this latter course; in Crocodiles also it passes through the angle formed by the divergent pubis and ischium. In birds it also passes out between these bones, yet not through the aperture nearest to the acetabulum, but at a lower point, piercing the obturator membrane below the obt.-ischiatic process (*Rhea*). It would be more exact to define the foramen with reference to the nerve, and to give the name "cordiform" or "thyroid," used by continental anatomists, to the ischio-pubic interspace. But this would do violence to long-established usage here, so that under the circumstances it is better, as least liable to create misunderstanding, to designate by "obturator" the interspace between the os pubis and the ischium without reference to the course taken by the obturator nerve.]

The homologies of the os pubis in the subclass Dinosauria, or rather in its order Ornithopoda (Marsh)—for in Sauropoda they do not offer any difficulty, which have greatly engaged the attention of palæontologists—have been discussed by Dollo; and since the subject is of much interest it claims some notice.

The conclusion at which Dollo arrives (drawn, it would seem, chiefly from a consideration of the pelvis of *Allosaurus*, Marsh, whose restored figure he reproduces, and of the chick) is "that the pubis and the post-pubis are primitively separate elements, and that Dinosauria and birds alone possess the latter."

Now Marsh tells us that the presence of the post-pubis in *Allosaurus* was inferred by him from the occurrence of a lower, and apparently articular, facet on the pubic border of the ischia; and also that he inferred its form from that of *Laosaurus*. In addition to this the delineation of the post-pubis in his figure of *Allosaurus* is by a dotted outline, a method always used by this trustworthy palæontologist, wherever the parts of a figure are not drawn from an actual specimen.

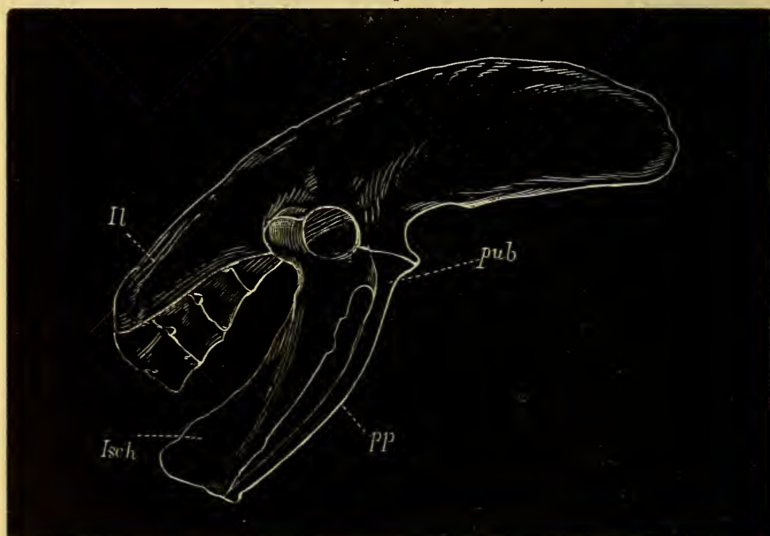
The presence of a ventral symphysial union of the distal ends of the pubes in *Allosaurus* had always made me doubt the presence of a post-pubis in this Dinosaurian, because a post-pubis (if present) being the homologue of the post-pubis in the bird, and this the homologue of the pubis in the Lizard, of which latter the pubis in *Allosaurus* is also the homologue, it must follow that in each half of the pelvis of this Dinosaur there would be two bones, each the morphological equivalent of the Lacertian pubis, a thing altogether unintelligible. But I gather from his having placed *Allosaurus* in Theriopoda that Marsh himself has abandoned the idea of its possessing a post-pubis. After this I think I am scarcely putting it too strongly when I say that all reasoning from *Allosaurus* as to the interpretation of the (pubis) post-pubis in Dinosauria rests on an unproved foundation.

In *Iguanodon*, *Hypsilophodon* (and *Omosaurus*), in which alone I have had an opportunity of studying the os pubis, I have never, even in immature individuals, seen any mark of the primitive separateness of the two parts of the os pubis which Marsh distinguished by the names præ- and post-pubis; and this has left me unconvinced of such original distinctness in respect of these Dinosaurs; I have therefore always used Marsh's excellent terms as short, convenient names by which to refer to the præ- and postacetabular parts of the os pubis, without attaching to them the idea of a distinct individuality.

The homology of the postpubis in Dinosaurs with the pubis of birds, first pointed out by Huxley, is very generally accepted. Any difficulty that at first sight appears, in consequence of their different direction, in homologizing these with the pubis in the Lizard, will disappear when it is remembered that in the embryo bird the os pubis and the ischium are directed at a right angle to the long axis of the ilium, which is nearly the direction of these bones in the Lizard.

To what part, if any, of the pubis in other vertebrates is the prepubis in Dinosauria (*Iguanodon*) the morphological equivalent? In birds its equivalent has been thought to be the angular tubercle or spur which projects from the front border of the acetabulum. This is well marked in the Ostrich and the Apteryx. In Dollo's figure of the pelvis of the chick, it lies in front of the suture which indicates the anterior limit of the acetabular contribution of the (post-) pubis, separated from this by a distinct interval. Such a disposition would place this tubercle, or spur, completely within the ilium; and were this so, it would constitute a strong argument against regarding it as the homologue of the Dinosaurian prepubis. Gegenbaur, however, represents, in the chick, the ilio-pubic suture as passing through the tubercle; and this is its situation in *Apteryx* (fig. 5), and in *Rhea*, immature individuals of which I ex-

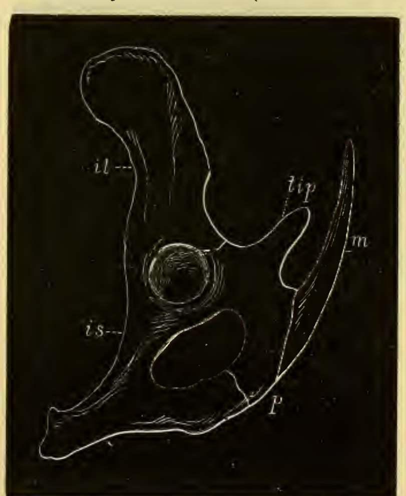
Fig. 5.—*Pelvis of* Apteryx. (Original from a specimen in the Middlesex-Hospital Museum.)



Il. Ilium. *Isch.* Ischium. *pub.* Pre-pubis. *pp.* Post-pubis.

amined with reference to this point: the tubercle is manifestly that known to anatomists as the ilio-pectineal eminence, tuberculum ilio-pectineum, tub. ilio-pubicum, of higher vertebrates. Its dual composition in birds, though it seems to weaken the supposition of its being the homologue of the Dinosaurian prepubis, does not destroy it; since in these latter the pubic component of the tubercle may grow and largely increase, the ischiatic element not augmenting, until the latter is ultimately absolutely dominated by the former, and that which in its origin was dual, finally appears to be, and is, wholly composed of an outgrowth of the pubis alone, and the ilio-pubic tubercle becomes a pubic tubercle. Now something of this kind can be traced out in those singularly reptile-like Monotremes, the *Echidna* (fig. 6) and *Ornithorhynchus* (fig. 7). And I have

Fig. 6.—*Pelvis of* Echidna. (After Wiedersheim.)



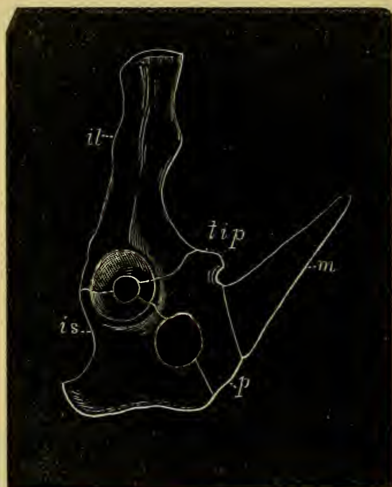
il. Ilium. *is.* Ischium. *p.* Pubis. *m.* Marsupial bone.
tip. Tuberculum ilio-pubicum.

thought that the horn-shaped process which juts out from the front border of the os pubis in Chelonia (*Testudo*, fig. 8) may have a similar origin, and that here, in a living reptile, we find the morphological equivalent of the prepubis of the extinct Ornithopoda.

I have already, in treating of the presymphysial bone, incidentally referred to one of the latest additions to our knowledge of cranial structure in Dinosaurians, Prof. Cope's paper "On the Characters of the Skull in Hadrosauridæ." The description and figures of the skull of *Diclonius mirabilis* show that it had a skull in form "a good deal like that of a goose." Each maxillary bone contained 630 teeth, and each splenial 406 teeth, giving a grand total of 2072 teeth. Its dentition is so remarkable and so unique, and these details of construction are so singular, that I hope no long time will elapse before a fully descriptive and copiously illustrated memoir upon it will appear.

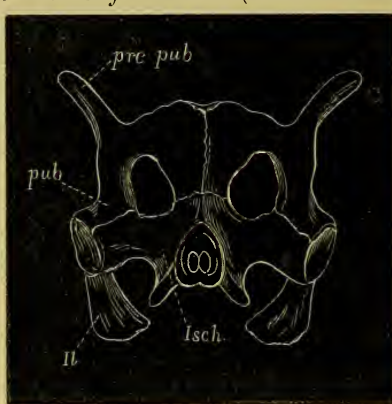
In my address last year I alluded to the remarkable works which were being issued by Prof. O. C. Marsh, and mentioned that he had in hand a large fully illustrated descriptive memoir on the Dinosauria, which would rival, if not excel, in interest his noble folio on the 'Toothed Birds.' In the autumn I received from

Fig. 7.—*Pelvis of* Ornithorhynchus. (After Wiedersheim.)



il. Ilium. *is.* Ischium. *m.* Marsupial bone. *p.* Pubis. *tip.* Tuberculum pubicum.

Fig. 8.—*Pelvis of* Testudo. (After Wiedersheim.)



Il. Ilium. *Isch.* Ischium. *pub.* Pubis. *pre pub.* Prepubis.

him, as precursor, a short paper on a "Restoration of *Brontosaurus*, *B. excelsus*." The admirable preservation of its remains makes it possible to draw every bone from an actual specimen. The individual was nearly 50 feet long, and is estimated to have weighed about 20 tons. Its head was small, and its neck long. It was plantigrade, and each footprint occupied an area of about 1 square yard.

Only two days ago, whilst writing these lines, I received from Prof. O. C. Marsh another token of his unflagging zeal in the study of these Jurassic forms of reptilian life, in a paper on the Diplodocidæ, Dinosaurs distinguished by the "doubleness" of their chevrons. The skull figured by Prof. Marsh is so perfect that every suture is discernible, and the general figure is undistorted. The teeth, in several rows, are weak, cylindrical, adapted for plucking soft vegetable food. The snout has a small oval vacuity in the maxilla, and a larger antorbital opening. "The orbit is situated very posteriorly, being nearly over the articulation of the lower jaw." The external nostril is large and on the top of the head, between the upper borders of the orbits.

The flood of light which is now coming from the New World to illuminate our darkness, in return for the feeble glimmerings of truth that we (whose best "finds" are commonly only a few mutilated fragments of a skeleton) have been able to evolve at the cost of much toil and frequent stumbling and many disappointments, would make us envious of their better fortune, were envy possible. Happily it is unknown among us, and we rejoice in their success.

And now, Gentlemen, I must conclude. I thank you for having listened so long to what, I fear, must have been somewhat wearisome to those whose chief interest is concentrated in the inanimate world. Yet some acquaintance with palæontology is indispensable even to such; for the light which the dry bones of the past cast upon the physical history of our globe, often is a very precious aid to the decipherment of its frequently almost illegible and obscure pages. Can these dry bones live again and tell their tale? Yes, they not only can, but they do; being dead they yet speak a language audible to the attentive ear, and intelligible to the receptive mind.

As the palæontologist surveys the past, he sees, as in Ezekiel's allegory, bone come to its bone, sinews and flesh come upon them, and the skin cover them; his imagination breathes into them life; and the past is no more the region of the dead, but peopled with a countless multitude of living beings, links in that wonderful chain of life, of which the earliest were forged in the remotest ages, when our globe first was habitable; the intermediate ones are those around us; and the latest are those of a far distant future..

February 20, 1884.

Prof. T. G. Bonney, D.Sc., F.R.S., President, in the Chair.

Thomas Lionel Bates, Esq., Fence Cottage, near Rotherham; G. J. Williams, Esq., Higher Elementary School, Blaenau Festiniog; and Alfred Prentice Young, Esq., I.N., Assistant Superintendent, Revenue Survey, Bombay, were elected Fellows of the Society.

The List of Donations to the Library was read.

The Secretary announced that a specimen of Trowlesworthite had been presented to the Museum by R. N. Worth, Esq., F.G.S.

The following communications were read:—

1. "On a recent Exposure of the Shelly Patches in the Boulder-clay at Bridlington." By G. W. Lamplugh, Esq. Communicated by Dr. J. Gwyn Jeffreys, F.R.S., F.G.S.

2. "On the so-called *Spongia paradoxica*, S. Woodward, from the Red and White Chalk of Hunstanton." By Prof. T. M'Kenny Hughes, M.A., F.G.S.

3. "Further Notes on Rock-fragments from the South of Scotland imbedded in the Low-level Boulder-clay of Lancashire." By T. Mellard Reade, Esq., C.E., F.G.S.

4. "Ripple-marks in Drift." By T. Mellard Reade, Esq., C.E., F.G.S.

Specimens and microscopic sections were exhibited by Prof. T. M'Kenny Hughes, in illustration of his paper.

March 5, 1884.

Prof. T. G. Bonney, D.Sc., F.R.S., President, in the Chair.

F. N. Maude, Esq., R.E., Naval and Military Club, 94 Piccadilly, W.; John Potts, Esq., Thorntree House, Chester Road, Macclesfield; and Corbet Woodall, Esq., M. Inst. C.E., 34 Fitzjohn's Avenue, Hampstead, N.W., were elected Fellows, and Dr. Charles Barrois, of Lille, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Structure and Formation of Coal." By E. Wethered Esq., F.G.S., F.C.S.

[Abstract.]

The author, having referred to the work of previous investigators, pointed out that seams of coal do not always occur in one bed, but are divided by distinct partings, some of which, as in the case of the Durham main seam, contain *Stigmariæ*. It is important to notice this feature for several reasons, but especially as the beds of coal, defined by the partings, show differences both in quality and structure. In the case of the shallow seam of Cannock Chase there is at the top a bed of coal 1 foot 10 inches thick, the brown layers of which are made up of macrospores and microspores. The bright layers are of similar construction, except that wood-tissue sometimes appears, also a brown structureless material, which the author looked upon as bitumen. He, however, objected to that term, and thought that "hydrocarbonaceous substance" would be preferable. What this hydrocarbonaceous material originated from is a question for investigation. In the lower bed of the Welsh "Four Feet" seam wood-tissue undoubtedly contributes to it; whether spores do is uncertain; it is true they can be detected in it. In the second bed of the shallow seam there is a very different coal from the upper one. It is made up almost as a whole of hydrocarbonaceous material. Very few spores can be detected in it. It is possible that the scarcity of these objects may be due to decomposition; but the author's investigations seem to show that spores resist decomposing influences more effectually than wood-tissue, which seems to account for the fact that where they occur they stand out in bold relief against the other material composing the coal. Below the central bed of the shallow seam comes the main division. In it the author detected a large accumulation of spores, but hydrocarbon formed a fair proportion of the mass. The author referred to other seams of coal from various parts of England, and pointed out the structure of each bed composing them. The conclusions on the evidence elicited from his investigations were (1) that some coals were practically made up of spores, others were not, these variations often occurring in beds of the same seam; (2) that the so-called bituminous coals were largely made up of the substance which the author termed hydrocarbon, to which wood-tissue undoubtedly contributed.

An appendix to the paper, written by Prof. Harker, Professor of Botany and Geology at the Royal Agricultural College, Cirencester, dealt with the determination of the spores seen in Mr. Wethered's microscopic sections. Taking the macrospores, the resemblance to those of *Isoëtes* could not fail to strike the botanist. He had procured some herbarium specimens of *Isoëtes lacustris* in fruit, and compared the spores with those from the coal. When gently crushed, the identity of the appearance presented by these forms from the coal was very striking. The triradiate markings of the latter were almost exactly like the flattened three radiating lines which mark the upper hemisphere of the macrospores of *Isoëtes lacustris*. The writer therefore concluded that the forms in the coal were from a group of plants having affinities with the modern genus *Isoëtes*, and from this Isoëtoid character he suggested the generic title of *Isoëtoides* pending further investigation.

Discussion.

Mr. Carruthers thanked the author for the trouble he had taken in these investigations, the results of which were of value, although he could not accept the conclusions arrived at. He remarked that there was no doubt as to the nature of the vegetation which formed the coal. The triradiate structure of the macrospores referred to was merely a superficial marking which threw very little light on the affinities of the spores. These spores had been found connected with leaves of *Sigillaria* and *Lepidodendron*. The coal itself had been a soil which supported the vegetation; it is penetrated by the *Stigmariæ*, roots of *Sigillaria* and *Lepidodendron*, and by roots of other plants. In the museum, either at Huddersfield or Leeds, there is a stem of a *Sigillaria* filled with white sandstone and penetrating far into the coal-bed, showing that the trees grew in the coal itself. Coal-seams are the remains of forests which grew upon swampy ground and were subsequently covered by clay. He had never found true wood-tissue in coal. Spores were first noticed in coal by Professor Morris. They abound in some places, but there is no reason to attribute them to *Isoëtes* or to any other form of submerged vegetation.

Prof. W. Boyd Dawkins agreed with Mr. Carruthers in differing from the author. He had never seen sporangia in coal, although macro- and microspores abounded. Coal is composed of two principal elements, carbon proper and a fossil resin, to which the blazing property of coal is due. He agreed with Prof. Huxley in the view that the latter is mainly due to the spores; but the blazing element cannot be wholly attributed to them. According to the highest chemical authority woody tissue cannot by ordinary process of decay be converted into resinous matter. The carbon is derived from the decomposition of vegetable tissue, the resin from the secretions of the cell in the living plant. The Carboniferous forests grew upon horizontal tracts of alluvium not far above the water-line.

Mr. E. T. Newton considered this paper to be the first systematic attempt that had been made to ascertain the microscopic structure of a consecutive series of coal-beds. Certain coals were undoubtedly made up of macro- and microspores. He remarked that there are three principal kinds of layers in coal—bright, dull, and intermediate. The dull layer contains dotted tissue, the intermediate macro- and microspores, and the bright a brown substance, usually without structure, but in one case within his knowledge entirely composed of spores, and Mr. Wethered had found this same brown substance formed by vegetable tissue.

Prof. T. Rupert Jones inquired of Prof. Boyd Dawkins how Conifers were to be traced in coal if not by structure. He thought that the spores would themselves supply the resinous or hydrocarbonaceous matter.

Mr. Bauerman commented on the value of the author's diagrams as showing very clearly the freedom of coal substance from mineral matter when the partings were separated. As regarded the latter, was there any distinction, as in the proportion of alkalies &c., between them and the under-clays? While agreeing with the author as to the unfitness of the term bituminous (as coals contained no constituent removable by the reagents in which natural bitumens were soluble), he thought the term hydrocarbon was no improvement. To him both the tissues and the structureless parts of the author's sections seemed to be of the same nature, namely, pseudomorphs in coal-substance. Crystalline hydrocarbons (paraffines) had been obtained by Mr. Thomas from the gases of some coals under conditions which seemed to indicate their existence as such in the coal; and if such substances were present they should be recognizable. As plants are made up of materials varying very considerably in their resistance to decomposition, and as only the more stable ones were likely to retain their structure, the fact of such structures as those of spores being recognized in microscopic sections seems to be no proof that whole seams were made up of them.

Mr. Kidston considered that there was no doubt that coal was a product of terrestrial vegetation, but said that it was doubtful if Conifers really occur in coal. Sporangia are abundant in parts; but he had found that they were rare in Scotch coal.

Mr. Carruthers, in explanation, said, that the macrospores were not originally composed of brown substance, but merely filled with it.

The Author, in reply, said, *Stigmariæ* might be roots of plants allied to *Isoëtes*. *Lepidodendron* and *Sigillaria* were regarded as allied to the existing *Lycopodia*, as also was *Isoëtes*, so that there was no reason why an Isoëtoid plant should not have *Stigmaria*-roots, and *Isoëtes* is the only existing plant of the group in which the macrospores show triradiate structure. His conclusions were entirely based on the evidence of the microscope. He remarked that Prof. Boyd Dawkins had formerly adhered to the views of Prof. Huxley, so that he must now have materially changed his opinion. In reply to Mr. Bauerman he said that some partings were very similar to under-clay, and that decomposed vegetable tissue could not well be crystalline. To Mr. Kidston he said that if sections were made thin enough, spores would probably be found even in some Scotch coals.

2. "On Strain in connexion with Crystallization and the Development of Perlitic Structure." By Frank Rutley, Esq., F.G.S.

3. "Sketches of South-African Geology. No. 1. A Sketch of the High-level Coal-field of South-Africa." By W. H. Penning, Esq., F.G.S.

The following specimens were exhibited:—

Canada Balsam dried on an iron plate, exhibiting artificial "Perlitic structure," exhibited by Prof. Judd, F.R.S., Sec. G.S.

Specimens and microscopic sections, exhibited by Messrs. Wethered and Rutley, in illustration of their papers.

March 22, 1884.

Prof. T. G. Bonney, D.Sc., F.R.S., President, in the Chair

The List of Donations to the Library was read.

The following communications were read:—

1. "On *Rhytidosteus capensis*, Owen, a Labyrinthodont Amphibian from the Trias of the Cape of Good Hope." By Sir Richard Owen, K.C.B., F.R.S., F.G.S.

2. "On the Occurrence of Antelope-remains in Newer Pliocene Beds in Britain, with the Description of a new Species, *Gazella anglica*." By E. Tulley Newton, Esq., F.G.S.

3. "A Comparative and Critical Revision of the Madreporaria of the White Lias of the Middle and Western Counties of England, and of those of the Conglomerate at the Base of the South-Wales Lias." By Robert F. Tomes, Esq., F.G.S.

The following were exhibited:—

Specimens and casts exhibited by E. T. Newton, Esq., F.G.S., in illustration of his paper.

Two Gazelle skulls, exhibited by R. Lydekker, Esq., F.G.S., in illustration of Mr. Newton's paper.

Stereoscopic drawings of skeleton models of crystalline forms, exhibited by James Love, Esq., F.G.S.

April 2, 1884.

Prof. T. G. Bonney, D.Sc., F.R.S., President, in the Chair.

Frank Gotto, Esq., 17 B, Great George Street, S.W., and Rio Janeiro; and George Varty Smith, Esq., The Luham, Edenhall, Penrith, were elected Fellows, and Dr. E. Mojsisovics von Mojsvár, of Vienna, a Foreign Correspondent of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "The Rocks of Guernsey." By the Rev. E. Hill, M.A., F.G.S. With an Appendix on the Microscopic Structure of some of the Rocks, by Prof. T. G. Bonney, D.Sc., F.R.S., Pres. G.S.

2. "On a new specimen of *Megalichthys* from the Yorkshire Coal-field." By Prof. L. C. Miall, F.G.S.

3. "Studies on some Japanese Rocks." By Dr. Bundjiro Kotô. Communicated by Frank Rutley, Esq., F.G.S.

The following objects were exhibited:—

Rock-specimens and microscopic sections, exhibited by the Rev. E. Hill, F.G.S., in illustration of his paper.

A specimen of *Megalichthys*, exhibited by Prof. L. C. Miall, F.G.S., in illustration of his paper.

Microscopic sections, exhibited by F. Rutley, Esq., F.G.S., in illustration of Dr. Kotô's paper.

A globe with a great circle, which nearly corresponds to the principal gold-producing mines of the world, exhibited by Mr. J. Baddeley. With reference to this last object the President stated that the exhibitor, who had been engaged for the last thirty years in gold-mining in various parts of the world, had marked upon a small globe a great circle of the earth, cutting the equator obliquely in long. 10° E. and 170° W., and with its northern and southern tropics in lat. 45°. This circle will be seen to correspond nearly in position to some of the principal gold-producing mines of the world, in Australia, in several parts of North America (from California to Nova Scotia), and in Africa. He wished especially to call attention to the circumstance that gold-mines on this belt are worked to greater depths than in Spain or other old gold-mining countries, and suggested that attention should be paid to the regions traversed by the circle in Africa, such as the head-waters of the Zambesi and Quango rivers.

April 23, 1884.

Prof. T. G. Bonney, D.Sc., F.R.S., President, in the Chair.

The Rev. Frank Ballard, M.A., Euston Grove, Birkenhead, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Geology of the Country traversed by the Canadian Pacific Railway, from Lake Superior to the Rocky Mountains." By Principal J. W. Dawson, C.M.G., F.R.S., F.G.S.

2. "On the Dyas (Permian) and Trias of Central Europe, and the true divisional line of these two formations." By the Rev. A. Irving, B.Sc., B.A., F.G.S.

The following objects were exhibited:—

Rock-specimens of the older formations (Laurentian) of Assouan, Egypt, exhibited by Principal J. W. Dawson, C.M.G., F.R.S., F.G.S.

Rock-specimens, exhibited by the Rev. A. Irving, B.Sc., B.A., F.G.S., in illustration of his paper.

A Photograph of *Stylonurus excelsior*, Hall, from the Catskills or Old Red Sandstone of the State of New York, exhibited by Dr. H. Woodward, F.R.S., F.G.S.

A Map of the Earthquake-wave of the 22nd April, in England, exhibited by W. Topley, Esq., F.G.S.

May 14, 1884.

Prof. T. G. Bonney, D.Sc., F.R.S., President, in the Chair.

John Ruscoe, Esq., Prospect House, Hyde, near Manchester, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. "On the Pre-Cambrian Rocks of Pembrokeshire, with especial reference to the St. Davids District." By Dr. Henry Hicks, F.G.S., with an Appendix by Thomas Davies, Esq., F.G.S.

2. "Note on a specimen of Iron Amianthus." By the Rev. J. Magens Mello, M.A., F.G.S.

The accompanying specimen was found at the bottom of one of the Wingeworth iron-furnaces, near Chesterfield, and was given to me by Mr. Arthur Carrington, one of the owners.

The furnaces have been lately blown out for repairs, and in the mass of slaggy refuse at the bottom a thin layer of the curious product known as iron amianthus was interposed between the sand and the iron refuse.

The red sand at the bottom of the furnace was converted in its upper part into a compact hard white sandstone, an inch or two in thickness, and upon the top of this the Iron Amianthus occurred in snow-white fibrous masses, the fibres radiating in a concentric manner, and forming more or less botryoidal concretions, somewhat resembling hæmatite in appearance, and separated by extremely thin plates or septa of iron, by which the entire mass is divided into irregular prisms of about half an inch in diameter.

A similar product is described by Percy as occurring in the blast-furnaces of the Harz, and is said to consist almost entirely of fibrous silica, with a few specks of iron and graphite, and minute cubes of nitro-cyanide of titanium. Both graphite and titanium occur in the Wingeworth refuse; the graphite is found in thin plates, the nitro-cyanide of titanium in masses of crystals.

Percy states that the origin of the iron amianthus is found in the oxidation of the silicon, which is separated in greater or less degree under the same conditions as graphite, and is oxidized at a high temperature.

The following specimens were exhibited:—

Microscopic Sections and Rock-specimens, exhibited by Dr. H. Hicks, F.G.S., in illustration of his paper.

Specimens of "Iron Amianthus," exhibited by the Rev. J. Magens Mello, M.A., F.G.S., in illustration of his Note.

May 28, 1884.

Prof. T. G. Bonney, D.Sc., F.R.S., President, in the Chair.

John George Goodchild, Esq., Geological Survey of England and Wales, 28 Jermyn Street, S.W.; Alexander Johnstone, Esq., Blairlodge School, Polmont Station, N.B.; and John Taylor, Esq., M. Inst. C.E., 6 Queen Street Place, E.C., were elected Fellows, and Professor G. Meneghini of Pisa, a Foreign Member of the Society.

The List of Donations to the Library was read.

The following Donation to the Museum was announced :—

Specimens of "Iron Amianthus," presented by the Rev. J. Magens Mello, M.A., F.G.S.

The Secretary announced that Prof. P. Martin Duncan, F.R.S., F.G.S., had presented a large framed photograph of himself ; and that Messrs. Maull and Fox had presented 47 photographs of Fellows of the Society

The following communications were read :—

1. "The Archæan and Lower Palæozoic Rocks of Anglesey." By Dr. C. Callaway, F.G.S. With an Appendix on some Rock-specimens, by Prof. T. G. Bonney, D.Sc., F.R.S., President G.S.

2. "On the new Railway-cutting at Guildford." By Lt.-Col. H. H. Godwin-Austen, F.R.S., F.G.S., and W. Whitaker, Esq., B.A., F.G.S.

3. "On the Fructification of *Zeilleria* (*Sphenopteris*) *delicatula*, Sternb., sp., with remarks on *Ursatopteris* (*Sphenopteris*) *tenella*, Brongn., sp., and *Hymenophyllites* (*Sphenopteris*) *quadridactylites*, Gutb., sp." By R. Kidston, Esq., F.G.S.

4. "On the Recent Encroachment of the Sea at Westward Ho !, North Devon." By Herbert Green Spearing, Esq. Communicated by Prof. Prestwich, M.A., F.R.S., V.P.G.S.

5. "On further discoveries of Footprints of Vertebrate Animals in the Lower New Red of Penrith." By George Varty Smith, Esq., F.G.S.

The following specimens were exhibited :—

Rock-specimens and microscopic sections, exhibited by Dr. Callaway, F.G.S., in illustration of his paper.

Rocks and fossils from Anglesey, exhibited by Prof. T. McK. Hughes, M.A., F.G.S.

Five Stereoscopic Drawings of ditetragonal crystalline forms, exhibited by James Love, Esq., F.G.S.

Casts, exhibited by G. Varty Smith, Esq., F.G.S., in illustration of his paper.

June 11, 1884.

Prof. T. G. Bonney, D.Sc., F.R.S., President, in the Chair.

Charles Edward Bainbridge, Esq., Middleton in Teesdale; John J. Evans, Esq., Bangor, North Wales; William Frederick Fremersdorff, Esq., Roseneath Villa, Castle Road, Cardiff; and Henry De Morgan Snell, Esq., Pernambuco, Brazil, were elected Fellows of the Society.

The following names of Fellows of the Society were read out for the first time in conformity with the Bye-laws Sec. VI. B. Art. 6, in consequence of the non-payment of the arrears of their contributions:—G. P. Bevan, Esq., B. P. Bidder, Esq., W. A. Byrom, Esq., J. Coates, Esq., Dr. W. B. Kemshead, Sergeant W. Parsons, R.E., T. J. Price, Esq., F. E. Randell, Esq., S. B. J. Skertchley, Esq., and Dr. J. Shaw, of Cape Town.

The List of Donations to the Library was read.

The following communications were read:—

1. "The Range of the Palæozoic Rocks beneath Northampton." By Henry John Eunson, Esq., F.G.S.

2. "On some Zaphrentoid Corals from British Devonian Beds." By A. Champernowne, Esq., M.A., F.G.S.

3. "On the Internal Structure of *Micrabacia coronula*, Goldf., sp., and its Classificatory Position." By Prof. P. Martin Duncan, M.B. (Lond.), F.R.S., F.G.S.

4. "A Correction in the assumed Amount of Energy developed by the Secular Cooling of the Earth as stated in two Papers by the late Robert Mallet, M.A., F.R.S., in the 'Philosophical Transactions,' 1874–5." By W. F. Stanley, Esq., F.G.S.

[Abstract.]

According to Mr. Mallet's theory, as detailed in the two papers named above, the amount of heat lost from the initial temperature of the earth will represent in units of energy the force of its contraction, which he assumed will be active, especially in surface phenomena. To the force of contraction developed by cooling Mr. Mallet attributes the inclination, upheaval, crumpling, and dislocation of all strata, past or present, together with all volcanic phenomena.

The calculations for the amount of energy upon which he most

relies for demonstration, and with which he commences his second paper, are stated in the following sentence, § 178 of his first paper:—

"The earth is still a cooling globe; and whether we adopt Elie de Beaumont's figures (0·0065), or Thomson's (0·0085), or J. D. Forbes's (0·007 millimetres) for the thickness of the plate of ice which, covering the whole earth's surface, if melted to water at 32° Fahr., would equal the heat lost annually by our globe, the result will be that from 575 to 777 cubic miles of ice liquefied to water at 32° represents the annual loss of heat at present from the globe."

This calculation was worked out in detail by the author, and shown to be entirely in error, as, according to the figures quoted of the above eminent physicists, an amount of energy represented by the melting of from ·7937 to 1·0387 cubic miles of ice only would be dissipated to cause contraction, or only about a 700th part of the amount calculated by Mr. Mallet from the figures named.

The following were exhibited:—

Specimens of Cores from well-borings, and microscopic sections, exhibited by H. J. Eunson, Esq., F.G.S., in illustration of his paper.

Specimens of Devonian Corals, exhibited by A. Champernowne, Esq., F.G.S., in illustration of his paper.

June 25, 1884.

Prof. T. G. Bonney, D.Sc., F.R.S., President, in the Chair.

James Campbell Christie, Esq., Old Cathcart, near Glasgow, was elected a Fellow, and Baron C. von Ettingshausen, of Graz, a Foreign Correspondent of the Society.

The following names of Fellows of the Society were read out for the second time in conformity with the Bye-laws Sec. VI. B, Art. 6, in consequence of the non-payment of the arrears of their contributions:—G. P. Bevan, Esq., B. P. Bidder, Esq., W. A. Byrom, Esq., J. Coates, Esq., Dr. W. B. Kemshead, Sergeant W. Parsons, R.E., T. J. Price, Esq., F. E. Randell, Esq., S. B. J. Skertchley, Esq., and Dr. J. Shaw of Cape Town.

The List of Donations to the Library was read.

The following communications were read:—

1. "Additional Notes on the Jurassic Rocks which underlie London." By Prof. John W. Judd, F.R.S., Sec. G.S.

2. "On some fossil Calcisponges from the well-boring at Richmond, Surrey." By Dr. G. J. Hinde, F.G.S.

3. "On the Foraminifera and Ostracoda from the deep boring at Richmond." By Prof. T. Rupert Jones, F.R.S., F.G.S.

4. "Polyzoa (Bryozoa) found in the boring at Richmond, Surrey, referred to by Prof. J. W. Judd, F.R.S." By G. R. Vine, Esq. Communicated by Prof. Judd, F.R.S., Sec. G.S.

5. "On a new Species of *Conoceras* from the Llanvirn beds, Abereiddy, Pembrokeshire." By T. Roberts, Esq., B.A., F.G.S.

6. "Fossil Cyclostomatous Bryozoa from Australia." By A. W. Waters, Esq., F.G.S.

7. "Observations on certain Tertiary Formations at the south base of the Alps, in North Italy." By Lt.-Col. H. H. Godwin-Austen, F.R.S., F.G.S.

8. "On the Geological Position of the Weka-Pass Stone." By Capt. F. W. Hutton, F.G.S.

9. "On the Chemical and Microscopical Characters of the Whin Sill." By J. J. H. Teall, Esq., F.G.S.

10. "A Critical and Descriptive List of the Oolitic Madreporaria of the Boulonnais." By R. F. Tomes, Esq., F.G.S.

11. "On the Structure and Affinities of the family Receptaculitidæ, including therein the genera *Ischadites*, Murch. (= *Tetragonis*, Eichw.), *Sphærospongia*, Pengelly, *Acanthochonia*, g. n., and *Receptaculites*, Defr." By Dr. G. J. Hinde, F.G.S.

12. "On the Pliocene Mammalian Fauna of the Val d'Arno." By Dr. C. J. Forsyth Major. Communicated by Prof. W. Boyd Dawkins, F.R.S., F.G.S.

13. "Notes on the Geology and Mineralogy of Madagascar." By Dr. G. W. Parker. Communicated by F. W. Rudler, Esq., F.G.S.

[Abstract.]

This paper commenced with a sketch of the physical geography of the island of Madagascar. A central plateau from 4000 to 5000 feet high occupies about half the island, rising above the lowlands that skirt the coast, and from this plateau rise in turn a number of volcanic cones, the highest, Ankaratra, being 8950 feet above the sea. With the exception of certain legends, there is no record of a period when the volcanoes were active: two such legends were given.

The known volcanic cones were enumerated. They extend from the northern extremity of the island to the 20th parallel of south latitude. Beyond this granite and other primitive rocks occur as far as lat. 22°, south of which the central parts of Madagascar are practically unknown to Europeans.

Some crater-lakes and numerous hot and mineral springs occur.

Earthquakes are occasionally felt in the island, most frequently in the months of September and October. The shocks are generally slight.

Only a single trap-dyke is known near Antananarivo. The hills around this city are of varieties of granite (? granitoid gneiss). The general direction of the strata is parallel to the long axis of the island.

Marine fossils have been found by Rev. J. Richardson and Mons. Grandidier in the south-west part of the central plateau. These fossils are referred by the last-named traveller to the Jurassic system. Remains of *Hippopotami*, gigantic Tortoises, and an extinct Ostrich-like bird have also been recorded. North and north-west of the fossiliferous rocks, between them and the volcanic district of Ankaratra, sandstone and slate occur. North of this volcanic district again is a tract of country in which silver-lead (mixed with zinc) and copper are found.

Near the north-western edge of the central plateau are granitic escarpments facing northwards and about 500 feet high. Some details were also given of valleys through the central plateau and of lagoons within the coral reefs on the coasts. To these remarks succeeded some details of the physical features exhibited by the province of Imerina as seen from Antananarivo.

14. "Notes on some Cretaceous Lichenoporidæ." By G. R. Vine, Esq. Communicated by Prof. P. Martin Duncan, M.B. Lond., F.R.S., F.G.S.

The following specimens were exhibited:—

Specimens of Jurassic Calcisponges and microscopic sections from them, exhibited by Dr. G. J. Hinde, F.G.S., in illustration of his paper.

Specimens of *Conoceras*, exhibited by T. Roberts, Esq., F.G.S., in illustration of his paper.

Specimens from the Whin Sill and of American diabase, exhibited by J. J. H. Teall, Esq., F.G.S., in illustration of his paper.

Specimens of *Receptaculites* from Canada, lent by J. F. Whiteaves, Esq., F.G.S.; of *Ischadites* from the Isle of Gotland, lent by Prof. G. Lindström; and microscopic sections of *Acanthochonia* from Bohemia; exhibited by Dr. G. J. Hinde, F.G.S., in illustration of his paper.

Specimens, exhibited by Dr. G. W. Parker, in illustration of his paper.

Specimens of the Core of the Richmond Boring, and the Thermometer with which the temperature was taken, exhibited by Collett Homersham, Esq., F.G.S.

ADDITIONS

TO THE

LIBRARY AND MUSEUM OF THE GEOLOGICAL SOCIETY.

Session 1883–84.

I. ADDITIONS TO THE LIBRARY.

1. Periodicals and Publications of Learned Societies.

Presented by the respective Societies and Editors, if not otherwise stated.

Academy. Nos. 581–608. 1883.

——. Nos. 609–633. 1884.

Adelaide. Royal Society of South Australia. Transactions, Proceedings, and Report for 1882–83. Vol. vi. 1883.

T. C. Cloud. A Catalogue of South Australian Minerals, 72.—R. Tate. The Botany of Kangaroo Island, with Notes on its Geology, 116.

Albany. New York State Library. Catalogue, 1882. First Supplement to the Subject-Index of the General Library for ten years, 1872–82. 1882.

——. ——. 62nd Annual Report of the Trustees, for the year 1880. 1880.

——. ——. 63rd —— 1881. 1881.

——. ——. 64th —— 1882. 1882.

Analyst. Vol. viii. Nos. 88–93. 1883.

——. Vol. ix. Nos. 94–99. 1884.

Annals and Magazine of Natural History. Ser. 5. Vol. xii. Nos. 67–72. 1883. *Purchased.*

E. D. Cope. On the Mutual Relations of the Bunotherian Mammalia, 20.—H. J. Carter. On the Microscopic Structure of thin Slices of Fossil Calcispongiæ, 26.—G. C. Wallich. Note on the Detection of Polycystina within the hermetically closed Cavities of certain Nodular Flints, 52.—S. V. Wood. The "Crag Mollusca," 65, 208.—J. Gwyn Jeffreys. The "Crag Mollusca," 143.—J. S. Newberry. Notes on some Fossil Plants from Northern China, 172.—T. Rupert Jones. Notes on the Palæozoic

Bivalved Entomostraca, No. xvi., 243.—W. O. Crosby. Elevated Coral Reefs of Cuba, 283.—H. A. Nicholson. Contributions to Micro-Palæontology: On *Stenopora Howsii*, Nich., with Notes on *Monticulipora? tumida*, Phill., and Remarks on *Tabulipora Urii*, Young, 285.—H. J. Carter. Spicules of *Spongilla* in the Diluvium of the Altmühl Valley, Bavaria, 329.—O. Heer. On the Fossil Flora of Greenland, 426.

Annals and Magazine of Natural History. Ser. 5. Vol. xiii. Nos. 73–78. 1884. *Purchased.*

H. A. Nicholson. Note on the Structure of the Skeleton in the Genera *Corallium*, *Tubipora*, and *Syringopora*, 29.—C. D. Walcott. Injury sustained by the Eye of a Trilobite at the time of the Moulting of the Shell, 69.—R. Kidston. On a Specimen of *Pecopteris* (? *polymorpha*, Brongn.) in Circinate Vernation, with Remarks on the Genera *Spiropteris* and *Rhizomopteris* of Schimper, 72.—R. Kidston. On a new Species of *Schutzia* from the Calciferous Sandstones of Scotland, 77.—G. Lindström. A Reply to the Remarks of Prof. Duncan on a Paper entitled "Contributions to the Actinology of the Atlantic Ocean," 102.—H. Alleyne Nicholson. Contributions to Micro-Palæontology: Notes on some Species of Monticuliporoid Corals from the Upper Silurian Rocks of Britain, 117.—T. Hincks. Note on Professor G. Seguenza's List of Tertiary Polyzoa from Reggio (Calabria), 265.—A. H. Foord. On three new Species of Monticuliporoid Corals, 338.—H. J. Carter. Note on the assumed Relationship of *Parkeria* to *Stromatopora*, and on a Microscopic Section of *Stromatopora mamillata*, Fr. Schmidt, 353.—L. F. Ward. On Mesozoic Dicotyledons, 383.—P. M. Duncan. On Prof. Lindström's Remarks on Prof. P. Martin Duncan's Criticisms, 416.—F. W. Hutton. On the Origin of the Fauna and Flora of New Zealand, 425.—J. W. Davis. Description of a new Genus of Fossil Fishes from the Lias, 448.—P. M. Duncan. On the Relation of the Pali of Corals to the Tentacles, 466.—R. Etheridge, jun., and A. H. Foord. Descriptions of Palæozoic Corals in the Collections of the British Museum, 472.

Army Medical Department. Report for the year 1881. Vol. xxiii. 1883.

Athenæum (Journal). Nos. 2904–2931. 1883.

——. Nos. 2932–2956. 1884.

——. Parts 665–671. 1883.

——. Parts 672–677. 1884.

Barnsley. Midland Institute of Mining, Civil, and Mechanical Engineers. Transactions. Vol. viii. Parts 66–68. 1883.

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