THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

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

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Page 538. For '*Didymograptus octobrachiatus*,' lines 3, 10, & 17 from bottom, read '*Dichograptus octobrachiatus*.'

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Part 1.

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[With Nine Plates, illustrating Papers by the late J. Carter, Miss J. Donald, Dr. F. H. Hatch, Mr. John Parkinson, the Rev. G. C. H. Pollen, and Messrs. C. I. Gardiner & S. H. Reynolds.]

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EVENING MEETINGS OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

Session 1897–98.

1898.

Wednesday,	February (*Anniversary*, Feb. 18th)	23
,,	March	9–23
,,	April	6–20
,,	May	4–18
,,	June	8–22

[*Business will commence at Eight o'Clock precisely each Evening.*]

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Vol. LIV.

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1. *The* Geology *of* Rotuma. By J. Stanley Gardiner, Esq., B.A. *With an* Appendix by H. Woods, Esq., M.A., F.G.S. (Communicated by J. E. Marr, Esq., M.A., F.R.S., Sec. G. S. Read November 17th, 1897.)

Contents.

I. Introduction.

Nothing of a detailed character has, so far as I am aware, been published on the geology of Rotuma. J. D. Dana mentions it as a high island with encircling reefs in 'Corals and Coral Islands.'[1] Darwin, in 'The Structure and Distribution of Coral Reefs,'[2] says that it possesses a fringing-reef only, and that it has an extinct volcano.

My notes were made in the months of September to December, 1896, which I spent on the island; I am indebted to Capt. Field and the officers of H.M.S. *Penguin* for their kindness, which enabled me to visit the island. I am further greatly indebted to Mr. J. E. Marr for his kindly advice and for reading through the accompanying paper, and also to Mr. H. Woods, who has examined the rocks which I obtained.

[1] 2nd ed. pp. 342 & 378.
[2] 3rd ed, 1889, p. 216.

II. Topography.

The island of Rotuma is situated in lat. 12° 30′ S. and long. 177° 1′ E.; it is thus about 260 miles almost due north of the Yasawas, the nearest islands in the Fijian group. According to the *Challenger*'s charts it lies in a general depth of 2000 fathoms, on a plateau which includes the Fijian, Tongan, Samoan, and Ellice Islands. The soundings of H.M.S. *Penguin*: 2438, 2715 fathoms, etc. in 1896, show that the Ellice Islands must be removed, while the most recently published chart of Samoa to Fiji shows that the former is separated from all neighbouring groups by a depth of at least 2200 fathoms.

Thus there is left a great plateau, including the Tongan and Fijian groups, having a northward extension of 4° to 5° of latitude with a depth not greater than 1500 fathoms in a general depth of 2000 to 3000 fathoms. Its breadth north of and including Tonga is about 10°, while in lat. 9° to 13° S. it has a westward extension to join the plateau on which the Santa Cruz and Solomon groups lie.

Between lats. 10° and 13° S. are on this plateau no less than ten islands, or shallow shoals. They are, from east to west, the Rookh Bank, Uea or Wallis Island, the Waterwitch Bank, the Isabella Bank, the Coombe Bank, Rotuma, the Alexa Bank, and three other banks mentioned by Admiral Wharton.[1] Of these Uea and Rotuma are high islands; while all the rest, with the possible exception of the Rookh Bank, are atoll-shaped shoals, with only a few fathoms of water over their rims.

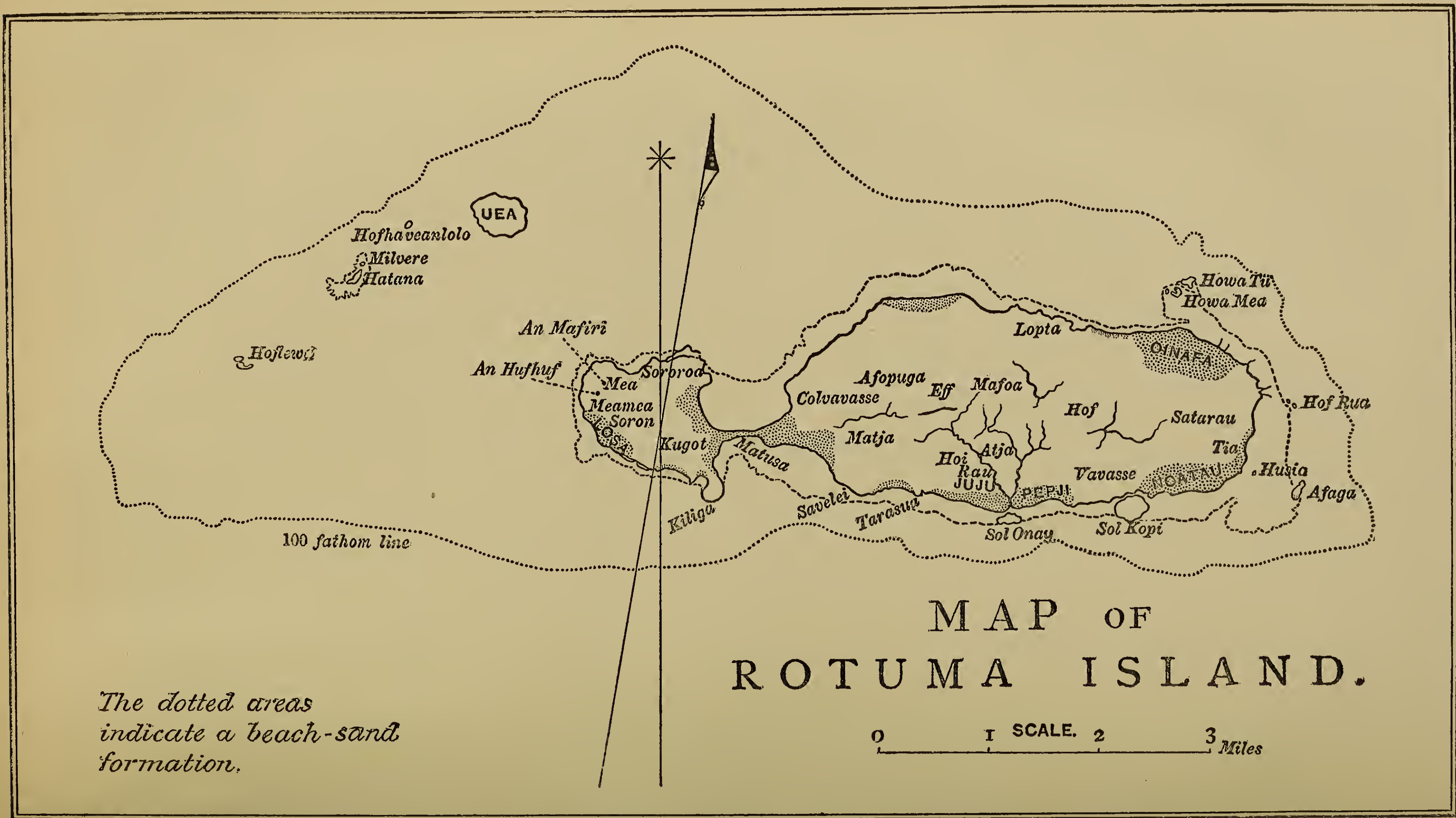
In the same line many other shoals are reported, but their positions are at present doubtful. Nurakita, or Sophia Island, however, in lat. 10° 45′ S., long. 179° 25′ E., probably belongs to the same. It is evidently on a very large shoal-bank, which the numerous soundings in the area make about 60 miles long by 30 broad. Sufficient, however, have been shown to indicate that along this line there appears to be a range of mountains varying in height above the general plateau of from 5000 to 8000 feet.

The general chart of the island shows that it consists of two parts, joined together by a very narrow neck of land, which tradition states to have been formed by the islanders on an intervening reef. It consists entirely of sand; the mountain bounding it to the west shows at its base signs of wave-action; there are no large trees on it, and in the reef a pool, 8 to 12 fathoms deep, lies in a direct line between the two largest passages on the northern and southern sides. Taking these as supporting this idea, I propose to treat these parts separately as the eastern and western ends. Off the island to the west, at a distance of 2 to 4 miles, lie three smaller islands, Uea, Hatana, and Hoflewa, in a line from north-east to south-west.

The Eastern End.

This part is very rectangular in shape, but slightly pointed at its western end; its long axis runs almost due east and west. It is

[1] 'Nature,' vol. lv. (1897) p. 390.



MAP OF ROTUMA ISLAND.

[*For* 'Soron' *read* 'Sorou'; *or* 'Kugot' *read* 'Kugoi'; *and for* 'Satarau' *read* 'Satarua.']

about 5 miles long by $2\frac{1}{2}$ broad, and the heights of its hills vary up to 860 feet. Along it the hills run in two lines, but to the east they are closed by Satarua, so that they appear to have a U-shape with a deep and, in places, very broad valley between, right up the centre. Round this, everywhere between the hills is a ridge with a general height of a little over 100 feet, and a minimum of about 60 feet between Satarua and Hof. On their outer faces, towards the sea, are extensive beach-sand deposits, especially to the north at Oinafa and to the south at Noatau and Pepji, while the flat land between the two ends is similarly formed. On the reef, which is fringing, with in places an approach to the barrier class, are several islets with a gradual slope towards the land, but precipitous cliffs to the sea.

On an examination of this U-shaped range of hills, which appear wonderfully uniform in height, they are found to have a flat summit with a central depression of varying depth, or to run up into a ridge. In both cases the angle of slope for the last 200 to 300 feet varies from 30° to 55°. This appearance is further often accentuated by the vegetation : large forest-timber on the summits and slopes of the first, but on the second planted land, sometimes right across the ridge itself.

Satarua, the most easterly of this range, combines to some extent the characters of both classes. From it to the north-east run out into the sea four prominent points, all of porous lava. Behind these the land rises with a slope of 1 in 30 to 1 in 20 for about $\frac{1}{2}$ mile, covered for the most part with rough, hard, vesicular lava, often in loose blocks, with very little earth. The rise then gradually increases to 1 in 6, or 4, for the next 300 feet, the rough lava being gradually more and more covered with earth. The steepness of the land continually increases, only small blocks of lava are to be found for the next 50 to 100 feet, and then there is an abrupt rise for the last 250 or 200 feet at an angle measured at 41° to 44°, the height of the mountain being a little over 700 feet. On the top is a crater 150 feet broad by 40 deep. The slopes into it are steeper than the external slope, while the bottom is perfectly flat, and indeed, as many of these craters do, gives evidence of having at some previous time been planted for food. The rim is about 10 yards broad, and consists, with both of the slopes, of loose earth, with only small lava-blocks here and there. From the rim of the crater there extends to the south-west a ridge, sloping downward, but undulating, about 150 yards long by 15 to 25 yards broad. Beyond it the slope again plunges down at an angle of about 40°, and the general character is the same.

This bare low-lying stretch of lava at the base of the hill, mentioned above, with a low angle of rise, passing into a rich and highly arable soil, is very characteristic of all the volcanic hills of the island. It usually presents an extremely rugged and rough, black appearance, sometimes covered with loose, large blocks, but more often completely bare.

Of the other hills in the range, Mafoa is a cone with a crater on the top about 240 feet deep, and an external slope of 50° to 60° near the summit; there are also craters on the summits of Atja and Hoi, and Matja is simply a crater with one side blown out.

Generally the rock is the same as on Satarua, a very vesicular lava (see Appendix, p. 10, No. 2); but at the bases of Hoi, Rau, Matja, and Vavasse, near the sea, a much finer-grained basalt (*loc. cit.* No. 3) is found.

At Oinafa, Noatau, Pepji, and many places along the coast the volcanic rock is shut off from the sea by the formation of a sand-flat, which also to some extent is found at the mouth of the U-shaped range of hills. At Noatau in places it is $\frac{1}{4}$ to $\frac{1}{3}$ mile broad, and is about 1 foot above high-tide level. Between it and the sea is a further small rise of 2 to 3 feet. Holes dug in it in places to a depth of 6 to 12 feet give nothing but loose sand with fragments of corals, shells, nullipores, etc. Towards the sea, on the beach between extreme tide-marks, it ends with a 'beach-sandstone formation' sloping down at an angle of from 6° to 12° to the sea, and showing corresponding stratification; in places, however, this beach-sandstone is much overlain with sand. It can be and is used for gravestones, split off in blocks of any dimensions, but the strata never run more than 4 to 7 inches in thickness. Below the first layer thus removed is a second, which, however, is never so firmly consolidated. It then becomes less firm till in 3 or 4 feet loose sand and fragments of coral, nullipores, etc., as on the flat, make their appearance. On the beach the projecting ends of six or seven layers, like so many steps, may be seen. Used as gravestones, exposed to the air and not acted on by the sea, it hardens, becomes more compact, and rings to the hammer. After the removal of a layer the under layer now exposed hardens considerably, and the place of the old layer is taken up by the sand. The part exposed to the air and waves is hardest, and where broken off from the stratum is usually covered with sand. Here, however, it is reformed, growing up under the covering sand, as it were, from the broken edge.

At Oinafa this sand-flat has a height at most parts of a few inches above high tide, but 100 yards in from the coast, immediately behind the anchorage, it descends to 1–3 feet below high-tide level. This area is nearly half a mile long by 300 yards in greatest breadth. In places in it are pools 6 to 7 feet deep, and much of the remainder is taken up by a swamp, in which papoi or broka, a species of arum, is cultivated for food. On it, more or less buried in the sand, are loose blocks of coral strewed about, and a crowbar cannot be forced down far without meeting solid rock, which is usually of coral formation. Between it and the sea to the north-east, the sand-beach is 3 to 4 feet above high tide, and the beach-sand rock is unusually well defined. It seems really as if a small lagoon in connexion with the sea had once existed here, but had been filled up by corals, sand, etc., and cut off from the sea by the formation to the north of a sand-beach.

Somewhat similar but much smaller swamps exist in Noatau and in Itomotu at the western end, but the level of the former seems little below that of high tide.

The outlying islands on the reef all seem to be of the same structure, a rough, reddish ash-rock, mixed with chips of harder, black rocks, which on examination appear to be lava, some other volcanic agglomerate, or of basaltic nature; they are, however, very rarely crystalline. Sometimes these foreign rocks occur in large masses, and indeed the southern end of Afaga is formed entirely of a basaltic rock. The two islands of Howa, opposite Oinafa, were obviously once joined, but the ash-rock has been washed away between them, leaving a channel, now covered by 2 to 3 feet of water. In it, however, are many blocks of hard black rock from the disintegration of the ash-rock. Two-thirds of the way from Howa to Afaga lie two rocks about 20 yards outside the breaking edge of the reef, apparently of a basaltic nature. Afaga, as before mentioned, has its southern end of a compact lava or basalt, together with many rocks lying in the reef off its southern end. Towards the sea it is precipitous, but the section fails to show any sharp distinction between it and the ash-rock. The latter has its strata dipping slightly at an angle of 2° or 3° to the N., while generally, if the strata show at all, they are perfectly horizontal. Between Afaga and the shore rises a small ash-rock island, Husia, with precipitous walls about 40 feet high. It has been considerably washed away within the memory of many Rotumans, a strong current with a deep channel (9 feet) running between it and the shore.

Sol Kopi is about 350 feet high, with precipices, often overhanging the sea to the outside from 50 to 200 feet high, while Sol Onau has a similar structure. Towards the sea, indeed, all these islands of volcanic ash end precipitously, but under them is always a narrow fringing-reef 10 to 20 yards broad. Some, too, show traces of extensive landslips.

The Western End.

The part thus designated is very sharply separated from the beach-sand flat at the isthmus by steep cliffs of 70 to 100 feet, surrounding the base of Kugoi, while the same hill continues to the south by a ridge into Kiliga, but to the north has a sharp drop into a valley from which Sororoa rises to the height of about 850 feet.

Kugoi and Kiliga are bounded on all sides by precipitous cliffs, 150 to 250 feet high, but on the west have been to some extent banked up by a flow of lava from a crater halfway up Sororoa, the greater part, however, of which mountain is of ash-rock, as also is the hill of Mea to the west.

Somewhat westward of Mea rises a small, perfectly conical-shaped hill, called Mafiri. It is nearly 200 feet above the general level and about 350 feet above the sea. It is covered everywhere with big rough blocks of black, extremely vesicular, but heavy lava, in which are many small caves, 15 to 25 feet deep. On the top is a large pit leading into a number of passages and caves. South of Mea is another such pit on a slight rise, called An Hufhuf (the Cave of Many Bats); the detailed descriptions of both are appended.

South of these are two hills, Sorou and Meamea, both of which are of volcanic ash; the former has, like Sororoa, a crater on the side away from the sea.

III. Caves, Pits, etc.

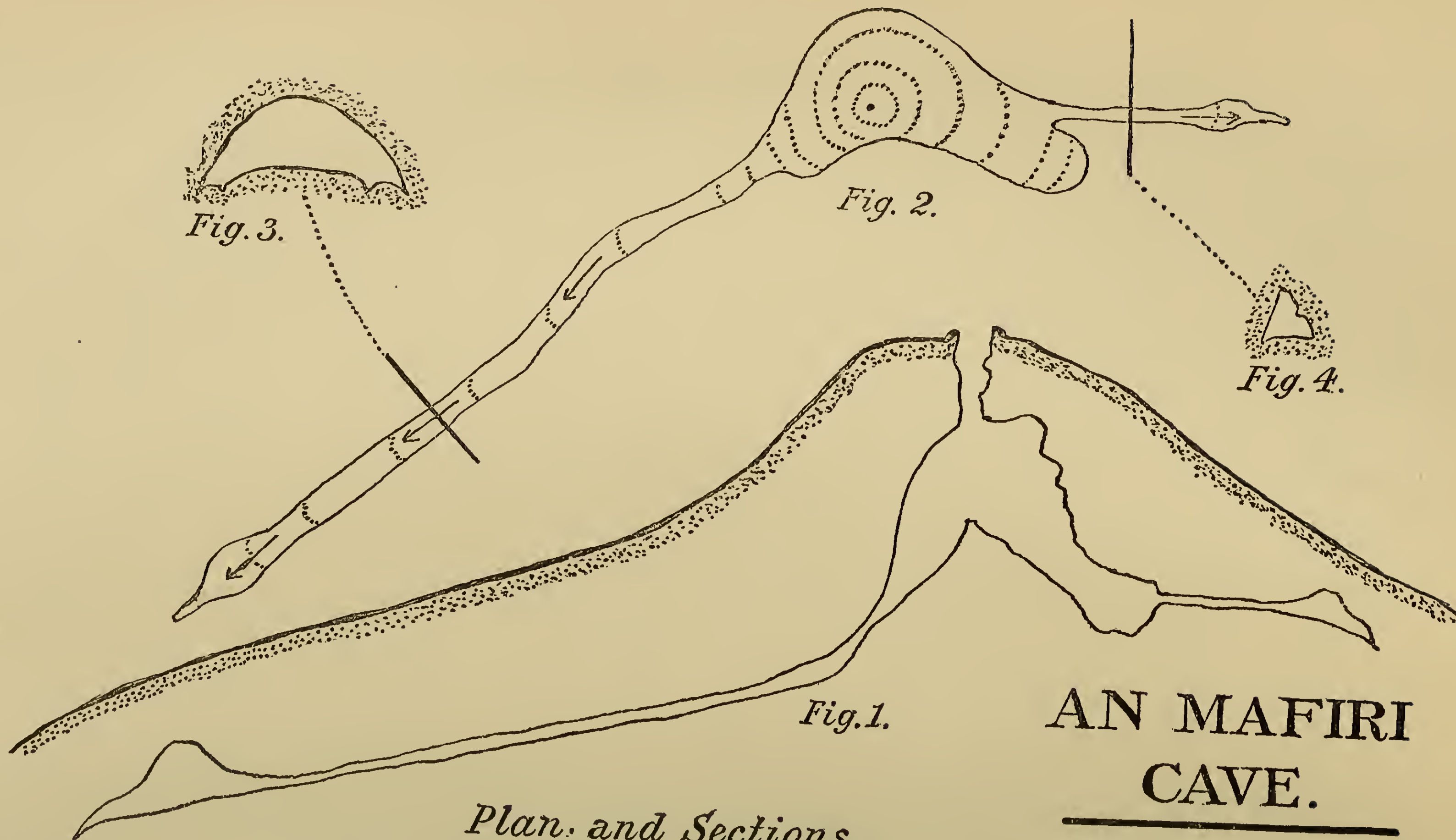
On the summit of Mafiri (see figs. 1–4, p. 8) is a pit 13 to 14 feet broad at the top and nearly circular in shape. Round the edge is a raised rim 1 to 2 feet high and 6 inches thick, consisting of much-weathered vesicular lava. Descending, the pit narrows to a breadth of 5 feet at a depth of 32 feet, and then opens into an immense chamber 70 feet long by 30 broad at the level of the summit of a mound, which has formed in the centre 82 feet below the mouth of the pit. The narrow pit to the depth of 32 feet has the appearance of a wall, built up by man, of great rectangular concave blocks of stone, owing to horizontal and vertical fractures. The mound consists of loose masses of lava, earth, decaying vegetable matter, etc., which have fallen in from the summit or the walls.

On one side the mound slopes down, at an angle of 45°, for 60 feet or so into a small chamber, which is much filled up by large fallen masses of rock. Twelve feet above one part of the slope is a narrow triangular tunnel, about 3 feet high by the same broad, running for 30 yards outward with a slight downward slope of 1° to 3°. Near its end it opens into a chamber 16 feet high. For the last two-thirds of this tunnel the floor has a rough, black, somewhat ropy appearance, showing clearly the direction of a lava-flow outward. On the roof hang a few small, sharp, conical stalactites, never more than 2 or 3 inches long. At the end the roof and floor approach each other at a very acute angle.

On the other side of the mound the first slope is steeper, and runs rather deeper down. It ends then in a tunnel about 110 yards long, sloping down at an angle of 10° or less. Its general height is about 6 feet in the centre, with a breadth of 12 to 15 feet. Its floor is slightly higher in the centre, and shows for most of its course, about $1\frac{1}{2}$ feet from the walls, two cracks or fissures, 10 to 12 inches deep by 3 or 4 broad at the top; these follow very regularly its course. Near its end it opens, as does the other tunnel, into a large chamber, and the angle at its end is likewise very acute. The structure of its walls, floor, and roof is the same as in the smaller cave; in no place, not even in the large chambers, is there any sign of the walls or roof falling in in any way. The ropy appearance of the floor, its raised centre and general trend, show conclusively the direction of the flow of lava along the tunnel. Examining the contour of the land above, there is a distinct rise, running out for a considerable distance to the south-west, but signs of any direct outflow from this tunnel or any difference of the lava could not be detected.

An Hufhuf seems to be directly comparable to Mafiri, only the

AN MAFIRI CAVE.



Plan. and Sections.

[Scale: Figs. 1 & 2, 96 feet = 1 inch; figs. 3 & 4, 16 feet = 1 inch.]

Fig. 1. Diagrammatic longitudinal section of external opening and cave, showing also the contour of the hill above the cave.
Fig. 2. Ground-plan of cave with contour-lines 10 feet apart, and arrows to show where the lava-flow is visible.
Figs. 3 & 4. Sections at the points marked in fig. 2.

pit is not situated at the top of a steep conical rise, but almost on the flat. Its pit, too, is much broader at the top and not nearly so deep. It has one long tunnel, out of which two caves run. The first rises at once to some extent and then has a sudden drop of 16 feet into a tunnel which proceeds almost at right angles to it, and down which a lava-flow has coursed, of the same character as in the tunnels of Sol Mafiri. The second has its lava-flow into the main tunnel.

The lava-beds in the neighbourhood of these two pits show many small caves or overhanging ledges, caused apparently by the lava underneath flowing away after the crust above has cooled. In one place just under Mafiri is a circular pit about 3 feet across. It is about 10 feet deep, and shows the flow of lava for 20 to 30 yards.

The tunnels seem to be comparable to that left by the lava-stream above Hilo, in the eruption of Mount Kea, Sandwich Islands, of 1880–81,[1] but the stalactites would seem to be absolutely dissimilar, and stalagmites are practically absent in the Rotuman tunnels.

IV. Western Islands.

Uea, to the north, is formed of essentially the same volcanic ash as the hill of Sororoa opposite to it. It is about 900 feet high, and is thus about 40 feet higher than any hill on the main island. On every side it is bounded by cliffs, which to the north and west are very high and precipitous. To the north-west near the summit they are over 800 feet. While round Sororoa there is even on the most precipitous face a small fringing-reef, none is present around Uea. Eastward the island slopes more gradually, but a landing, on account of the steepness and breakers, has nearly always to be effected by swimming. The strata in the cliffs round the island are generally horizontal, but at the landing-place have a tendency to dip or be curved slightly and show much false bedding. In the ash-rock embedded volcanic fragments occur, but rarely, and never in large blocks. In places under the action of fresh water, near certain streams, the rock becomes more like shale. Near these, too, a red earth is found, which lathers slightly, and is used as a soap.

Halfway between Uea and Hatana is a small reef, Hofhaveanlolo, about 60 yards across, partially uncovered at low tide. Hatana really consists of two islands inside the same fringing-reef, with cliffs to the west.

Hoflewa, 2 miles south-west, is a crescent-shaped island open to the north-east, with cliffs all round. The whole island is, like Hatana, a mass of dense, hard, black, very slightly vesicular lava.

V. Meteorological Conditions.

Except during December, January, February, and March, the prevailing winds are E. to S.; in the above months they vary from N. to W. Very heavy rainstorms often come up with the E.

[1] J. D. Dana, 'Characteristics of Volcanoes,' 1890, p. 209.

winds, but with N.W. winds the storms are of long duration and very dense. Hurricanes, with heavy rain, occur about every three years. The total annual rainfall is estimated by residents, from known Fijian statistics, at from 150 to 250 inches.

No pérennial streams flow except on Uea, where there are two. Deep channels have been cut by the rain, however, on Sororoa and Sol Kopi. In the regions of volcanic rock there are no signs of watercourses, but two streams flow perennially out of this rock between tide-marks at Lopta and Noatau. Towards the middle of this part of the island is an extensive watershed with no visible escape to the sea; possibly these two streams are fed from a reservoir filled by this.

Round the island is no current, except a drift, caused by and varying with the wind. The 100-fathom line follows the contour everywhere very regularly, but extends considerably to the north-east and south-west along the lines of Hoflewa and Uea.

VI. Conclusion.

From the foregoing evidence I am inclined to think that Rotuma was first formed of a kind of basaltic rock, such as is found in Kugoi now. This rock I believe to have extended along the whole island as it now runs, but to have been broken up by that great eruption, or series of eruptions, which formed the central U-shaped range of hills of the eastern end. By this eruption I believe that this same basaltic rock was in places loosely piled up, and then, by disintegration and admixture with lava, formed the hills and islands of volcanic ash. The last stage is the washing away of these, and the formation of the coral-reef and the beach-sand flats.

VII. Appendix.

Notes *on the* Rocks collected *by* Mr. Stanley Gardiner. By Henry Woods, Esq., M.A., F.G.S.

1. Olivine-Dolerite from Kugoi.

This is a light-greyish, moderately coarse-grained dolerite, containing much felspar. The rock is quite fresh, and consists of plagioclase-felspar, augite, olivine, magnetite, and apatite. Two generations of felspar are very distinct—the crystals belonging to the earlier showing good contours. It is probable that this is an intrusive rock.

2. Basalts from Tarasua Point, Mafiri Cave, and An Hufhuf.

These are very vesicular basalts, black or grey in colour. The specimen from Tarasua Point was found by Dr. W. Pollard to contain 48·86 per cent. of silica; the rock is dark in colour and consists of minute, but long, plagioclase-felspars (with a few larger crystals of the same mineral), augite, and magnetite. The small felspars have a parallel arrangement. The specimen from Mafiri is a fine-grained rock, in which the felspars have no regular arrangement.

3. Olivine-Basalts from Savelei Point, base of Hoi, and base of Vavasse (opposite Sol Kopi).

The specimen from Hoi is a greyish compact rock with light green crystals of olivine. Microscopic examination shows that it is fine-grained and not decomposed; it consists mainly of a mass of small, lath-shaped, plagioclase-felspars and augite, with larger crystals of augite and olivine. Magnetite is abundant. The felspars have a fairly well-marked parallel arrangement.

The rock from Savelei Point is darker and somewhat vesicular, resembling in general appearance the specimen from Tarasua Point, but containing olivine.

4. Ashes from Sol Kopi, Afaga, Howa, Kugoi, Kiliga Point, and Sororoa.

These are light-coloured rocks, varying in texture and compactness. The specimen from Sol Kopi is composed mainly of rather large fragments of glass containing numerous vesicles, and a fair number of crystals of augite. The specimen from Afaga is similar, but lighter in colour and finer-grained.

5. Calcareous Sand from Noatau, Oinafa, and Matusa.

This is a white, loosely-compacted rock, composed of calcareous grains, often as much as 3 mm. in diameter. Microscopic examination shows that the grains consist of calcareous algæ, fragments of echinoderms, and corals; a few pieces of volcanic rock (? andesite) are also seen. In a more compact example the cementing-material is calcite.

Discussion.

Prof. J. W. Judd and Mr. Marr spoke, and the Author replied.

2. *The* Laccolites *of* Cutch *and their* Relations *to the other* Igneous Masses *of the* District. By the Rev. J. F. Blake, M.A., F.G.S. (Read May 26th, 1897.)

[Abstract.]

The Author has observed thirty-two domes of various kinds in Cutch, distributed as follows:—(i) those connected with the northern islands; (ii) those of Wagir; and (iii) those along the northern edge of the mainland. They are divisible into four classes: (*a*) those which are so elongated on the line joining adjacent ones that they seem to be mere modifications of anticlinals, though the supposed anticline is not really continuous; (*b*) those which lie in a line, but are not elongated in that direction, and often in no other; (*c*) those which are related to a fault, which cuts them in half; and (*d*) those which are not in any particular relation to each other, or to any other stratigraphical feature.

The domes vary in degree of perfection: some are irregular, while some have the strata running in concentric circles, the outer and newer strata dipping away from the inner and older. In no less than ten of the thirty-two domes igneous bosses are found occupying the centre, and these are distributed amongst all of the above classes. The Author gives reasons for maintaining that the domes are the results of intrusion of igneous rocks in the form of laccolites, and are not anticlinal folds which have afterwards been affected by cross-folds. The domes are contrasted with igneous peaks which occur in abundance in a different part of the area, usually at a higher horizon of the strata and at a higher level above sea. These are probably volcanic pipes through which the lava was forced and extruded at the surface.

The Author compares the rocks of the bosses with those of the dykes and flows. Both are principally perfectly fresh dolerites, but the former are distinguished by the presence of intergrowths of micropegmatite as the last stage of consolidation, as in the 'Konga diabases.' There is also among them a felsite-breccia with micropegmatite developed in the cracks.

He considers that nearly all the igneous rocks of Cutch have been derived from a single magma, which in a solid condition must have contained large crystals of augite, olivine, and ilmenite in a groundmass of lime-felspars, and have been throughout of a basic character. Such a magma originated in more than one centre. One was possibly not far from the Sindree basin, whence lines of weakness diverged. Along these, owing to the thickness of the strata, there was no extrusion at the surface, and laccolite-domes were formed. Where the rock reached higher levels, it spread out into sheets between the domes and aided in the production of synclinals. Another centre was west of Bhuj, where the rock reached the surface without materially disturbing the sedimentary rocks, and formed the so-called

'stratified traps.' There were also areas here, especially to the south, where escape was impossible and domes were formed.

The Author observes that his conclusions, if correct, may be applied to explain the source of the Deccan trap without eruptive centres. It may have been forced out from innumerable orifices as from a sieve, none of these being so much larger than others as to make a definite centre.

Discussion.

Mr. W. W. Watts congratulated the Author on abolishing the mushroom-stalk-like dyke which disfigured most diagrams of laccolites, but failed to understand that the diagrams exhibited by Prof. Blake showed the typical structure of these igneous masses. Indeed, the whole of the sedimentary rocks of this region were represented as floating on a mass of igneous rock. He pointed out that in the Shelve and Corndon area the igneous rock occupied several positions—anticlinal spaces, arch-limb spaces, fault-planes, and twist-lines. The physical structure of the region, however, was just like that of areas from which igneous rocks were absent, making it clear that the structure was the result of lateral pressure, but that an igneous magma was at hand which welled up into all the regions of lower pressure. It was interesting to note that the rock-types of the laccolites described by the Author corresponded with those described in British masses, and not with those whose petrography had been the subject of the recent memoir by Whitman Cross, published in the 14th Annual Report of the United States Geological Survey.

Mr. Rutley said that he felt the limited time allotted to the reading of the paper had prevented the Author from doing justice to his work. After emphasizing the relation of the terms 'pegmatitic' and 'micropegmatitic,' he suggested that it would be well to supplant the latter by 'micrographic,' as employed by Harker, restricting the term 'graphic structure' to the well-known coarse intergrowths of quartz and felspar which are at times associated with pegmatite proper or 'Riesengranit.'

The President and Gen. McMahon also spoke.

The Author replied that the points raised by those who had discussed his brief résumé would all be found dealt with in the paper itself.

3. *An* Explanation *of the* Claxheugh Section (Co. Durham). By D. Woolacott, Esq., M.Sc. (Communicated by Prof. G. A. Lebour, M.A., F.G.S. Read June 23rd, 1897.)

[Abstract.]

The section of which an explanation is offered in this communication occurs about 2 miles west of Sunderland, and has been noticed by Messrs. King & Howse, and Prof. Lebour. The base shows the Permian Yellow Sands, which are succeeded at the western end of the section by the Marl Slate, thin-bedded limestones, and at the top crystalline limestones without any trace of bedding. At the eastern end the Marl Slate and thin-bedded limestones are absent, and except when a breccia intervenes the crystalline limestones rest on the Yellow Sands, though the thin-bedded limestones and Marl Slate show no signs of thinning out. There are also minor complications. The Author suggests that the section may be explained by supposing that denudation occurred in a cavern, the roof of which afterwards fell in, and that disturbances were also produced by 'creep'-movements.

4. A CONTRIBUTION *to the* PALÆONTOLOGY *of the* DECAPOD CRUSTACEA *of* ENGLAND. By the late JAMES CARTER, F.R.C.S., F.G.S. (Communicated by Prof. T. McKENNY HUGHES, M.A., F.R.S. Read November 3rd, 1897)

[PLATES I & II.]

CONTENTS.

INTRODUCTORY NOTE.

[THE following memoir deals mainly with the Brachyura. It contains descriptions of several new forms, and gives much fresh information with regard to the morphology, affinities, and distribution of species previously described. The author bequeathed his collection of Crustacea, together with his scientific library, to the Woodwardian Museum, where both are now accessible to palæontologists. This work has been edited by Mr. Henry Woods, M.A., F.G.S., at the request of the author's daughter, Mrs. J. E. Foster.—T. McK. H.]

I. Macrura.

Family Astacomorpha.

Genus Nephrops, Leach.

Nephrops Reedi, sp. nov. (Pl. I, fig. 1.)

Description.—Chelæ elongate; basal portion of propodite—'hand'—more than twice as long as wide; a double row of large bluntly-conical tubercles, the apices of which are directed forward, runs along both the outer and inner borders as far as the base of the fingers. On the dorsal surface a series of 10 to 12 tubercles, larger than those on the border, and placed upon a broad ridge, extends from the carpal end to the base of the fixed finger; the spaces between the median and the marginal rows are slightly concave and nearly smooth. The palmar surface also bears a median series of large tubercles of unequal size, which are arranged on the proximal two-thirds of the hand in two rows, which coalesce and terminate as a single row at the base of the fixed finger. Fingers imperfect, rather slender, half (?) as long as the hand when perfect. Length of hand from carpal to dactylopodal articulation = $2\frac{1}{2}$ inches.

Affinities.—This species differs from its existing representative, *N. norvegicus*, by its larger size, by the form and magnitude of the tubercles, and by the arrangement of the median rows on the dorsal and palmar surfaces; in the living form these are placed approximately opposite each other and about equidistant from the inner and outer borders; in the fossil the palmar is much nearer the inner, and the dorsal nearer the outer border of the hand.

Remarks.—The only portions of this species which have been hitherto determined are the chelæ of the first pair of limbs, but the characters which these members afford are so distinctive as to warrant a positive generic reference.

It is of phylogenetic interest to recognize in this Eocene form the vigorous prototype of one of the most graceful of existing British species, *N. norvegicus*, and it is of biological importance as affording partial evidence of the kind and degree of modification of character which has taken place.

I am indebted to the authorities of the York Museum for kind permission to describe this addition to the list of British fossil Crustacea, and I have great pleasure in dedicating this species to the late William Reed, F.G.S., to whose profuse liberality that museum owes one of the most valuable of the many provincial collections in this country.

Distribution.—Crag of Boyton—derived from the London Clay. Four specimens exist in the York Museum.

Genus Gebia, Leach.

Gebia clypeatus, sp. nov. (Pl. I, fig. 2.)

Description.—Carapace rather compressed laterally; length—exclusive of rostrum—nearly twice the metabranchial height. Rostrum produced, broadly lanceolate, deeply grooved dorsally; the distinct carinæ, which border the rostrum on each side, extend backward and outward, and bound a space which anteriorly and laterally encloses the mid-gastric lobes; a central ridge runs along the dorsal groove of the rostrum and the mesogastric lobe, and bifurcates midway towards the cervical sulcus. Between the mid-gastric lobes and the antero-lateral margin occurs another indistinct ridge, which terminates as a slight blunt process on the frontal border. A narrow, sinuous, cervical sulcus crosses the dorsum about midway between the frontal and the posterior border, and extends obliquely forward to the antero-lateral border. On the scapular region a median ridge commences at the cervical sulcus, becomes gradually wider and more elevated, and ends as a distinct, blunt process near the posterior border of the carapace. Branchial lobes indistinctly defined; surface minutely punctate. A rather wide, shallow sulcus apparently indicates the separation of the metabranchial from the anterior branchial lobes. An elevated ridge subtends the posterior and lateral margin of the carapace.

Abdomen seven-jointed, as long as the carapace; segments of nearly equal length, slightly increasing in width from the first to the fifth; mesotergal portion of each segment large, slightly punctated, and sparsely granulated near the epimera. Epimera broadly rounded, slightly granulated, marked off from the mesotergal portion by a ridge. Caudal appendages largely developed. Telson with distinct lateral ridges, and gradually widening towards the posterior border, which is slightly rounded. Endopodite and exopodite respectively equal to the telson in width; strongly ridged centrally.

First pair of limbs monodactylous; the meropodite has a row of acute tubercles on the outer border; carpopodite subterete, nearly half as long as the propodite. Propodite rather more than half the length of the carapace; surface granulated. Fixed finger rudimentary. Dactylopodite slender, half as long as the propodite, its inner border trenchant.

Specimens vary in length from 13 to 20 mm.

Remarks.—The long slender abdomen, the largely-developed caudal appendages, and the conformation of the chelæ are so similar to those of *Gebia* that I provisionally refer this species to that genus.

Specimens of this species usually occur in the form of casts, the most characteristic feature of which is the sharply-defined shield-shaped dorsal lobe occupying the mid-gastric region; this character has suggested the specific name. Examples in which portions of the test are preserved show that the surface of the cephalic region is granulated, and that the elevations which occur as sharp carinæ in the cast are indicated by corresponding, but broader, ridges bearing granules of a larger size than those on the rest of the carapace. Eleven specimens have been examined.

Distribution.—Great Oolite of Northampton; in the Woodwardian Museum, the collection of Mr. T. J. George, of Northampton, and in my own cabinet.

II. Brachyura.

Family Dromiacea.

Genus Gastrosacus, H. v. Meyer.

Gastrosacus Wetzleri, H. v. Meyer, 1854. (Pl. I, fig. 3.)

1854. *Gastrosacus Wetzleri*, H. v. Meyer, 'Jurass. u. Trias. Crust.,' Palæontographica, vol. iv, p. 51 & pl. x, figs. 3 & 4.
1858. *Prosopon aculeatum*, Quenstedt, 'Der Jura,' p. 779 & pl. xcv, figs. 46 & 47.
1860. *Gastrosacus Wetzleri*, H. v. Meyer, 'Die Prosoponiden,' Palæontographica, vol. vii, p. 219 & pl. xxiii, fig. 34.
1867. *Prosopon aculeatum*, Quenstedt, 'Handb. d. Petrefaktenkunde,' p. 315 & pl. xxvi, fig. 14.

Description.—Length, from base to rostrum, one-sixth greater than the width. Surface minutely granulated. The rostrum occupies the median third of the orbito-frontal border; it is acutely pointed, and about one-fourth the length of the carapace; it bears a sharp granulated dorsal carina. Orbits rather small, with thin margins. Cephalic area somewhat smaller than the scapular. Surrounding the gastric lobes is an unusual annular sulcus, bearing granules which tend to assume a radiate or linear arrangement; an indistinct radiate depression divides this area into four portions:—the normal branchial lobes separated by slight sulci; the linear urogastric lobe; and the pentagonal cardiac lobe.

Length of carapace from base of rostrum = 11 mm.

Affinities.—The form of the carapace, the conformation of the rostrum, and the annular sulcus surrounding the median gastric lobes distinguish this species.

Distribution.—A single imperfect—but certainly recognizable—specimen in the Woodwardian Museum, from the Coral Rag of Upware, is the only evidence I have of the occurrence of this species in England. It is found abundantly in the Upper White Jura of Germany, where, as in England, it is associated with *Prosopon marginatum*. In the specimen figured by Meyer (pl. x, fig. 4), the rostrum is imperfect, and is wrongly represented as being short and trifid.

Genus Dromilites, Milne-Edwards.

Dromilites Bucklandi, Milne-Edwards.

1858. Bell, Monogr. pt. i, p. 31 & pl. vi, figs. 1–11.

Supplementary.[1]—Bell has described this well-marked species in detail. I have not been able completely to determine the characters of the orbito-frontal border. Bell states that the rostrum is pointed, but in the cast of the interior it is widely bifid.

To this species it is exceptionally difficult to assign definite characters which will apply to all stages of growth, so considerably do they vary according to age. Bell's description applies accurately to the earlier stages. *Dr. Bucklandi* may usually be recognized at

[1] The remarks made under this heading throughout are intended to supplement the descriptions given by Bell in his Monograph on the Malacostracous Crustacea (Palæont. Soc.).

first sight by the series of four bosses upon the mesogastric and metabranchial lobes, arranged in a semicircle in front of the cardiac lobe.

Distribution.—Examples from the Red Crag (derivative) of Sutton and Waldringfield are in the British Museum, the Museum of Practical Geology, the Woodwardian Museum, and the Ipswich Museum.

Dromilites Lamarckii (Desmarest).

1858. Bell, Monogr. pt. i, p. 29 & pl. v, figs. 1–9.

Supplementary.—The interorbital portion of the frontal border is very prominent, triangular, and deeply grooved dorsally. Basal joint of inner antennæ robust. Epistome equilaterally triangular. Sternal plastron narrow, longitudinally hollowed. Episternum acutely pointed, half the length of the sternal plastron. Meropodite of the chelæ dentate on both borders.

In the preface to Part II of his 'Monograph,' Bell suggests that *Dromilites* may be the Tertiary representative of the Greensand genus *Homolopsis.* Certainly aged individuals of *Dr. Lamarckii* so closely resemble specimens of *Homolopsis Edwardsii* as to confirm this view. The variation of character according to age and stage of growth, to which Bell alludes in his description of *Dr. Bucklandi*, is equally remarkable as regards *Dr. Lamarckii.*

Distribution.—Specimens from the Red Crag of Sutton and Waldringfield are in the Woodwardian and the Ipswich Museums.

Genus Diaulax, Bell.

Supplementary.—The two transverse sulci upon the dorsum of the carapace, which suggested to Prof. Bell the name of this genus, constitute a character which is not peculiar to it, but exists, more or less distinctly marked, as a normal feature in other genera. The anterior represents the cervical sulcus, and the posterior that which separates the meso- and metabranchial lobes. This latter sulcus is interrupted by the intervention of the cardiac lobe, as is accurately represented in Bell's figure (pl. i, fig. 14). Bell mentions that it is almost obsolete in many specimens of *D. Carteriana.*

Diaulax Carteriana, Bell.

1863. Bell, Monogr. pt. ii, p. 6 & pl. i, figs. 14–16.

Supplementary.—Carapace approximately hexagonal in outline; nearly half as high as wide; considerably convex longitudinally in the young, less so in the adult stage. Orbito-frontal border as wide as the carapace is long. Rostrum slightly produced, pointed, broadly triangular, with a median longitudinal depression. Orbits obliquely oval, occupying the outer fourth of the orbito-frontal border; a shallow notch in both the upper and lower margins. Ophthalmic peduncle constricted and granulated. Antero-lateral margin trenchant, meeting the thickened oblique postero-lateral at a considerable angle. Posterior margin not so wide as the orbito-frontal. Epibranchial lobe tectiform, its outer portion forming the lateral angle.

Pterygostomate region large, granulated. Buccal orifice slightly narrowed posteriorly. Sternum nearly twice as long as wide. Episternum acutely pointed. Chelæ equal, about one-eighth shorter than the carapace. Dorsum of the hand considerably convex, covered by small tubercles of various sizes, by the removal of which the surface may be rendered pitted or reticulate; palm flattened; fingers short, a third of the length of the hand; fixed finger reflexed; carpopodite with a few coarse tubercles. Meropodite large, upper face convex; lower face flattened; posterior border with a few tubercles. Width of carapace = 15 to 24 mm.

Remarks.—Dr. Woodward regards the Gault form as a distinct species, and has named it *D. feliceps.* It is of smaller size than *D. Carteriana*, but I do not recognize any characters by which it can be distinguished.

Distribution.—Rare in the Gault of Folkestone. In the Cambridge Greensand it is less rare than was supposed by Bell. I have upwards of thirty specimens of the carapace in my collection, and others are in the British Museum, the Museum of Practical Geology, and the museums of York and Folkestone.

DIAULAX OWENI (Bell).

1850. *Platypodia Oweni*, Bell, in Dixon, 'Geol. Sussex,' p. 345 & pl. xxxviii,* fig. 9.

Supplementary.—Bell figured a carapace, from the Chalk, which he regarded as that of a species of *Platypodia*, but he did not describe it; and, so far as I can ascertain, no description of the form has yet been published. Specimens, evidently of the same species, are in the British and Woodwardian Museums, but, unfortunately, they are not sufficiently well preserved to admit of specific description. They are clearly referable to the genus *Diaulax*, and closely resemble and may even be identical with *D. Carteriana*, but the carapace is of considerably larger size than in the last-mentioned species.

Distribution.—Lower Chalk of Maidstone (Woodwardian Museum). Chalk of Dover (British Museum).

DIAULAX, sp.

A single specimen of a carapace of a small species of *Diaulax* is too imperfect for specific description. It is of interest as showing the existence of the genus in the Tertiary period. Size of carapace: width = 14 mm.; length = 10 mm.

Distribution.—Middle Headon of Whitecliff Bay (Woodwardian Museum).

Genus CYPHONOTUS, Bell.

CYPHONOTUS INCERTUS, Bell.

1863. Bell, Monogr. pt. ii, p. 8 & pl. i, figs. 17–19.

Supplementary.—The epigastric and mesogastric are the only cephalic lobes which are separately definable. The scapular lobes are more readily distinguishable. The transverse sulcus between the urogastric and cardiac lobes is usually sharply marked. The granulation of the surface of the carapace is remarkable; the summit of each granule is excavated and holds a minute central papilla. The pterygostome is regularly and minutely granulated. The epistome is slender, minutely granular, and has a median condyloid tubercle on the anterior border which meets the apex of the depressed rostrum.

Remarks.—The carapace is the only portion known to me. I have examined twelve or fourteen specimens, of which two are in the British Museum, and six in my own collection. A single carapace from the Chloritic Marl of Chard is in the Woodwardian Museum.

A Tertiary species, described by Bittner, as *Dromia Hilarionis*,[1] bears considerable resemblance to *Cyphonotus incertus*; both forms appear to be distinctly referable to the same genus.

Genus Plagiophthalmus, Bell.

Plagiophthalmus oviformis, Bell.

1863. Bell, Monogr. pt. ii, p. 9 & pl. ii, figs. 1–3.
1875. *Prosopon oviformis*, Tribolet, Bull. Soc. géol. France, ser. 3, vol. iii, p. 457.

Supplementary.—The details, both generic and specific, which Bell has given as to the characters and conformation of the orbits are probably inaccurate. I apprehend that this pretty little crustacean was far more comely of feature than Prof. Bell recognized. Careful examination of the specimens in the British Museum (Cunnington Collection), which the distinguished author figured and described, leads me to regard the small irregular depressions 'in the substance of the carapace,' observable in one only of the specimens, as really not the orbits but as accidental fractures. Large oval depressions occupying the outer thirds of the orbito-frontal border, as the artist has faintly but accurately represented in Bell's fig. 2 (pl. ii), are traceable in most of the specimens, and probably indicate the true orbits. If this determination should be confirmed by the discovery of better-preserved examples, the generic name, as indicating squint, or oblique vision, would be literally inapplicable.

Bell's figures (pl. ii) are enlarged to $1\frac{1}{2}$ natural size.

Tribolet refers this species to the genus *Prosopon*, but probably a reference to the subgenus *Pithonoton* would be more accurate.

Distribution.—Upper Greensand, Warminster.

Genus Homolopsis, Bell.

Homolopsis Edwardsii, Bell. (Pl. I, fig. 4.)

1863. Bell, Monogr. pt. ii, p. 23 & pl. v, figs. 1 & 2.

Supplementary.—Carapace slightly convex dorsally; quadrate in general outline and also in transverse section. The height of the carapace is equal to half its width. The granules upon the surface are irregular both in size and disposition. Rostrum broadly prominent. Orbito-frontal region half as wide as the carapace. Epi-

[1] Denkschr. k. Akad. Wissensch. Wien, vol. xlvi (1883) p. 306 & pl. i, fig. 5.

branchial process remarkably prominent; postero-lateral margin thick. Most of the areolar tubercles become more or less obliterated in aged individuals. The normal regions are distinctly defined in young specimens, but become gradually confluent as growth advances. Epistome equilaterally triangular, granulated, larger than the endostome. Female abdomen broadly lanceolate; all the segments distinct; surface minutely punctate; chelæ rather small; propodite as long as the orbito-frontal margin is wide; meropodite as long as the carapace, slightly granulated and sulcated longitudinally; carpodite cuboid; hand about twice as long as wide, oval in transverse section; fingers slender, as long as (or longer than) the hand. All the ambulatory limbs are well-developed; the meropodite is as long as the carapace, angular, granulated, and spinulose on both borders. Length of carapace = 8 to 25 mm.; average adult size = 20 mm.

Remarks.—Several obvious mistakes occur in Bell's description of this species. It is one of the most variable of brachyurous forms. Specimens differ considerably according to age, rendering specific description exceptionally difficult; the Gault examples at first sight appear to differ much in general aspect—particularly old individuals—from the Cambridge Greensand form; the difference, however, arises almost entirely from the degree to which the system of areolar tubercles on the cephalic area and the processes upon the lateral margin are developed. The carapace of a specimen in the British Museum, from the Gault, near Aylesford (no. 51210), is nearly even—the areolar tubercles and the prominences characteristic of the species being so indistinctly expressed as to suggest that it may be a distinct form. It would be of interest to examine other examples from this locality.

As usually found most specimens have a fracture on one or both sides, extending from the orbit towards the posterior border, probably the result of pressure upon the highly-vaulted carapace; not unfrequently the lateral portions are completely broken away, and the central portion only, showing the median lobes, is preserved. Bell has alluded to the close resemblance of this species to *Dromilites Lamarckii*, from the London Clay, which is very marked in old individuals.

Distribution.—Gault and Cambridge Greensand. Specimens are in the British Museum, Museum of Practical Geology, Woodwardian Museum, and my own collection.

Homolopsis depressa, sp. nov. (Pl. I, fig. 5.)

Description.—Carapace approximately hexagonal in outline, flattened dorsally. Rostral portion of the orbito-frontal border prominent. An undulating cervical sulcus crosses the carapace about midway between the anterior and posterior borders. Most of the normal cephalic regions are indistinctly defined; those of the scapular area are more distinctly marked. The dorsal surface is minutely granulated throughout, but the areolar tubercles are obsolete, except two of small size, with granulated summits on the metagastric lobes. The orbits are large, shallow depressions, with sharp irregular margins, opening forward and outward, and occupying the outer thirds of the orbito-frontal border. Most of the other characters correspond with those of *H. Edwardsii.* Length of carapace = 10 to 16 mm.

Affinities.—This species is readily distinguished from *H. Edwardsii* by the smaller size and more compressed form of the carapace, the absence of areolar tubercles, the much smaller branchial lateral process, and by the situation and direction of the cervical sulcus.

Distribution.—Cambridge Greensand and Gault of Folkestone. I have three specimens in my collection from the Cambridge Greensand, and one from the Gault of Folkestone; the latter agrees precisely with a specimen in the British Museum labelled 'Sheppey' (Gardner Coll. No. 59811).

Genus Goniochele, Bell.

Goniochele angulata, Bell. (Pl. I, fig. 6.)

1858. Bell, Monogr. pt. i, p. 26 & pl. iv, figs. 3–9.

Supplementary.—A nearly straight row of five areolar tubercles crosses the cephalic region opposite the second antero-lateral marginal process. In many specimens the longitudinal striation of the urogastric lobe is not observable. Penultimate segment of the female abdomen twice longer than any of the anterior segments, resembling in this character the abdomen of *Xanthopsis* and some other genera. Sternal plastron broadly ovate, two-fifths the width of the carapace. Episternum considerably longer than wide, much produced, pointed, minutely granulated.

Distribution. — Specimens from the London Clay are in the Woodwardian Museum, the Museum of Practical Geology, the Ipswich and Warwick Museums, etc. Specimens from the Red Crag (derivative) are in the Woodwardian and Ipswich Museums.

Family Raninoidea.

Genus Ranina, Lamarck.

The characters of the genus *Ranina*, established by Lamarck in 1801, are well marked and recognizable. The general form of the carapace is indicated by the figure here given (Pl. I, fig. 7). The orbito-frontal border is remarkably wide; the dorsal surface in most of the species is singularly sculptured by numerous transverse, minutely serrated markings, or is finely stippled. The sternum is peculiar in conformation; the episternum is widely trifid, and the posterior portion is narrow—almost linear.

The genus is represented by living species and by 18 or 20 extinct forms from the foreign Tertiary and Cretaceous beds, but I am not aware that the occurrence of any representative of it in the British rocks has been recorded hitherto. A valuable history of the genus and full notice of the fossil species is published by Reuss.[1]

[1] 'Zur Kenntniss foss. Krabben,' Denkschr. k. Akad. Wissensch. Wien, vol. xvii (1859) p. 19.

Ranina, as defined by Lamarck, has been divided by Brocchi into the subgenera *Ranina* proper, *Raninella*, and *Palæonotopus*.

RANINA (RANINELLA ?) ATAVA, sp. nov. (Pl. I, fig. 7.)

Description.—Carapace about a fourth longer than wide, moderately convex transversely; in outline elongate-ovoid. Width of orbito-frontal border equal to half that of the carapace. Buccal orifice large, two-fifths of the carapace in length. External maxillipeds correspondingly elongated, supported upon large basal segments. Anterior portion of sternum widely trifid, largely excavated laterally for the insertion of the chelæ; posterior portion rapidly reduced in width so as to become linear. Length of carapace = nearly 50 mm.; width = 38 mm.

Distribution.—The only specimens known to me are:—One in the Brighton Museum (G, 2329 Willett Coll.), from the Upper Greensand of Chute Farm, Wiltshire; and another in the British Museum (No. 59527, Cunnington Coll.), also from the Upper Greensand of Wiltshire.

Family Oxystomata.

Genus PALÆOCORYSTES, Bell.

PALÆOCORYSTES NORMANI, Bell.

1863. Bell, Monogr. pt. ii, p. 16 & pl. iii, figs. 10–12.

This form appears to have very slender claim to specific distinction; it occurs only in the Chalk, and can scarcely be regarded as other than a robust, vigorously-grown, variety of *P. Stokesi*. Nearly all the Crustacea which are common to the Chalk and Upper Greensand attain fuller development in the former than in the latter rock. The type is in the Woodwardian Museum (Leckenby Coll.); four other specimens from the Grey Chalk of Dover are in the British Museum.

PALÆOCORYSTES STOKESII (Mantell). (Pl. I, fig. 8.)

1863. Bell, Monogr. pt. ii, p. 15 & pl. iii, figs. 1–9.

Supplementary.—The small lateral teeth upon the rostrum, to which Bell refers, are seldom observable. The gastric lobes are indistinctly defined. The base of the mesogastric lobe in Gault examples bears a single areolar tubercle, but the Greensand form bears three or four. The posterior border is slightly narrower than the orbito-frontal. The orbits have a single fissure in the lower border and two in the upper. The sides of the buccal opening are curved. The episternum is unusually small, and pentagonal in shape. A solitary specimen, in the Woodwardian Museum, of a detached propodite which may almost certainly be referred to this species suggests the probability that in the fossil form—as in its living representative *Corystes Cassivelanus*—the first pair of limbs was much longer in the male than in the female. I have not, however, met with a male carapace having the chelæ intact.

In Gault specimens the marginal processes and the areolar tubercles are more or less pointed, but in Greensand examples they are obtuse. Specimens having the branchial region on one or both sides rendered tumid by parasitic infestation are of frequent occurrence.

Additional Localities.—Lower Chalk, Dover (British Museum, No. I, 2011). Gault of Puttenham (Woodwardian Museum). Upper Greensand of Lyme Regis.

Genus Eucorystes, Bell.

Eucorystes Broderipii (Mantell).

1863. *Palæocorystes Broderipii*, Bell, Monogr. pt. ii, p. 14 & pl. ii, figs. 8–13.

Supplementary. — The armature of the antero-lateral border varies considerably in degree of development, the processes being prolonged in some specimens into acute spines. The chelæ resemble those of *E. Carteri*, but are larger and the fingers are relatively longer. The hand is about as wide as long; the dorsum smooth; both borders have a few teeth; the outer border of the dactylopodite is flat and has marginal ridges, that on the palmar edge being toothed. Carpopodite tuberculate or spinulose. Bell has described the ambulatory legs as 'nearly cylindrical'; but specimens in my own and other collections show them to be of large size and much compressed, both borders being sharply spinulose.

Length of carapace = 19 to 38 mm.

Remarks.—The characters which Bell assigned to his genus *Eucorystes* apply so precisely to *E. Broderipii* that I do not hesitate, notwithstanding the remarks of that experienced author, to transfer this species from the genus *Palæocorystes* to *Eucorystes*. The specific alliance between *E. Carteri* and *E. Broderipii* is very close. The feature which especially distinguishes them is the series of singular ligulate markings which occur on the cephalic area of *E. Carteri*, but are entirely absent in *E. Broderipii*. The orbito-frontal border is relatively narrower, but in other characters the two species correspond so precisely as even to suggest the probability that they may be local varieties of the same form, characterized by the difference of surface-features.

Distribution.—*E. Broderipii* is peculiar to the Gault. Specimens are in the British Museum, the Museum of Practical Geology, the Woodwardian and York Museums, and my own collection.

Eucorystes Carteri (M'Coy).

1863. Bell, Monogr. pt. ii, p. 17, pl. ii, figs. 14–17 & pl. xi, fig. 16.

Supplementary.—Rostrum bifid or rendered trifid by a prolongation of the slender process of the mesogastric lobe. Orbito-frontal border equal to two-thirds the length of the carapace. In many specimens the cervical sulcus is interrupted in the middle—the lateral portions terminating at minute puncta between the meso- and urogastric lobes. Mesogastric lobe divided posteriorly into two lobules. Buccal opening rather narrow in front; sides slightly curved. External maxillipeds slender; exopodite and endopodite nearly equal in width; meros of the endopodite elongated, two-thirds as long as the ischios. Chelæ of moderate size; meros sub-terete, granulate, dentate on both borders; carpus cuboid; hand compressed, rather longer than wide, both borders somewhat trenchant and serrated by several teeth. The chelæ correspond closely with those of *E. Broderipii*. Abdomen seven-jointed; penultimate segment twice as long as the fifth. Telson rounded at its extremity, rather longer than wide. Length of carapace = 15 to 35 mm.; length of average adult = 25 mm.

Remarks.—I have examined upwards of 200 specimens of this species, all of which were obtained from the Cambridge Greensand. I am not aware that it has been found elsewhere.

M'Coy regarded the peculiar series of strap-shaped markings on the surface of the carapace as representing the normal dorsal lobes; but Bell does not assent to this opinion. I would suggest it as probable that they are modifications produced by the confluence or expansion of prominences which occur in the form of areolar tubercles in *Necrocarcinus*, *Campylostoma*, and other genera. This interpretation of their morphological significance is suggested by a specimen in my own collection figured by Bell (pl. xi, fig. 16) which has three elevated lobes on the scapular region, similar to those on the cephalic area: in this respect corresponding precisely with the position normally occupied by areolar tubercles in other genera.

Distribution.—Cambridge Greensand. Specimens are in the British Museum, the Museum of Practical Geology, the Woodwardian, York, Glasgow, Northampton, Nottingham, and other Museums.

Genus Cyclocorystes, Bell.

Cyclocorystes pulchellus, Bell.

1858. Bell, Monogr. pt. i, p. 24 & pl. iv, figs. 1 & 2.

1863–64. *Necrozius Bowerbankii*, Milne-Edwards, Ann. Sci. Nat. ser. 4, vol. xx (1863) pl. xii, fig. 2; ser. 5, vol. i (1864) p. 58.

1867. *Necrozius Bowerbankii*, Milne-Edwards, Geol. Mag. p. 531 & pl. xxi, figs. 2 & 3.

Supplementary.—Carapace rotundo-quadrate in outline, deflexed in front, rather wider than long. Orbito-frontal border equal to three-fifths of the width of the carapace, nearly straight. Granules on the dorsal surface uniform in size and regular in disposition; inter-spaces very minutely punctated (seen with a lens). Most of the normal cephalic and scapular lobes distinct, separated by unusually wide smooth sulci; central portion of each lobe granulated, basal portion smooth. Orbits rather small, with granulated edges; two distinct fissures in the upper and one in the lower border. Antero-lateral border with two or three slightly-produced processes, which have granulated summits and are surrounded at the base by a smooth space. Posterior border delicately and regularly granulated. Abdomen, in the male, seven-jointed, rapidly tapering to a small triangular telson. Chelæ strong, very unequal in size; meropodite robust, expanding rapidly towards the distal end, which is nearly as wide as the joint is long, is circumscribed by a distinct sulcus, and has the upper border prolonged into a stout spine; hand as long as the carapace is wide, and a third longer than wide, oval in section; dorsum smooth. Fingers nearly as long as the hand, prehensile borders with several blunt teeth. Posterior pairs of limbs slender, and nearly equal in size. Bell and Milne-Edwards describe the orbits as being without marginal fissures; but a specimen in the Woodwardian and another in the British Museum (No. 59218) show distinctly the characters which I have described; probably these notches become obliterated by age.

Remarks.—In 1865 Milne-Edwards figured and described a species from the London Clay of Sheppey, which he named *Necrozius Bowerbankii.* In 1867 Dr. Woodward discovered a specimen in the British Museum (No. 59400), from the London Clay of Holloway, which he recognized as the form described by Milne-Edwards; and he afterwards published an excellent description and an enlarged figure of it in the 'Geological Magazine,' with remarks on its generic alliance. Subsequent examination of this and other specimens, however, has convinced me that the species described by Milne-Edwards is identical with that previously determined by Bell and named *Cyclocorystes pulchellus.*

Distribution.—The specimen figured by Bell is in the British Museum (No. 59101), as also four others from the London Clay of Sheppey; also a carapace from 'Copenhagen House' which is 29 mm. wide. A nearly perfect example from the London Clay of Clacton is in the Woodwardian Museum. Specimens from the Crag (derived from the London Clay) are in the Woodwardian and Ipswich Museums.

Genus Necrocarcinus, Bell.

Necrocarcinus Bechei (Deslongchamps). (Pl. I, fig. 9.)

1863. Bell, Monogr. pt. ii, p. 20 & pl. iv, figs. 4–8.

Supplementary.—The armature of the antero-lateral border of the carapace is irregularly expressed; small tubercles not unfrequently occur on the postero-lateral border. The dorsum bears 16 or 18 areolar tubercles, those on the lateral gastric and the hepatic lobes forming an undulating row (in *N. Woodwardii* these tubercles are arranged in a straight line). The normal interruption of the cervical sulcus, and the minute puncta between the meso- and urogastric lobes, indicating the attachment of gastric muscles, are well marked in this species. Orbits approximate, oval, widely open inwardly, directed obliquely upward; two notches in the upper and one in the lower margin. Endopodite of external maxillipeds slightly wider than the exopodite. The abdomen, which is seldom preserved, is seven-jointed; in the first 5 segments the mesonotum is raised into a sharp transverse rib; the penultimate segment is twice as long as that preceding it. The abdomen of the female is half as wide again as that of the male. The chelæ are of moderate and equal size; meropodite compressed, dorsal surface convex and smooth; anterior border rounded, posterior thin; propodite about a fourth longer than wide, dorsum highly convex, with a median longitudinal row of three tubercles and others of smaller size near each of the borders; palmar surface flat; fingers shorter than the hand; outer border of dactylopodite flat, edged by a delicate, slightly dentate ridge on each side; the dentary border trenchant. Chelæ identical in form with those of *N. Woodwardii*, but scarcely one-third as large.

The claw which Bell has figured (pl. v, fig. 3) certainly cannot be referred to this species. Specimens having the branchial region rendered tumid by some Bopyriform parasite are of frequent occurrence.

Distribution.—Numerous examples from the Cambridge Greensand are in the Woodwardian, British, Jermyn Street, and York Museums, and in my own collection. It occurs sparingly in the Upper Greensand of Warminster, and specimens from the Gault of Puttenham are in the Woodwardian Museum.

NECROCARCINUS TRICARINATUS, Bell.

1863. Bell, Monogr. pt. ii, p. 21 & pl. iv, figs. 9–11.

Supplementary.—Carapace approximately hexagonal in outline, a fifth wider than long; surface minutely and uniformly granulated. Rostrum prominent, broadly triangular (with a small tooth at the base on each side?). Orbito-frontal border slightly exceeding half the greatest width of the carapace. The antero-lateral border bears four or five rather large marginal tubercles, the last of which forms the prominent lateral angle. Postero-lateral border nearly straight. Posterior margin not quite so wide as the orbito-frontal. The areolar tubercles are somewhat smaller than in any of the other species; about fourteen occur on the dorsal surface, and a series of five or seven crosses the cephalic area transversely; those upon the mesogastric and the cardiac lobes form a median series, and a lateral row of three occurs upon the branchials. The longitudinal carina, which gives the specific name, is indistinctly marked in many specimens. Orbits large, with two notches in the upper and a large one in the lower margin. First pair of limbs:—meropodite triangular in section, with acute spines on the posterior angle; carpopodite about as long as wide, tuberculated; hand two-thirds of the width of the carapace in length; a double row of spines runs along the border and terminates at the base of the fixed finger, and a single row occurs on the dorsal surface; fingers slender, half as long as the hand. Length of carapace = 15 to 25 mm.

Distribution.—Cambridge Greensand and Gault of Folkestone. About thirty specimens examined. Gault examples are in the British, Jermyn Street, and Woodwardian Museums.

Necrocarcinus Woodwardii, Bell. (Pl. II, fig. 1.)

1863. Bell, Monogr. pt. ii, p. 20 & pl. iv, figs. 1–3.

Supplementary.—The small lateral teeth at the base of the rostrum, mentioned by Bell, are not usually observable. The antero-lateral border bears four or five small tubercles. The meso-gastric lobe, in Gault specimens from Folkestone, bears a single areolar tubercle, whereas, in Cambridge specimens, three or five tubercles occur on this lobe.

I have not met with examples of this species in which the chelæ are retained *in situ*; but detached propodites of large size, which I do not hesitate to regard as those of large specimens of *N. Woodwardii*, are frequently found in the Cambridge Greensand. Except that they are twice or thrice larger, they precisely resemble the chelæ of *N. Bechei*; but I have no evidence that that species ever attains so large a size as its congener. The two forms, however, have in all other characters a close correspondence. In these large Cambridge specimens the hand is robust, slightly compressed, and rather longer than wide; the dorsal surface bears a median series of three equidistant tubercles, and a double row of smaller size on both borders, frequently with a few others between these lateral rows; the palmar surface is very slightly convex; the outer border of the dactylopodite is flattened, and is bounded by a slender, slightly denticulated ridge; the dentary border is trenchant.

The chela which Bell figured (pl. v, fig. 4) as that of *N. Woodwardii* certainly does not belong to that species, nor, I apprehend, do the other portions figured in the same plate (figs. 5, 6 & 7). The chela is probably that of a new species.

This species may be distinguished from *N. Bechei* by having a large number of areolar tubercles—of which three or five are placed upon the mesogastric lobe—and by having those on the cephalic region placed in an almost straight transverse row, whereas in *N. Bechei* they assume an undulating arrangement. Specimens from the Chalk generally attain a considerably larger size than those from the Gault or Greensand: a specimen in the Woodwardian Museum from the Chalk Marl of Cherry Hinton is more than 60 mm. wide. Width of Gault specimens = 8 to 24 mm. Width of Greensand specimens = 25 to 50 mm.

Distribution.—Tolerably abundant in the Gault of Folkestone and in the Cambridge Greensand. Examples occur in the British and Jermyn Street, Woodwardian, Folkestone, York, and other Museums.

Genus Orithopsis, Carter.

Orithopsis Bonneyi, Carter.

1868. *Necrocarcinus tricarinatus*, H. Woodward, Geol. Mag. p. 259 & pl. xiv, fig. 4.
1872. *Orithopsis Bonneyi*, J. Carter, Geol. Mag. p. 529 & pl. xiii, fig. 1.

Description.—Carapace rather wider than long, considerably arched transversely, less so longitudinally; dorsal surface minutely granulated, and still more minutely punctated. Orbito-frontal region rather less than half the greatest width of the carapace. Rostrum widely bifid, with elongated lateral spines. Orbits opening forward; upper border with two distinct lobes, which are separated from each other by a deep sinus and from the external orbital lobe by a sharp fissure; external angle of orbit much produced, extending nearly as far forward as the rostral spines. The antero-lateral border, in addition to the external orbital spine, bears four other well-developed acute processes. Postero-lateral margin nearly straight, inclining inward and rendering the posterior about equal to the orbito-frontal border. A distinct sinuous cervical sulcus marks off the anterior third of the dorsal area from the scapular portion. Gastric regions obscurely indicated. Branchial regions sharply defined; the epibranchial terminates about midway between the margin and the median dorsal ridge, and is separated from the mesobranchial lobe by an undulating sulcus; a similar and nearly parallel groove—the inner half of which is obliquely crossed by a series of interdigitations—divides the meso- from the metabranchial lobes. A granulated longitudinal ridge, slightly inflected in the middle, carinates each metabranchial lobe, and a median carina extends the whole length of the carapace. Of the faintly-marked areolar tubercles, two occur on the protogastric and three or four on the median ridge. Length of carapace = 31 mm.; width (not measuring marginal spines) = 44 mm.

Affinities.—In general form this species closely resembles *Necrocarcinus tricarinatus*, but it differs from all the species of *Necrocarcinus* in the structure of the rostrum and in the conformation of the orbital regions, as also by the greater development of the spines[1] of these antero-lateral margins.

The characters of the carapace indicate an affinity, as Dr. Woodward has remarked, rather with the Portunidæ than with the Corystidæ. The orbito-frontal characters are very similar to those of *Orithyia*; but the armature of the antero-lateral margin, especially the well-developed metabranchial spine, approximates to that in *Matuta*. The zoological position of *Orithopsis* appears to lie between these genera.

Distribution.—Upper Greensand, Lyme Regis, and (?) Isle of Wight; Gault of Folkestone. I have seen fifteen specimens, which are preserved in the British Museum, the Museum of Practical Geology, the Woodwardian Museum, and my own collection.

Genus Campylostoma, Bell.

CAMPYLOSTOMA MATUTIFORME, Bell.

1858. Bell, Monogr. pt. i, p. 23 & pl. iii, figs. 8–10.

Supplementary.—Granules occupy the sulci and obscure the outline of the normal lobes. Orbito-frontal margin nearly equal to half the width of the carapace. Orbits large, transversely oval, opening obliquely upward; the margin thin, divided into flattened

[1] These are more slender than represented by the figure in the Geol. Mag.

lobes by two notches in the upper and one in the lower portion. A specimen in my collection has an elongated ophthalmic peduncle divided by slender longitudinal ridges into three or four spaces, in one of which numerous minute corneal facets are distinctly visible. Pterygostomate regions steeply inclined and minutely granulated.

Bell's figure represents the marginal orbital lobes as pointed, but in a well-preserved specimen in my collection these processes exist as flattened, quadrate lobes, separated by distinct parallel-sided fissures.

Distribution.—London Clay. Specimens are in the Woodwardian and Malton Museums, and my own collection, etc. Derivative examples occasionally occur in the Crag.

Genus Mithracia, Bell.

Mithracia libinioides, Bell. (Pl. II, fig. 8.)

1858. Bell, Monogr. pt. i, p. 9 & pl. v, figs. 10–12.

Supplementary.—The inflated lobes which occupy the lateral portions of the scapular area represent the confluent meso- and metabranchials. Two slight eminences occur between the cardiac lobe and the posterior border of the carapace. The characters of the limbs have yet to be ascertained.

Affinities.—This species is readily distinguishable by the semiglobose form of the carapace, and by the sharp definition and inflation of the principal dorsal lobes. The surface-granules are unusually prominent.

Mithracia is probably represented in foreign Tertiaries by the genus *Micromaia*, Bittner. There is a general resemblance in the character of the carapace of these genera, but they differ in the conformation of the orbito-frontal region, the rostrum of *Micromaia* being prominent and widely bifid.

Distribution.—Of this rather rare species there are eight specimens in the British Museum and two in the Woodwardian Museum, all from the London Clay of Sheppey.

Mithracia oblita, sp. nov. (Pl. II, fig. 4.)

Description.—Carapace broadly ovoid in outline, rather longer than wide, highly vaulted transversely, strongly deflexed in front. Rostrum small, entire. Orbito-frontal border equal to two-thirds the length of the carapace. Posterior border slightly wider than the orbito-frontal. A sharp cervical sulcus indents the antero-lateral border, crosses the carapace, and marks off the cephalic region, which occupies scarcely the anterior third of the dorsal area, and is rendered nodular by the prominent gastric lobes. The two nodules near the base of the rostrum represent the epigastric lobes; a small tubercle intervenes between the epigastric and the orbit; three nodules occur upon the mesogastric, and one on each metagastric; the hepatic lobe is very small; the urogastric is unusually large; cardiac lobe pentagonal, and slightly elevated. A deep sulcus extends from the angles of the cardiac lobe and runs parallel with the cervical sulcus. Epibranchial lobe piriform; inner half of the mesobranchial bilobed; metabranchials large and confluent posteriorly. The whole of the dorsal surface of the carapace bears traces of depressed tubercles of moderate size. Orbits small, round, four diameters apart. Abdomen of the female seven-jointed (?); each segment trilobed, and the penultimate the largest; telson rather small. Limbs and other appendages undetermined. Length of carapace =16 mm. Width (metabranchial) =15 mm.

Affinities.—This species has a general resemblance to *M. libinioides* of the London Clay, of which it is probably an ancestral form. It is of smaller size, and may be further distinguished from that species by the more delicate granulation of the surface, and by the nodulated cephalic area; the hepatic and branchial lobes are less inflated, and the anterior branchial lobes relatively larger, consequently the space between the cervical and transverse branchial sulci is greater than in *M. libinioides*. The granulation of the dorsal surface being much less distinctly marked than in *M. libinioides* renders the carapace comparatively smooth.

Distribution.—Cambridge Greensand.

Genus Mithracites, Gould.

Mithracites vectensis, Gould.

1859. Gould, Quart. Journ. Geol. Soc. vol. xv, p. 237 & figs. 1–3.
1863. Bell, Monogr. pt. ii, p. 1 & pl. i, figs. 2 & 3.

Supplementary.—Orbits large, shallow, nearly round, twice their diameter apart, directed forward and slightly upward. The eyes are not lodged in the natural orbits, but rest in slight depressions behind them. Antero-lateral margin with three or four obtuse processes. Scapular area rather larger than the cephalic; the posterior border is slightly wider than the orbito-frontal. In the early stages of growth the whole of the dorsal surface of the carapace bears small granules, two or three diameters apart, which become obsolete with age, as also do the areolar tubercles. The disposition of the areolar tubercles is normal; the hepatic and protogastric, together with one on the prolonged tongue of the mesogastric, form a transverse row upon the cephalic area; the base of the mesogastric lobe has one or three tubercles which soon become obsolete; the anterior branchials bear one, and the metabranchials four; the summits of these tubercles, when well-preserved, are granular. The epigastric lobes are unusually large, and obliquely elongated.

The female abdomen is ovate, and the segments distinct; telson very small, triangular. Chelæ equal in size; meropodite with a stout spine at the distal end; length of propodite equal to half the width of the carapace; dorsum of hand finely granulated, strongly convex; palm flattened. Fingers rather shorter than the hand; on the sides of the dactylopodite are setigerous puncta, and the outer border is flat; a single tooth occurs on the dentary border. Length of carapace =10 to 36 mm.; length of average adult =18 mm.

Affinities.—The more ovate form of the carapace, the larger and more prominent rostral portion, the difference in the number and arrangement of the areolar tubercles on both the cephalic and the scapular regions, distinguish this species from *Homolopsis Edwardsii*, some of the several forms of which it approximately resembles. The slight depression, which apparently performed the functions of a false orbit, is a character which occurs in *Homolopsis* and also in the recent form *Homola*. Bell's reference to an alliance of the genus with *Mithrax*, as Dr. Woodward has remarked, is not very evident; probably *Mithracites* may be more correctly placed between *Hyas* and *Micippe*.

Distribution.—Lower Greensand. There are twenty specimens in the Woodwardian Museum, one of which is 38 mm. in diameter; others occur in the British Museum and in the Museum of Practical Geology—all coming from Atherfield, Isle of Wight.

Genus Trachynotus, Bell.

Trachynotus sulcatus, Bell.

1863. Bell, Monogr. pt. ii, p. 2 & pl. i, fig. 1.

Supplementary.—The only examples of this species known to me are those in the British Museum (Cunnington Coll.) described and figured at twice the natural size by Bell. The singular transverse sulcation of the scapular area is more strongly expressed in the figure than in the specimen, and the arrangement of the sulci is not quite accurately shown. The carapace bears a general resemblance to that of *Dromiopsis* from the Faxö Beds, and suggests a phylogenetic alliance with that genus.

Distribution.—Upper Greensand, Wiltshire.

Family Cyclometopa.

(i) Subfamily Portunidæ.

Genus Neptunus, de Haan, emend. Milne-Edwards.

Neptunus vectensis, sp. nov. (Pl. II, fig. 2.)

Description.—Carapace about a fourth wider than long, slightly convex transversely. Interorbital portion of the frontal margin straight, slightly prominent, quadridentate (sex-dentate, including the internal orbital processes). Orbits large, transversely oval. Dorsal surface slightly and sparsely granulated; the normal cephalic and scapular lobes indistinctly defined. Sternal plastron broadly obovate, half as wide as the carapace, minutely punctated; episternum bearing the large external maxillipeds—three-fourths the length of the sternal plastron, a fifth wider than long, slightly pointed and retroflexed. Male abdomen wide at the base, tapering rapidly to a small triangular telson; third, fourth, and fifth segments coalescent. Third joint of the endopodite of the external maxilliped thrice as long as wide; exopodite half the width of the endopodite. Limbs undetermined. Width of carapace = 2 inches.

Remarks.—The specimens which have afforded the foregoing scanty detail of character are of interest because they constitute, so far as I know, the only evidence obtained as to the occurrence of any representative of the genus *Neptunus* in British rocks. A considerable number of species—some twelve or fifteen—occur in foreign Tertiary beds and have been described by Milne-Edwards and by Stoliczka.

Affinities.—All the species are characterized by having a series of eight or ten pointed processes upon the antero-lateral margin, the last of which is prolonged into a long spine. The British examples, although not well-preserved, are clearly referable to the genus *Neptunus*. The characters of *N. vectensis*, so far as known, closely resemble those of *N. Larteti*, Milne-Edw.

Distribution.—Hamstead Beds (*Corbula*-bed), Hamstead, Isle of Wight. Two specimens are in the Woodwardian Museum.

Genus Portunites, Bell.

Portunites incerta, Bell.

1858. Bell, Monogr. pt. i, p. 21 & pl. iii, figs. 1–5.

Supplementary.—The dorsal surface of the carapace is smooth or minutely granulated. Areolar tubercles almost obsolete. I have not met with specimens showing the retroflexion of the last pair of legs or the form of their terminal joint. Average width of adult carapace = 20 to 40 mm.; average length = 16 to 26 mm.

In stating the dimensions Bell accidentally reversed the relative proportion of length to width.

Affinities.—The wide orbito-frontal border, the three equally prominent meso- and protogastric lobes, and the narrow, arcuate, transverse epibranchial lobe readily distinguish this species. It is well described by Milne-Edwards, who refers to the zoological alliance of the genus, and agrees with Bell in classifying it with the Portunidæ. Reuss described a species from the London Clay which he named *Leiochilus Morrisi*; subsequently he considered *Portunites incerta*, Bell, to be identical with this species, but his description and figure apply so much more closely to the form which he described in the same paper as *Pseuderiphia M'Coyi* (= *Xanthilites Bowerbankii*, Bell) than to *Portunites incerta* as to suggest the probability that *Leiochilus Morrisi* may be a variety of the former of these species.

Distribution.—London Clay. I have two specimens in my collection; another from the Red Crag (derivative) is in the Woodwardian Museum.

Genus Rhachiosoma, Woodward.

Rhachiosoma bispinosum, Woodward.

1871. Woodward, Quart. Journ. Geol. Soc. vol. xxvii, p. 91 & pl. iv, fig. 3.
1873. Woodward, *ibid.* vol. xxix, p. 26 & pl. i, figs. 1–6.

Description.—Carapace about one-fourth wider than long (excluding the lateral spines). Orbito-frontal border rather more than a third the width of the carapace; the interorbital portion quadridentate. Rostrum slightly bifid. Orbits nearly round, with two notches in the upper and one in the lower margin. Antero-lateral border with four pointed processes, the first three gradually increasing in size; the portion of the border between them flattened into a trenchant edge which is indented by a sharp cleft; the fourth, or epibranchial, process prolonged into a spine, the length of which, in some specimens, is equal to half the width of the carapace. Postero-lateral border thickened. Posterior border rather wider than the orbito-frontal; the postero-lateral angles slightly produced. Dorsal surface minutely granular in well-preserved specimens. An areolar tubercle occurs on each protogastric lobe, two (or three) on the mesogastric, one near the base of the long epibranchial spine, and an oblique longitudinal series of three on each metabranchial lobe. The cardiac lobe bears a single median tubercle. Two minute punctures marking the attachment of the posterior gastric muscles are noticeable behind the mesogastric lobe. The several normal dorsal regions are defined by shallow depressions.

Female abdomen seven-jointed. In the male the fifth and sixth segments are coalescent. Telson small. Sternum broadly ovate; endopodite of the external maxilliped twice as wide as exopodite, furrowed longitudinally.

Buccal opening large. Chelæ nearly equal in size; hand smooth, approximately twice as long as wide, ovate in section; palm less convex than the dorsum. Fingers slender, rather shorter than the hand; prehensile border serrated by eight to twelve teeth. All the posterior pairs of limbs are well-developed and nearly equal in size, the last pair being as large as, or rather larger than, the penultimate, as in most Portunidæ. Width of carapace (excluding the epibranchial spine) = from 25 to 50 mm.

Distribution.—I have examined upwards of twenty examples, all of which were obtained from the London Clay of Portsmouth. Specimens are in the British Museum, and a large series in the Woodwardian Museum; a single example, labelled '*Psammocarcinus*,' is in the Manchester Museum.

(ii) Subfamily Cancridæ.

Genus Actæopsis, Carter.

Actæopsis Wiltshirei, sp. nov. (Pl. II, fig. 3.)

Description.—Carapace approximately hexagonal in outline, slightly and equally convex, both transversely and longitudinally;

wider than long—in the proportion of 28 to 23 mm. Orbito-frontal border half the width of the carapace. Antero-lateral border moderately arcuate, trenchant, bearing four (or five?) pointed processes; two or three similar processes occur upon the postero-lateral border. Posterior border as wide as the orbito-frontal. Rostrum large, longitudinally sulcated. Orbits of moderate size, with two slight notches in the upper edge. A wide, unusually shallow, undulating cervical sulcus marks off the cephalic region, the area of which is rather larger than that of the scapular. Most of the gastric lobes exist as nodular prominences, which are separated by wide and smooth interspaces. The summit of each of these lobes bears numerous minute, sharply-defined granules. A slightly-curved row of seven granulated tubercles crosses the carapace opposite the first marginal process. The mesogastric, as usual, sends forward, to the base of the rostrum, a slender prolongation which separates the protogastric lobes. The several branchial lobes are indistinctly defined. Upon the metacardiac lobe are two large granulated prominences; and two or three of a similar size occur on the metabranchial.

The abdomen and limbs are not preserved.

Width of carapace = 28 mm.; length = 23 mm.

Affinities.—This is quite unlike any British fossil species with which I am acquainted. It somewhat resembles an imperfect specimen of *Xanthilites verrucosus*, Schafh., from the Bavarian Nummulitic beds figured and described by Milne-Edwards, but is, I think, distinct from that form. The characters of the carapace decidedly support an alliance with the recent genus *Actæa*. I dedicate this species to Prof. Wiltshire.

Distribution.—Lower Greensand of Atherfield.

Genus Etyus, Mantell.

Etyus Martini, Mantell.

1863. Bell, Monogr. pt. ii, p. 5 & pl. i, figs. 7–9 (not fig. 11).

Supplementary.—Orbito-frontal border about a third of the width of the carapace. Rostrum slightly produced. Antero-lateral margin tumid, with three or four small tubercles supported on a slight ridge. Posterior border rather wider than the orbito-frontal. An areolar tubercle occurs on each of the metagastric, hepatic (close to the antero-lateral border), and mesobranchial lobes. The sulcus between the epi- and mesobranchial lobes scarcely reaches the postero-lateral margin; mesogastric lobe distinctly defined. Pterygostomate region tumid, surface minutely granulated; on the inner portion of the inferior branchiostegite is an unusual oblique sulcation. Sternum rather narrow; episternum granulated, sharply retroflexed. Epistome granulated; endostome narrowing posteriorly and deeply emarginate. Exopodite of external maxilliped about half as wide as the endopodite, which is furrowed longitudinally and has the inner distal angle produced. Abdomen seven-jointed, the penultimate twice as long as the segment preceding it; each segment divided into a median and lateral portions by longitudinal grooves. Chelæ elongate; propodite about a third of the width of the carapace in length, oval in section. Fingers very slender, nearly as long as the hand; inner border with irregular acicular denticles. Width of carapace = 7 to 26 mm. Length of average adult = 20 mm.

Remarks.—In Cambridge Greensand specimens the tubercles on the dorsal surface of the carapace are much less acutely prominent than in those from the Gault—a condition which Bell attributes to attrition. The difference is certainly normal and not accidental; nor is it peculiar to this species; a similar modification of surface-character occurs in most of the forms which are common to the two deposits. The delicate chelæ are very seldom preserved *in situ* in Cambridge specimens, but they occasionally occur in those from the Gault. The detached hand (Bell, pl. i, fig. 11) which Bell supposed to be that of *Etyus Martini* belongs to *Diaulax Carteriana.* M'Coy's figure is inaccurate as regards the course of the scapular sulci, and also in representing the mesobranchial lobe as bearing two tubercles instead of one.

Distribution.—Abundant in the Cambridge Greensand. Specimens from the Gault of Puttenham are in the Woodwardian Museum.

Genus Xanthosia, Bell.

Xanthosia gibbosa, Bell.

1863. Bell, Monogr. pt. ii, p. 3 & pl. i, figs. 4–6.

Supplementary.—The resemblance of *X. gibbosa* with *X. granulosa*, to which Bell alludes in his description of the latter form, is so close that it may well be regarded as a variety of that species. Almost the only distinctive character refers to the processes of the antero-lateral margin, which in this species are more or less pointed, but in *X. granulosa* are quadrate. The marginal armature is, in all the Brachyura, an unstable character, by reason of the variation in form and in degree of development, according to the age of the individual. I have not been able to detect the punctation of the posterior portion of the carapace which Bell mentions as a character. Portions of the test preserved on the cephalic area of specimens which I have seen are distinctly, but minutely, granulated. The fissures in the borders of the orbit are very distinct.

I have met with no other specimens than those described by Bell, four in number, now in the British Museum (Cunnington Coll.). The carapace is the only portion that has been determined. The name *Xanthosia* has been applied by De Candolle to a genus of Umbelliferous plants.

Xanthosia granulosa (M'Coy). (Pl. II, fig. 5.)

1854. *Reussia granulosa*, F. M'Coy, 'Contrib. Palæont.' p. 272.
1863. *Xanthosia granulosa*, Bell, Monogr. pt. ii, p. 4 & pl. i, fig. 13.
1865. *Reussia granosa*, Milne-Edwards, 'Monogr. Crust. Foss. Fam. Cancériens,' Ann. Sci. Nat. ser. 4, vol. xviii, p. 78 & pl. v, fig. 2.

Description.—Carapace a third wider than long, depressed.

Rostrum broadly triangular, slightly prominent. Orbito-frontal border equal to half the width of the carapace. Antero-lateral border compressed to a thin marginal edge, which is divided into three or four quadrate lobes by notches or clefts. Postero-lateral border thickened, inclining inward, and rendering the posterior border narrower than the orbito-frontal. Dorsal surface uniformly covered by small granules—about four in a square millimetre. Areolar tubercles not observable. Most of the normal regions of both the cephalic and scapular areas are separately indicated: lateral gastric lobes inflated; mesogastric lobe small; urogastric undefined; the pyriform epibranchials terminate in the lateral angles; in some specimens a linear, indistinctly defined, mesobranchial extends obliquely forward and inward; cardiac region large, inflated: the metabranchials occupy the postero-lateral two-fifths of the scapular area. A sharp impression occurs in the sinus between the anterior cardiac and the branchial lobes. Pterygostomate region granulated like the dorsal surface. Sternum moderately wide, lanceolate. Episternum sharply retroflexed, acutely pointed. Epistome granulated; cavities for insertion of external antennæ large. Endostome large, with a median, and oblique lateral, ridges. Orbits large, transversely oval, rather less than two diameters apart; two notches in both the upper and lower margins. Ophthalmic peduncles constricted, granulated. Buccal opening rather widened in front. Exopodite of external maxillipeds a third of the width of the endopodite, which latter is longitudinally furrowed and granulated.

Female abdomen seven-jointed; penultimate segment quadrate; telson triangular.

Width of carapace = 10 to 30 mm.; average adult width = 28 mm.; average length = 15 mm.

Remarks.—In his generic diagnosis Bell quotes emargination of the orbito-frontal border as a character; but the frontal border of the specimen which he has described and figured is imperfect, and is made to appear emarginate by the accidental fracture of the rostrum. Specimens in which this border is well preserved show a slightly prominent, but distinct, rostrum.

Affinities.—This species may be readily distinguished from its allies by the depressed form of the carapace, by the trenchant antero-lateral border, and by the uniformity in size and regularity of disposition of the surface-granules.

Distribution.—Cambridge Greensand. Upper Greensand, Warminster (*fide* Milne-Edwards). A single example from the Gault near Aylesford is in the British Museum (No. 44311). I have examined upwards of fifty specimens in the Woodwardian Museum, the British Museum, the Museum of Practical Geology, the York Museum, etc.

XANTHOSIA SIMILIS (Bell). (Pl. II, fig. 9.)

1863. *Etyus similis*, Bell, Monogr. pt. ii, pp. 6, 39 & pl. i, fig. 12, pl. xi, fig. 15.
1865. Milne-Edwards, Ann. Sci. Nat. ser. 5, vol. iii, p. 347 & pl. vi, fig. 7.

Description.—The carapace is almost identical in character with that of *X. granulosa*, except as regards the granulation of the cephalic portion of the dorsal surface; this area, instead of being uniformly and minutely granulated as in *X. granulosa*, bears larger and pointed tubercles, which vary considerably both as to size and arrangement—not being disposed in any constant order, but scattered irregularly over the gastric and hepatic lobes, differing in disposition in each individual. The cephalic lobes are more inflated and more prominent than in *X. granulosa*. The antero-lateral border is so compressed as to be rendered trenchant.

Length of carapace = 11 to 16 mm.; width = 18 to 28 mm.

Affinities.—*X. similis* is smaller in size than its congener—*X. granulosa*—and has a general aspect which suggests the probability that it may be an abnormal form of that species. It was first recognized by Bell, who referred it to the genus *Etyus*, but well-preserved specimens present characters so completely identical with those of *Xanthosia* that I do not hesitate to transfer it to that genus. The difference in form, the irregularity of the granulation of the carapace, and the compressed, trenchant, antero-lateral margin, at once distinguish it from *Etyus Martini*.

The posterior portion of the carapace figured by Bell (pl. xi, fig. 15) is broken away, so that it is made to appear disproportionately wide.

Distribution.—Cambridge Greensand. I have examined altogether about twenty specimens, which are preserved in the British and Woodwardian Museums, and in my own collection. This species is probably represented in the Gault of Sainte-Croix by *X. Fischeri*, Milne-Edwards.

Genus Xanthopsis, M'Coy.

The diagnosis of *Xanthopsis* is given by Bell in detail amply sufficient for determination. It may be added that the sternal plastron is broadly ovate and a fourth longer than wide. Genital pores exist in the third segment of the female. The episternum is half the width of the sternum and twice as wide as long. As regards the abdomen, it is difficult to determine whether the middle segments in the male were free or coalescent during life; but transverse markings distinctly indicate the seven normal segments. The chelæ are unequal, and in some examples the difference in size is very considerable—one being only a third as large as its fellow. The fingers of the larger claw are robust, and have the dentary margin coarsely tuberculated; those of the small chela are slender and usually nearly edentulous. A similar difference occurs normally in many other genera, both recent and fossil.

Xanthopsis is abundantly represented in the Tertiary deposits by a variety of forms, of which 14, including 10 foreign, have been described as distinct species. Milne-Edwards has expressed an opinion that several of the foreign forms, to which specific names have been applied, can be considered as varieties only; Bell's careful investigations led him to a similar conclusion relative to the several British forms, which he regarded as varieties of one species, of which *X. Leachi* is the type. I fully concur with these experienced carcinologists in this opinion. It may, however, be permissible and convenient provisionally to regard these varieties as specifically distinct, and to continue the names employed by Bell, with the object of determining by future observation any special value or interest, either biological, phylogenetic, or geological, which may attach to them.

XANTHOPSIS BISPINOSA, M'Coy.

1858. Bell, Monogr. pt. i, p. 15 & pl. i, figs. 5 & 6.

Supplementary.—I apprehend that the dentition of the inner border of the dactylopodite represented by Bell (fig. 5) is inaccurate.

XANTHOPSIS LEACHII (Desmarest).

1858. Bell, Monogr. pt. i, p. 14 & pl. i, figs. 1–4.

Supplementary.—The punctation of the dorsum of the carapace varies according to the stage of growth. In small specimens the puncta are so close as to produce a reticulated appearance; they become more widely separated as growth advances, and in large specimens they are more than a diameter apart. The large tubercle upon the dorsum of the hand, near the carpal articulation, and those upon the marginal crest are more or less obsolete in many specimens.

Bell figured a nodulated form which he considered to be that of a variety of *X. Leachi*. I have met with a number of similar examples, most of them from Alum Bay, Isle of Wight; but it is not peculiar to that locality, as specimens from the London Clay of Sydenham and Bognor are in the British Museum. This form nearly resembles a variety of *X. Dufourii*, Milne-Edw., but Milne-Edwards regards it as a nodulated variety of *X. hispidiformis*, Schloth., the occurrence of which at Sheppey is quoted by M'Coy. *X. hispidiformis* and its varieties are fully described and profusely figured by Reuss and by Milne-Edwards. I am, however, unable positively to determine the precise form to which Schlotheim originally applied this name.

Distribution.—London Clay.

Genus PLAGIOLOPHUS, Bell.

PLAGIOLOPHUS WETHERELLII, Bell. (Pl. II, fig. 6.)

1858. Bell, Monogr. pt. i, p. 19 & pl. ii, figs. 7–13.

1859. *Glyphithyreus affinis*, Reuss, 'Zur Kenntniss foss. Krabben,' Denkschr. k. Akad. Wissensch. Wien, vol. xvii, p. 53 & pl. x, figs. 4 & 5.

1861–65. *Plagiolophus Wetherelli*, Milne-Edwards, 'Hist. des Crust. Podophth. Foss.' Ann. Sci. Nat. ser. 4, vol. xiv, p. 358, pl. xxxii, fig. 2 & pl. xxxiv, fig. 1. [?]

Supplementary.—Carapace approximately quadrate in outline, as long as wide in the early stage of growth, becoming a fourth or fifth wider as growth advances. Orbito-frontal border as wide as the carapace is long. Mesogastric lobe small, confluent posteriorly with a small angular urogastric lobe of unusual form—which is separated from the cardiac by a V-shaped sulcus. Posterior margin of the carapace abruptly declivous. Buccal opening as wide as long. Sternal plastron large, broadly ovate. Male abdomen hastate, tapering rapidly to a small telson; sulci between the third, fourth, and fifth segments indistinct. Chelæ rather unequal in size; meropodite remarkably robust, as large as, or larger than, the propodite.

Distribution.—London Clay of Sheppey and Portsmouth. Red Crag (derivative) of Felixstowe.

Genus Xanthilites, Bell.

Xanthilites Bowerbankii, Bell.

1858. Bell, Monogr. pt. i, p. 17 & pl. ii, figs. 2–6.

1859. *Pseuderiphia M'Coyi*, Reuss, 'Zur Kenntniss foss. Krabben,' Denkschr. k. Akad. Wissensch. Wien, vol. xvii, p. 54 & pl. xviii, figs. 4–6.

1859 ? *Leiochilus Morrisi*, Reuss, *ibid.* p. 56 & pl. xviii, fig. 7; see *Portunites incerta.*

1863–64. *Xanthilites Bowerbankii*, Milne-Edwards, Ann. Sci. Nat. ser. 4, vol. xx (1863) pl. xi, figs. 1 & 2; ser. 5, vol. i (1864) p. 47.

Supplementary.—Antero-lateral margin of the carapace slightly arcuate. The postero-lateral margin—described by Bell as very short—is longer than the antero-lateral, nearly straight, inclining inward. Dorsal surface bears granules, ten to twelve in a square centimetre, irregularly disposed, most of them having an apical (setigerous?) pit. A triangular lobe occurs between the base of the mesogastric and the branchial lobes, representing an unusually distinct hypogastric. Sternal plastron broadly lanceolate, a fifth longer than wide; episternum trilobate, minutely granulated, half the width and a fourth the length of the sternal plastron.

Remarks.—Bell has given a diagram (fig. 6) of the abdomen, which he considered to be that of the female, but I venture to doubt that determination. In all Brachyura, both fossil and recent, so far as I can ascertain, the segments of the female abdomen, posterior to the third, are as wide as, or wider than, those preceding it, and thus are rendered adaptive for the normal function of supporting and protecting the ova. In some genera this lateral expansion is slight, but it is always recognizable. The hastate form appears to be peculiar to the male: as all the specimens of the abdomen of this species which I have examined are of this form, I regard them as belonging to that sex.

This species, together with *Plagiolophus Wetherellii* and *Portunites incerta*, was concurrently and independently described, but under different names, by Reuss and by Bell. The description is given by Reuss in a valuable communication made in 1857, but not published in full until 1859.[1] The volume of the Palæontographical Society containing Bell's monograph, dated 1857, was issued in 1858, and became available for reference at an earlier date than the German publication. Under these circumstances I have recognized Bell's claim to priority, and have continued the names which he employed. Reuss alludes to this coincidence of publication in a copious note appended to his paper.

[1] Denkschr. k. Akad. Wissensch. Wien, vol. xvii.

Distribution.—London Clay. Specimens are in the Woodwardian and Jermyn Street Museums. Examples (derivative) from the Red Crag are in the Woodwardian Museum, etc.

Genus Podopilumnus, M'Coy.

Podopilumnus Fittoni, M'Coy. (Pl. II, fig. 7.)

1849. M'Coy, Ann. & Mag. Nat. Hist. ser. 2, vol. iv, p. 166.
1854. M'Coy, 'Contrib. Palæont.' p. 121.
1854. Morris, 'Cat. Brit. Foss,' 2nd ed. p. 114.
1859. Reuss, 'Zur Kentniss foss. Krabben,' Denkschr. k. Akad. Wissensch. Wien, vol. xvii, pp. 8, 79.
1865. Milne-Edwards, Ann. Sci. Nat. ser. 5, vol. iii, p. 315 & pl. vi, fig. 6.

Description.—Carapace about a third wider than long; slightly convex transversely, cephalic portion strongly deflexed in front. Orbito-frontal border nearly straight; width rather less than half that of the carapace; interorbital portion occupied by a broad, flattened, quadridentate rostrum. Orbits transversely oval, margins irregular. Antero-lateral border moderately arcuate, slightly keeled, and bearing three small, distant, pointed processes. The postero-lateral margin is longer than the antero-lateral and undulates inward, making the width of the posterior margin about equal to that of the orbito-frontal. The normal dorsal regions are indistinctly defined. A shallow median sulcus extends from the rostrum. The whole surface of the carapace is nearly smooth, but under the lens small granulations of various sizes are visible, especially near the borders. The inferior branchiostegite is sparsely granular, and bears a sharp, curved, granulated ridge. Sternal plastron broadly ovate, half as wide as the carapace. Female abdomen broadly ovate, segments apparently distinct; the five anterior are of equal length and much wider than long. Chelæ robust; meropodite considerably shorter than the propodite; carpopodite large, rhomboid, granulated; hand rather longer than wide; the dorsal surface is singularly sculptured by minute *Cypris*-like markings, and bears several rows of small tubercles extending from the carpal articulation towards the fixed finger; anterior border tuberculated; fixed finger shorter than the hand, and calcareous, the inner border being coarsely dentated. The four posterior pairs of limbs are large and long: the meropodite of the fourth pair measuring half the width of the carapace.

Length of carapace = 36 mm.; width = 48 mm.

Affinities.—This genus is clearly referable to the Portunidæ. Milne-Edwards has fully discussed the alliance of this form, and regards its relationship with *Pilumnus* as remote.

Distribution, etc.—The only known specimen of this species is that in the Woodwardian Museum described by Sir Frederick M'Coy. It is labelled 'Greensand, Lyme Regis,' but there is doubt both as to the rock and the locality from which it came. Sir Richard Owen[1] regarded it as 'probably from some Tertiary deposit.' It is quoted and figured as a British fossil by Milne-Edwards, Bronn & Rœmer, and Pictet. The figures given by these

[1] 'Palæontology,' Edinburgh, 1860, p. 46.

authors respectively are copies of the woodcut accompanying M'Coy's description, which is stated by the author to be diagrammatic only, and not intended as an accurate representation of the specimen.

Family Catometopa.

Genus Goniocypoda, Woodward.

Goniocypoda sulcata, sp. nov. (Pl. II, fig. 10.)

Description.—Carapace quadrate in outline, a fourth wider than long; slightly convex transversely, more so longitudinally. Orbito-frontal border nearly straight; width in proportion to that of the carapace as 17 to 20; the median fifth occupied by the obtuse, square rostrum. Portions of the elongated ophthalmic peduncles are preserved. The antero-lateral borders bear the normal external orbital, hepatic, and branchial processes. The postero-lateral margin undulates inwardly and renders the posterior border considerably narrower than the orbito-frontal. Dorsal surface of carapace smooth; the median are separated from the lateral gastric lobes by an unusually wide, shallow sulcus, which extends on each side from the base of the rostrum to the cervical sulcus; hepatic lobes large, but most of the normal dorsal lobes are indistinctly defined. Cardiac region very wide, occupying fully the median third of the scapular area. Sternum large, broadly oval, five-sixths the width of the carapace; the segments are of nearly equal size. The abdomen in the male gently narrows towards the telson; the second, third, and fourth segments are coalescent. Chelæ of equal and moderate size; hand scarcely half the length of the carapace; surface smooth. Fingers shorter than the hand.

Length of carapace = 16 mm.; width = 20 mm.

Affinities.—I refer this form to the genus *Goniocypoda*, established by Dr. Woodward for the reception of a Tertiary species, *G. Edwardsi*, Woodw. The carapace differs from that of its Eocene ally in both form and size, being considerably larger, wider in proportion to the length, and less acutely quadrangular; also by the existence of processes on the antero-lateral margin. The specific name refers to the strongly-marked sulcus which surrounds the mid-gastric lobes.

Distribution.—Lower Greensand of Shanklin. The only specimen that I have seen is in the Museum of Practical Geology; it is a male, and the chelæ are of moderate size.

EXPLANATION OF PLATES I & II.

The figures are of the natural size, unless otherwise stated.

Plate I.

Fig. 1. *Nephrops Reedi*, sp. nov. Left chela. 1 *a*, palmar surface; 1 *b*, dorsal surface. Crag of Boyton, derived from the London Clay. York Museum.

2. *Gebia clypeatus*, sp. nov. 2 *a*, dorsal surface of cephalothorax, × 2;

2 *b*, lateral view of same; 2 *c*, lateral view of abdomen; 2 *d*, dorsal surface of body; 2 *e*, posterior view (telson, etc.), × 2. Great Oolite, Northampton; Woodwardian Museum.

Fig. 3. *Gastrosacus Wetzleri*, v. Meyer. Dorsal surface of cephalothorax. 3 *a*, ×1; 3 *b*, × 2. Coral Rag, Upware (southern pit). Presented to the Woodwardian Museum by Prof. W. J. Sollas, F.R.S.

4. *Homolopsis Edwardsii*, Bell. 4 *a*, carapace; 4 *b*, transverse section of carapace; 4 *c*, female abdomen. Cambridge Greensand.

5. *Homolopsis depressa*, sp. nov. 5 *a*, Gault, British Museum. 5 *b*, Cambridge Greensand, Author's collection. × 1½.

6. *Goniochele angulata*, Bell. Female abdomen. London Clay. Author's collection. Slightly reduced.

7. *Ranina* (*Raninella?*) *atava*, sp. nov. Upper Greensand, Chute Farm, Warminster. Willett Collection, Brighton Museum.

8. *Palæocorystes Stokesii* (Mantell). Sternum, maxillipeds, first pair of legs, and abdomen. Cambridge Greensand. Author's collection. Enlarged.

9. *Necrocarcinus Bechei*, Desl. Female abdomen. Cambridge Greensand. × 3.

Plate II.

Fig. 1. *Necrocarcinus Woodwardii*, Bell. 1 *a*, hand; 1 *b*, *c*, sections. Cambridge Greensand. Author's collection.

2. *Neptunus vectensis*, sp. nov. Ventral aspect, showing plastron, etc. Hamstead Beds (*Corbula*-bed), Hamstead. Woodwardian Museum.

3. *Actæopsis Wiltshirei*, sp. nov. Lower Greensand, Atherfield.

4. *Mithracia oblita*, sp. nov. Cambridge Greensand. × 2.

5. *Xanthosia granulosa* (M'Coy). 5 *a*, epistome and endostome, enlarged; 5 *b*, abdomen, enlarged. Cambridge Greensand.

6. *Plagiolophus Wetherellii*, Bell. Male abdomen. London Clay, Sheppey?

7. *Podopilumnus Fittoni*, M'Coy. 7 *a*, ventral view; 7 *b*, anterior view. Greensand, Lyme Regis. Woodwardian Museum.

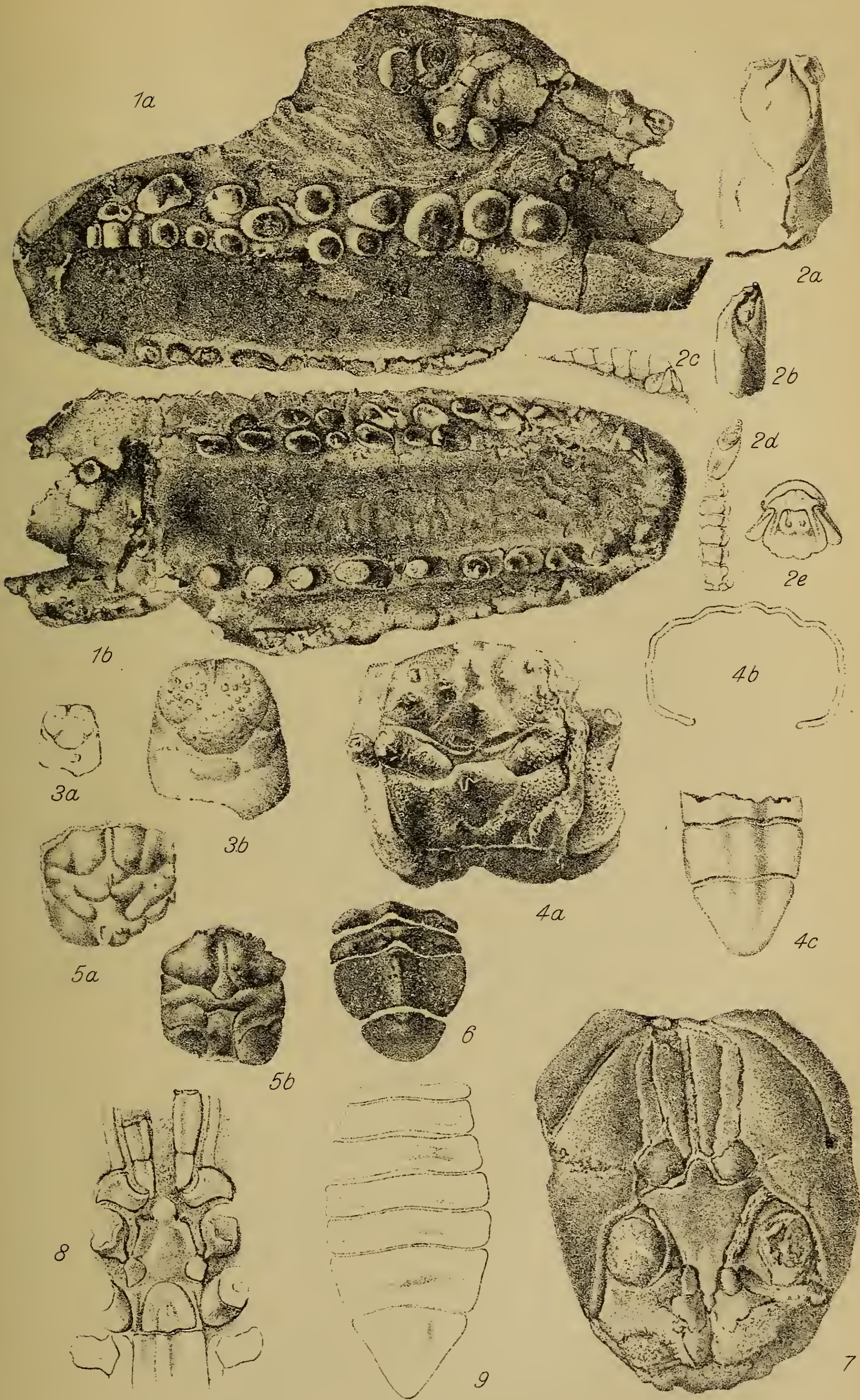
8. *Mithracia libinioides*, Bell. London Clay, Sheppey. Woodwardian Museum. × 1¼.

9. *Xanthosia similis* (Bell). Cambridge Greensand. Author's collection. × 1½.

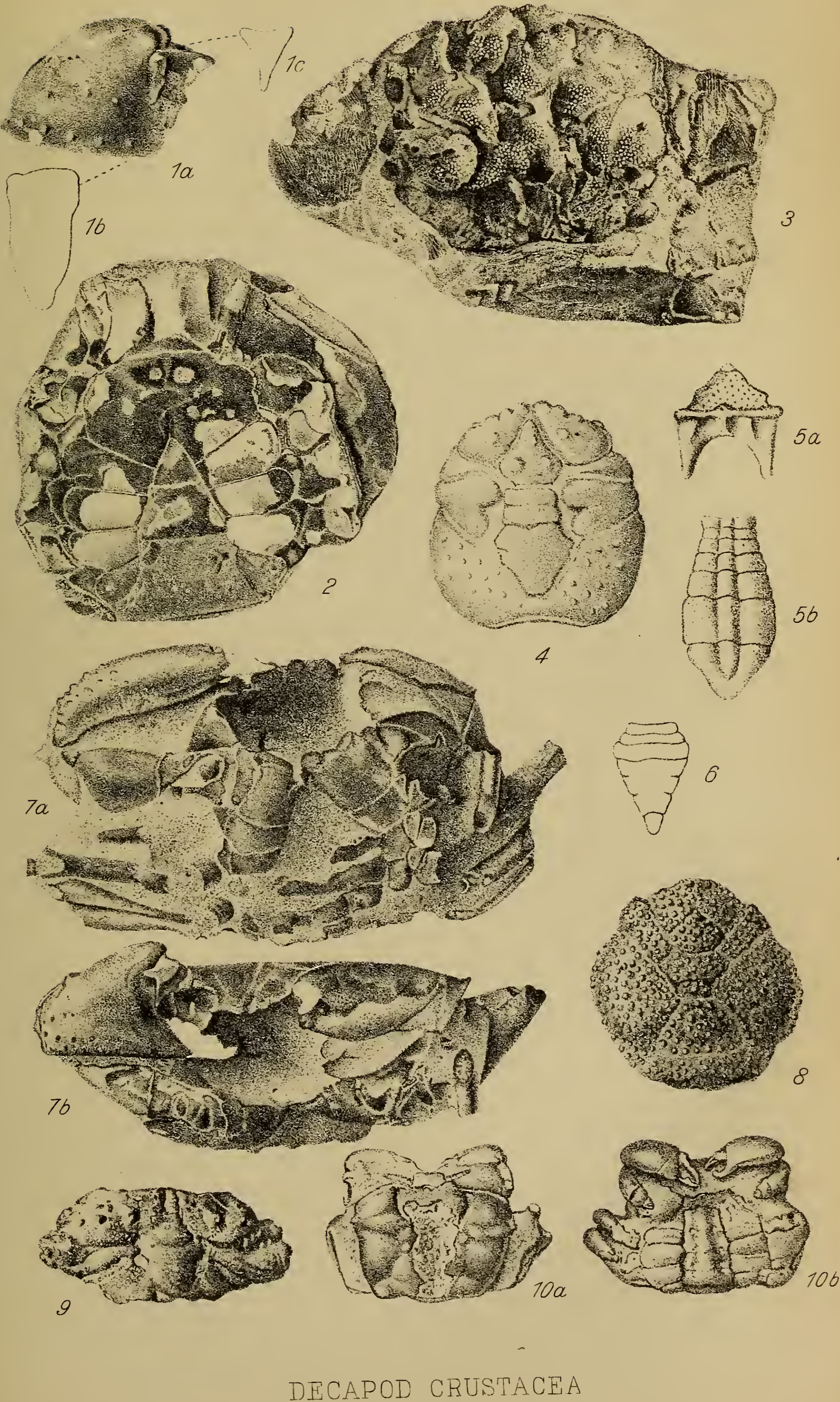
10. *Goniocypoda sulcata*, sp. nov. 10 *a*, dorsal; 10 *b*, ventral aspect. Lower Greensand, Shanklin. Museum of Practical Geology (No. 6375).

Discussion.

Mr. Marr regretted the absence of Prof. Hughes, who, as a Delegate of the Society to the International Geological Congress, had been so occupied that he had only recently returned to Cambridge, and consequently, owing to stress of work, was unable to be present that evening. Prof. Hughes had requested him (the speaker) to express his regrets, and to record the Woodwardian Professor's appreciation of the value of the late Mr. Carter's work, which he was glad to do, as it enabled him to bear personal testimony to the way in which Mr. Carter had ever placed his stores of knowledge at the disposal of geologists, and to his deep regard for the welfare of this Society.



DECAPOD CRUSTACEA



DECAPOD CRUSTACEA

5. Observations *on the* Genus Aclisina, De Koninck, *with* Descriptions *of* British Species *and of* some other Carboniferous Gasteropoda. By Miss J. Donald. (Communicated by J. G. Goodchild, Esq., F.G.S. Read November 17th, 1897.)

[Plates III–V.]

Introduction.

In 1881 De Koninck, in his 'Faune Calc. Carb. Belg.' Ann. Mus. Roy. Hist. Nat. Belg. vol. vi, pt. iii, p. 86, created the genus *Aclisina* to include some small shells which had previously been placed in one or other of the genera *Murchisonia, Loxonema, Aclis, Turbonilla* or *Turritella*, and he thus defines it: 'Petite coquille allongée, conique, à tours convexes, striés en spirale; ouverture ovale; bord externe mince, entier et non saillant: columelle non arquée, légèrement épaissie; axe non perforé.'

Three species are described as belonging to this genus, but none is especially regarded as the type. I have examined the shells labelled as the types in the Brussels Museum, and find that they are severally quite distinct from one another in character, so much so, indeed, that each must form the type of a separate genus. It remains, therefore, to be decided which should be regarded as most typical of De Koninck's definition of *Aclisina*. The first-mentioned, *Murchisonia striatula*, was referred by De Koninck in a former work to the genus *Murchisonia*,[1] but he here removes it to *Aclisina*, because he states there is no slit ('fente') in the outer lip.

The surface of the specimen from Visé in the Brussels Museum, marked as the type of this species, is much worn, but it is sufficiently preserved to prove its identity with other individuals from the same locality in the Brussels Museum, in the Museum and in the Collection of M. Destinez at Liége, and also with two shells (65080) in the British Museum (Nat. Hist.). None of these specimens agree exactly with either the figures or descriptions of De Koninck. The whorls are less convex and the sutures are not so oblique as in figs. 41 and 42, pl. xxxiii, vol. viii, pt. iv, but the ornamentation is more like that of these figures than of figs. 57 and 58, pl. ix, vol. vi, pt. iii, where there is a band of four fine threads near the middle of the whorl, while on the specimens I have seen this band is formed of three rather strong threads, with the exception of two individuals where the central thread is wanting. As this part of the type is especially worn on the lower whorls, the fine threads may have been inserted in the figure by the artist if he had not a better preserved specimen to which to refer. Very few of De Koninck's figures are really portraits of the individuals marked as types which I have examined, but they appear to have been generalized from several specimens, and they do not

[1] 'Descr. Anim. foss. Terr. Carb. Belgique,' 1842–44, p. 415.

always give a correct idea of the species. The lines of growth, which are represented only in pl. xxxiii, fig. 42, are also different, as they come more directly down the whorl than on the specimens which I have observed. On these the lines of growth curve backward and form a sinus situated on the space occupied by the band of three threads referred to above, and they curve forward again below in a manner similar to *Murchisonia.* The ornamenting threads agree with the description of De Koninck in being about ten in number, and in varying in strength, though this variation in strength is not quite so regular either on the same individual or on different ones as De Koninck describes. In spite of the discrepancy pointed out between the description and figures and the actual character of the specimens referred to, it seems as if these latter must be considered as typical of the species *Murchisonia* [*Aclisina*] *striatula*, De Kon., as they are the only specimens which in any degree tally with the representations of De Koniuck. More especially does this appear the proper course to be taken when it is noted that, besides the specimen in the Brussels Museum marked as the type, the two shells in the British Museum (Nat. Hist.) are so named in De Koninck's own handwriting.

This species cannot, however, be regarded as the type of *Aclisina*, as it possesses a sinus in the outer lip, and does not therefore agree with the description of that genus; but it must be retained among the *Murchisoniæ*, where De Koninck first placed it.

The two other species referred to this genus are *Aclisina pulchra*, De Kon., pl. vii, figs. 26–28, and *A. nana*, pl. vii, figs. 29 & 30. The type of the latter in the Brussels Museum is very small, and is distorted by pressure, but there are good specimens of it in the Liége Museum from the same locality, and also one in the collection of M. le Chanoine de Dorlodot from Tournai. One from the Liége Museum has the lines of growth well preserved; they are sinuated on the earlier whorls of the spire, and on the body-whorl of the adult this sinuation appears to become deeper, so as to indicate a shallow notch in the outer lip, but not a slit as in the outer lip of *Murchisonia.* This notch is situated higher on the whorl than the sinus of *M. striatula*, and the lines of growth do not make so great a sweep either backward or forward as in that species. The notch of *A. nana*, like the sinus of *M. striatula*, occupies the space between two of the ornamenting threads, and there is sometimes a fine thread down the middle.

This shell also diverges from the generic description of *Aclisina* in the form of the outer lip, but it cannot be referred to *Murchisonia*, not having either the characteristic slit in the outer lip or the band of that genus. I would suggest the name *Micrentoma* for the genus, with *Aclisina nana*, De Kon., as the type.

A. pulchra displays, however, a character very different from *M. striatula* and *Micrentoma* [*Aclisina*] *nana.* A specimen in the collection of M. le Chanoine de Dorlodot shows the form of the outer lip better than De Koninck's type in the Brussels Museum, or the other two specimens associated with it. Here the outer lip is nearly entire, and is strongly sigmoidal; it retreats from the suture above, so as to give almost the appearance of a broad and shallow sinus; it then comes prominently forward and retreats again anteriorly. This shell accords more nearly with the generic description of *Aclisina*, De Kon., than either of the others associated with it, and it therefore appears advisable to regard it as the type of the genus, more especially as some palæontologists have since referred similar fossils to *Aclisina*. The description of the form of the outer lip, however, needs emendation, as De Koninck states that it is not prominent, but in this and allied species it certainly is prominent.

Representatives of the three genera occur in the British Isles, and often in a wonderfully good state of preservation. The Scottish specimens deserve special mention, many of them having the protoconch intact, and some also showing the lines of growth distinctly. The examples from Glencart and Law, Dalry, and also from Crawfield, Beith, Ayrshire, are of a creamy colour, and look more like shells of Tertiary or even more recent age, instead of being so ancient as the Lower Carboniferous Period. Dr. John Young has written a most interesting paper upon the Glencart fossils, published in Proc. Nat. Hist. Soc. Glasgow, 1882, p. 234. He states that these fossils are found in cavities filled with clay in weathered calcareous shale-beds, which were discovered by Mr. John Smith, of Kilwinning. He conjectures that these cavities were originally calcareous nodules which enclosed the organisms lying in the stratum in which the nodules were segregated, and that the calcareous matter was afterwards dissolved by the passage through the beds of water containing carbonic acid, which left behind only the clay originally mixed with the lime. The fossils remained so free in the clay that they could easily be disengaged by washing.

The shells from Law and Crawfield were obtained from fissures and partings in limestone and shales, where the rock had become rotten *in situ* through the percolation of surface-water in recent times.

It is worthy of remark that many of the Scottish Carboniferous gasteropoda are of much smaller size than their representatives in England and Belgium; this discrepancy may be owing to the different physical conditions that prevailed in the two areas.

I am greatly indebted to Prof. Hughes, Mr. James Bennie, Dr. John Young, Dr. Hunter-Selkirk, Mr. James Thomson, Mr. John Smith, Mr. Neilson, Mr. Platnauer, and M. le Chanoine de Dorlodot, for the loan of specimens. I must also record my gratitude to all those in charge of the public collections which I have had occasion to consult, for rendering me every assistance in their power while preparing this paper. I may especially mention Mr. E. T. Newton, Mr. H. A. Allen, Mr. R. B. Newton, Dr. Traquair, Prof. Cole, M. Béclard, Mr. Howse, and Mr. Goodchild. In the conchological department of the British Museum (Nat. Hist.) Mr. E. Smith and Mr. Pace have given me special facilities for studying recent

shells in order to compare them with fossil ones. Mr. McHenry, of the Irish Geological Survey, has been very good in giving me information about the Irish horizons. Mr. G. F. Harris has kindly given me some valuable hints with regard to the study of the protoconchs. I must also thank Mr. Goodchild for revising these notes.

Family Turritellidæ.

Genus Aclisina, De Kon. emend.

Aclisina, L. G. De Koninck, 1881, 'Faune Calc. Carb. Belg.' Ann. Mus. Roy. Hist. Nat. Belg. vol. vi, t. iii, pp. 86.

Terebra or *Turbo* ? (pars), D. Ure, 1793, 'History of Rutherglen & E. Kilbride,' p. 308 & pl. xiv, fig. 11.

Turritella ? (pars), J. Fleming, 1828, 'Brit. Animals,' p. 305; ? (pars), J. Phillips, 1836, 'Geol. Yorks.' vol. ii, p. 229 & pl. xvi, figs. 23 & 25; ? (pars), E. d'Eichwald, 1860, 'Lethæa Rossica,' pp. 1120, 1121 & pl. xlii, figs. 4 & 5; ? F. B. Meek & A. H. Worthen, 1866, 'Pal. Illinois,' vol. ii, p. 382 & pl. xxix, fig. 8.

Loxonema (pars), F. M'Coy, 1844 (*non* J. Phillips), 'Syn. Char. Carb. Limest. Foss. Irel.' p. 30, pl. iii, fig. 1 & pl. v, fig. 6; ? J. W. Dawson, 1868, 'Acad. Geol.' 2nd ed. fig. 122 & pp. 309, 310; ? A. H. Worthen, 1890, Geol. Surv. Illinois, Pal. vol. viii, p. 140 & pl. xxiii, figs. 9 & 9 *a*.

Aclis, R. P. Stevens, 1858 (*non* Sv. Lovén), Am. Journ. Sci. ser. 2, vol. xxv, p. 259; F. B. Meek & A. H. Worthen, 1873, 'Pal. Illinois,' vol. v, p. 596 & pl. xxix, figs. 6 *a* & *b*; ? C. A. White, 1882, 'Rep. on the Carb. Invert. Foss. New Mexico,' U.S. Geograph. Surv. W. of 100th Merid., Appendix, p. 35 & pl. iii, fig. 9

? *Murchisonia* (pars), G. C. Swallow, 1858, Trans. St. Louis Acad. Sci. vol. i, p. 203.

Murchisonia (pars), J. Armstrong, J. Young, & D. Robertson, 1876, 'Cat. W. Scot. Foss.' p. 56.

? *Turbonilla*, H. B. Geinitz, 1866 (*non* A. Risso), 'Carbonformation u. Dyas in Nebraska,' p. 5 & pl. i. fig. 19.

Aclisina, J. Donald, 1885, Trans. Cumberl. & Westmorl. Assoc. no. ix, p. 131 & pl. ii, figs. 2–5; D. P. Œhlert, 1887, 'Descr. de qq. Espèces Dévon. de la Mayenne,' Bull. Soc. d'Études Scient. d'Angers, p. 10 & pl. viii, fig. 4; S. A. Miller, 1889, 'N. Am. Geol. & Palæont.' p. 395, & 1891, 'Geol. Surv. Indiana,' Pal., 17th Ann. Rept. p. 695 & pl. xiv, fig. 10; G. F. Whidborne, 1896, 'Monogr. Dev. Fauna S. of England,' Palæont. Soc. vol. iii, pt. i, p. 52 & pl. v, fig. 10.

Description.—Shell small, elongated, conical, composed of numerous whorls. Apex blunt. Protoconch formed of about one smooth whorl, which is sometimes more or less detached from the highest whorl of the spire on the umbilical region. A faint rib indicates its junction with the conch, upon which the ornamentation begins almost immediately. Whorls convex, spirally striated. Sutures deep. Outer lip as indicated by the lines of growth sigmoidal, retreating from the suture and forming a wide shallow sinus, then arching prominently forward and retreating again below on the base of the shell. Aperture ovoid. Columella nearly straight, slightly thickened. Inner lip reflected on the body-whorl. Base convex. Umbilicus closed.

Dimensions.—The length varies from 2 or 3 mm. up to about 15 mm.

Remarks.—The protoconch of *Aclisina* is a very distinctive feature. It is frequently somewhat irregular, but not sinistral. The initial part in many cases appears to be central, and the whorl coils round it on nearly the same plane. The protoconch does not always adhere to the highest whorl of the conch, but sometimes stands nearly erect (as in Pl. III, figs. 3*a*, 3*b*); at other times it is but slightly (Pl. IV, figs. 13*a*, *b*, *c*) or not at all raised[1] (Pl. IV, figs. 14*a*, *b*) from the spire, which it occasionally overhangs (Pl. IV, figs. 12*a*, *b*). The protoconchs of all the specimens that I have examined are invariably smooth, but some are too much worn to show any signs of ornamentation, even if it had originally existed. Where the apex is fairly preserved, the junction of the protoconch with the conch is marked by a faint rib or varix; and the ornamenting threads begin almost immediately, and are similar in character to those on the adult, though less numerous. Whether this posterior part of the conch, or whether the varix at the junction, represents the brephic stage, it is difficult to ascertain; at any rate, it is interesting to note the early development of the characteristic ornamentation. Both Dr. Jackson[2] and Mr. G. F. Harris[3] observe that characters similar to those of the adult frequently appear in the brephic stage.

Resemblances.—The genus which this most resembles is *Streptacis*, Meek[4] (non *Streptaxis*, Gray), of which *Str. Whitfieldi*, Meek, is the type. They are similar in general form, in having sigmoidal lines of growth, and in possessing an irregular protoconch. They differ in *Streptacis* having perfectly smooth whorls instead of being ornamented by spiral lines and grooves, and also it is not stated whether the inner lip is reflected on the body-whorl as in *Aclisina*. These two genera are, however, evidently closely allied.

Aclisina is very like *Aclisoides* in general appearance, and where aperture, lines of growth, and protoconch are not preserved, it is often difficult to distinguish between the two genera; the outline of the outer lip and the protoconch are seen to be quite distinct in well-preserved specimens. In the character of the outer lip *Aclisina* resembles *Loxonema*, but it differs from that genus in being ornamented by spiral threads, in having more convex whorls, and also in the form of the protoconch.

From the typical Turritellidæ the genus under consideration may be distinguished by having more convex whorls, and by having the aperture of a different shape. Prof. E. Koken,[5] however, believes it to be the direct forerunner of certain *Turritellæ*. It certainly bears

[1] It is a question whether these specimens with the protoconch entirely attached, and coiled on the same plane as the rest of the spire, should be grouped with the typical *Aclisina*. Though they agree with the genus in general appearance, the lines of growth are not preserved on any of them, and it is possible that they may be more closely allied with the subgenus *Rhabdospira*, which has straighter lines of growth. We are, however, ignorant at present of the form of the protoconch and aperture of *Rhabdospira*.

[2] 'Phylogeny of the Pelecypoda,' Mem. Boston Soc. Nat. Hist. vol. iv, no. 8, 1890, p. 290.

[3] 'Catal. Tert. Mollusca Brit. Mus. (Nat. Hist.),' pt. i. Australasia, 1897, p. xiii.

[4] 'Descr. of New Sp. of Foss. from Ohio & other Western States & Territories,' Proc. Acad. Nat. Sci. Phil. 1871, p. 173.

[5] 'Ueber die Entwickelung der Gastropoden vom Cambrium bis zur Trias,' Neues Jahrb. Beilage-Band vi (1889) p. 458.

a great likeness to some Mesozoic forms, such as the Triassic *Turritella pædopsis*, Kittl,[1] *T. Bernardi*, Kittl,[2] and the Liassic *T.* [*Mesalia*] *Guembeli*, von Ammon,[3] in form, ornamentation, and in the structure of the outer lip.

The character of the protoconch greatly resembles that of *Promathildia*, Andreæ, as represented by Koken[4] and Kittl,[5] from the St. Cassian Beds, which does not appear to be heterostrophe like that of *Mathilda*, Semp., but merely irregular and partially detached from the conch. The form of the outer lip is similar, but the aperture of *Aclisina* is not channelled below like that of *Promathildia*.

A consideration of the above-mentioned points of comparison must show how difficult it is to decide in which family this genus should be classed. De Koninck refers it to the Turbinidæ, with the members of which, however, it does not appear to me to have much in common. In his 'Handb. der Paläont.' vol. ii (1881–85) p. 188, Zittel also places it in the Turbinidæ; but in his later work, 'Grundzüge der Paläont.' 1895, p. 338, he includes it in the Scalariidæ. Fischer ('Man. Conch.' 1885, p. 778), Tryon ('Man. of Conch.' vol. viii, p. 53), and Whidborne ('Monogr. Dev. Fauna,' Pal. Soc. vol. iii, pt. i, 1896, p. 152) refer it to this last-named family, and Fischer considers it identical with *Holopella*; but it differs in being ornamented by spiral striæ, instead of being smooth or having longitudinal ribs. S. A. Miller (Geol. Surv. Indiana, 17th Ann. Rep. 1891, p. 695) gives it a place in the Turritellidæ, where it seems advisable to let it remain for the present, as it appears to combine characteristics both of the *Turritellæ* of the older rocks and also of *Promathildia*. There is a difference of opinion as to the position of the latter genus; some place it in the Turritellidæ, while others class it in the Cerithiidæ, and others again in the Pyramidellidæ. *Aclisina* differs from the Cerithiidæ in not having a channelled aperture. It agrees with the Pyramidellidæ, as defined by Zittel,[6] in the outer lip being sigmoidal and in possessing an irregular protoconch.

Range.—In the present state of our knowledge it is almost impossible to ascertain the exact range in time and space of *Aclisina*, for the distinction between the members of the genus and other small spirally-striated shells has not hitherto been noted. Koken ('Die Leitfossilien,' 1896, p. 111) states its range as being from the Carboniferous to the Permian. He considers the American forms

[1] 'Die Gastr. der Schichten von St. Cassian der südalpinen Trias,' Annal. k.-k. naturhist. Hofmus. vol. vii (1892) p. 55 & pl. vi, fig. 1.

[2] 'Die triadischen Gastr. der Marmolata u. verwandter Fundstellen in den weissen Riffkalken Südtirols,' Jahrb. k.-k. geol. Reichsanst. vol. xliv (1894) p. 149 & pl. vi, fig. 24.

[3] 'Gastr. aus dem Plattenkalk,' Abh. zool. min. Ver. Regensburg, vol. xi (1878) p. 59 & pl. i, figs. 12 *a–e*.

[4] 'Ueber die Entwickelung der Gastr. vom Cambrium bis zur Trias,' Neues Jahrb. Beilage-Band vi (1889) p. 459, fig. 25.

[5] 'Die Gastr. der Schichten von St. Cassian der südalpinen Trias,' Annal. k.-k. naturhist. Hofmus. vol. ix (1894) p. 224 & pl. ix, fig. 36.

[6] 'Grundzüge der Paläont.' 1895, p. 340.

from the Upper Coal Measures as probably of Permian age. The genus is, however, older than the Carboniferous, for two Devonian species have been described: one, *A. longissima*, by the Rev. G. F. Whidborne from the Pilton Beds, the other, *A. multicristata*, by D. P. Œhlert from France.

It appears to have been most numerous in the Carboniferous Period, and I am here describing fourteen British species and five varieties of that age. Some of these have been previously described, though not always referred to *Aclisina*, namely:—*A. elongata*, Flem.; *A. costatula*, Don.; *A. grantonensis* was referred by R. Etheridge, Jun., doubtfully to *Murchisonia striatula*, De Kon., as was also *A. tenuistriata* by me; *Loxonema sulcatula*, M'Coy, has the appearance of a species of *Aclisina*, but it is known only by somewhat imperfect moulds of the exterior; *Loxonema polygyra*, M'Coy, is probably identical with one of the varieties of *A. elongata*, Flem.; *Turritella triserialis*, Phil.,[1] and *T. acicula*, Phil.,[2] may possibly belong to this genus, but the types appear to be lost, for they are not in the Gilbertson Collection. There is one specimen in this collection marked *T. acicula* from Otterburn, but it is not the type, and the surface is too imperfect to discern what it really is. *A. pulchra*, var. *tenuis*, De Kon., has not hitherto been recorded as a British species.

In Belgium there have been described *A. pulchra*, De Kon., and the variety *tenuis*, De Kon. Another species, *A. gemmata*,[3] has been figured by De Koninck, but not described; the lines of growth, however, on the figure appear to be too straight for *Aclisina*.

Eichwald[4] describes and figures two small spirally-striated shells from Russia as *Turritella acus* and *T. spiculum* which should probably be referred to this genus.

In America nine Carboniferous species have been described which may belong to *Aclisina*, namely, *Aclisina bellilineata*, Miller, *Aclis robusta*, Stevens, *A. minuta*, Stev., *Aclis (?) Stevensoni*, White, *Murchisonia minima*, Swallow, *Turritella? Stevensana*, Meek & Worthen, *Loxonema quadri-carinatum*, Worthen, *L. acutula*, Dawson, and *Turbonilla Swallowiana*, Geinitz. Of these *A. bellilineata*, Mill., *Aclis robusta*, Stev., and *Turritella (?) Stevensana*, M. & W., are represented as having the sigmoidal lines of growth and lineated whorls characteristic of *Aclisina*. In *Turbonilla Swallowiana*, Gein., the greatest sinuosity of the lines of growth appears to be situated lower on the whorls than in the typical *Aclisina*. The lines of growth are not given on *Loxonema acutula*, Daws., nor on *L. quadri-carinatum*, Worth.; the former has the general appearance of *Aclisina*, but the latter has more flattened whorls than usual, and may possibly belong to the genus *Orthonema*. *Aclis (?) Stevensoni*, White, greatly resembles *A. robusta*, Stev. No figures are given of *Murchisonia minima*, Swall., nor of *Aclis minuta*, Stev.

[1] 'Geol. Yorks.' vol. ii (1836) p. 229 & pl. xvi, fig. 25.
[2] *Ibid.* p. 229 & pl. xvi, fig. 23.
[3] 'Faune Calc. Carb. Belg.' vol. viii, pt. iv (1883) pl. xxxiii, figs. 43 & 44.
[4] 'Leth. Ross.' vol. i (1860) pp. 1120, 1121 & pl. xlii, figs. 4 & 5.

Description of the British Species.

Aclisina pulchra, De Kon., var. tenuis, De Kon. (Pl. III, figs. 1–5.)

Aclisina pulchra, L. G. De Koninck, 1881, 'Faune Calc. Carb. Belg.' Ann. Mus. Roy. Hist. Nat. Belg. vol. vi, pt. iii, p. 87 & pl. vii, figs. 26 & 27.
Murchisonia tenuis, L. G. De Koninck, 1883, *ibid.* vol. viii, pt. iv, p. 22 & pl. xxxii *bis* figs. 3 & 4.

Description.—Shell small, conical, composed of from eight to ten whorls. Protoconch irregular, consisting of about one complete smooth revolution, detached from the spire on the umbilical region, and standing nearly erect; a faint rib marks its junction with the conch, and the ornamenting threads begin almost immediately. Whorls convex below, rather flat above, ornamented by from one to three somewhat fine raised threads on the upper third, and by from three to five stronger threads on the lower two-thirds, with numerous additional finer threads below on the body-whorl, some of which are occasionally visible on the spire below the stronger threads. The spaces between the threads vary slightly in width on different individuals. The lines of growth show the strongly sigmoidal form of the outer lip, which recedes above and comes prominently forward below. Aperture ovoid. Inner lip reflected on the body-whorl, where it forms a thin shelly layer. Columella nearly straight, but curving round below to meet the outer lip. Umbilicus closed.

Remarks.—The actual specimen figured by De Koninck as the type of *Aclisina pulchra* in the Brussels Museum is much larger than any of the Scottish shells that I have seen, but approaches them nearly in general form and in ornamentation. The figures and description of De Koninck represent the various ornamenting threads as equal in strength, whereas in reality on the lower part of the spire the three upper threads are finer than the four lower ones and there are several additional fine threads on the body-whorl; on the higher part of the spire only one of the fine upper threads is present, situated just below the suture.

The collection of M. le Chanoine de Dorlodot contains an individual of still greater size, whose aperture is almost entire and the form of the outer lip is seen to accord with the lines of growth on the British fossils.

Murchisonia tenuis, De Kon., appears to be a small variety of this species, for the contour of the whorls and the ornamentation agree with that of the upper part of the spire of *A. pulchra*. The specimen figured by De Koninck as the type has only three strong keels on the lower part of the whorl and a single fine one above, immediately below the suture. The different examples on the tablet in the Brussels Museum, however, show the same variation in the strength and disposition of the keels as the Scottish shells, and they also agree more nearly in size.

Since the specimens from Scotland bear a closer resemblance to *M. tenuis* than to the typical *A. pulchra*, I consider it advisable to retain the name *tenuis* for them and the small Belgian shells which were originally so called, and to regard them as a distinct variety of *A. pulchra*.

The contour of the whorls varies in different individuals, some, especially those with coarser ornamenting threads, being more angular than others with finer threads. The spiral angle also shows a considerable amount of variation, so much so that the two extremes without the intervening forms might be regarded as distinct species.

Two or three small specimens from Swindridge and one from Law vary so markedly, in being much more slender, that they appear to constitute a distinct variety, for which I would suggest the varietal name *intermedia*. They are immature, but if fully grown it is unlikely that the spiral angle would equal that of the type. They are intermediate in form between *A. pulchra* and *A. costatula*.

Resemblances.—This species somewhat resembles *Aclisoides striatula*, but it is more robust, the whorls are generally more angular, there is no slit in the outer lip, and the form of the protoconch is different. It is also like *Loxonema sulcatula*, M'Coy,[1] but it is difficult to make a just comparison with that species as it is only represented by three imperfect external moulds. The ornamentation and form of the protoconch are very similar to those of *A. costatula*; but the latter has not the numerous additional threads on the body-whorl, and it is also much more slender.

Dimensions.—As before stated, the Belgian type of this species is much larger than the Scottish examples; it has seven whorls preserved, whose length = 12 mm. The specimen belonging to M. de Dorlodot has ten whorls in a length of $13\frac{1}{2}$ mm. The type of *Murchisonia tenuis* has eight whorls in a length of 8 mm. The most perfect Scottish specimen (Pl. III, fig. 1) that I have seen consists of ten whorls, its length = 7 mm., width = 2 mm. It is from Swindridge, and is in the collection of Mr. James Thomson. The shell represented in Pl. III, fig. 2, consists of seven and a half whorls in a length of $4\frac{3}{4}$ mm., its width = nearly 2 mm. It is from Robroyston and is in the collection of Mr. Neilson. Another individual with greater spiral angle and fewer and stronger ornamenting threads is in my own collection from Craigenglen; it has five whorls in a length of 3 mm., and its width = $1\frac{1}{8}$ mm. (Pl. III, fig. 2 *a*). Other examples would be larger if entire.

The variety *intermedia* from Law is in Mr. Bennie's collection; it consists of eight whorls besides the protoconch, its length = $2\frac{3}{4}$ mm., width = about $\frac{3}{4}$ mm. (Pl. III, figs. 5 & 5 *a*). A specimen of this variety from Swindridge has the protoconch larger and more orbicular than usual.

Locality and Horizon.—This species has a wide range, occurring in the Calciferous Sandstone Series (d^2) at Randerstone, Fife; in the Lower Limestone Series (d^3) at Craigenglen and at Law, Dalry, and in the Upper Limestone Series (d^3) at Swindridge; Raesgill,

[1] 'Syn. Char. Carb. Foss. Irel.' 1844, p. 30 & pl. v, fig. 6.

Carluke; Bowertrapping; Robroyston: Auchenbeg, Lesmahagow; and at Glencart, Dalry. It is remarkably abundant at Swindridge, from which locality I have seen about thirteen specimens with the protoconch more or less intact. Examples with the protoconch also occur at Law, Raesgill, and Bowertrapping.

The Belgian specimens are all from Tournai, and none that I have examined retain the protoconch.

Aclisina elongata, Fleming. (Pl. III, figs. 6–10.)

Terebra or *Turbo clavicula longissima,* pars, D. Ure, 1793, 'History of Rutherglen & E. Kilbride,' p. 308 & pl. xiv, fig. 11.

Turritella elongata, J. Fleming, 1828, 'Brit. Animals,' p. 305; H. G. Bronn, 1848, 'Index Palæont.' p. 1333; T. Brown, 1849, 'Illustr. Foss. Conch. Gr. Brit. & Irel.' p. 71; J. Morris, 1854, 'Cat. Brit. Foss.' p. 284; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 335; R. Etheridge, 1888, 'Foss. of Brit. Is.' vol. i, Pal. p. 308.

? Loxonema polygyra, M'Coy, 1844, 'Syn. Char. Carb. Foss. Irel.' p. 30 & pl. iii, fig. 1.

Murchisonia elongata, J. Armstrong, J. Young, & D. Robertson, 1876, 'Cat. of W. Scot. Foss.' p. 56.

Aclisina elongata, J. Donald, 1885, 'Carb. Gaster. from Penton, etc.' Trans. Cumberl. & Westmorl. Assoc. no. ix, p. 132 & pl. ii, figs. 3, 4, 4 *a* & 4 *b*.

Description.—Shell small, elongated, conical, composed of about sixteen whorls. Protoconch of the type imperfectly known, the anterior portion elevated and showing a faint rib at its junction with the conch, upon which the ornamenting threads begin immediately. Whorls convex below, rather flat above. The convex part is ornamented by from five to seven raised threads, the flat part by two threads, one situated a short distance above the lower ones, the other just below the suture, one or both of these frequently absent; one or more additional threads on the body-whorl. Sutures deep. Aperture subovoid. Inner lip reflected on the body-whorl. Columella simple. Base convex, imperforate.

Remarks.—When I wrote my paper on the 'Carboniferous Gasteropoda from Penton' I was not aware of the existence of the Ure Collection, and I then regarded an elongated spiral shell collected by Dr. John Young, from the same horizon as Ure's specimens, as the type of *Turritella elongata.* I afterwards heard of the collection being preserved in the rooms of the Royal Society, Edinburgh, and through the kindness of Mr. Gordon I obtained access to it.

In his 'History of Rutherglen & E. Kilbride,' 1793, p. 308, the Rev. D. Ure briefly describes this species as 'striated spirally,' and states that it, with another shell which is 'striated transversely' (*Loxonema Urei,* fig. 7), 'is found in a recent state on all the shores of Europe. The till in which they are enveloped lies between the two strata of limestone at Stuartfield and Laurieston. Many specimens are no thicker than a fine thread, and about $\frac{1}{12}$ inch in length. By a microscope they are found to be equally perfect, and to contain the same number of spires with the largest specimens.' He calls both species *Terebra* or *Turbo clavicula longissima.* Later, in 1828, Fleming, in his 'British Animals,' p. 305, names the spirally-striated shell *Turritella elongata,* but he neither describes it more fully nor gives a new figure. The original figure does not show the arrangement of the ornamenting striæ, and upon examination of the actual specimens I found that several distinct spirally-striated shells had been included under one specific name. There are fragments of the form I described as *A. elongata*, Fleming, one of which consists of four and a half whorls, the upper part of the spire being broken, its length $=1\frac{3}{4}$ mm., width = about $\frac{3}{4}$ mm. To prevent confusion I have thought it expedient to retain this shell as the type of *A. elongata*. Besides this species there are representatives of shells I have described as *A. costatula*, *A. attenuata*, *A. pulchra* var. *tenuis*, as well as a specimen which I regard as a variety of *A. elongata*.

The type of *A. elongata* has five or six raised threads on the lower convex part of the whorl, with equal spaces between them, and two threads on the upper flattened part, with wide spaces between them, one a short distance above the lower threads, and the other immediately below the suture. One or both of these upper threads is frequently absent. It is worthy of remark that this lack of ornament on the upper part of the whorl is not a peculiarity of this species alone, but it may be frequently observed in others. It is impossible to say whether this portion of the ornamentation was not originally present, or whether its absence arises from wear either in the natural state or subsequent to fossilization.

In beds where this species is abundant there is a certain amount of variation from the type in the strength, disposition, and number of the ornamenting threads, and I here note under distinct names two well-marked varieties. A fragment of one (Pl. III, fig. 9) is preserved in the Ure Collection; six whorls are intact and have a length of 2 mm., width of about 1 mm. There are six or seven threads on the convex part of the whorl, rather finer than those on the type, and with narrower spaces between, with the exception of the uppermost space, which is wider and is about equal to that next above on the flat part of the whorl; in other respects this variety is similar to the type. I would suggest for it the name *varians*.

The other variety has the threads separated by wider spaces above and below, with a band of two or three fine threads separated by narrower spaces between. Otherwise it agrees with the type. It may be called *cingulata* (Pl. III, figs. 10 & 10 *a*).

A small specimen (Pl. III, figs. 7 *a*, *b* & *c*) in Mr. John Smith's collection from Crawfield has the protoconch entire; the whole shell is contorted, and the apex is much worn. The protoconch is more or less orbicular, smooth, and detached from the highest whorl of the spine on the umbilical region. Its junction with the conch is indicated by a faint rib, but the commencement of the spiral threads is not seen.

The spiral angle also varies to some extent.

Loxonema polygyra, M'Coy (Pl. III, fig. 11), is probably identical with this species and more nearly agrees with the type than the varieties. There is but one specimen in the Museum of Science and Art, Dublin. It is partly embedded in the matrix of shale, and consists of eleven whorls in a length of $4\frac{1}{4}$ mm. It occurs in arenaceous shale at Cullion, Draperstown, about the horizon of the lower part of the Carboniferous Limestone.

Locality and Horizon.—The largest specimen (Pl. III, figs. 6 & 6 *a*) is from the Carboniferous rocks (d^3) at Penton; it consists of thirteen whorls, the apex is broken, and there are traces of three additional whorls in the matrix. Its length = 8 mm., width = $2\frac{1}{2}$ mm. I have also several smaller specimens from the same locality. Other examples are found in the Lower Limestone Series (d^3) at Law, Craigenglen, Capelrig, High Blantyre, and Brankam Hall; this last place is the 'Laurieston' of Ure. It occurs in the Upper Limestone Series (d^3) at Glencart, Dalry, and at Boghead, Hamilton; also in the Calciferous Sandstone (d^2) at Randerstone, Fife.

The variety *varians* is from the Lower Limestone Series (d^3) at Craigenglen and Capelrig, as well as from Laurieston. The variety *cingulata* is found in the Lower Carboniferous at Penton; the Lower Limestone Series (d^3) at Craigenglen, Crawfield, and Capelrig; and also in the Upper Limestone Series (d^3) at Glencart and Boghead. A specimen from Penton measures $5\frac{1}{2}$ mm. in length and $1\frac{3}{4}$ mm. in width. Another individual (Pl. III, figs. 10 & 10 *a*) is from Glencart. Its length = 3 mm.

ACLISINA COSTATULA, Don. (Pl. III, figs. 12–15.)

Aclisina costatula, J. Donald, 1885, 'Carb. Gaster. from Penton, etc.' Trans. Cumberl. & Westmorl. Assoc. no. ix, p. 133 & pl. ii, figs. 5 & 5 *a*.

Terebra or *Turbo clavicula longissima* (pars), D. Ure, 1793, 'History of Rutherglen & E. Kilbride,' p. 308, pl. xiv, fig. 11.

Turritella elongata (pars), J. Fleming, 1828, 'Brit. Animals,' p. 305.

Description.—Shell small, slender, conical, composed of about fourteen whorls in the adult. The protoconch consists of about one complete smooth revolution, nearly orbicular in outline, detached from the highest whorl of the spire below, with which it forms an acute angle; its junction with the conch is indicated by a faint rib. Whorls more or less convex, increasing gradually. The lower part of the whorl is ornamented by five threads; the two upper are generally the strongest, but sometimes the third is equally strong; the lowest is the finest, and is frequently hidden beneath the suture on the higher whorls; there are occasionally one or two additional fine threads on the body-whorl. On the upper part of the whorl there is a fine thread below the suture, which is sometimes absent; the widest space lies between it and the uppermost of the five threads. Aperture rounded. Columella simple, nearly straight. Inner lip reflected on the body-whorl. Base convex. Umbilicus closed.

Resemblances.—This shell resembles *A. elongata*, Flem., but the keels with which it is ornamented are stronger and less numerous, and the spiral angle is smaller. It also bears a likeness to *A. pulchra* var. *intermedia*, but is still more slender and less robust. It is somewhat similar to *A. bellilineata*, Miller; the figure of this species is not, however, sufficiently distinct for accurate comparison.

Locality and Horizon.—My own collection contains five specimens from the Lower Carboniferous of Penton, the largest of which consists of twelve whorls, whose length = 6 mm. The specimen figured (Pl. III, fig. 12) has the surface better preserved; its apex is broken, and only nine whorls remain, of which the length = 5 mm., width = barely $1\frac{1}{2}$ mm. Other examples occur in the Lower Limestone Series (d^3) at Law, Dalry; Capelrig; Craigenglen; Cunninghambaidland; High Blantyre; and Brankam Hall. There are several fragments of this species in Ure's collection at the Royal Society's rooms, Edinburgh. A specimen (Pl. III, figs. 13, 14 *a*, *b* & *c*) from Law, in the collection of Dr. Hunter-Selkirk, is remarkable for having the protoconch preserved, but the surface is much worn; it consists of thirteen whorls in a length of barely $4\frac{1}{2}$ mm., and its width equals rather less than 1 mm. An individual from the same locality in Mr. Bennie's collection consists of fourteen whorls; its length is nearly $4\frac{1}{2}$ mm. Though the aperture is very imperfect, it appears to give evidence of the reflection of the inner lip on the body-whorl.

This species also occurs in the Upper Limestone Series (d^3) at Glencart, Dalry.

There is a distinct variety which has a smaller spiral angle and more elongated form, for which I would suggest the varietal name *dubia*. The largest specimen of it figured (Pl. III, fig. 15) is from Craigenglen, in the collection of Mr. Thomson; it has seven whorls preserved, the apex being broken, and measures $6\frac{1}{2}$ mm. in length and 2 mm. in width. I have a much smaller example in my own collection from the neighbourhood of Glasgow: its length = $2\frac{1}{4}$ mm., width = $\frac{3}{4}$ mm.; it shows the reflection of the inner lip. These specimens, as well as others from East Kilbride and Cunninghambaidland, occur in the Lower Limestone Series (d^3).

A small fragment from the Upper Limestone Series, Glencart, which is probably this variety, has a portion of the protoconch preserved; it shows that the ornamenting threads commence on the conch immediately after its junction with the protoconch.

ACLISINA SIMILIS, sp. nov. (Pl. III, fig. 16, & Pl. IV, fig. 1.)

Description.—Shell elongated, conical, composed of more than eight whorls. Whorls increasing gradually, flattish in outline, barely convex. Ornamentation consisting of five strong threads near the middle of the whorl, and two or three finer ones below, with several additional fine threads on the body-whorl; the spaces between the strong threads are the widest. Sutures moderately deep. Aperture subovoid. Columella simple, nearly straight. Base convex, imperforate.

Resemblances.—This species bears some likeness to *A. pulchra* in the character of the ornamentation, but it is distinguished by its more elongated form, flatter whorls, and smaller spiral angle.

Dimensions.—There are six specimens in Mr. Bennie's collection. The largest (Pl. IV, fig. 1) has both apex and base broken, leaving seven and a half whorls, whose length = about $8\frac{3}{4}$ mm., width $=2\frac{1}{2}$ mm. The smaller example (Pl. III, fig. 16) has five whorls preserved, of which the length =5 mm., width $=1\frac{1}{2}$ mm.; its whorls are slightly more exsert, and therefore appear higher in proportion to the width than the others.

Locality and Horizon.—Law, Dalry, in the Lower Limestone Series (d^3). Mr. Neilson possesses one specimen from the Upper Limestone Series of Glencart, Dalry (d^3).

A shell in the collection of M. Destinez at Liége, from Visé, strongly resembles this species; the lines of growth are distinctly preserved on it, and are those characteristic of the genus, being sigmoidal, and coming prominently forward below.

ACLISINA ATTENUATA, sp. nov. (Pl. IV, figs. 2 & 3.)

Terebra or *Turbo clavicula longissima* (pars), D. Ure, 1793, 'History of Rutherglen & E. Kilbride,' p. 308 & pl. xiv, fig. 11.

Turritella elongata (pars), J. Fleming, 1828, 'Brit. Animals,' p. 305.

Description.—Shell slender, elongated, composed of more than nine whorls. Whorls rather wide in proportion to the height, convex below, flat or slightly concave above, increasing very gradually. Whorls ornamented on the lower two-thirds by five raised threads, the two uppermost of which are the strongest and furthest apart; there are several additional fine threads on the body-whorl; the upper third of the whorl is smooth, or sometimes there is a very fine thread near the middle. Sutures not much inclined. Base convex. Aperture rounded. Columella nearly straight, slightly thickened.

Remarks.—None of the specimens that I have examined have the protoconch entire. One has a small portion preserved showing the junction with the conch, upon which the ornamenting threads commence almost immediately.

Resemblances.—This shell strongly resembles *A. elongata* var. *varians* in its ornamentation, but the space between the two strongest threads is greater, and the fine threads below are not so numerous. It also differs in having a smaller spiral angle. It bears some likeness to *A. costatula* in its slender form, but the two upper threads are much stronger in comparison with the lower ones. It appears to be a well-marked form intermediate between these two species.

Locality and Horizon.—There are six specimens in the Ure Collection in the rooms of the Royal Society of Edinburgh. One has five whorls preserved whose length =2 mm., width = rather less than 1 mm. There are specimens from High Blantyre in my own collection, given me by Dr. Young, and in Dr. Hunter-Selkirk's collection from East Kilbride. The latter also possesses examples from Brankam Hall. In the collection of Mr. Neilson there are several individuals from Capelrig. All the above are from the Lower Limestone Series (d^3). It also occurs in the Upper Limestone Series (d^3) at Glencart and at Gare near Carluke. Dr. Hunter-Selkirk and Dr. Young have specimens in their collections from the former locality, and I also have some given me by Dr. Young, one of which is figured (Pl. IV, fig. 2); it has nine whorls preserved, and its length $=3$ mm., width $=\frac{3}{4}$ mm.

ACLISINA ACICULATA, sp. nov. (Pl. IV, figs. 4–6.)

Description.—Shell slender, very elongated, composed of about fifteen gradually-increasing whorls. Whorls convex, the lower two-thirds ornamented by four or five sharp raised threads; the lowest of these threads appears just above the suture on the anterior part of the spire, but is hidden on the posterior part; there is sometimes an additional fine thread below on the body-whorl, and also one above just below the suture. The spaces vary slightly in width on different individuals: on some the widest is that between the third and fourth threads, on others it is between the fourth and fifth, while on others again the three lower spaces are nearly equal and the uppermost is narrower. Lines of growth sigmoidal and very oblique. Sutures deep. Aperture rounded, inner lip reflected on the body-whorl. Columella nearly straight, slightly thickened. Base convex, imperforate.

Resemblances.—From *A. costatula* this species is distinguished by its very attenuated form, by the greater convexity of the whorls, and by the ornamenting threads being finer and sharper. A young specimen (Pl. IV, figs. 6 *a*, *b* & *c*) having the protoconch entire is so much worn that it is impossible to state whether it should be referred to this species or to *A. costatula*. The protoconch is more orbicular and less inclined than that of the only example of *A. costatula* with which I am acquainted, but it does not differ from it more than different specimens of *A. pulchra* var. *tenuis* from each other. *A. aciculata* also resembles the Devonian species *A. longissima*, Whidborne, in its slender form, but the threads are not so evenly disposed over the surface of the whorl. I am uncertain whether some very elongated shells from Law collected by Mr. Bennie should be identified with this species or not; the whorls are rather more angular, and there are only four threads visible on them, with nearly equal spaces between, and a very fine thread below on the base; but I place them with it for the present. One consists of thirteen whorls, whose length $=4\frac{1}{2}$ mm., width = nearly 1 mm.

Locality and Horizon.—The collection of Dr. John Young contains four specimens from the Upper Limestone Series (d^3) of Gillfoot, Carluke. That figured (Pl. IV, fig. 4) has fifteen whorls in a length of $8\frac{1}{4}$ mm., its width $=1\frac{1}{2}$ mm. In the British Museum (Nat. Hist.) there is a single example of this species (G. 80), of which the locality is not given, but both the fossil and matrix bear a great likeness to those from Gillfoot. This species also occurs in the Lower Limestone Series (d^3) at Craigenglen, Law, and Capelrig. Several from the first-named locality are remarkable for showing the lines of growth distinctly. One is figured (Pl. IV, fig. 5); it consists of five and a half whorls, of which the length $=3\frac{3}{4}$ mm. A specimen from Law in Mr. Bennie's collection possesses fifteen whorls in a length of $4\frac{3}{4}$ mm.; it shows the reflection of the inner lip.

ACLISINA GRANTONENSIS, sp. nov. (Pl. IV, figs. 7–9.)

Murchisonia striatula, De Kon.?, R. Etheridge, Jun., 'Invert. Fauna Lower Carb. or Calcif. Sandst. Series of Edinburgh, etc.' Quart. Journ. Geol. Soc. vol. xxxiv (1878) p. 19 & pl. ii, fig. 29.

Description.—Shell minute, elongated, conical, composed of about ten whorls. Protoconch consisting of about one smooth whorl, partly detached, and forming a considerable angle with the highest whorl of the spire. Whorls convex, slightly flattened above, and more or less angular and prominent near the middle. The lower two-thirds of each whorl ornamented by about nine raised threads, alternately coarse and fine; upper third apparently smooth. Lines of growth distinct, strongly sigmoidal, curving forward below. Sutures deep. Aperture subovoid. Columella simple, nearly straight. Base convex, imperforate.

Resemblances.—This shell was referred, with a query, by R. Etheridge, Jun., to *Murchisonia striatula,* De Kon., but it is quite distinct, being much smaller, having the lines of growth sigmoidal instead of forming a narrow sinus in the outer lip, and the protoconch also of different form. It most resembles *A. tenuistriata*; the whorls, however, are less convex, and the fine threads with which it is ornamented do not form bands, but alternate more or less regularly with the coarser threads. It is remarkable for having the protoconch well preserved, there being eighteen specimens showing it in Mr. Bennie's collection. Its junction with the conch can generally be discerned, but the surface is too much worn to show where the ornamentation begins. The form of the protoconch resembles that of *A. pulchra* var. *tenuis.*

Dimensions.—The specimen figured (Pl. IV, fig. 7) consists of ten whorls, whose length $=4$ mm. and width $=1\frac{1}{4}$ mm.; it is in the Geological Survey Collection, Museum of Science & Art, Edinburgh, where six more examples are shown. The same museum contains the specimen figured by Mr. Etheridge and two others in the General Collection. Other individuals would be larger if entire; one in Mr. Bennie's collection has five whorls in a length of $3\frac{1}{4}$ mm., and its width $=1\frac{3}{4}$ mm. The protoconch is figured (Pl. IV, figs. 9 *a*, *b* & *c*) from shells in his collection.

Locality and Horizon.—It is very abundant in the Calciferous Sandstone Series (d^2) at Woodhall, near Edinburgh.

ACLISINA TENUISTRIATA, sp. nov. (Pl. IV, fig. 10.)

Aclisina striatula, J. Donald, 1885, 'Carb. Gaster. from Penton, etc.' Trans. Cumberl. & Westmorl. Assoc. no. ix, p. 131 & pl. ii, figs. 2 & 2 *a.*

Description.—Shell small, conical, composed of about ten convex whorls. Ornamentation consisting of numerous spiral threads and grooves; on the five or six earlier whorls the threads are fewer and stronger, but on the lower two-thirds of the later whorls they are finer and more numerous, being from ten to twelve in number; the grooves also vary in width, a variation which gives the whorl a banded appearance. Sutures deep. Base convex.

Resemblances.—In my paper in Trans. Cumberl. & Westmorl. Assoc. I confounded this shell with *A. striatula*, De Kon., the type of which I had not then seen, but I am now convinced that this is quite a distinct form. Young specimens might be taken for *A. elongata* from the resemblance in the arrangement and number of the threads; but the fine banded appearance of the later whorls is very distinctive; the whorls also appear to be more convex. Nevertheless this may possibly be a variety of that very variable species, especially as there are forms which appear intermediate between the var. *cingulata* and *A. tenuistriata*. It is distinguished from *A. grantonensis* by its more evenly convex whorls and by the fine threads not being so regularly intercalated between the coarser ones. The apex of all the specimens that I have seen is broken.

Locality and Horizon.—The specimen figured (Pl. IV, fig. 10) is from the Lower Carboniferous rocks at Penton; it has ten whorls preserved, and its length = 5 mm.; its width = $1\frac{1}{2}$ mm. One other example occurs in the Lower Limestone Series (d^3) at Law, Dalry. It is in the collection of Mr. Bennie, and it possesses eight whorls, whose length = 2 mm.

Aclisina quadrata, sp. nov. (Pl. IV, figs. 11, 11 *a*, 12, 12 *a* & *b*.)

Description.—Shell elongated, slender, composed of thirteen whorls. Whorls increasing gradually, moderately convex, slightly quadrate in form: the lower whorls are rather high in proportion to the width, and the upper are wider. Ornamentation consisting of numerous fine threads and grooves, about fifteen in number on the penultimate whorl, with several more on the base. Two or three grooves near, or immediately below, the middle of the whorl are wider than the others; the threads and grooves are more equal and less numerous on the higher part of the spire. Sutures deep, moderately oblique. Aperture longer than wide. Columella slightly thickened, rather oblique.

Remarks.—The surface of the upper part of the whorl is not well preserved, and the threads on it are faint or absent altogether.

I know of only two specimens of this species. The finest (Pl. IV, fig. 11) is in Mr. Bennie's collection; it consists of thirteen whorls, whose length = $5\frac{1}{2}$ mm., width = $1\frac{1}{3}$ mm. The other belongs to Mr. Smith and possesses only nine and a half whorls, both apex and base being broken: its length = $4\frac{1}{2}$ mm.

A more slender form, which appears to be a variety of this species, occurs in the same locality and is more abundant. It is distinguished by being less compactly coiled, by having the whorls more exsert and consequently higher in proportion to the width. A specimen in Dr. Hunter-Selkirk's collection has the protoconch entire; it is figured in Pl. IV, fig. 12, and consists of ten whorls in a length of $3\frac{1}{4}$ mm. The protoconch (Pl. IV, figs. 12 *a* & *b*) is composed of little more than one smooth revolution, coiled somewhat obliquely and rather overhanging the highest whorl of the conch, but not detached from it nor standing as erect as in some species; its junction with the conch is marked by a slight rib, but the surface is too much worn to show where the ornamentation begins.

The largest example is in Dr. Hunter-Selkirk's collection; both apex and base are broken, leaving only nine whorls, which measure 5 mm. in length. Besides these Dr. Hunter-Selkirk possesses two other specimens, Mr. Bennie and Mr. Smith each two, and I one, which was given to me by Dr. Young. The last-named shell is imperfect, but six whorls are left, which measure $3\frac{1}{4}$ mm. I would suggest the name *striatissima* for this variety.

Resemblances.—Both the type and variety somewhat resemble *A. elongata* var. *cingulata*, but the whorls are higher and less compactly coiled, the ornamenting threads are finer, and the protoconch is less elevated. It may be distinguished from *A. tenuistriata* by having higher whorls, and by the fine threads continuing all over the conch, instead of being coarser on the earlier whorls.

Locality and Horizon.—Lower Limestone Series (d^3), at Law, Dalry.

ACLISINA ELEGANTULA, sp. nov. (Pl. IV, figs. 13, 13 *a*, *b* & *c*.)

Description.—Shell elongated, composed of about thirteen gradually-increasing whorls. Apex blunt; protoconch consisting of little more than one smooth whorl, slightly raised from the highest whorl of the conch. Whorls convex and rather ventricose, ornamented by eight raised threads almost equally disposed, the two uppermost finer and placed a little nearer together than the others; one or two additional threads on the body-whorl. Sutures deep. Aperture subovoid. Inner lip reflected on the body-whorl. Columella slightly thickened, nearly straight. Base convex, imperforate.

Resemblances.—This species may be distinguished from *A. elongata* by the whorls being higher in proportion to the width, less flattened above and slightly ventricose, the sutures more oblique, the ornamenting threads differently disposed, and the protoconch more depressed.

Remarks.—In the collections of Mr. Bennie and Mr. John Smith there are numerous specimens. The collection of the latter contains the largest (Pl. IV, fig. 13); this consists of twelve whorls, whose length $=10\frac{1}{2}$ mm., width$=2\frac{3}{4}$ mm. The usual size appears to be about half this. Five examples in Mr. Bennie's and one in Mr. Smith's collection have the protoconch preserved; they are all much worn, so that the junction with the conch is very indistinct, and the point of commencement of the ornamentation is not seen. Two specimens belonging to Mr. Bennie are remarkable for having the axis of the upper part of the spire bent at a small angle to the lower part.

Locality and Horizon.—The specimens mentioned above are all from Law, Dalry, in the Lower Limestone Series (d^3). Mr. James Thomson has two examples from Cunninghambaidland.

ACLISINA PUSILLA, sp. nov. (Pl. IV, figs. 14, 14 *a*, *b*, & 15.)

Description.—Shell slender, conical, composed of eleven convex whorls. Protoconch consisting of one smooth whorl, coiled on the same plane as the rest of the spiro and not detached from it. Whorls increasing gradually, ornamented by six or seven raised threads, with an additional one on the body-whorl; the uppermost thread is generally the finest. The spaces between are about equal with the exception of that between the two upper threads, which is rather narrower. Sutures deep. Aperture rounded. Inner lip reflected on the body-whorl. Columella simple, slightly thickened. Base convex, imperforate.

Resemblances.—This species differs from *A. elegantula* in having a smaller spiral angle, fewer ornamenting threads, more evenly convex whorls, and a more depressed protoconch. It greatly resembles *A. parvula*, but is distinguished by being more slender and having finer threads.

Locality and Horizon.—The collections belonging to Dr. Hunter-Selkirk, Dr. Young, Mr. Smith, Mr. Bennie, Mr. Neilson, and myself all contain specimens of this species. The largest example belongs to Mr. Neilson; its apex and base are both broken, leaving only six whorls whose length $= 4\frac{1}{2}$ mm. A portion of one whorl is figured in Pl. IV, fig. 15. It is from the Upper Limestone Series (d^3) at Glencart, Dalry. Some of the best-preserved examples are from the Lower Limestone Series (d^3) at Law, Dalry; four have the protoconch intact (Pl. IV, figs. 14 *a* & *b*). That figured (Pl. IV, fig. 14) is in Mr. Smith's collection; it consists of eleven whorls, and is 4 mm. in length.

External casts of this species also occur in an impure limestone (the Shell Bed) of Yoredale age, at Widdle Fell, Wensleydale.

ACLISINA TEREBRA, sp. nov. (Pl. IV, figs. 16 & 16 *a*).

Description.—Shell slender, very elongated, composed of more than ten whorls. Whorls moderately convex, bead-like, high in proportion to the width, increasing very gradually. Ornamentation consisting of seven raised threads; the lowest appears just above the suture, and is invisible on the higher whorls; the two upper threads are finer and somewhat nearer together than the lower. Sutures moderately deep. Aperture and apex unknown.

Resemblances.—There is a great likeness between this species and *A. pusilla*, but it is more attenuated and the whorls are less convex; nevertheless it may possibly be a variety. It resembles *A. aciculata* in its elongated slender form, but may be distinguished by the difference in ornamentation and by the whorls being less convex and higher.

I know of only one specimen, which is in the collection of Dr. John Young. It is imperfect, both apex and base being broken; the eight and a half whorls which remain measure 7 mm. in length; width $=1\frac{1}{4}$ mm.

Locality and Horizon.—Crawfield Quarry, Beith. Lower Limestone Series (d^3).

Aclisina parvula, sp. nov. (Pl. V, figs. 1, 2, 2 *a*, *b* & *c*.)

Description.—Shell conical, elongated, composed of about ten whorls. Apex blunt, protoconch consisting of one smooth revolution coiled on the same plane as the rest of the spire, and adhering to the highest whorl of the conch. Whorls convex, wide in proportion to the height, ornamented by six or seven raised threads separated by nearly equal spaces; uppermost thread sometimes absent; one or two additional threads on the body-whorl. Sutures slightly inclined. Aperture subovoid. Columella simple, slightly thickened. Base convex, imperforate.

Resemblances.—This species greatly resembles *A. pusilla*, but it differs in having a greater spiral angle, and in having fewer and stronger ornamenting threads. It may be distinguished from *A. elongata* by having fewer threads, and in the protoconch adhering to the spire instead of being raised from it.

Locality and Horizon.—There are five specimens from Law in the collection of Mr. Bennie, only one of which has the protoconch entire (Pl. V, figs. 2 *a*, *b* & *c*). The largest consists of ten whorls: its length $=3\frac{1}{2}$ mm. That figured (Pl. V, fig. 1) is from Crawfield, and was given to me by Dr. Young; it possesses nine whorls, whose length = 3 mm., width = 1 mm. From the Lower Limestone Series (d^3).

? Aclisina sulcatula, M'Coy. (Pl. V, fig. 3.)

Loxonema sulcatula, F. M'Coy, 1844, 'Syn. Char. Carb. Foss. Irel.' p. 30 & pl. v, fig. 6; H. G. Bronn, 1848, 'Index Palæont.' p. 670; J. Armstrong, J. Young, & D. Robertson, 1876, 'Cat. W. Scot. Foss.' p. 56; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 325; R. Etheridge, 1888, 'Foss. Brit. Is.' vol. i, Palæozoic, p. 300.

Description.—Shell elongated, conical, composed of seven or eight convex whorls, increasing at a moderate rate. Whorls ornamented by five strong spiral threads, with numerous finer additional threads below on the body-whorl. Sutures deep. Aperture subovoid. Columella simple, slightly thickened. Base convex.

Remarks.—This species is represented only by three more or less imperfect external casts, and the figures are drawn from wax impressions. M'Coy refers it to *Loxonema*, but it has not the characteristic longitudinal ribs of that genus nor the adpressed whorls; the spiral threads also serve to distinguish it. He describes it as having 'about ten equal spiral sulci,' but the best-preserved specimens only show four or five, which are separated by the same number of strong raised threads. One specimen, of which the surface is much worn, appears to show traces of finer threads intercalated between the coarse ones. The lines of growth are very indistinct, so that it is impossible to refer it to any genus with certainty, and I merely place it in *Aclisina* provisionally and reproduce the figures for the sake of comparison with other forms.

The largest shell shows about eight whorls, whose length = 14 mm., width = 5 mm.

The specimens are in the Museum of Science and Art, Dublin.

Locality and Horizon.—Carrickroughter, Kesh. Yellow Sandstone (d^3).

Subgenus Rhabdospira nov.

Shell of moderate size, conical, composed of numerous convex whorls, which are ornamented by spiral threads or keels. Outer lip, as indicated by the lines of growth, very slightly sigmoidal. Aperture and protoconch unknown.

Resemblances.—This subgenus greatly resembles the genus *Aclisina* in form and ornamentation, but it is distinguished from that genus by the contour of the outer lip, which is much less sigmoidal and not so prominently produced in front.

I know of only two species which are referable to it, and they occur as external casts, so the whole structure of the shell itself is unknown. These species are *Rh. compacta* and *Rh. Selkirkii.* The outer lip of *Rh. compacta* is still less sigmoidal than that of *Rh. Selkirkii*, and none of the whorls are plicated as in that species. These distinctions are hardly sufficient to warrant their separation in different genera, especially as our knowledge of them is incomplete. I therefore group them together for the present.

Rhabdospira Selkirkii, sp. nov. (Pl. V, fig. 4.)

Description.—Shell elongated, turreted, composed of numerous whorls, which are convex, very prominent in the middle, high in proportion to the width, gradually increasing. Ornamentation consisting of eight strong raised threads with nearly equal spaces between, except in the middle of the whorl, where the space is rather wider and has either two or three finer threads down it; there is also a fine thread intercalated in one space above and two spaces below the middle. Sutures deep. Lines of growth somewhat sigmoidal, and but slightly arched below. On the penultimate whorl there are faint ribs or plications following the course of the lines of growth. Aperture and protoconch unknown.

Resemblances.—There is but one specimen of this species, which is in the collection of Dr. Hunter-Selkirk, and it is a mould of the external form in limestone. In appearance it somewhat resembles *Aclisoides striatula*, De Kon., but the lines of growth show no indication of a sinus in the outer lip, the whorls are more convex and the sutures deeper. The figure (Pl. V, fig. 4) is drawn from a wax impression; there are but four whorls and a portion of a fifth, the length $= 16\frac{1}{2}$ mm., width $= 7\frac{1}{4}$ mm. The highest whorl appears narrower than it really is, through not being wholly preserved.

Locality and Horizon.—'Main Lime,' Lower Limestone Series (d^3), Braidwood, Carluke.

RHABDOSPIRA COMPACTA, sp. nov. (Pl. V, figs. 5 & 5 *a*.)

Description.—Shell conical, of moderate size, composed of about eight whorls. These are convex, broad, compactly coiled, ornamented by seven strong raised threads, with nearly equal spaces between, and two additional threads below on the body-whorl. Sutures rather deep. Lines of growth curved, scarcely sigmoidal, coming almost direct down the whorl. Base convex. Aperture and protoconch unknown.

Resemblances.—This species occurs as an external mould in an impure limestone. It bears more resemblance to *Aclisina (?) sulcatula*, M'Coy, than to any form I know, but the threads with which it is ornamented are more numerous and less strong, also there are not so many fine additional threads on the body-whorl.

The specimen figured in Pl. V, fig. 5, is in the Museum of Practical Geology, London; it is drawn from a wax impression, and measures $10\frac{1}{4}$ mm. in length, $4\frac{1}{4}$ mm. in width.

Locality and Horizon.—Hollin Gill, Hawes, Wensleydale. Yoredale Rocks (d^3).

Family Murchisoniidæ, Koken.

Genus MURCHISONIA, D'Arch. & De Vern.

Section ACLISOIDES, Donald.

(For the synonymy, see p. 67.)

Description of the Section.—Shell small, elongated, conical, composed of numerous whorls. Protoconch smooth, simply coiled on the same plane as the rest of the spire. Whorls moderately convex, spirally striated. Aperture ovoid, outer lip as indicated by the lines of growth possessing a sinus, towards which the lip retreats above and from which it arches forward below. Base convex. Umbilicus closed.

Dimensions.—The length of the British species varies from 2 or 3 up to 16 mm.; as none of the specimens that I have seen are entire their dimensions would probably be greater if perfect. De Koninck states that the Belgian forms attain 3 cm. in length. The specimen in the Brussels Museum marked as the type of *A.* [*Murchisonia*] *striatula* is only $9\frac{1}{2}$ mm. in length.

Resemblances.—This section or subgenus may be distinguished from the typical *Murchisoniæ* by possessing more convex, bead-like whorls, ornamented by numerous spiral threads, by the filling up of the sinus in the outer lip not giving rise to so distinct a band, for the sinus merely occupies the space between two or three of the ornamenting threads. In this latter particular it is most like the section *Hypergonia*, from which it differs in having less angular whorls and in the sinus being situated on the widest part of the whorl, instead of above it. In general appearance it comes very near some of the recent *Turritellæ*, especially such forms as *T. accisa*, Watson, and *T. runcinata*, Watson, where the sinus merely lies between the ornamenting carinæ, not forming a distinct band; but the aperture is different here, being more quadrangular, and the whorls also differ in being flatter.

MURCHISONIA [ACLISOIDES] STRIATULA, De Kon. (Pl. V, figs. 6–8).

Turritella striatula, L. G. De Koninck, 1843, 'Préc. Elém. de Géologie,' par J. J. d'Omalius d'Halloy, p. 516.

Murchisonia striatula, L. G. De Koninck, 1843, 'Descr. Anim. Foss. Terr. Carb. Belg.' p. 415 & pl. xl, fig. 7; H. G. Bronn, 1848, 'Index Palæont.' pt. i, p. 748; A. d'Orbigny, 1850, 'Prodr. Paléont. Stratigr.' vol. i, p. 122; ? J. Armstrong, J. Young, & D. Robertson, 1876, 'Cat. W. Scot. Foss.' p. 56; J. J. Bigsby, 1878, 'Thes. Dev.-Carb.' p. 327; R. Etheridge, 1888, 'Foss. Brit. Is.' vol. i (Palæozoic) p. 302.

Aclisina striatula, L. G. De Koninck, 1881, 'Faune Calc. Carb. Belg.' vol. vi, pt. iii, p. 86 & pl. ix, figs. 57 & 58; 1883, vol. viii, pt. iv, pl. xxxiii, figs. 41 & 42.

Description.—Shell elongated, conical, composed of more than ten whorls. Protoconch consisting of one smooth, convex whorl, simply coiled on the same plane as the rest of the spire. Whorls moderately convex below, flat above. Ornamented by nine or ten raised threads of irregular strength, separated by grooves varying in width; there are several additional threads on the body-whorl. Sutures not very deep. The lines of growth indicate the existence of a sinus in the outer lip of moderate depth, situated on the widest part of the whorl, near the middle of the body-whorl, but rather below the middle on the whorls of the spire. It lies between two threads, with generally a third thread between them. Aperture ovoid. Base produced, convex. Umbilicus closed.

Remarks.—There is always more or less variation in the strength and arrangement of the ornamenting threads on different individuals; as a rule the lower threads are the strongest, and the spaces between them the widest, but sometimes finer threads are intercalated. The depth of the suture also differs, as some individuals are less compactly coiled than others; this is especially noticeable in two specimens from Visé in the British Museum (Nat. Hist.), where the sutures are deeper than usual, owing to the whorls being more exsert.

Resemblances.—*Micrentoma nana* resembles this species to a certain degree in the form of the whorls and in the compactness of the spire, but it differs in not possessing a deep sinus on all the whorls, in having the threads strongly crenulated, and in the threads being more equal in strength and less numerous.

Locality and Horizon.—There are nine specimens in the Woodwardian Museum, Cambridge, from the Carboniferous Limestone (d^2) of Settle. The largest of these has the apex broken, leaving seven whorls, which have a length of 16 mm. That figured (Pl. V, fig. 6) also has the apex broken; six and a half whorls remain, whose length $=12$ mm., width $=4\frac{1}{4}$ mm. The body-whorl of another is figured (Pl. V, figs. 7 & 7 *a*) to show the lines of growth. In the British Museum (Nat. Hist.) there is a portion of a shell from Settle consisting of four and a half whorls; also three specimens of which the locality is not known: they bear a great resemblance to the other example, and are probably from the same place.

This species also occurs in the Lower Limestone Series (d^3) at Craigenglen, and in the Upper Limestone Series (d^3) at Glencart, Dalry. These shells are much smaller than the English and Belgian specimens. One (Pl. V, figs. 8 & 8 *a*) from the former locality is remarkable for having the protoconch entire; the apex is somewhat worn, so that the junction of the protoconch is not very distinct, and the point of commencement of the ornamentation is not shown.

De Koninck states that this species also occurs at Gare, Orchard, Robroyston, Swindridge, and Auchenbeg, but I have not met with it from any of these places, and I therefore think that he has probably confounded it with *Aclisina pulchra*, var. *tenuis*, of which I have seen specimens from the three latter localities.

In Belgium it is found at Visé (Assise VI), from which locality there are examples in the British Museum (Nat. Hist.), Brussels Museum, Liége Museum, and the collection of M. Destinez at Liége.

The validity of this species rests upon the examination of about thirty specimens.

Aclisoides striatula, var. Armstrongiana. (Pl. V, figs. 9 & 10.)

Description.—Shell elongated, conical, composed of about eight whorls. These are flat above, convex below, slightly angular a little below the middle. Whorls ornamented by about nine nearly equal raised threads separated by equal spaces, with several additional threads on the body-whorl; two or three of the upper threads are absent on some specimens. The lines of growth curve backward above, form a sinus of moderate depth, and then curve forward below. The sinus is situated on the widest part of the whorl, in the space occupied by three of the threads, there being a thread on each side of it and one down the middle. Sutures deep. Aperture longer than wide. Columella nearly straight, slightly thickened. Base convex.

Resemblances.—This shell resembles *A. striatula* so much that I am more inclined to regard it as a variety of that species than as a distinct species itself. The general form of the whorls and sinus are similar. It differs in the whorls being rather more angular and prominent in the middle, in having deeper sutures, and in the ornamenting threads being equal in strength with the exception of those bordering the sinus, which are generally slightly stronger. This species is also somewhat like *Murchisonia dalryensis*, Don.[1] in the contour of the whorls, but the ornamenting threads are differently disposed. An enlarged portion of a whorl of *M. dalryensis* is figured (Pl. V, fig. 11) for comparison. *M. dalryensis* probably has greater

[1] 'Notes on the Genus *Murchisonia* & its Allies,' Quart. Journ. Geol. Soc. vol. li (1895) p. 224 & pl. ix, fig. 3.

affinity with *Aclisoides* than with *Murchisonia* sensu stricto, but the only known specimen is not sufficiently well preserved to decide with certainty.

Locality and Horizon.—Three specimens have been collected by Mr. Bennie at Law, Dalry, one of which (Pl. V, fig. 9) has eight whorls preserved, but the apex is broken; its length =10 mm., width =3 mm. Dr. Young (Hunterian Museum) and Mr. Neilson have several specimens, and I possess one given me by Dr. Young from Craigenglen. An example (Pl. V, fig. 10) in the Armstrong Collection, Museum of Science & Art, Edinburgh, from the same locality, is of greater size than any of the others, having six whorls preserved with a length of 15 mm., width=6 mm. It is crushed and partially embedded in the matrix; the lower whorls also are so much worn that the ornamenting threads are nearly obliterated. Owing to these defects the whorls appear less angular, and the spiral angle seems somewhat greater, than is the case in the other specimens from the same locality and in those from Law. The last whorl also may have originally been more convex through age; the contour of the higher whorls, however, resembles that of the other individuals, and the ornamentation is exactly the same. This shell is remarkable for showing the lines of growth very distinctly on the whorls that are worn. These are from the Lower Limestone Series (d^3). Dr. Young has also several small specimens from the Upper Limestone Series of Glencart, Dalry (d^3).

In Scotland the varietal form is more abundant than the type, but in England the reverse is the case, for I have not met with a single specimen of the variety there.

Genus Micrentoma nov.

Aclisina, pars L. G. De Koninck, 1881, 'Faune Calc. Carb. Belg.' Ann. Mus. Roy. Hist. Nat. Belg. vol. vi, pt. iii, p. 86.

Description. — Shell conical, composed of numerous whorls. These are flat above, convex below, becoming more convex with increase in age, compactly coiled. Ornamentation consisting of several spiral keels. Lines of growth indicating a shallow notch in the outer lip, which becomes rather deeper near the aperture in the adult. It is situated on the higher part of the whorl, lying between two of the keels, and it never gives rise to the formation of a band. Aperture imperfectly known, probably subovoid. Columella slightly oblique, and thickened. Umbilicus closed.

Resemblances.—This genus most resembles *Murchisonia*, especially the section *Aclisoides*, from which it is distinguished by not having a deep narrow slit in the outer lip, but merely a notch; also the lines of growth do not sweep either backward or forward so strongly. It is somewhat like the genus *Pseudomurchisonia*, Koken,[1] but on it the lines of growth are simply curved on the

[1] 'Die Gastrop. der Trias um Hallstatt,' Jahrb. k.-k. geol. Reichsanst. vol. xlvi (1896) p. 86, figs. 12 & 13.

higher part of the spire; they gradually become sinuated, till on the lower whorls a sinus is formed, the filling up of which produces a band. This band is absent from the higher whorls, which are quite smooth. *Pseudomurchisonia* is further distinguished by having the sinus in the widest part of the whorl.

The type of this genus is *M.* [*Aclisina*] *nana*, De Kon., which is at present the only known species.

Micrentoma nana (De Kon.). (Pl. V, figs. 12 & 13.)

Aclisina nana, L. G. De Koninck, 1881, 'Faune Calc. Carb. Belg.' Ann. Mus. Roy. Hist. Nat. Belg. vol. vi, pt. iii, p. 87 & pl. vii, figs. 29 & 30.

Description.—Shell small, conical, composed of more than nine whorls. Protoconch unknown. Whorls flat above, slightly convex below, becoming more convex as they increase in size. Whorls ornamented by six strong, crenulated spiral threads, only four or five of which are visible on the upper whorls. Crenulations so strong as sometimes to form by their confluence longitudinal ribs, which follow in general the course of the lines of growth. The lines of growth indicate a slight notch in the outer lip, which apparently becomes rather deeper in the mature state; it is situated between the second and the third threads from the upper suture, and there is sometimes a very fine thread down the middle of this space. Sutures of moderate depth. Base convex. Aperture imperfectly known, probably subovoid. Columella simple, slightly oblique, thickened. Umbilicus closed.

Remarks.—I have seen the specimen marked as the type of this species in the Brussels Museum; it is very small, having nine whorls in a length of $3\frac{1}{2}$ mm. It is embedded in the limestone matrix, and somewhat distorted by pressure. It agrees, however, with the British shells referred to this species in character. The locality is Visé (Assise VI). There are also several larger individuals from the same place in the Museum at Liége. On one the longitudinal ribs are so strong on the upper whorls that it somewhat resembles a species of *Loxonema*, but on the last whorl these ribs become less strong, and the lines of growth give distinct evidence of the notch in the outer lip. M. le Chanoine de Dorlodot has a single example from Tournai in his collection.

Resemblances.—This shell resembles *Aclisoides striatula*, De Kon., in general appearance, but it may be distinguished by the whorls being less convex, the ornamenting threads stronger, fewer, and decidedly crenulated, and also by the lines of growth not forming a deep sinus in the outer lip, but merely a notch. It bears a superficial likeness to *Pleurotomaria serrilimba*, Phil.,[1] from which it differs in the spiral threads being more numerous and in possessing a notch in the outer lip.

Locality and Horizon.—There are six specimens in the Museum of Science & Art, Edinburgh, from Park Hill, Derbyshire; the apex and base are imperfect in all. The specimen figured (Pl. V, fig. 13)

[1] 'Geol. Yorks.' vol. ii (1836) p. 228 & pl. xv, fig. 30.

has about five and a half whorls preserved, its length =7 mm., its width =4 mm. The York Museum possesses two individuals from Settle; that figured in Pl. V, fig. 12, has five whorls in a length of 8 mm.; its width $=4\frac{1}{2}$ mm. Another larger specimen, of which the apex is broken, has seven and a half whorls; its length =10 mm., width =5 mm. All from the Mountain Limestone (d^2).

EXPLANATION OF PLATES III–V.

Plate III.

Figs. 1–4. *Aclisina pulchra*, var. *tenuis*, De Koninck. Fig. 1, front view, ×8. Swindridge. Coll. Thomson. Fig. 2. Back view, ×8. Robroyston. Coll. Neilson. Fig. 2 *a*. Whorl of specimen with coarser and fewer striæ, ×12. Craigenglen. Own Coll. Figs. 3 *a* & 3 *b*. Views of protoconch, ×30. Fig. 4. View of aperture showing reflection of lip and lines of growth, ×16. Randerstone, Fife. Coll. Bennie.

Fig. 5. Var. *intermedia*, side view with protoconch, ×16. Fig. 5 *a*. View of protoconch, ×28. Law, Dalry. Coll. Bennie.

Figs. 6–10. *A. elongata*, Fleming. Fig. 6, ×5. Fig. 6 *a*. Portion of whorl of another specimen, ×14. Penton. Own Coll. Figs. 7 *a*, *b* & *c*. Views of protoconch of var. *cingulata*, ×34. Shell contorted. Crawfield. Coll. John Smith. Fig. 8. View of aperture, showing reflection of inner lip, ×20. Law, Dalry. Own Coll. Fig. 9. Var. *varians*, ×16. Ure Coll. Fig. 10. Var. *cingulata*, front view, ×12. Fig. 10 *a*. Portion of whorl enlarged. Glencart, Dalry. Coll. John Young.

Fig. 11. *A. polygyra*, M'Coy. View of type, ×12. Cullion, Draperstown. Museum of Science & Art, Dublin.

Figs. 12–15. *A. costatula*, Donald. Fig. 12. Front view, ×9. Penton. Own Coll. Fig. 13. Back view of specimen with protoconch, ×12. Figs. 14 *a*, *b* & *c*. Protoconch, ×27. Law, Dalry. Coll. Hunter-Selkirk. Fig. 15. Var. *dubia*, back view, ×6. Craigenglen. Coll. Thomson.

Fig. 16. *A. similis*, sp. nov. Front of portion of specimen, ×10. Law, Dalry. Coll. Bennie.

Plate IV.

Fig. 1. *Aclisina similis*, sp. nov., $\times 6\frac{1}{2}$. Law, Dalry. Coll. Bennie.

Figs. 2 & 3. *A. attenuata*, sp. nov. Fig. 2. Back view, ×12. Glencart. Dalry. Own Coll. Fig. 3. View of aperture, ×23. Glencart. Coll. Hunter-Selkirk.

4–6. *A. aciculata*, sp. nov. Fig. 4. Back view, ×6. Fig. 4 *a*. Single whorl of another specimen, ×12. Gillfoot, Carluke. Coll. John Young. Fig. 5. Front view of specimen showing lines of growth, ×12. Craigenglen. Own Coll. Figs. 6 *a*, *b* & *c*. Views of the protoconch of a small specimen doubtfully referred to this species, ×30. Law, Dalry. Coll. Hunter-Selkirk.

7–9. *A. grantonensis*, sp. nov. Fig. 7. Front view, ×12. Geol. Surv. Coll., Museum of Science & Art, Edinburgh. Fig. 7 *a*. Portion of whorl of another specimen showing lines of growth, ×30. Coll. of Museum of Science & Art, Edinburgh. Fig. 8. View of aperture, ×16. Figs. 9 *a* & *c*. Views of protoconch, ×27. Fig. 9 *b*. Protoconch of another specimen, ×27. Woodhall. Coll. Bennie.

Fig. 10. *A. tenuistriata*, sp. nov. Back view, ×10, Penton. Own Coll.

11. *A. quadrata*, sp. nov. Front view, ×10. Fig. 11 *a*. View of aperture, ×16. Law, Dalry. Coll. Bennie.

PLATE IV (*continued*).

Fig. 12. *A. quadrata*, var. *striatissima*. Front view of specimen with protoconch intact, ×16. Figs. 12 *a* & *b*. Views of protoconch, ×26. Law, Dalry. Coll. Hunter-Selkirk.

13. *A. elegantula*, sp. nov. Front view, ×5¼. Coll. John Smith. Figs. 13 *a*, *b* & *c*. Views of protoconch of another specimen, ×27. Coll. Bennie. Law, Dalry.

Figs. 14 & 15. *A. pusilla*, sp. nov. Fig. 14. Front view, ×12. Coll. John Smith. Figs. 14 *a* & *b*. Views of protoconch of another specimen. ×22½. Coll. Bennie. Law, Dalry. Fig. 15. Portion of body-whorl of another specimen to show spiral threads, ×10½. Glencart, Dalry. Coll. Neilson.

Fig. 16. *A. terebra*, sp. nov. ×6. Fig. 16 *a*. View of penultimate whorl, ×12. Crawfield Quarry, Beith. Coll. John Young.

PLATE V.

Figs. 1 & 2. *Aclisina parvula*, sp. nov. Fig. 1. Back view, ×12. Crawfield. Own Coll. Fig. 2. View of aperture. ×26. Figs. 2 *a*, *b* & *c*. Views of protoconch, ×26. Law, Dalry. Coll. Bennie.

Fig. 3. ? *A.* [*Loxonema*] *sulcatula*, M'Coy. Type, drawn from wax impression, ×3. Carrickoughter, Kesh. Museum of Science & Art, Dublin.

4. *Rhabdospira Selkirkii*, sp. nov. Drawn from a wax impression, ×3. Braidwood. Coll. Hunter-Selkirk.

5. *Rh. compacta*, sp. nov. Back view, drawn from a wax impression, ×3. Fig. 5 *a*. View of body-whorl, ×6. Hollin Gill, Hawes, Wensleydale. Museum of Practical Geology, London.

Figs. 6–8. *Murchisonia* [*Aclisoides*] *striatula*, De Koninck. Fig. 6. Front view, ×4. Fig. 7. View of body-whorl of another specimen, ×5. Fig. 7 *a*. Portion of the surface greatly enlarged to show the ornamentation and lines of growth. Settle. Woodwardian Museum. Fig. 8 *a*. View of portion of small specimen with protoconch. Fig. 8. View of same from above, ×21. Craigenglen. Own Coll.

Figs. 9 & 10. *M.* [*A.*] *striatula*, var. *Armstrongiana*. Fig. 9. Front view, ×5. Law, Dalry. Coll. Bennie. Fig. 10, ×3. Craigenglen. Armstrong Coll., Museum of Science & Art, Edinburgh.

Fig. 11. *M. dalryensis*, Donald. Portion of whorl to show the ornamentation, ×10. Dalry. Coll. Thomson.

Figs. 12 & 13. *Micrentoma nana* (De Koninck). Fig. 12. Back view, ×4. Settle. York Museum. Fig. 13. Front view, ×6. Park Hill, Derbyshire. Museum of Science & Art, Edinburgh.

J. Donald del.

Geo. West & Sons lith. et imp.

ACLISINA.

J. Donald del.

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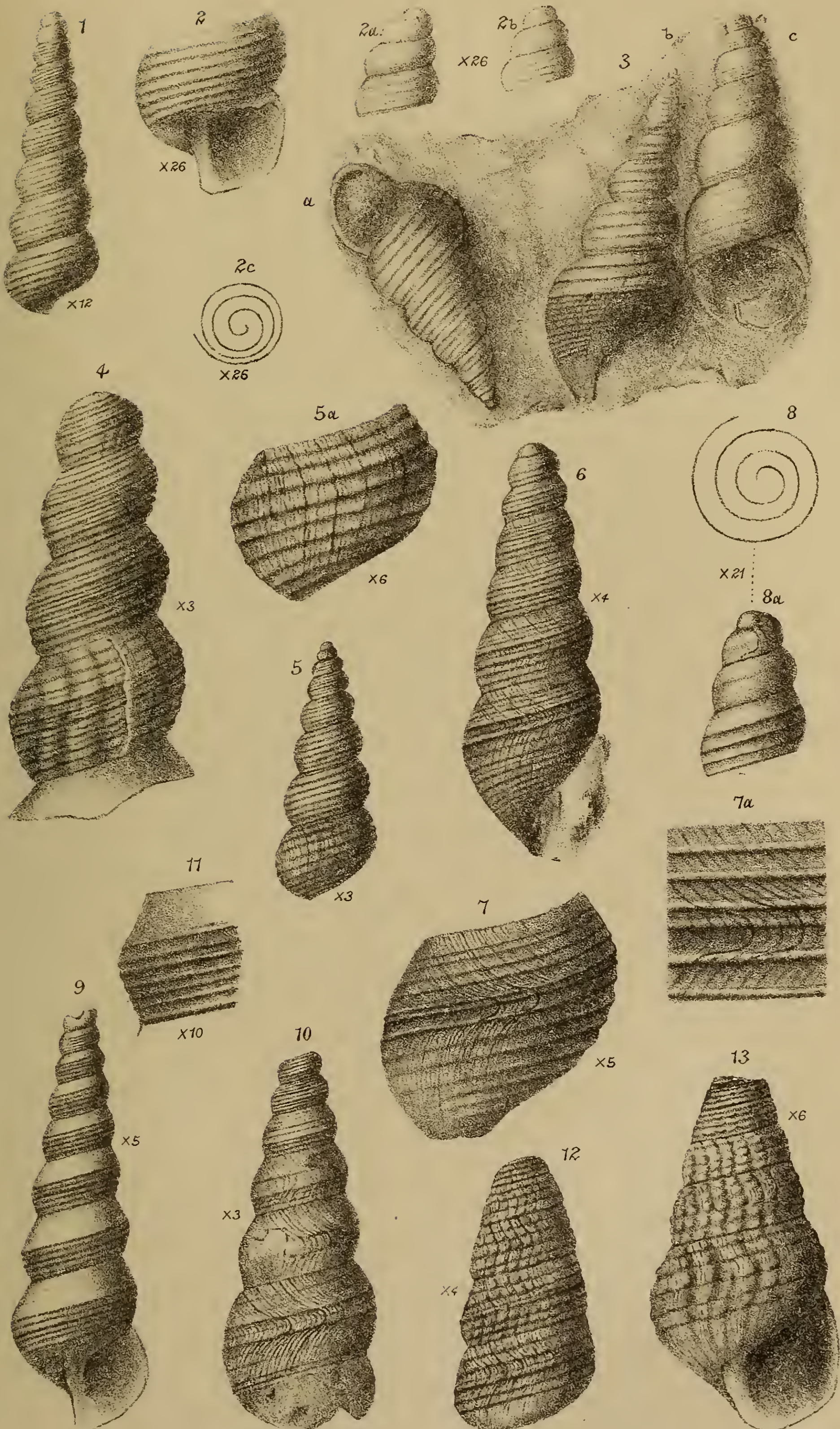
ACLISINA.



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ACLISINA, RHABDOSPIRA,
MURCHISONIA, & MICRENTOMA.

6. A GEOLOGICAL SURVEY *of the* WITWATERSRAND *and* OTHER DISTRICTS *in the* SOUTHERN TRANSVAAL. By FREDERICK H. HATCH, Ph.D., F.G.S., Assoc.M.Inst.C.E., formerly of the Geological Survey of England and Wales. (Read November 17th, 1897.)

[PLATE VI—Map & Sections.]

CONTENTS.

I. INTRODUCTION.

THE importance of the Witwatersrand as a gold-producing area has given an impetus to geological enquiry in this part of South Africa. The result has been the appearance of numerous books, pamphlets, and papers.[1] My apology for adding to their number by the present communication is a five-years' residence in the Transvaal, during which time I have had perhaps unusual opportunities and facilities for closely studying the geology of the Southern Transvaal, or more correctly the region lying between the Magaliesberg Range and the Vaal River. Having in the course of professional duties to journey backward and forward through this country, I gradually became acquainted with its geological structure; and as a means of crystallizing and correlating the information thus obtained, I began to lay it down on a map and have continued to do so until now. The survey of some 8000 square miles of country, embracing the districts of the Witwatersrand, Potchefstroom, and Heidelberg, and a portion of those of Rustenburg and Pretoria, being now completed, I desire to lay the results before the Geological Society.

The difficulties of geological mapping in a sparsely-inhabited country, and where the inhabitants since the Jameson raid have not been particularly disposed to welcome the Uitlander, may be easily imagined. I do not claim for my map that accuracy in detail which can only be obtained by leisurely work on a large scale; still, the main geological boundaries have been drawn with as near an approximation to correctness as was possible under the

[1] Mostly German and French.

circumstances, and certain sections, where stratigraphical complexities made it desirable, have been mapped in greater detail.

The physical features of the South African plateau or 'High Veldt' have been so often described that I will only briefly refer to them here. To the traveller by train from the south, with the eye wearied by the interminable stretches of uniformly flat and uninteresting country in the Orange Free State, the Southern Transvaal presents by contrast a pleasing aspect, on account of its more broken and diversified scenery. Ranges of low hills alternate with stretches of rolling and grassy uplands, which, in the summer or rainy season, have a delightfully fresh and green appearance.

The highest elevation is reached at the Witwatersrand (highest point 6000 feet above sea-level), which forms the water-parting between the tributaries of the Vaal River, flowing into the Atlantic Ocean, and the Limpopo or Crocodile River and its tributaries, flowing into the Indian Ocean.[1]

The lines of elevation have mainly an east-and-west trend, conforming almost invariably with the strike of the bedding. Usually there is an abrupt escarpment on one side, while the opposite flank corresponds to the angle of dip of the beds. The hill-ranges are of unimportant height relative to the surrounding plains, being rarely above 300–400 feet.[2]

The Magaliesberg forms the natural northern boundary of the district under description. The sedimentary strata of which it is composed are on its northern side faulted up against massive igneous rocks of basic character, belonging to a portion of the ancient crystalline floor of South Africa; while to the south there is a varied series of sedimentary and volcanic rocks of Palæozoic age, through which the ancient crystalline rocks here and there protrude. This series of beds, which is generally known as the Cape Formation, extends to the Vaal River, where it disappears under the flat-lying strata of the Karoo Formation, the latter constituting almost the sole rocky covering of the Free State and the Eastern Province of the Cape Colony.

We have therefore, in describing the rocks of the Southern Transvaal, to deal with three principal subdivisions, namely :—

(1) The Karoo System.
(2) The Cape System.
(3) The Archæan System.

The following description of these formations will be greatly facilitated by reference to the map and sections that accompany this paper. (See Pl. VI.)

[1] The most important streams in the district under consideration are the Blesbok Spruit, Klip R., Mooi R., Kockemoor Spruit, and Schoon Spruit, tributary to the Vaal river; and the Pienaars R., Aapies R., Hennops R., Yokeskey R., Crocodile R., Magaliesberg R., and Hex R., tributary to the Limpopo.

[2] The principal hill-ranges are the Magaliesberg, Witwatersberg or Daspoort range, Kalkheuvel, Witwatersrand, Klipriversberg, Gatsrand, Zuickerboschrand, and the Venterskroon Hills. Isolated hills are the Losberg, Tafelkop, Spitskop, and Platberg—names indicating the configuration of the hills designated.

II. The Archæan Rocks.

Distribution.

As already pointed out, these rocks protrude in a few places through the sedimentary beds which cover the greater part of the area under consideration. In the Northern Transvaal and Rhodesia they bulk largely, consisting there of granites, gneisses, and basic crystalline schists derived from the deformation of igneous rocks.[1] But in the Southern Transvaal their appearance is quite local and of limited extent. Besides the occurrence of basic eruptive rocks (in part gabbro) north of the Magaliesberg, three principal masses of the Archæan rocks crop out. The largest of these is that lying between Pretoria and Johannesburg, its southern margin being immediately north of the Witwatersrand range. This mass has an extent from north to south of about 18 miles, and of about 28 miles from east to west. The granitic rocks of which it is composed form no conspicuous or striking outcrop, the surface of the ground being either flat or of a gently undulating or rolling character. Next in importance is the mass which crops out on the Vaal River some 28 miles S.E. of Potchefstroom. The greatest portion of this mass lies on the Free State side of the river; but the Transvaal portion is about 10 miles long by $3\frac{1}{2}$ miles wide. The outcrop is of a broken character near the Vaal, but on the Free State side the hills diminish as they recede from the river.

The third mass, measuring 8 miles long by 7 broad, is situated on the farms Frischgewaagd, Uitkyk, Langzeekoegat, Witkop, and Palmietfontein, etc., about 40 miles south-east of Johannesburg. Here, also, the surface of the country is flat or gently rolling.

Description of the Archæan Rocks.

These ancient crystalline rocks do not constitute a single granite *massif* in any of the occurrences mentioned; they are rather members of an igneous complex of rocks of varied composition, although rocks of ultra-acid composition are rare. A series of these rocks collected by Cohen in 1872–73 has been described by P. Dahms.[2] He mentions the following types:—biotite-granite (Müller's Farm, south-west of Pretoria), amphibole-granite (Rietfontein, near Yokeskey River), granite-porphyry (Müller's Farm), mica-syenite-porphyry (between Grobler's and Müller's Farm).

Molengraaff[3] is of the opinion that the predominant rock in the

[1] J. Götz, 'Untersuchung einer Gesteins-suite aus der Gegend der Goldfelder von Marabastad, im nördlichen Transvaal,' Neues Jahrb. Beilage-Bd. iv (1886) p. 110; and J. A. Chalmers & F. H. Hatch, 'Notes on the Geology of Mashonaland & Matabeleland,' Geol. Mag. 1895, p. 193.

[2] 'Ueber einige Eruptivgesteine aus Transvaal in Süd-Afrika,' Neues Jahrb. Beilage-Bd. vii (1891) p. 90.

[3] 'Beitrag zur Geologie der Umgegend der Goldfelder auf dem Hoogeveld in der südafrikanischen Republik,' Neues Jahrb. Beilage-Bd. ix (1894–95) p. 184.

granitic complex north of the Witwatersrand is a microcline-granite, of which he describes a type from the Halfway House on the Johannesburg-Pretoria road. He also mentions tonalite or plagioclase-granite as of frequent occurrence.

Sections made from specimens of granite collected by me on the Vaal River near Venterskroon show that the rock is a holocrystalline aggregate of quartz, orthoclase, and plagioclase, with a little brown and green mica. The felspar is much clouded through kaolinization, and the quartz is full of inclusions.

Crystalline schists are of rare occurrence in the Southern Transvaal; but Cohen [1] mentions sericite-schist from Grobler's Farm near the Halfway House, and Molengraaff [2] refers to actinolite-schist at Vredefort in the Orange Free State. A. Schenck [3] also speaks of metamorphic schists at Grobler's Farm, Kromdraai, and Sterkfontein, and correlates them with his Swasi Schists of the De Kaap and Zoutpansberg.

Associated with the granitic rocks are eruptive masses of basic rocks (norite, gabbro, dolerite), while the whole complex is pierced in many places by dykes and veins of pegmatite, granophyre, microgranite, and felsite. No doubt there were several periods of eruption, and a portion of the rocks, especially the dykes, are possibly of much later age than the original Archæan formation.

The gabbros of the Zwartkoppie hills, north of the Magaliesberg, are well described by Dahms.[4] He divides them into (*a*) gabbros rich in plagioclase and (*b*) gabbros rich in pyroxene. A section [5] of gabbro from the north side of the Magaliesberg range (8 miles north of Rustenburg) shows it to be a beautiful specimen of hypersthene-gabbro or norite, consisting of a holocrystalline aggregate of unclouded plagioclase and fresh highly-pleochroic hypersthene.

A section of a specimen from Uitkyk, in the Heidelberg district, discloses a quartz-felsite, composed of rounded crystals of quartz embedded in a cryptocrystalline (felsitic) groundmass.

III. The Cape System.

The Cape System is capable of division into five distinct groups or series of beds.

At the bottom lies a series of quartzites and ferruginous shales, locally known as the Hospital Hill Series. Next follow the sandstones and conglomerates (partly auriferous) of the Witwatersrand. Lying unconformably above the latter, and resting on a sheet of basic volcanic rock ('Klipriversberg amygdaloid'), is a small bed of quartzite and conglomerate known as the Black Reef. Above this is a thickly-bedded dolomite, followed by a series of alternating quartzites, shales, and volcanic flows for which the name Magaliesberg and Gatsrand Series is well adapted.

[1] Dahms, Neues Jahrb. Beilage-Bd. vii (1891) p. 116.
[2] Neues Jahrb. Beilage-Bd. ix (1895) p. 194.
[3] Zeitschr. d. Deutsch. geol. Gesellsch. vol. xli (1889) pp. 578 & 579.
[4] *Op. supra cit.* p. 90.
[5] In the possession of the British Museum (Nat. Hist.).

I am inclined with Molengraaff[1] to separate the formation into an Upper and a Lower Division; but whereas he puts the division between the dolomite and the Black Reef, I include the latter and the underlying Klipriversberg amygdaloid in the Upper Division namely:—

UPPER BEDS.	Magaliesberg and Gatsrand Series. Dolomite. Black Reef and Klipriversberg Amygdaloid.
LOWER BEDS.	Witwatersrand Beds. Hospital Hill Series.

1. THE HOSPITAL HILL SERIES.

This series has been variously named. It is the 'Schistose Rocks' of Alford,[2] the 'Lower Quartzite-and-Shale Group' of Gibson,[3] and the 'Alte Schieferformation' of Molengraaff.[4]

Its typical occurrence is in the hill-range on which the Johannesburg Hospital stands, and generally known as Hospital Hill. The formation invariably goes by this name locally; and the term clearly indicates, without chance of confusion, the beds to which it is meant to be applied.

Distribution.

This formation consists of four or five alternating series of quartzites and shales, the former, as a rule, cropping out on the hill-ridges and the latter in the valleys. Its outcrop measures 3 to 6 miles across the strike. The east-and-west hill-range, on the southern flank of which Johannesburg is situated, runs north of the Main Reef Series of conglomerates from near Boksburg to Krugersdorp, a distance of 45 miles. The dip of the beds is southerly, mostly at a high angle; in places the beds are even vertical at the outcrop. West of Krugersdorp the strike changes to the south-west, the new direction being maintained for about 20 miles until the beds disappear under the unconformably overlying dolomite near Wonderfontein. The same beds reappear at a point about 10 miles west of Frederikstad, whence they run in a well-defined hill-range striking south-west past Buffelsdoorn and on to Klerksdorp, the dip of course being to the south-east. East of Johannesburg the Hospital Hill Series can be traced to Klipfontein, about 12 miles north-east of Boksburg, where it disappears under the dolomite. It is next found at Boschmanskop and Vlakfontein, some 10 miles north-west of the Nigel, and is there striking nearly due south and dipping west. It is apparent therefore that, while hidden by the Dolomite and the coal-beds of the Karoo Formation, the strata of the Lower Cape Formation have swerved round to the south—an im-

[1] Neues Jahrb. Beilage-Bd. ix (1895) p. 209.
[2] 'Geological Features of the Transvaal,' London, 1891, p. 5.
[3] 'On the Geology of the Gold-bearing & Associated Rocks of the Southern Transvaal,' Quart. Journ. Geol. Soc. vol. xlviii (1892) p. 420.
[4] *Op. supra cit.* p. 194.

portant point in connexion with following up the auriferous conglomerates of the Main Reef Series beyond Klipfontein. The outcrops of this formation on Uitkyk, Frischgewaagd, and Kuilfontein closely resemble those of Hospital Hill, and, like the latter, the beds are faulted up against the granitic rocks of the Archæan formation.

Another important occurrence of these beds is north of the Vaal River granite on the farms Kodoeslaagte, Kodoesfontein, Witkoppiefontein, etc. The dip here is south, namely, towards the granite, the contact-line being here also a faulted one.

There remain to be noted several small inliers of the Hospital Hill Series in the Heidelberg district, as for instance on Modderfontein and Klipfontein, some 12 miles south of Heidelberg.

Description of the Rocks.

The rocks of which this formation is composed consist of granular, sugary quartzites, and banded, highly ferruginous shales. As already pointed out, the quartzites generally appear as ridges, while the shales, on account of their feebler resistance to the weather, are hollowed out into valleys. Occasionally, however, when the shales are very highly impregnated with iron, the beds resist rapid weathering, and ridges are formed. The quartzites are generally of a white saccharoidal type, consisting of subangular quartz-grains which, under the microscope, are seen to be in close juxtaposition, there being no interstitial matter, a result brought about, no doubt, by a secondary accretion of crystalline silica on to the original quartz-grains.

The iron in the ferruginous shales is present, partly in the form of specular ore, partly as magnetite. The shales are occasionally striped or banded, ferruginous layers alternating with bands of jaspery quartz. They show much diversity in colour, dependent on the state of oxidation of the iron.

W. H. Penning[1] and D. Draper[2] attach considerable importance to certain of the magnetite-beds as a clue to, and as a means of identifying, the Main Reef, the idea being that they are continuous and always present at practically the same distance from the outcrop of the Main Reef. As, however, changes in the dip of the beds cause a great variation in the distance between the outcrops, and further, since there are many such 'magnetite-beds,' no one of which can be traced continuously for any great distance, the proposed method of prospecting is of no practical utility.

With regard to stratigraphical relations, the junction of the Hospital Hill Series with the Archæan formation is always a faulted one. As to the overlying strata, I see no reason to assume (with Molengraaff[3]) an unconformity between this series and the quartzites and conglomerates of the Witwatersrand Beds. Wherever

[1] 'A Contribution to the Geology of the Southern Transvaal,' Quart. Journ. Geol. Soc. vol. xlvii (1891) p. 455.

[2] Trans. Geol. Soc. S. Africa, vol. ii, pt. i (1897) p. 7.

[3] Neues Jahrb. Beilage-Bd. ix (1895) p. 178.

the latter appear the subjacent Hospital Hill Series is invariably present, and although there may be occasionally some variation in the dip of the two series, this may be attributed to the action of strike-faults, as already suggested by Gibson.[1] I have observed no evidence of folding, and estimate the thickness of the Hospital Hill Series at 8000 to 10,000 feet.

2. The Witwatersrand Beds.

This name was used by Penning to embrace the whole of the quartzite-and-conglomerate series, including the underlying Hospital Hill Series; and since no better name has been suggested I shall continue to use it, but in the more restricted sense, excluding the Hospital Hill Series.

Distribution.

In the main section (Witwatersrand) the quartzites and conglomerates of this series crop out on fairly flat or gently sloping ground south of the Hospital Hill range. The strike is here east-and-west, and the dip south. The industry of the Witwatersrand is concentrated along the line of outcrop of the conglomerates known as the 'Main Reef,' and an uninterrupted line of head-gears, smoke-stacks, machine-shops, and other structures demarcates its course from Boksburg to Krugersdorp, a distance of 30 miles.

At Krugersdorp the beds turn to the south-west; the conglomerates are clearly exposed on Randfontein, Droogeheuvel, Haartebeestfontein, Witfontein, and Elandsfontein. On the latter farm they pass under the dolomite. Like the Hospital Hill Series, they emerge again west of Frederikstad, and can be followed past Buffelsdoorn on to Klerksdorp and thence to the Vaal River.

Twelve miles east of Johannesburg, namely, at Boksburg, the Witwatersrand Beds are covered by the Coal-beds of the Karoo Formation; but 4 or 5 miles farther east they emerge again on the farm Benoni, and can be followed thence through Vlakfontein and Modderfontein to Klipfontein, where they once more pass under the Karoo Formation. Their next appearance is at the Nigel Mine, striking east and west, but dipping north. A section drawn between Johannesburg and the Nigel, a distance of about 30 miles, discloses the existence of a very complete syncline. Starting immediately north of Johannesburg, we have above the Archæan rocks the following succession of beds dipping south:—

Hospital Hill Series.
Witwatersrand Beds, with the different series of conglomerates.
Klipriversberg Amygdaloid.
Black Reef.
Dolomite.

Continuing the section, the same beds are then recrossed, but outcropping in the reverse order and dipping north, the section terminating with the Archæan rocks.

[1] Quart. Journ. Geol. Soc. vol. xlviii (1892) p. 423.

From the Nigel Mine the beds can be traced to Heidelberg, and, following the trend of the hills of the Zuickerboschrand, they run through the farms Boschhoek, Schickfontein, etc. to Stryfontein and Boschkop on the Vaal River, east of Vereeniging, where they are again covered by the Karoo Formation.

Farther east there are several inlying portions of the Witwatersrand Beds, extending as far as Greylingstad, and constituting a synclinal trough, the axis of which runs south-east. The conglomerates are found outcropping on the northern side of the syncline on the farms Rietfontein, Rietbult, Van Kolders Kop, Witpoort, and Doornhoek; and on the southern side at Roodepoort, Driefontein, Hex River, Barnards Kop, Roodevaal, Rietvlei, Witpoort, Daspoort, Tweefontein, Driefontein, and Malans Kraal. The central portion of the trough is much disturbed by igneous intrusions of a basic character.

An interesting occurrence of these beds is at Venterskroon, where they lie north of the Hospital Hill Series on the farms Rooderand, Buffelskloof, Kodoesfontein, Buffelshoek, Witkoppiesfontein, etc. The beds dip south, and apparently underlie the Hospital Hill Series; but it is evident that they owe their position here to reversed faulting, and not to an inversion of the beds by folding, as described by H. B. Bunkell.[1]

Description of the Beds.

The Witwatersrand Beds consist of alternating quartzitic sandstones, grits, and conglomerates, forming a series which has an aggregate thickness of from 11,000 to 15,000 feet. The sandstones consist of particles of white quartz, and are cemented to hard compact quartzite by secondarily deposited silica. They are of a dark bluish-grey where unoxidized, but weather at the surface to reddish and yellow tints. Occasionally, on exposed surfaces, current-bedding and ripple-marks are observable. The pebbles of the conglomerates consist almost entirely of a dark-coloured but pellucid quartz, apparently derived from the breaking-down of ancient vein-quartz. The pebbles vary in size from a pea to a hen's egg, though occasionally much bigger pebbles are found. Examination under the microscope shows that the cementing material of the conglomerates consists of a mosaic of minutely granular but distinctly crystalline quartz. The rock is so firmly knit together by this secondarily deposited silica that, when broken, the fracture passes irrespectively through pebbles and matrix. In places the newly-deposited quartz has grown on to the pebbles in such a manner as to obliterate their original margin and to produce a rock resembling a homogeneous and glassy variety of vein-quartz. Of other minerals, finely-divided iron pyrites is the most common, being disseminated through the matrix of the rock in fine crystalline particles; and native gold,

[1] 'Notes on the Venterskroon Goldfields,' Trans. N. Eng. Inst. Min. & Mech. Eng. vol. xlvi (1896) pp. 58–61.

when present, is in intimate association with this mineral. Galena, blende, and copper pyrites occur but rarely. In the surface-rocks, down to about 100 feet, the sulphides of iron are replaced by the oxides of that metal.

The silicification, or more generally the mineralization, of these conglomerates is, in my opinion, the result of secondary processes of infiltration and crystallization. It is significant in this connexion that when most mineralized the conglomerates are often seamed with veins of white quartz (as, for example, Ferreira Mine and New Rietfontein Mine); and there can be little doubt that these veins were formed in connexion with the mineralization of the conglomerates. There is no reason for ascribing a special method of origin to the gold; and I hold, therefore, that the gold has been introduced with the pyrites with which it is in intimate association, as a part of the general process of mineralization, and I cannot agree with those authors who describe the conglomerates as deposits in which the gold was either pre-existing (alluvial gold) or was introduced contemporaneously with the deposition of the pebbles and sand.

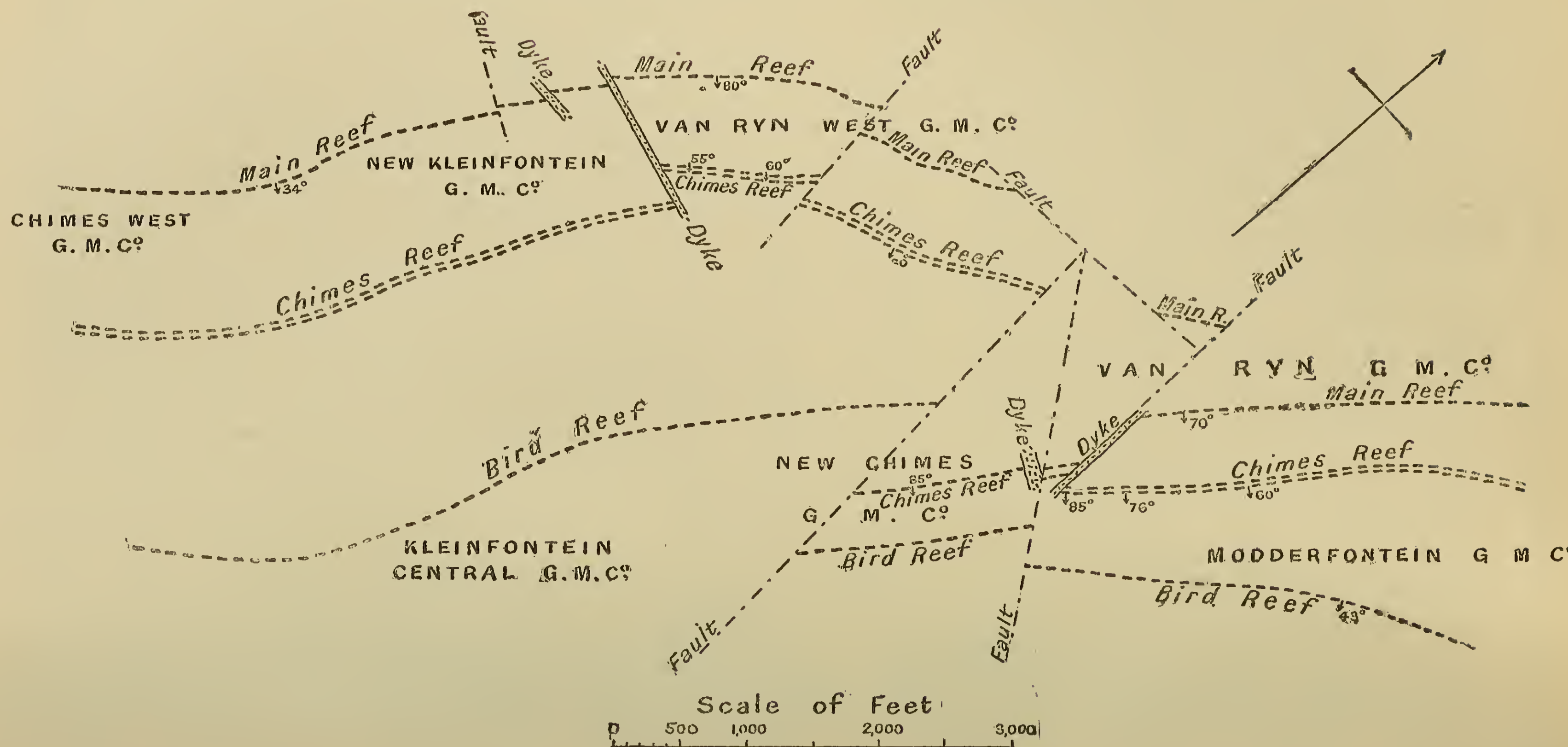
Some particulars of the Auriferous Conglomerates or 'Banket Reefs' of the Main Reef Series.

Much detailed information relating to the auriferous conglomerates, now generally known as the 'Main Reef Series,' has been already published.[1] Consequently I shall confine myself here to a few points only.

The outcrop of these conglomerates or 'Banket Reefs' follows a fairly regular line, extending east and west of Johannesburg from Witportje at the western extremity to Boksburg at the eastern extremity, a distance of close on 30 miles. In the central section, that is, near Johannesburg, the strike is east and west; but as Boksburg is approached the outcrop turns towards the south-east, passing finally under the coal-beds of the Karoo Formation at Boksburg. On emerging some 4 or 5 miles farther east they strike to the north-east, appearing successively on the farms Benoni, Kleinfontein, Vlakfontein, Modderfontein, and Klipfontein. On the latter farm they again disappear under the Karoo Formation. Although much complicated by faulting on these farms (see fig. 1, p. 82), the different series of conglomerates (Main, Bird, and Kimberley) can be recognized, both by stratigraphical position and petrological character. Turning now to the western section of the Rand, we find on the farm Witportje, near Roodepoort, 13 miles west of Johannesburg, the Main Reef Series thrown north a distance of 3 miles by a great fault, known as the 'Witportje break.' The beds resume their normal

[1] Gibson, Quart. Journ. Geol. Soc. vol. xlviii (1892) p. 409; Schmeisser, 'Ueber Vorkommen u. Gewinnung der nutzbaren Mineralien in der südafrikan. Republik,' Berlin, 1894; Hatch & Chalmers, 'The Gold Mines of the Rand,' London, 1895, pp. 22–87; Karl Futterer, 'Afrika in seiner Bedeutung für die Goldproduktion,' Berlin, 1895; De Launay, 'Les Mines d'Or du Transvaal,' Paris, 1896; also Trans. Fed. Inst. Min. Eng. vol. xi (1896) p. 378.

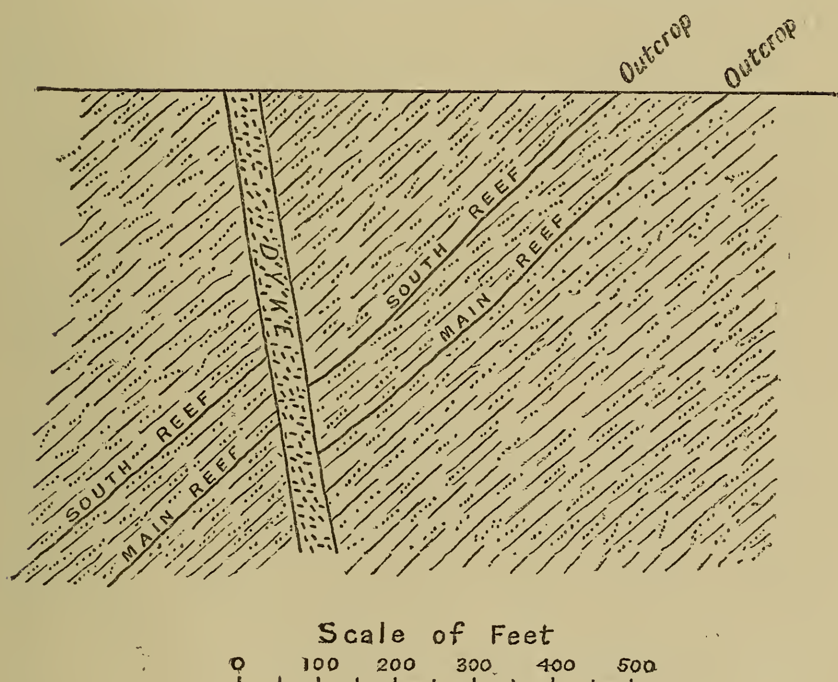
Fig. 1.—*Plan of Reef outcrops in the Chimes District.*



course, namely, east, on the properties of the French Rand and Champs d'Or Gold Mining Companies. On these properties the Main Reef Series is known as the 'Bothas Series,' while the Kimberley Series is called the 'Battery Reef Series.' Traced still farther, the beds swerve to the south through Randfontein and Uitvaalfontein, until again cut off by an east-and-west fault, which carries them on to the farms Droogeheuvel, whence they may be followed south-west through Haartebeestfontein and Witfontein.

Examined in detail in the mine-workings, the beds are found to have suffered numerous minor dislocations by cross-courses, the faulting being in many cases accompanied by igneous intrusion (as in fig. 2). Several instances of overthrust and reduplication by

Fig. 2.—*Upthrow fault in the Crown Reef Mine.*



reversed faults, coursing with the strike of the beds, have also been observed, reference to which will be made in the sequel. With regard to gold-contents, the best section of payable ore extends for about 10 miles in the central part of the Rand (near Johannesburg). Outside this section occasional patches of payable or even rich ore are found, but the general average is low-grade, and there are many places where the auriferous contents are not sufficient to repay working.

Several good sections through the Witwatersrand Beds have been obtained by deep borings in different parts of the Rand. These have been carried down to various depths, in one case exceeding 3000 feet, and the results obtained show a remarkable degree of uniformity in regard to the sequence and continuity of the different conglomerate-beds. Thus, the Bezuidenville borehole, put down at a point 5800 feet south of the outcrop of the Main Reef at the Meyer & Charlton Mine, near Johannesburg, intersected the Main Reef at 3200 feet, the dip at that depth being about 27°. A section of the strata passed through is as follows:—

	Feet.
Quartzite with shale-bands	1120
Quartzite with conglomerate-beds (Bird Series)	350
Quartzite with occasional epidiorite-dykes	1550
Quartzite with conglomerate-beds (including South and Main Reef Series)	230
Quartzites	330
Shales to bottom of borehole	150

A borehole ('New Rand Mines borehole'), put down 3500 feet south of the Aurora West, struck the Main Reef at a depth of 2040 feet, the dip being 27°. This borehole being located a few feet north of the outcrop of the Bird Reef Series, it just missed them. It passed through 2600 feet of quartzites and grits with epidiorite-dykes. At 2030 feet the Main Reef Leader was intersected, at 2038 feet the Main Reef, at 2089 feet the Bird Reef, and the borehole passed into the Bottom Shales (Hospital Hill Series) at a depth of 2438 feet (see fig. 3, facing this page).

The Rand Victoria borehole, put down 4400 feet south of the outcrop of the Main Reef at the Simmer & Jack, intersected the conglomerates of the Bird Series at 400 feet, those of the Livingstone Reef at 1620 feet, the South Reef at 2348 feet, and the Main Reef at 2390 feet.

The Chimes Mines borehole, put down 3820 feet south of the outcrop of the Main Reef at the Kleinfontein Mine, 7 miles east of Boksburg, passed through the upper portion of the Bird conglomerates at 210 to 228 feet, and through the lower portion of the same series at 430 to 454 feet. It intersected the Chimes or South Reef Series between 1154 and 1194 feet, the Main Reef Leader at 1738 feet, and the Main Reef at 1754 feet. The dip at this depth was 22°.

The following section, which gives the estimated thickness of the different beds of the Witwatersrand Series, has been constructed partly from information obtained by boring, partly from measurements across the outcrop of the beds:—

		Feet.
From the base of the Klipriversberg Amygdaloid to the base of the Elsburg Series ...	conglomerates and quartzites (Elsburg Series)	3000
Kimberley Series to Elsburg Series, quartzites		4000
Kimberley Series, conglomerates		440
Kimberley Series to Bird Series, quartzites		1450
Bird Series, conglomerates		100
Bird Series to South Reef, quartzites		1700
South Reef to Main Reef, quartzites		140
Main Reef Series, conglomerates		20
Main Reef to Bottom Shales, quartzites		400
Total		11250

The mine-workings on the auriferous conglomerates (Main Reef Series) have disclosed the presence of a great number of dykes traversing the formation. These dykes are invariably of basic character, and vary in width from a few feet up to several hundred. In depth, where unaltered, they are close-grained, dark-green coloured rocks, but near the surface they weather into a reddish clay.

I have had sections made from specimens collected from the deeper levels of the mines (Ferreira, Meyer & Charlton, Robinson Deep, Simmer & Jack, etc.) and from some of the deep bore-holes. They are all practically of the same description, belonging to the epidiorite group. To give examples, a section of the Wemmer dyke in the Ferreira Mine shows fragmentary crystals and shreds of strongly pleochroic hornblende (brown and green) in a felt-like aggregate of pale green to colourless hornblende, a little plagioclase-felspar, apatite, ilmenite, leucoxene, and calcite.

The margins of dykes are invariably schistose, and the smaller dykes are sometimes completely transformed into hornblendic and chloritic schist.

A section from the margin of the big dyke in the Ferreira Mine showed a mass of minute interlacing needles of hornblende (uralite) with occasional granules of felspar; in fact, a typical hornblende-schist. This transformation from massive dolerites of purely igneous origin into

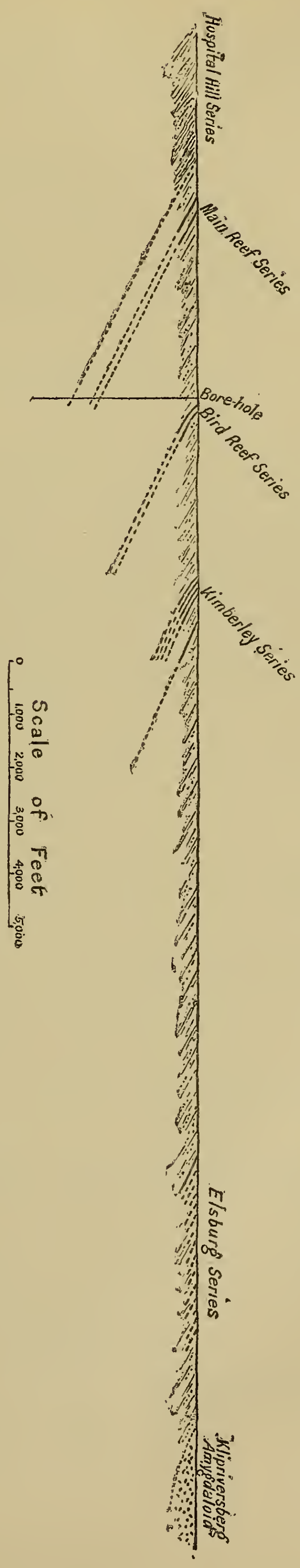


Fig. 3.—*Section through the Witwatersrand Beds, at the New Rand Mines borehole.*

typical crystalline schist is, of course, due to dynamic causes which are connected with the reversed faulting, and other earth-movements that have affected these beds, to which I shall have occasion to refer later on.

3. The Black Reef and Klipriversberg Amygdaloid.

The Black Reef formation consists of a thin band of quartzites, not more than 50 feet thick at the most, but inclined at a very slight angle, and therefore in places spreading out over a comparatively large area. These quartzites have at their base a thin, narrow seam of pebbles, which is often highly mineralized with sulphides and oxides of iron. In places also it carries gold. The pebbles consist of quartz, as in the Witwatersrand conglomerates, but a distinguishing feature is the presence of pink and dark-coloured cherty and jaspery pebbles. The matrix is also much more pyritic, and the pyrites is sometimes present in the form of nodules. It is this seam which, on account of its dark colour, gives the name to the formation. The name is universally adopted in the Transvaal; although Molengraaff[1] uses the designation 'Boschrand Series,' from the name of a small ridge formed near Klerksdorp.

The Black Reef overlies unconformably the Witwatersrand Beds, and although along the Rand proper it may appear to conform to the older series, there are several places where it can be seen overlapping them: for instance, at Randfontein, Hill's Waterfall, and Elandsvlei, west of Randfontein; also at Middelvlei, Rietfontein, Blaauwbank, and Elandsfontein, near Wonderfontein. The sinuous course pursued by the Black Reef will be well seen on the accompanying map. An interesting little inlier of the Black Reef is worthy of note at Katdoornbosch, close to Frederikstad.

Between the deposition of the Witwatersrand Beds and the Black Reef formation there was a considerable eruption of basic volcanic rock now forming the Klip River Hills, and known as the Klipriversberg Amygdaloid, on account of the number of infilled vesicles which distinguish it. These vesicular cavities are filled with the usual secondary minerals, chiefly chlorite, quartz, and calcite. A section of the rock shows a felt-like aggregate of felspar-needles and augite-granules, in which are embedded small porphyritic crystals of augite, and less frequently large crystals of plagioclase-felspar.

The flows are of immense thickness, amounting in the aggregate to at least 5000 feet. They were produced by the volcanic outpourings which took place after the deposition of the Witwatersrand sediments; and this fact may help to explain the unconformity which exists between those beds and the Black Reef.

4. The Dolomite Formation.

The Dolomite is one of the most interesting and widespread members of the Cape System in South Africa. It was first

[1] Neues Jahrb. Beilage-Bd. ix (1895) p. 216.

recognized as a dolomitic limestone by A. Schenck,[1] who noted its widespread occurrence, mentioning it near the Magaliesberg, in Bechuanaland, the Western Transvaal, the Drakensberg, and Great Namaqualand. Penning[2] called it chalcedolite, and described it as a calcareo-siliceous rock with 'chalcedonic texture'; and Alford[3] described it as a 'calcareous quartzite . . . which in some places passes into dolomite.' Cohen[4] mentions its occurrence in the Transvaal and in Griqualand West. Gibson does not appear to have come across it, since he does not mention it. Molengraaff calls it Malmani Dolomite,[5] from its occurrence at that locality. Mr. Draper has also described this rock.[6]

Distribution in the Southern Transvaal.

The Dolomite and its accompanying cherts bulk more largely among the rocks of this district than perhaps any other formation. The most northerly belt has its northern margin immediately south of Pretoria, while its southern margin is in contact with the granite, the junction being of course a faulted one. The dip is to the north, the beds constituting the northern limb of an anticline, the southern limb of which is found some 10 miles south of Johannesburg. The two belts come together at Wonderfontein, 20 miles south-west of Krugersdorp, the older beds disappearing entirely under the dolomite arch. Twenty miles farther west they reappear, and separate the Dolomite again into a northern belt with a south-easterly dip and a southern with a north-westerly dip. The southern belt can be followed to the Vaal River, which it crosses a few miles south-east of Klerksdorp.

South-east of Johannesburg the southern dolomite-belt circles round and, striking south-west, forms the valley of the Klip River, and finally passes under the Karoo Formation at Vereeniging. A narrow band of the Dolomite forms the outer ring of the southerly-dipping beds round Venterskroon. According to its dip, it would appear to underlie the quartzites and conglomerates of the Witwatersrand Beds that occur here; but its anomalous position is due to reversed faulting.

No recognizable fossils have yet been found in the Dolomite Formation, although Cohen[7] mentions the occurrence, near the Makwassispruit, between Klerksdorp and Potchefstroom, of impressions of crinoids and brachiopods resembling *Orthis* and *Chonetes*. In places a well-developed oolitic structure is observable in the rock, especially in the siliceous layers.

[1] Zeitschr. der Deutsch. geol. Gesellsch. vol. xli (1889) p. 578.

[2] Quart. Journ. Geol. Soc. vol. xli (1885) p. 576.

[3] 'Geological Features of the Transvaal,' London, 1891, p. 6.

[4] Dahms, Neues Jahrb. Beilage-Bd. vii (1891) p. 117, and Götz, *ibid.* Beilage-Bd. iv (1886) p. 116.

[5] *Op. jam cit.* p. 218.

[6] Quart. Journ. Geol. Soc. vol. l (1894) p. 561.

[7] Dahms, *op. jam cit.* p. 118.

Description of the Dolomite.

This formation has an aggregate thickness, according to my estimate, of from 6000 to 8000 feet. It is made up of two types of rock :—

(1) A compact bluish-grey magnesian limestone.
(2) A hard white or grey chert.

These two rocks appear in close association, the limestone almost invariably having layers of chert interbedded with it. Sometimes, however, the siliceous rock entirely replaces the dolomite, and nothing but hard, smooth masses of chert are then seen outcropping. It is this fact that gave rise, no doubt, to Penning's designation of the formation as chalcedolite, and Alford's description as calcareous quartzite. The cherty layers are occasionally much brecciated. By weathering the dolomite acquires a whitish-brown crust and a curiously wrinkled or corrugated appearance, which has given rise among the Boers to the name of Elephant Rock (Olifants Klip), on account of its resemblance to the skin of an elephant. This appearance is caused by the removal of the softer calcareous portions of the rock, leaving the hard siliceous ribs and nodules sticking out. The weathered surfaces are invariably coated with a brown dust, consisting of hydrated oxide of manganese (wad). This manganese is derived from the dolomite in which it is present in the form of carbonate of manganese.

A remarkable feature of the limestone is the frequent occurrence of large swallow-holes, like those found in the Carboniferous Limestone of this country. Another interesting feature is the great quantity of water carried by the strata of this formation. The beautifully clear water of the Mooi River springs from this formation, the water welling out from the rocks in considerable abundance. One of these so-called 'eyes' or springs of the Mooi[1] River is situated 20 miles to the north-east of Ventersdorp and another close to Frederikstad. These springs are probably connected by an underground channel with the strong stream of water which is seen underground in the Wonderfontein caves, 22 miles south-west of Krugersdorp. Another similar spring or 'eye' is the source of the Schoon[2] Spruit, 6 miles north of Ventersdorp, and there is one at the source of the Klip[3] River.

With regard to the physical and chemical composition of the dolomite, a section examined under the microscope shows it to be of thoroughly crystalline character, having almost the appearance of marble. The chemical composition is shown by the following analysis, kindly made by Mr. G. T. Prior, of the Mineralogical Department of the British Museum :—

[1] Mooi = beautiful.
[2] Schoon = fair, bright.
[3] Klip = rock.

CaO	29·61 per cent.
MgO	19·71
FeO	1·35
MnO	1·18
SiO_2	0·94
CO_2+H_2O	46·69
	99·48

This analysis shows that the dolomite has the following percentage proportion of carbonates :—

$CaCO_3$ = 52·87
$MgCO_3$ = 41·39
$FeCO_3$ = 2·17
$MnCo_3$ = 1·99

The specific gravity is 2·88. Ignited strongly on platinum foil, the powdered dolomite turned chocolate-brown, due to the oxidation of the manganese.

Certain portions of the dolomite are highly impregnated with silica; and almost every graduation appears to exist between dolomite and chert. A specimen of siliceous dolomite analysed by Mr. Prior gave 6·84 per cent. of residue after treatment with hydrochloric acid. The percentage of silica, however, was only 2·81 per cent. A siliceous layer in the dolomite analysed by Dahms gave the following result[1] :—

SiO_2	62·16 per cent.
CaO	9·07
MgO	3·01

Veins of quartz (sometimes carrying gold) are of fairly frequent occurrence in the Dolomite Formation. Often these veins occupy a horizontal position. They are always associated with deposits of oxides of manganese (pyrolusite, wad, etc.). Other mineral deposits are also found (galena, copper sulphides).

Some interesting dykes occur in the dolomite. Two of these, lying 5 miles apart at Wonderfontein, 22 miles south-west of Krugersdorp, strike north and south. They are handsome pink porphyry-rocks and are quarried for ornamental building-stone. A section of the western dyke shows under the microscope porphyritic crystals of orthoclase, plagioclase, and augite embedded in a holocrystalline and granophyric groundmass of quartz and felspar. It may be termed a 'granophyric syenite.' This rock has been described by Dahms[2] under the name of syenite-porphyry. The eastern dyke is of similar composition, but contains no quartz. It consists of green augite, brown mica, and large lath-shaped crystals of orthoclase-felspar. It is an augite-syenite.

[1] Neues Jahrb. Beilage-Bd. vii (1891) p. 118.
[2] *Ibid.* p. 129.

5. The Magaliesberg and Gatsrand Series.

The Magaliesberg and Gatsrand Series consists of quartzites, flagstones, and shales with interbedded sheets of volcanic rock. As in the case of the Hospital Hill Series, the harder rocks (quartzites and flagstones) crop out in the hills, while the softer rocks (shales and decomposed volcanic rocks) occur in the intervening valleys. Referring again to a north-and-south section, these beds (immediately overlying the Dolomite Formation) constitute the crest of the great anticlinal arch, the northern limb being formed by the Magaliesberg and the southern by the Gatsrand. The Magaliesberg rocks were thought by Schenck to be related to the Hospital Hill Series north of Johannesburg. Molengraaff held the same view, correlating the Magaliesberg Beds (which he called Pretoria Beds [1]) with the Hospital Hill Series, although he correctly placed the Gatsrand Beds above the Dolomite.[2]

Penning,[3] however, recognized their true relation, and connected the Magaliesberg Beds (his 'Megaliesberg Formation') with the Gatsrand Beds (his 'Klip River Series'). He estimates the whole series, including the interstratified traps, at 18,000 feet thickness, and with this figure my estimate agrees very closely.

Distribution.

This formation occurs, as already shown, in two distinct outcrops. The northern belt embraces the Magaliesberg and Witwatersberg hill-ranges, a width of some 10 miles, while the southern belt extends from the Gatsrand range southward for a distance of 15 miles, a large portion of this area being occupied by contemporaneous volcanic flows of immense thickness. The beds are well seen on the road between Potchefstroom and Klerksdorp, striking south-west, towards the Vaal River.

The eastern continuation of the Gatsrand Hills makes a sudden bend at a point 12 miles south of Johannesburg and, striking then south-west, crosses the Vaal River west of Vereeniging.

Description of the Rocks.

The quartzites are of a similar type to the other quartzitic members of the Cape System, that is, they consist of grains of quartz cemented firmly together by redeposited silica. The shales consist chiefly of clay; they are closely associated with basic volcanic rocks, and it is probable that they owe their origin partly to the decomposition of the latter, partly to the original association of the flows with deposits of volcanic ash or tuff (schaalstein). Mineral deposits of galena and zinc-blende are found in the shales. Shaly flagstones, intermediate in petrological character between the quartzites and the shales, also occur, especially in the Gatsrand range.

[1] Neues Jahrb. Beilage-Bd. ix (1895) p. 205. [2] *Ibid.* p. 230.
[3] Quart. Journ. Geol. Soc. vol. xlvii (1891) p. 456.

With regard to the volcanic rocks, they are of a basic character, consisting chiefly of very fine-grained to compact aphanitic rocks of the basaltic or diabasic type. The following description of thin sections, prepared from some of the more typical specimens in a collection of these volcanic rocks made by me, will give an idea of their microscopic structure. A section of a specimen from a basic flow near Potchefstroom shows under the microscope the character of an altered basalt, consisting of a plexus of microlitic felspar and granular augite. Its vesicular cavities are filled with secondary quartz. A compact aphanitic rock from the Witwatersberg is seen, under the microscope, to consist of fragments and granules of augite and magnetite in a groundmass of minute felspathic needles. A section of a specimen taken from an outcrop near Lindique discloses a characteristic diabase with ophitic structure. A dolerite from the Witwatersberg shows well-crystallized hypersthene, with well-marked pleochroism, striped felspar in subordinate quantity, and a little pleochroic brown mica in small shreds and patches. A quartz-diabase from the Vaal River consists of plagioclase, augite, and quartz, the microstructure being distinctly granophyric.

Summary of the Cape System.

Summarizing the above information, we find that the Cape System, as developed in the Southern Transvaal, has an aggregate thickness of, roughly, 50,000 feet, the estimated thickness of the different formations being as follows :—

	Feet.
Magaliesberg and Gatsrand Series	16,000 to 20,000
Dolomite Formation	6000 to 8000
Black Reef Formation	20 to 50
Klipriversberg Amygdaloid	5000 to 6000
Witwatersrand Beds	11,000 to 15,000
Hospital Hill Series	8000 to 10,000

IV. The Karoo System.

The northern fringe of the formations belonging to this system, so largely developed in the Cape Colony and the Orange Free State, is represented by the Coal Measures [1] at Vereeniging and the district bordering on the Vaal south of Heidelberg, by the Boksburg, Brakpan, and Springs coal areas and by numerous small outlying patches. In all these places the coal, which is associated with shales, is overlain by a well-bedded coarse sandstone, which forms an excellent freestone, and underlain by grits, breccias, and fireclays corresponding to the gannister of the English Coal Measures.

The coal seams are usually of considerable thickness, and embrace varieties of gas-, coking-, smithy-, and steam-coal.

A general section at Vereeniging (for which I am indebted to Mr. Noble, Consulting Engineer to Messrs. Lewis & Marks), which may be taken as fairly representative, shows the following beds :—

[1] The 'High Veldt Beds' of Penning (*op. jam cit.* p. 457).

	Feet.
Sandstone	250
Shale	120
Coal	Thin seam.
Shale	75
Coal	14
Shale and sandstone	11
Breccia and fireclay	50
Resting unconformably on dolomite.	

Certain bands in the overlying sandstones are rich in fossil plant-remains. Mr. Leslie, the owner of a quarry at Vereeniging, was good enough to make for me a collection of these plant-remains; the specimens have been submitted to Mr. A. C. Seward, who favours me with the following description of them.

Notes on the Plant-Remains.
By A. C. Seward, Esq., M.A., F.G.S.

The specimens sent to me from Dr. Hatch are in the form of impressions on a fine-grained sandstone from Vereeniging. They consist of *Glossopteris Browniana*, Brongn., *Gangamopteris cyclopteroides*, Feist., *Nœggerathiopsis Hislopi* (Bunb.), and an imperfectly preserved *Sigillaria*, with portions of stems which I am unable to identify from the imperfect fragments. This association of species, which has been recently described from the Vereeniging rocks,[1] points to a Permo-Carboniferous age. The large parallel-veined leaves referred to as those of *Nœggerathiopsis Hislopi* are much better than any of the specimens sent to me by Mr. Draper from the same locality; their striking resemblance to European species of *Cordaites* suggests the possibility that some at least of the Southern Hemisphere leaves referred to *Nœggerathiopsis* would be more correctly designated *Cordaites*. Recent discoveries have made us acquainted with new points in common between the northern and southern Permo-Carboniferous floras, and it is probable that the genus *Cordaites* may be another type which existed in the two botanical provinces of Upper Palæozoic times.

1. Gangamopteris cyclopteroides, Feist. (cf. *G. cyclopteroides*, var. *attenuata*). The midrib is rather apparent than real, the veins radiating from the base of the frond. Probably identical specifically with the species sent by Draper.[2]
2. Portions of two leaves, possibly *Glossopteris*, which probably formed part of a tuft of long narrow fronds.
3. Fragment, most likely *Glossopteris*.
4. (*a*) Part of a frond of *Gangamopteris cyclopteroides*. The broad ridge in the middle of the leaf is a feature which appears to characterize these South African specimens. Indian examples occasionally show a similar median line, but most of them are without anything suggestive of a midrib.[3]
   (*b*) Frond of *Glossopteris Browniana*, var. *indica*, Brongn.[4]

[1] Quart. Journ. Geol. Soc. vol. liii (1897) p. 315.
[2] *Ibid.* pl. xxii, fig. 1.
[3] Compare Feistmantel, 'Flora of the Talchir-Karharbari Beds,' Pal. indica, vol. iii (1879) pl. xxvii, fig. 3, *G. cyclopteroides*.
[4] Compare Quart. Journ. Geol. Soc. vol. liii (1897) pl. xxi, figs. 2 & 3.

5. (*a*) *Gangamopteris cyclopteroides.*
   (*b*) A large frond of *Glossopteris Browniana*, var. *indica*, characterized in this specimen by the lateral veins being almost at right angles to the midrib. Bunbury has figured precisely this type of frond from Nagpur, India.[1]
   (*c*) Smaller frond of *Glossopteris Browniana.*
6. Part of a long parallel-veined leaf, tapering gradually towards one end. This is no doubt the same plant as that which I recently figured[2] as probably an Equisetaceous stem. I spoke of Draper's specimen as either a leaf or stem, but the present example shows obvious leaf-characters, and makes it probable that these finely-veined fossils from Vereeniging are the leaves of some plant like the European *Cordaites* or the Southern Hemisphere *Nœggerathiopsis Hislopi* (Bunb.). Feistmantel has figured some species of the latter plant from the Talchir-Karharbari beds which resemble the African leaves.
7. A large leaf similar to specimen 6, probably *Nœggerathiopsis Hislopi* (Bunb.).[3]
   On the other side of the rock, *Gangamopteris cyclopteroides* and *Glossopteris Browniana.*
8. Probably part of a very large leaf, similar to nos. 6 and 7. Compare *Titanophyllum*, figured by Renault & Zeiller from the Commentry Coal-field.[4] There is a striking resemblance between the large leaves (6, 7, and 8) and those from Commentry and elsewhere referred to *Dorycordaites.* Compare especially specimen 7 and *Dorycordaites* from Commentry.[5]
9. Identical with Draper's fossil recently figured.[6] This may be a small and imperfectly-preserved *Sigillaria Brardi* (Brongn.), but it is difficult to be sure, owing to the absence of detail in the impression.
10. Two long and narrow leaves which are apparently folded along the median line of the lamina. Probably fronds of *Gangamopteris*, not fully expanded.[7]
11. *Glossopteris Browniana*, and fragments of an unknown stem.
12. Stem?

The Transvaal Coal Beds have been so often described[8] that it is unnecessary here to go into any further detail concerning them.

[1] Quart. Journ. Geol. Soc. vol. xvii (1861) pl. viii, fig. 1.
[2] *Ibid.* vol. liii (1897) pl. xxii, fig. 4 *b.*
[3] Compare Feistmantel, *op. jam cit.* pl. xiv, fig. 1.
[4] 'Flor. Foss. Commentry,' Atlas Soc. Ind. Minér. ser. 3, vol. iv (1890) pl. lxix.
[5] *Ibid.* pl. lxvi.
[6] Quart. Journ. Geol. Soc. vol. liii (1897) pl. xxii, fig. 3.
[7] *Ibid.* pl. xxi, fig. 6.
[8] Penning, Quart. Journ. Geol. Soc. vol. xl. (1884) p. 658, & vol. xlvii (1891) p. 457; Molengraaff, Neues Jahrb. Beilage-Bd. ix (1895) p. 232; Draper, Quart. Journ. Geol. Soc. vol. liii (1897) p. 310, & Seward, *ibid.* p. 315; A. R. Sawyer, 'Coal-mining in South Africa,' Newcastle (Staffs), 1890.

V. The Volcanic Rocks.

The period during which the beds constituting the Cape System were deposited was undoubtedly one of great volcanic activity; an activity which was probably continued intermittently until the Karoo Beds were deposited, since contemporaneous lava-flows are quite a common feature in the Karoo Beds of South Africa. The Dwyka Conglomerate, which has given rise to so much discussion in South African geology, lies at the base of the Karoo formation, and although opinions are divided as to its mode of origin I should be inclined to regard it as evidence of the enormous volcanic activity developed at that period. Specimens of this rock collected by the late Prof. Green,[1] and examined microscopically by myself, have a very marked resemblance to the aspect of a volcanic breccia or tuff, consisting of distinctly angular fragments of quartz, felspar, augite, olivine, epidote, magnetite, mica, besides chips of volcanic rocks embedded in a minutely fragmental groundmass.

With regard to the Southern Transvaal, at least $\frac{1}{6}$ of the whole area described is made up of volcanic rock. I have already referred to the vast eruption of basic volcanic rock which took place between the deposition of the Witwatersrand Beds and that of the unconformably overlying Black Reef, and known as the Kliprivers-berg Amygdaloid. I have also described some of the types of the contemporaneous flows of the Magaliesberg and Gatsrand Beds, and mentioned the epidiorite-dykes which teem in the Witwatersrand Beds. I have now to refer to a huge outpouring of lavas, some of which are of a more acid type—rhyolites and andesites—whose age I have not been able to determine. It is certain, however, that they are younger than the Witwatersrand Beds. This volcanic area is met with immediately west of Klerksdorp, extending thence in a northerly direction towards Ventersdorp, a distance of 40 miles, and having in the widest sections a breadth of 10 miles. One of the centres of this eruption or series of eruptions appears to have been at Platberg, a flat-topped hill 12 miles north of Klerksdorp. A part of the rock occurring at this locality is of a true rhyolite or liparite-type; but rocks of a more basic (andesitic) character occur at the same locality, and may be portions of flows emitted at a different period.

A section of the rhyolite examined under the microscope shows it to consist of a cryptocrystalline or 'felsitic' groundmass, in which are embedded porphyritic crystals of quartz with characteristic 'corroded' edges and, less frequently, crystals of both orthoclase and plagioclase. This rock has also been described by Dahms,[2] under the name of quartz-porphyry, from the Makwassi Hills. The andesite-type is distinctly vesicular, the vesicles being filled with secondary minerals (chlorite, quartz, etc.). Under the microscope it is seen to be composed of a mesh of felspar-microlites and granules of augite, with few porphyritic constituents.

[1] Quart. Journ. Geol. Soc. vol. xliv (1888) p. 242.
[2] Neues Jahrb. Beilage-Bd. vii (1891) p. 108.

VI. The Age and Geotectonic Relations of the Formations of the Southern Transvaal.

It has been shown above that the Karoo formation rests unconformably on the much older Cape formation. The age of the former system has recently been discussed in this Journal by Mr. A. C. Seward,[1] who places it at the close of the Palæozoic and beginning of the Mesozoic eras, corresponding to the Permo-Carboniferous system of Europe. With regard to the age of the Cape formation, there is very little to help one to a correlation with European systems, owing to the absence of fossils. It is remarkable that strata of such immense thickness, including beds of the most varied composition, such as sandstones, shales, and limestones, should show no trace of fossiliferous remains. One reason for this is, no doubt, the fact that the beds show evidence of considerable metamorphism since their first deposition; thus we find the sandstones converted into quartzites, the shales into hæmatite- and magnetite-schists, the limestones silicified and marmorized, while the accompanying basic igneous rocks are in part changed to hornblendic and chloritic schists.

For the sole indication of the age of these beds we have to look to the Cape. In the Cape Peninsula an occurrence of Devonian fossils has been recorded in the Bokkeveld Shales.[2] These shales have no counterpart in the Transvaal, but they lie on the Table Mountain Sandstone, of which the Witwatersrand sandstones and conglomerates are generally held to be the Transvaal facies. But this, although extremely probable, has not been proved, and nothing short of the completion of a geological survey of South Africa is likely to prove it.

As already pointed out, the Cape System in the Transvaal is separated by an unconformity into an upper and a lower portion. The upper beds include the sandstones and shales of the Gatsrand and Magaliesberg Series and the wide-spread Dolomite Formation, while the lower beds comprise the Witwatersrand Beds and the Hospital Hill shales and quartzites. Consequently, if we assume that the lower beds are of Devonian age, it is possible that the upper beds may correspond to the Lower Carboniferous of Europe.

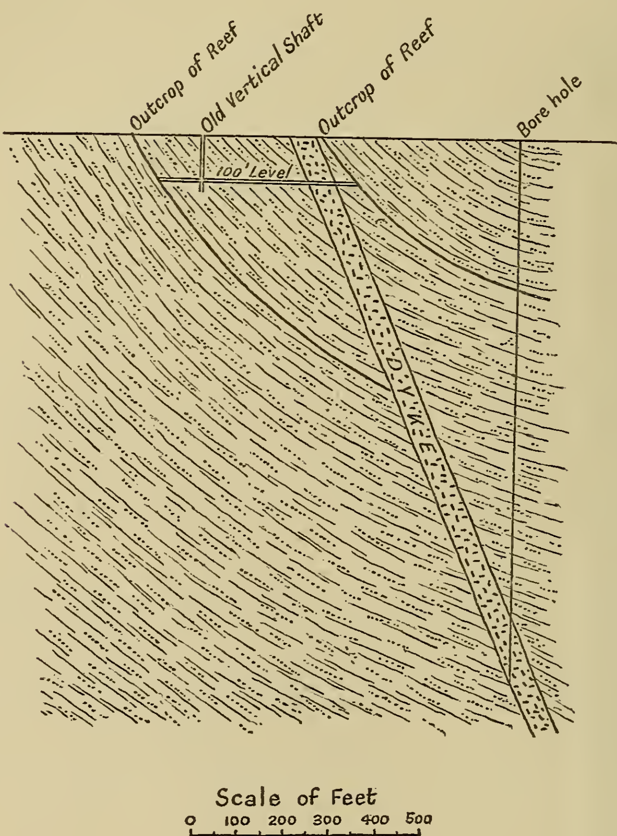
Turning now to the geotectonic relations of the district, we find that the central portion of the great anticline formed by the Dolomite Formation and the overlying Magaliesberg and Gatsrand Series has been removed by denudation, so as to bring to view the older beds of the Witwatersrand, and with them the igneous complex of Archæan rocks. The presence of the latter can be explained only by the assumption that they have been elevated to their present position by earth-movements of considerable magnitude, or that the beds of the Cape System have been lowered by 'trough-

[1] Vol. liii (1897) p. 334.

[2] D. Sharpe and J. W. Salter, Trans. Geol. Soc. ser. 2, vol. vii (1856) p. 203, and F. Sandberger, Neues Jahrb. 1852, p. 581.

faulting.' The latter assumption is by far the more probable.[1] But, whether caused by an elevation of the Archæan rocks or by the sinking of the Cape Beds, the relative displacement has had a marked effect on the latter, producing in them all the results of strong dynamic influences. Lateral thrusting has turned the Witwatersrand Beds sharply up on edge near their outcrop, and several well-marked reversed faults have been observed in the course of the development of the mines.[2]

Fig. 4.—*Reversed Fault in the Witwatersrand Mine.*



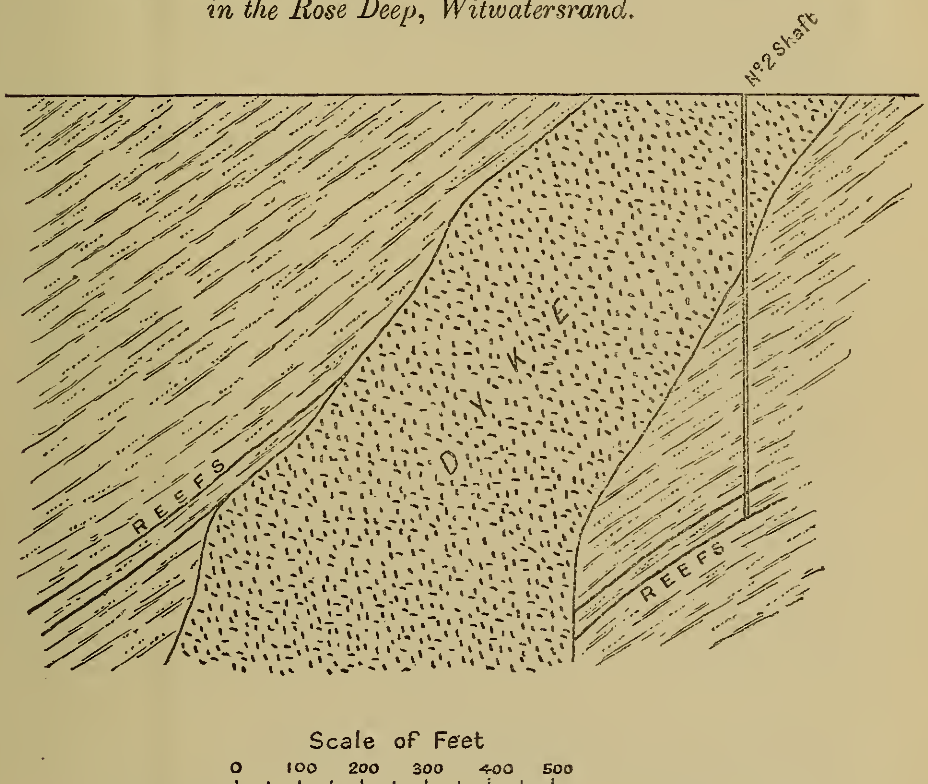
A good example of these reversed faults is that which causes a double outcrop of the Main Reef Series of conglomerates on the properties of the Witwatersrand and Glenluce Gold Mining Companies (see fig. 4), the distance between the two outcrops being 400 feet, and the vertical displacement 450 feet. Another fault of

[1] Prof. Suess, to whom I sent my map, writes me (Nov. 6th, 1897):— 'Your work shows in full clearness the picture of a curved, complex syncline sunk into Archæan rocks between faults.'

[2] It may be noted that these dislocations are caused by strike-faults; numerous cross-faults have also been observed, but they produce displacements of a normal type.

the same character, and possibly identical with the fault just described, exists in the eastern portion of the Simmer & Jack Mine, and extends into the Rose Deep. This fault strikes to the south-east, and dips south-west at an angle of 60°. The trace of the fault-plane at the surface makes an angle of 37° with the reef-outcrop. The horizontal displacement is 650 feet, and the vertical displacement about 400 feet. A considerable extrusion of igneous matter has taken place along the plane of faulting (see fig. 5).

Fig. 5.—*Reversed fault by the Great Simmer Dyke, in the Rose Deep, Witwatersrand.*



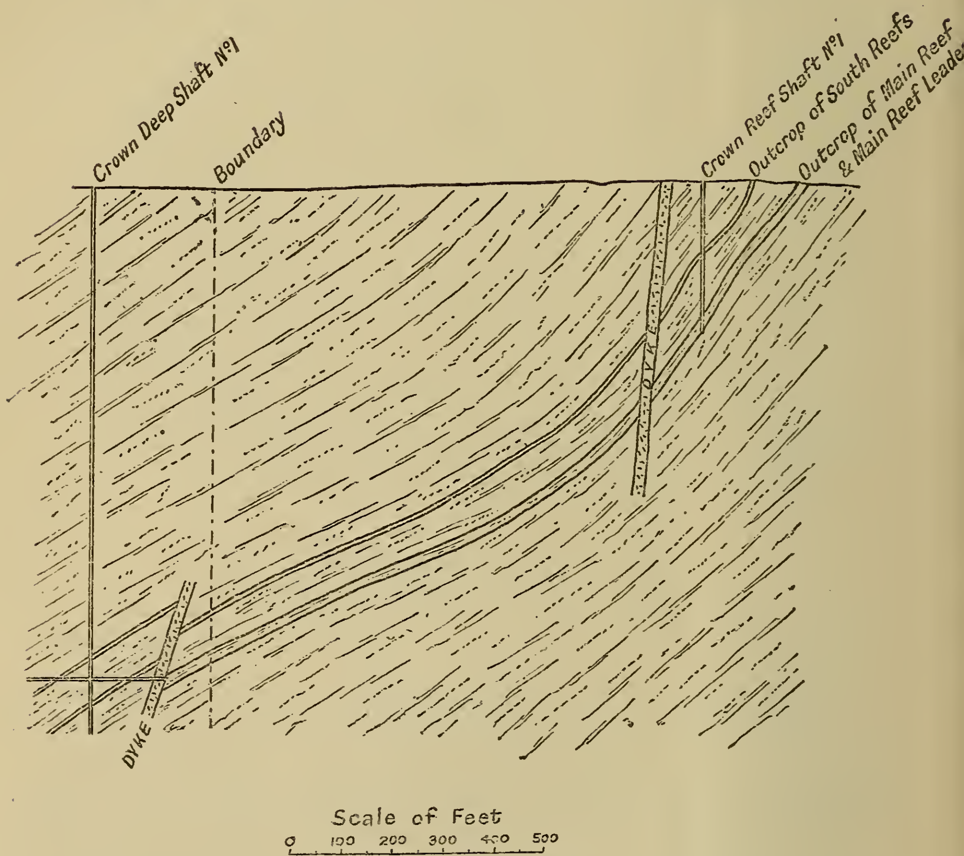
[The position of the reefs shown on the left of the figure is conjectural.]

Another fault in the Metropolitan Mine caused a repetition of the Main Reef, so that the same reef was worked down from the surface for several levels in two parallel stopes. Similar overthrust-faults have been observed in many of the mines, as, for example, the George Goch and Nourse Deep, the Crown Deep (fig. 6, p. 98), Langlaagte Royal, Simmer & Jack, etc. On a property known as the Rip, in the Western Rand, a series of parallel strike-faults causes a four- or five-fold repetition of the outcrop of the Battery Reef conglomerates. Instances could be multiplied, but sufficient has been said to show that reversed faulting exercises an important influence on the tectonic character of the Witwatersrand Beds.[1]

[1] Compare also Gibson, Quart. Journ. Geol. Soc. vol. xlviii (1892) pp. 412 & 428.

Certain mineralogical changes are likewise observable as a consequence of the dynamic influences. Thus a white silvery mica or sericite is commonly developed in the conglomerates; this mineral is found in filmy layers round the pebbles, and in those portions of the beds where differential movement has been sufficiently great to develop schistose structure. The pebbles themselves have occasionally been fractured, or even completely shattered, and the fragments re-cemented by secondary quartz. The silicification of the quartzites by the deposition of secondary quartz, as described above, is probably also a consequence of dynamic metamorphism. The alteration of the dolerite-dykes, first to epidiorites, thence to hornblende-schists, and finally to chlorite-schists must be ascribed to the same influences.

Fig. 6.—*Reversed fault in the Crown Deep Mine.*



The curiously complicated structure of the Venterskroon district, near Potchefstroom, on the Vaal, where the normal succession of the members of the Cape System is reversed, is undoubtedly caused by reversed or overthrust-faulting on a large scale (see Pl. VI). We find here, as already pointed out, the Magaliesberg and Gatsrand Series dipping apparently under the Dolomite, the Dolomite under the Witwatersrand Beds, the Witwatersrand Beds under the Hospital

Hill Series, and the latter dipping in towards the granite. The explanation of this inverted sequence is to be sought in the existence of a series of parallel strike-faults along which each successive older series has been thrust up and over the younger beds. The beds are highly tilted, and the outcrop of each series forms a distinct range of hills. The fault-planes are masked by vast outpourings of igneous rock, which probably followed closely on the dynamic disturbances.

In conclusion, I have only to add that in writing this paper I have endeavoured to give an accurate account of facts as they appeared to me, and have purposely avoided going into theoretical or controversial matters. Consequently, among other things, the interesting question as to the mode of origin of these formations, whether by oceanic, lacustrine, or fluviatile action, I have preferred to leave for others to settle.

EXPLANATION OF PLATE VI.

Geological Map of the Southern Transvaal, on the scale of about 11½ miles to the inch[1]; general section across the Witwatersrand from the Magaliesberg through Johannesburg and the Nigel Mine; and section from the Gatsrand across the Vaal River to Parys.

Discussion.

The President congratulated the Author on his important communication, and asked whether there was any fossil evidence to show the age of the beds under those of Permo-Carboniferous age. The unconformities were important, and might indicate that there were rocks in the area older than those of Palæozoic age. Would it not be better to avoid using the term 'Primary' for crystalline rocks suggested to be of 'Archæan' age?

Mr. C. Dawson pointed out the great lithological resemblance of the specimens on the table from the Hospital Hill Series to some of the fluviatile rocks of the English Wealden group; particularly to the lower beds of the Hastings Sands and Ashburnham group. The Cape Series, of course, was a much older formation and had suffered change, but the rocks of the Hospital Hill Series appeared to have suffered least. He thought that palæontological evidence of the age of the Cape Series should be specially sought for in the Hospital Hill Beds.

Prof. Le Neve Foster said that he considered that all persons interested in gold-mining were much indebted to the Author for his very valuable contribution to our knowledge of the geology of a great gold-bearing region. He desired information upon two points: (i) whether the conglomerate beds on the southern side of the synclinal are as rich in gold as those which have been so largely worked on the northern side; and (ii) what surface-indica-

[1] [This map is published in colours, on the scale of 4½ miles to the inch, by Mr. E. Stanford, Cockspur St., S.W.]

tions guide the prospector in searching for the outcrop of the beds. Is their existence indicated by quartz-pebbles on the surface, or by ferruginous outcrops, or what? In conclusion, he complained of the use by the Author of the expression 'mineralization of the conglomerate;' he wished in season and out of season to protest against this use of the word 'mineralization.' He quite understood that the Author meant by 'mineralization' the deposition of iron-pyrites and silica in the interstices between the pebbles; but this implies that the conglomerate was not mineral matter beforehand.

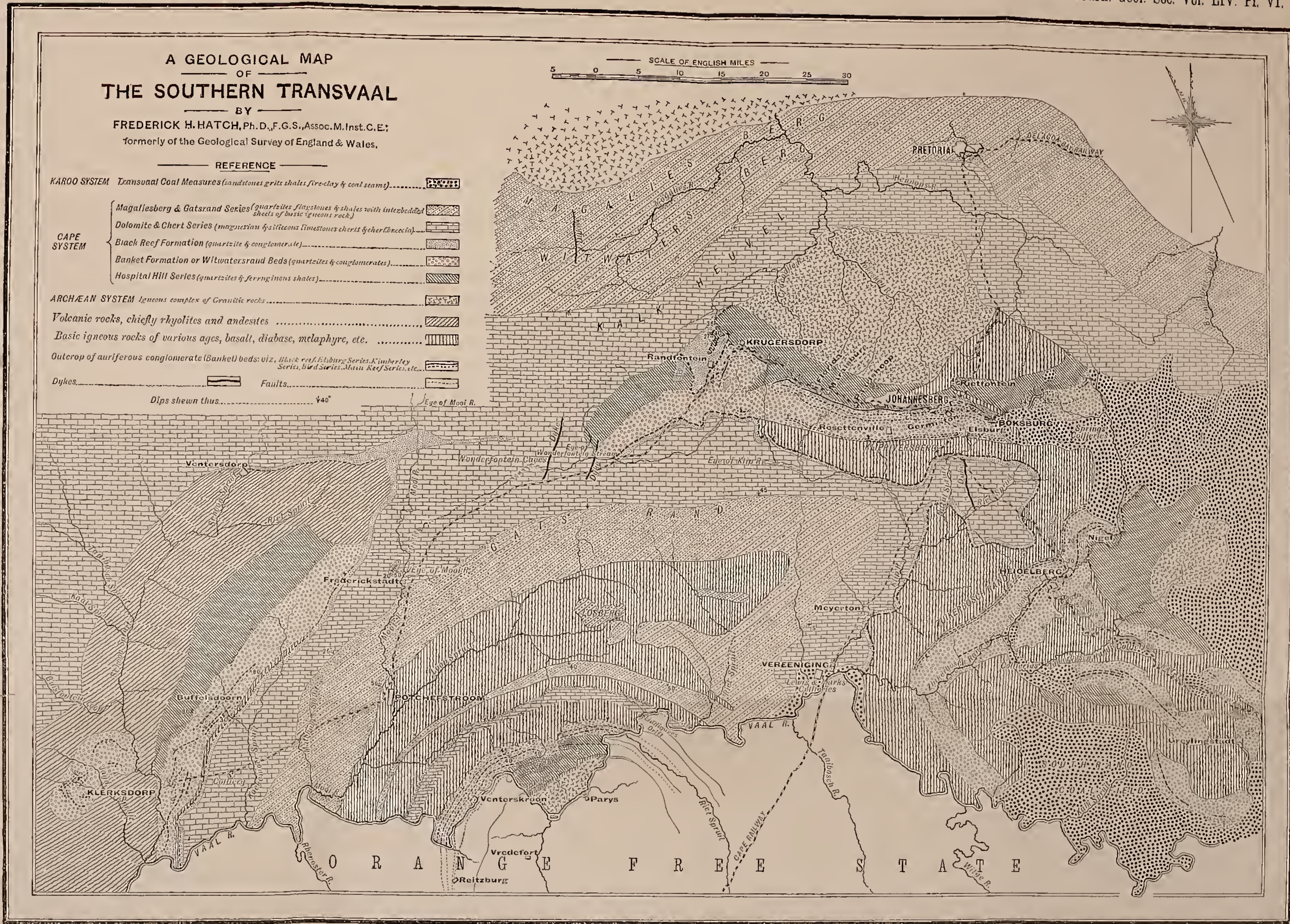
Mr. W. H. Merritt thought the term 'mineralization,' in the sense objected to by the previous speaker, was in more common use on the North American continent than on this side of the Atlantic. He, however, suggested 'metallization' as a more correct term. He congratulated the Author on his paper, and said that what he thought of special interest was the mode of occurrence of the gold in these conglomerates. He said that this showed that auriferous solutions may occur in a very unexpected manner, and in very unexpected places; and in confirmation of this he alluded to a locality in British Columbia, where gold occurred and was worked in deposits of cupriferous pyrrhotite containing virtually no free quartz and occurring chiefly in gabbro.

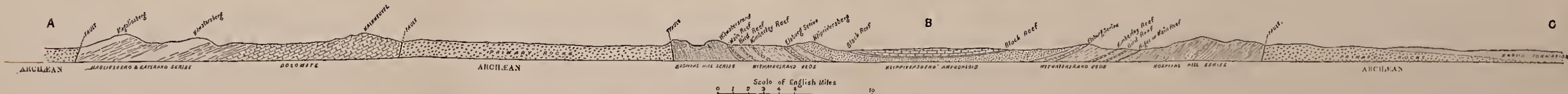
The Rev. J. F. Blake and Dr. J. W. Gregory also spoke.

The Author, replying to the President, admitted that in describing the ancient crystalline rocks he had used the term 'Primary' indiscriminately with 'Archæan.' He agreed that it would perhaps be better to discard the former, and to use the latter term in preference. With regard to the age of the Cape Formation, he had pointed out in the paper that the Witwatersrand Beds were probably correctly correlated with the Table Mountain Sandstone, and that the latter was underlain by the Bokkeveld Shales, in which characteristic Palæozoic (Devonian) fossils had been found.

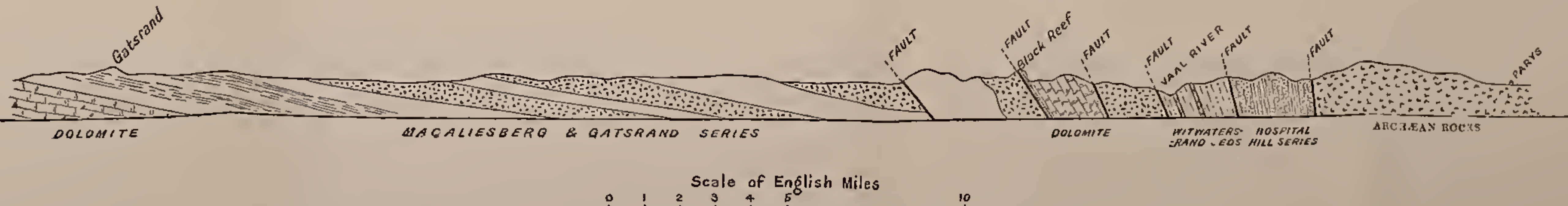
Replying to Prof. Le Neve Foster, he instanced the Nigel Mine as one that had been opened up in payable ore on the southern side of the synclinal. There was nothing to indicate which of the conglomerate-beds might carry gold, short of taking samples for panning or assay. He saw no objection to the use of the word 'mineralization' to indicate a secondary impregnation with mineral matter.

He was glad to find that Dr. Gregory confirmed him in the idea that the Dwyka Conglomerate was a volcanic breccia, and consequently indicative of volcanic activity.





SECTION FROM THE MAGALIESBERG THROUGH JOHANNESBURG AND THE NIGEL, BEARING OF SECTION A TO B 40° E. OF S. & B TO C 71° E. OF S.



SECTION FROM THE GATSRAND ACROSS THE VAAL RIVER TO PARYS, BEARING OF SECTION 29° W. OF S.

7. *On the* Pyromerides *of* Boulay Bay (Jersey). By John Parkinson, Esq., F.G.S. (Read December 15th, 1897.)

[Plate VII.]

Contents.

I. Introduction.

The acid lavas forming the more easterly part of the northern coast of Jersey have been the subject of investigation by many geologists. M. de Lapparent, in a note on the eruptive rocks of the Isle of Jersey[1] published in 1884, summarized these accounts, and his paper was extensively quoted by M. Noury in his 'Géologie de Jersey,' published a few years later, the quotations including those paragraphs which relate to the work of previous authors. The earliest is that of Macculloch, in 1817, in which a hornstone-porphyry is noticed from this neighbourhood. A geological map of the island was published by A. Transon[2] in 1851, in which the northern half of Boulay Bay is represented as being occupied by porphyries, the southern by grit, while the line of demarcation between the latter rock and the more easterly conglomerate is correctly indicated. In 1879 the 'spherular character' of the rhyolites of Boulay Bay was briefly noticed by Mr. Thomas Davies, principally from specimens supplied to him by Dr. Dunlop, of Jersey.[3]

M. Noury, in his work, supplements his quotations from M. de Lapparent with additional observations of his own on the characteristics and origin of the structures exhibited by the rhyolite, at the same time giving a map wherein the principal locality at which pyromerides occur is indicated. Since the publication of Noury's book, a few notes on Jersey have been intercalated in some general observations[4] on the Channel Islands by M. A. Bigot; and the Rev. Edwin Hill has also referred to both the rhyolites and neighbouring conglomerates in his account of the geology of Alderney.[5]

II. General Characteristics of the Rock.

Almost in the centre of the Bay, at the crags marked as L'Islet, occurs a darkly-weathering red felstone, typical of much in the vicinity. Flow-structure is conspicuous, the surfaces being in general straight, though occasionally wavy, and in a few places showing complicated flow-contortions on a small scale. Just below high-water mark, the fine flow gives place to a coarser banded structure.

[1] Bull. Soc. géol. France, ser. 3, vol. xii (1884) p. 284.
[2] Annales des Mines, ser. 4, vol. xx (1851) p. 501.
[3] Min. Mag. vol. iii (1879) p. 118.
[4] Bull. Soc. géol. France, ser. 3, vol. xvi (1888) p. 412.
[5] Quart. Journ. Geol. Soc. vol. xlv (1889) p. 380.

Vicart Point (which may be considered as forming the western boundary of Boulay Bay) is composed, on its southern face, of rock essentially similar to that just described from the back of L'Islet. The top of the cliff consists of a dark drab or brownish-coloured felstone, with light irregular pinkish veins or streaks, and containing porphyritic quartz-crystals. La Tête des Hougues, which is the easternmost point of the Bay at which the igneous rock is found, is interesting, not only from the presence of large pyromerides with exceptionally big cavities, but for the varieties of the rhyolite which it shows. One of these is a red-brown rock characterized macroscopically by a quantity of porphyritic felspars. These, somewhat altered, are orthoclase. The rock contains quartz-crystals rather plentifully, in some cases irregular in shape. It is also interesting to note the presence of a few very bleached mica-crystals. By incident light a section appears brick-red, and the flow-structure, which is well marked, is of the familiar gnarled or wavy type.

On the beach behind L'Islet, the reddish felstone mentioned above apparently passes into a pale green rock, which resembles a true fragmental, owing to the presence of very numerous 'inclusions,' generally pinkish in colour; these, owing to their superior hardness, weather out of the softer rock in which they are set.

A similar rock occurs near the jetty, a few hundred yards away, showing practically the same arrangement of 'matrix' and red or purple fragments. These may be of large size, say 3×2 feet, and weather so as to form ridges in their softer surroundings. They are occasionally found with very irregular outlines and tongue-like ends, suggestive of the softening and drawing-out so often seen in fragments, similar in nature to the lava, which have been included in the flow.

Moreover, the rock contains other and dark green patches representing those portions of the magma itself, which, by some such reason as local cooling or a slightly different composition, have become individualized from their surroundings. Such facts point either to a remarkable case of differentiation of one magma, or, what may be more probable, the mixing of two in different stages of solidification.

An almost identical rock occurs immediately south of the jetty, and may be briefly noticed now. Macroscopically, it is of a light green colour, showing small darker patches and numerous sub-angular fragments; while microscopically, as might be anticipated, it shows a great resemblance to a true fragmental rock. The structure in thin section is obscured, and its interpretation rendered more difficult by the presence of a considerable quantity of a pale green mineral, almost inert with one nicol, and with two giving tints of about the middle of the first order. The slide contains numerous fragments (say $\cdot 2 \times \cdot 15$ inch as an average size), which, although not differing greatly in colour and appearance from the rock in which they lie, are distinguished without difficulty, more especially as they show occasionally an attempt at a flow-structure. These help to produce the resemblance to an agglomerate;

examination of the rest of the slide brings out, however, the fact that it is truly igneous. The red fragments differ principally in a ferriferous staining.

The pyromerides which form the subject of the following notes, and are so characteristic of the Boulay Bay rock, occur in two principal positions; the first, and certainly the best for general purposes of study, is that indicated in Noury's map on the northern side of the jetty and a few hundred yards from it. Here in places the cliffs are practically made up of pyromerides, clustered thickly together, and producing the same remarkable effect as in North Wales and elsewhere, owing to the fact that they resist weathering agencies better than the rest of the rock.

The second locality is just above high-water mark at the Tête des Hougues farther east, and almost at the point where the rhyolite is overlain by the conglomerate which forms the north-eastern corner of the island.

It may be well, before considering the pyromerides themselves more closely, to notice the relation that they bear to the rock in which they lie and to each other. A series of specimens from the cliff-top on the northern side of the jetty, where the pyromerides are most abundant, seems to show this best, though it is by no means intended to suggest that the stages represented indicate more than one of the methods by which these nodules have been produced.

The rock, which shows traces of flow-structure often markedly, is traversed in places by bands having a different appearance from that of the rock immediately surrounding them. These bands are obviously due to a difference in the nature of the material, as in the common case of a banded lava.

A piece of one of these, about $1\frac{1}{4}$ inch in breadth, was detached from the softer greenish-grey rock which surrounded it. As this was taken from a flat surface, one surface of the band was of course also flat; but the other and buried side was roughly cylindrical, so that a transverse section would give an approximately semicircular outline. Examining the flat surface more closely, it is seen that its edges are not quite straight lines, but become slightly indented in places, thus forming a series of flat arcs. There are developed also small knobs or lumps, which give a mammillated appearance to the cylindrical surface.

In a thin section, the structure of this flow-band is identical with that of the pyromerides to be described later. In transmitted light it is rather structureless, of a light brown colour, with innumerable black microliths[1] having no relation to the faint radial growth which is just visible, although they have a decided parallel tendency among themselves. Between the two nicols, the section resolves itself into a mosaic of separately polarizing, but extremely irregular areas, the size of which varies considerably in different parts of the slide. The radial structure is, so far as can be seen, normal to the

[1] See Quart. Journ. Geol. Soc. vol. xlv (1889) p. 258.

sides, and when at one point the irregular mammillated edge of the nodular band has given rise to an indentation which is included in the section, the radial structure is seen to keep normal to it also. There results, of course, a line analogous to that formed by the ingrowing microliths in the devitrified glass described by Prof. Bonney[1]; and it seems fairly obvious that such a surface of discontinuity must have represented a factor of importance in determining the position of rupture under the strains to which the rock has been subjected.

In the second specimen of the series, the constrictions or indentations which were but slightly developed in the first become more marked, giving a corrugated appearance, with a very fairly circular section, to the band. It may, in fact, be described as a series of spheres, each of which has been ground down in two parallel planes and the ground edge of one applied to the ground edge of another. The band itself is dark purple, and harder than the surrounding rock, breaking with a clean fracture; it is, in a word, identical with the felstone forming the pyromerides.

A third specimen essentially resembles the last, but shows a mammillated appearance which is rather characteristic, the nodules appearing as though covered with imperfectly differentiated buds, while the larger lumps, from which those have as it were sprung, may be seen clearly outlined, though not clearly differentiated the one from the other. A thin section of this specimen has been prepared, but it presents no points of especial interest. The slide, as seen by the unaided eye, resembles two mutually-interfering pyromerides, and the microscope shows no points of difference therefrom, either with ordinary or with polarized light (Pl. VIII, fig. 1). Each pyromeride contains at its centre a roughly circular patch, rather darker and with a more confused type of depolarization than that shown by the surrounding matter. Occasionally the constituents of these patches are arranged so as to leave irregular and clearer areas, which polarize uniformly, in an opaque setting which is much more inert between crossed nicols. This structure is by no means uncommon in pyromerides, though varying much in the extent to which it is developed. In relation with the two constituent pyromerides are two crescentic areas of quartz, 10 times as long as broad, very nearly concentric with the respective edges, and in both cases at the same distance from them. The curvature of the two arcs is, of course, not identical, since the diameters of the component pyromerides are not the same.

Continuing the series, it is seen that the next step to this is an irregularly oval pyromeride with a suggestion of tapering at the ends, and irregularly mammillated. Stages can be found easily enough in these cliffs, in which one egg-shaped pyromeride has been apparently constricted off from its neighbours: they themselves being perhaps not so clearly defined, but occurring in a little group of three or four mutually-interfering individuals. It is interesting

[1] Quart. Journ. Geol. Soc. vol. xli (1885) *Proc.* p. 92, also Herman & Rutley, Proc. Roy. Soc. vol. xxxix (1885) pl. i, fig. 1, pl. iii, fig. 5 & p. 90.

also to observe that the pyromerides occur frequently in seams, and that in adjacent bands in the rock there may be developed little rounded knobs or lumps, even though the band itself has not been converted into pyromerides, as one must believe to have happened in the instances which have been just described.

As a type of the nodules which bear no quartz-mass in their interior (the 'globules normaux' of Delesse) the following instance may be taken. The length slightly exceeds $1\frac{1}{2}$ inch, the breadth $1\frac{1}{4}$ inch, so that, as is very often the case, the pyromeride is oval[1] and not circular in longitudinal section. The external surface has inequalities and mammillations; and, when fractured, there is no trace of a radial structure, a condition which, though very usual, is not invariable. The surface is of a reddish-brown, rather chocolate colour, with the exception of an irregular area, rather lighter, suggestive of the streaky or banded rock of the immediate vicinity.

In a thin section, as might be expected, the pyromeride is rather opaque. Over the greater part, a process perhaps best described as a 'settling-down,' seems to have taken place, so as to produce an irregular sorting-out of the various constituents, an arrangement more marked in some parts of the slide than in others. Independently of this, there is a very slight radial structure. A ferruginous constituent in a finely-divided state is present in the slide in some quantity, and this in places, having been largely excluded by the segregatory process, forms a black meshwork which is brick-red by reflected light. The part mentioned as being lighter macroscopically is strikingly marked off in thin section from the rest. It is quite clear, shows finely fibrous radial structure between the two nicols, and contains a few quartz-grains.

An equally common type is purple rather than red, and shows a more uniform structure in a thin section: the radial growth, always faint, being perhaps slightly more pronounced towards the exterior. The type of depolarization is decidedly characteristic.[2] It is distinguished by the patchy mosaic into which the field is resolvable: each constituent area, though often extremely irregular, polarizing separately. Occasionally a cryptocrystalline groundmass is interposed, in various degrees, between the areas of depolarization, resembling the structure of a rock from the Fishguard district described by Mr. Cowper Reed.[3] Frequently, clear and uniformly polarizing patches are seen in a more opaque fibrous setting, which shows dull golden yellow when the fibres are inclined at an angle of 45° to the vibration-planes of the crossed nicols. Typically, however, no indication of the presence of a mosaic can be seen in ordinary light; and, when developed best, the

[1] The foregoing remarks are not intended to suggest that pressure may not be responsible for the oval form of many nodules. See Quart. Journ. Geol. Soc. vol. xxxviii (1882) p. 289.

[2] See Quart. Journ. Geol. Soc. vol. li (1895) p. 149; also many other references contained in Mr. Reed's paper.

[3] It is also seen occasionally in the rhyolite itself, as, for example, near Bonne Nuit Bay.

definite dovetailing edges allow of no blurred appearance as the stage is rotated. Accordingly several structures can be seen normally in these nodules, formed probably in the following order:—(i) A flow-structure marked by black microliths, (ii) a radial structure, and (iii) the patchy structure seen only between crossed nicols.

In many cases part of the original surrounding matrix is found still adherent, after the pyromeride has been detached. This frequently is much less opaque in a thin section than the nodule itself. It contains no microliths, but has much of a secondary green mineral developed, which, in addition to being spread irregularly in patches, also defines lines and curves more or less concentric with each other; these seem certainly to be perlitic cracks. Now, as a rule the rock is microcrystalline.

It is common to find very small spherulites, which have sprung from the surface of the nodule, forming growths which resemble a mushroom without its stalk. Apparently the surface of the nodule has been one of discontinuity and has favoured these growths, as in the partially-fused sheets of glass described by Prof. Bonney.[1]

A further characteristic of structural importance remains to be considered in the frequent presence of a crescent of quartz, visible usually towards the edge of the nodule when it is broken open. For the sake of simplicity, it may be well to take a definite case from such an example as that just described.

The pyromeride measures $2 \times 1\frac{1}{2}$ inches; the quartz crescent, about $\frac{1}{4}$ inch from the top, $1\frac{1}{2} \times \cdot 075$ inch. It tapers slightly at either end, and has a zoned appearance suggestive of infiltration. At about $\frac{1}{4}$ inch from one extremity the crescent turns upward[2] towards the edge of the nodule; at the other, it follows with some exactness a change in the curvature of the periphery, and at this point has internally to it other less well-developed crescents of quartz. At the other end also it can be seen in a thin section to bend slightly upward, although not so markedly as at the first. These are analogous to the 'points de rebroussement,'[3] described by Delesse.

In a section taken at right angles to the longer axis, the crescent is seen to be continued for $\frac{1}{4}$ inch, and here also, near the point where it dies out, its concave and not its convex side is turned outward. The general appearance suggests that the contraction of the nodule has resulted in a crack, and it may be well to see what evidence there is for this in other cases.

One instance of these quartz-filled arcs has been given already in discussing the microscopic appearance of the band-like aggregation of pyromerides in an earlier part. Some points then mentioned, such as each crescent having the same thickness of external wall, although the diameters of the component nodules are different,

[1] Quart. Journ. Geol. Soc. vol. xli (1885) *Proc.* p. 91.
[2] The change of direction at this point is about 150°.
[3] Mém. Soc. géol. France, ser. 2, vol. iv (1852) pt. ii, p. 314.

contrasted with a practical identity in change of curvature of each crescent in correspondence with that of the edge of the specimen,[1] seem significant as to their origin. Some other instances are not less interesting. Occasionally one finds a nodule in which an outermost layer is easily separable from the rest, peeling away in flakes so as to leave a fresh and fairly smooth surface. Sometimes this tendency is pronounced, as in the following :—

Internally to the outer coat or layer ($\frac{1}{4}$ inch thick) and about $\frac{1}{2}$ inch nearer the centre, the pyromeride being roughly $2\frac{1}{4}$ inches in diameter, a distinct line about $\frac{1}{100}$ inch across, extending at least halfway round the nodule, is clearly visible. Not only so, but about ·45 inch nearer the centre is another, not quite so regular as the last, but still plainly to be seen. At one place immediately on the outer side of the second crack, there is a concentric combined with an approach to a radial structure, but the nodule does not differ materially from those previously described. Microscopically these cracks are not so conspicuous as might have been supposed, for, instead of forming a continuous and evenly-bounded curve, the appearance is only one of incipient rupture, apparently consisting of a series of small sinuous cracks. Sometimes the formation of the spherical surface has resulted in the separation of two otherwise closely-united pyromerides, which lie to one another in the relation of cup and ball, inequalities of the one being reproduced in the other ; the 'ball' in fact consists of two undifferentiated pyromerides, an arrangement plainly shown also in the concave cup, which, besides reflecting minor inequalities, consists in the same way of two spherical surfaces. The above instances are from pyromerides obtained from the cliff on the northern side of the jetty. A similar structure from the Tête des Hougues deserves a few words.

This, or as much of it as can be seen, consists of a large pyromeride imperfectly marked off from the surrounding rock. At what would be the centre, if the whole were visible, is a mass of quartz surrounded by reddish felstone, suggesting, more than absolutely showing, a concentric structure. This is followed by a large circular crack, nearly $\frac{1}{4}$ inch across, which after subtending an angle of 45°, suddenly changes its direction so as to represent roughly the figure 3. Externally to this again is apparently the outer zone of the pyromeride, which in turn is surrounded by the body of the rock. This structure, due no doubt to the results of unequal cooling, is precisely the same as that described by Prof. Bonney from North Wales.[2] (See fig. 1, p. 108.)

Before going further, it may be well to see whether any evidence of a confirmatory character can be found.

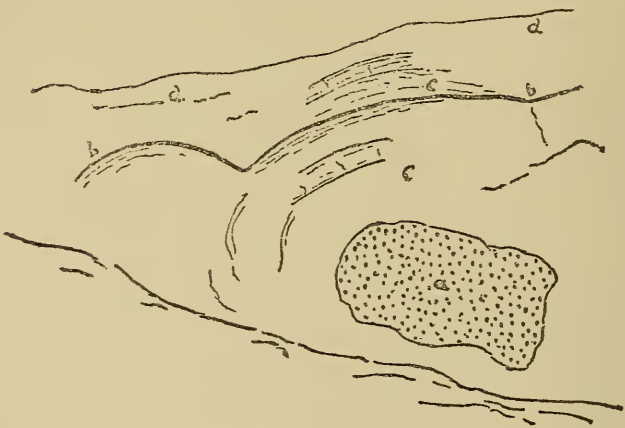
In the harbour itself, below the road leading to the jetty, there are hard, greenish, greyish, and drab-coloured felstones, which in

[1] In this slide, in addition to the two crescents, there are at least twenty brecciation-veins of different ages. Despite these manifold opportunities, decomposition has failed to produce any effect; but see G. A. J. Cole, Quart. Journ. Geol. Soc. vol. xlii (1886) p. 183.

[2] Quart. Journ. Geol. Soc. vol. xxxviii (1882) p. 295.

themselves present no great peculiarity. Overlying these comes a spherulitic rock, identical with, or at all events closely resembling, that recently analysed by Mr. Hyndman.[1] Slightly farther up these spherulites (or pyromerides) become larger, the size of a small cherry, often showing concentric and radial structure in a greater or lesser degree. There is often a crescent-shaped mass of quartz present, although solid specimens without conspicuous radial structure are not uncommon. The rock in which they are set is softer than they themselves are, and pale green in colour.

Fig. 1.—*Diagram (see explanation below).*



a = central quartz-mass.	c = ill-developed pyromeride, passing into
b = crack nearly $\frac{1}{4}$ inch broad.	d = mass of rock.

A few yards farther on the rock becomes of a streaky nature; that is, a rock which, although plainly showing flow-structure, has yet the flow-bands with irregular boundaries on the fractured face, and these, instead of remaining strictly parallel, often join and mingle with each other: in other words, a rock part of which has not been particularly fluid.

The bands and pyromerides are formed partly of a purplish material, partly of a material similar except for the absence of ferrite, and consequently of colour; while the rest of the rock is of a yellowish-brown tint inclining to green, the difference in colour causing the relations of the two principal constituents to be conspicuous. The tendency to segregation into spherical forms, which the more ferruginous matter shows, studs the rock with pyromerides seemingly in all stages of perfection, an effect partly due to the absence of the ferrite just mentioned in much of the pyromeride-forming matter, the whole of this not being at once obvious. With these pyromerides are found many gas-vesicles. These 'spheres' occur in patches often suggestive of a sort of flow-brecciation; an irregular but band-shaped patch where 'spheres' are abundant, may be succeeded by a

[1] Geol. Mag. 1896, p. 365.

band of rock with flow-structure but no 'spheres.' Taken over the whole area (which is not large, forming but a few crags on the beach), the general direction of flow is maintained; yet, taken in detail, the appearance is much less distinct, and in many places the various constituents have a very clotted look.

The structures in a thin section of this rock, showing well-marked purplish pyromerides set in a yellowish-green 'matrix,' are as follows:—This 'matrix,' although slightly obscured by the presence of secondary decomposition-products, is still quite clear enough to show that this part of the rock (now microcrystalline) exhibits perlitic structure on a fine scale, the cracks, as in other cases, being outlined by a green mineral.

In comparison with this 'matrix' the pyromerides are almost opaque. They have a wavy, almost scalloped boundary, and there seems to be at least a suggestion that the shape of the edge of a pyromeride has determined the shape and proximity of the neighbouring perlitic fissures. The pyromerides themselves show indications of radial structure such as have been mentioned before, together with the formation of more opaque patches, which, while preserving a general radial direction, constitute a kind of irregular meshwork more extensively developed in some places than in others.

Often the periphery of the spheroids is even and comparatively regular, but often too there is an irregular and clotted appearance, with edges drawn out into short and blunt tongues (Pl. VII, fig. 2); these, practically destitute of any attempt at radial growth, succeed to a more central part, which, although structurally a pyromeride, obviously forms part of the same mass.

This suggests the presence of material identical with that forming the pyromerides, but unable, owing to local conditions, to adapt itself to their characteristic mode of growth. It is interesting therefore to note that there are frequently present in the rock irregular patches of the same purplish constituent, which, although found quite locally, may under these circumstances take on the functions of the 'matrix.'

In a thin section, as in the hand-specimen, this less specialized material is at once distinguishable from the adjoining true matrix: the latter, as before mentioned, being finely microcrystalline, and containing some quantity of a greenish filmy mineral.

On the other hand, the material in which the pyromerides are partly embedded is slightly more opaque, more ferriferous, and, between crossed nicols, the regular mosaic of grains shown by the 'matrix' proper is replaced by a more irregular patchy type of depolarization, the boundaries of the constituent areas into which it breaks up being ill defined. In addition, within the limits of this material itself there are distinct evidences of flow. Although the enclosed pyromerides are clearly distinguishable, yet it is evident that the characters of the differentiated and undifferentiated materials are nearly alike, and the intimate relation which exists between them points inevitably to the conclusion that they are indeed the same.

It seems then fairly evident that, taking this rock as a whole, two materials were present in the magma. One, the more fluid, has solidified as a glass, now represented by the yellowish-green 'matrix;' the other, which was in a sticky state, has been drawn out into irregular flow-bands, or left as lumps and clots. That it was occasionally melted is shown by the fact that flow-lines may in places be seen traversing uninterruptedly both pyromeride and 'matrix.' On the cessation of movement in the lava, and as the temperature fell, the radial structure of the pyromeride would be set up when this was possible. In one case the outer part of one of the purplish masses has distinctly more of the structure of a pyromeride, in a well-defined zone, than the more central, which has indications of flow.

Nevertheless, definite spheroidal forms do occur, which have strongly-marked characteristics of their own, resembling, in these and in general relations those recorded above, which appear to have originated each at a separate point, like true spherulitic individuals, from a magma homogeneous at the initial stage of their formation. Such a rock as that described and analysed by Prof. Bonney and Mr. Hyndman forms an example.

Among those rocks which show evidence of flow, the relation of which to the pyromerides has just been discussed, occur patches about the size of one's hand, in which a network of polygonal cracks is conspicuous. These, often irregular, are frequently developed round darker and roughly circular spots showing the structure of pyromerides; the feeble radial structure is not, however, confined to this more central and definite part, but is continued throughout the space which any one set of the cracks encloses.

Crescents of quartz are found occasionally towards the outer edge of the darker centre.[1] In general, there is a decided resemblance to the spherulitic felsite figured by Prof. Bonney from Arran.

III. Comparison with other Districts.

Structures similar to many of those from Boulay Bay which have been described above have been recorded in a very valuable work by M. Delesse so far back as 1852.

The following remarks will scarcely bear condensation. In describing some spheroids (from Siberia), after remarking that they are usually irregular, he says:—'Tantôt ils sont complètement isolés; tantôt ils sont accolés à des bandes jaspées qui leur servent de parois, et il semble même que le globule résulte de la réunion en sphères de ces bandes jaspées.'[2] Apart from external form, Delesse also clearly understood that contraction during cooling had had much to do with the structure of pyromerides[3]; distinguishing between 'des cavités petites et assez régulières' produced by such an

[1] 'Pitchstones & Felsites in Arran,' Geol. Mag. 1877, p. 499.
[2] Mém. Soc. géol. France, ser. 2, vol. iv (1852) pt. ii, p. 316.
[3] *Ibid.* p. 336.

agent, and the very large and irregular cavities which characterize his division of 'globules anormaux.'

The description and illustrations which M. Michel-Lévy[1] gives of the rock from Gargalong, near Fréjus, show that it bears a great resemblance to that from Boulay Bay, both in the characters of the pyromerides and of the 'matrix.'

Miss Raisin has referred to rings of quartz—often incomplete, and possibly due to contraction—from Careg-y-defaid.[2] In the same paper also (pp. 264–267) flow-brecciation is recorded as one of the causes to which formation of pyromerides is due; and I have made a similar suggestion in describing some acid lavas from Pembrokeshire.

The resemblances existing in many respects between the spheroids of the Jersey rocks and those of the Yellowstone district naturally suggest a common origin, or at all events that similar factors may have been operative in their production. The clotting in the magma which, in some instances, seems to have been the cause of the formation of nodules in Boulay Bay, forcibly suggests itself in the case of some of the Yellowstone rocks. Through the kindness of Prof. Bonney I have had the advantage of examining some specimens from the last-named district, in which the resemblances to Boulay Bay rocks were very strong. However, in the thin sections examined there was no evidence, such as that brought forward above, to suggest that the spherulites represent in any way an element foreign to their more immediate surroundings.

In Prof. Iddings's report on the rocks of Obsidian Cliff,[3] chemical analyses are given to show that the spherulite is 'nothing more than a small portion of the magma which has crystallized with a particular structure.'

Hence, and the study of the literature of the Yellowstone brings out the point strongly,[4] the difference which exists between these growths and their 'matrix' is due to a particular crystalline structure; in many of the Boulay Bay, and, so far as I know them, in many of the North Wales and Wrockwardine nodules, this particular crystalline structure is of secondary import. Indeed, in many cases, it is not only entirely absent, but superseded by a kind of fluidal structure, which renders the formation of any radial growth highly improbable.[5] In the case of the Wrockwardine specimens the uninterrupted continuance (in many instances) of fluxion-lines from matrix to pyromeride, and a certain haziness at

[1] Bull. Soc. géol. France, ser. 3, vol. iii (1875) pp. 224–235, and Fouqué & Michel-Lévy, 'Min. Micr.' pl. xv, fig. 2.

[2] 'Nodular Felstones of the Lleyn,' Quart. Journ. Geol. Soc. vol. xlv (1889) p. 256.

[3] Seventh Ann. Report U.S. Geol. Surv. (1888) p. 283.

[4] *Ibid.*, and Iddings on 'Spherulitic Crystallization,' Bull. Phil. Soc. Washington, vol. xi (1891) p. 445.

[5] Of such a type as that figured by Prof. Bonney from near the Conway Falls, Quart. Journ. Geol. Soc. vol. xxxviii (1882) pl. x, fig. 4. Some nodules from the Lledr Valley show a similar structure. One of these is interesting, from the fact that it contains a few ill-shapen pink garnets altering to chlorite.

the boundaries of the latter, do not indicate the presence of two materials of different constitution, but rather the differentiation of one.

The following figures are diagrams from Conway Mountain which recall the characteristics of the Boulay Bay rocks.

In fig. 2 the relation to flow-structure is evident enough. In fig. 3 the weathered surface of the matrix is rough to the touch and eye; the surface of the nodules, on the other hand, is smooth; they appear more flinty and more compact. In a few cases the pyromerides were distinctly mammillated. Thin sections of both matrix and pyromeride have been cut; the differences are sufficiently interesting to merit a short description.

Fig. 2.

$\frac{1}{10}$ nat. size.

The matrix is characterized by minute circular clear spaces, outlined by flakes and fibres of a greenish chloritic mineral. Between crossed nicols these are seen to be spherulitic, with the characteristic black cross; the greenish mineral is very inert. Examination of the slide with a lens shows what the microscope does not

Fig. 3.

$\frac{2}{3}$ nat. size.

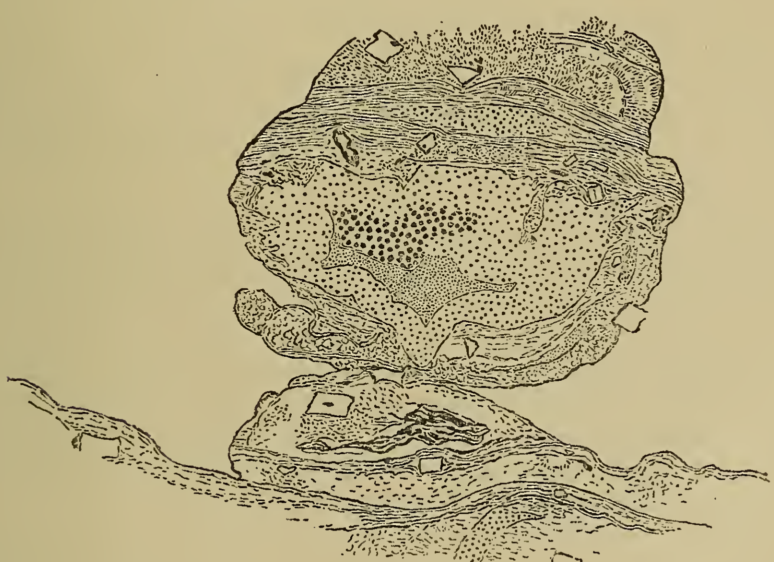
[Figs. 2 & 3 represent pyromerides from Conway Mountain, affected in form by fluxional movement.]

so easily reveal, namely, that the rock is perlitic, the cracks showing as clear lines and curves; devitrification has largely hidden this structure.

The pyromeride, which was a large one, some 5 or 6 inches in diameter, and, so far as the eye can see, quite identical with others from the more immediate neighbourhood, is of a totally different type. In a thin section the suggestion of a network which characterized the matrix is replaced by a much more uniform appearance, owing to the great development of indefinite films and specks rendering the slide rather opaque—in large part due, perhaps, to the presence of a chloritic mineral. There are some shadowy felspar-microliths and no trace of a radial structure. Between crossed nicols the field breaks up into large irregular areas, each polarizing separately. In fact it closely resembles the patchy type of the Boulay Bay rocks before described.

Slides have also been prepared of an egg-shaped nodule and the adjacent matrix from Digoed, on the road from Bettws-y-coed to Penmachno. In the hand-specimen the 'matrix' appears slightly bluer than does the nodule; minute specks of a greenish mineral are present which, in a thin section, are arranged in a manner suggestive, but not strikingly so, of flow. As in the former instance, the rock is perlitic, but the cracks are not outlined by a chloritic mineral,

Fig. 4.—*Diagram showing the relation of a nodule to flow-brecciation. (From the Wrockwardine district.)*



[The dotted portion represents siliceous infiltration. Length of part figured = about ·75 inch.]

as is so frequently the case. The nodule, on the other hand, shows wavy and contorted flow-lines resembling the specimen figured by Prof. Bonney [1] from near the Conway Falls Inn.

The chocolate-brown rocks of the Wrockwardine district resemble strikingly some of those from Boulay Bay, and the likeness between the nodules of the two localities is equally strong in thin sections.

[1] Quart. Journ. Geol. Soc. vol. xxxviii (1882) pl. x, fig. 4.

The same brick-red colour is manifest by incident light, the radial structure present in both has the same characteristics, the black microliths found in the one are seen in the other, the types of depolarization have many points in common. It is then interesting to find that here, as in those cases from Boulay Bay where the pyromerides are sufficiently small to enable their relations to the surrounding matter to be certainly made out, the evidences of flow as a factor of importance, which were described in the Jersey rocks, are, as the diagram on the preceding page will show, also to be found in connexion with the nodules from Shropshire. (See fig. 4.)

The tongue-like ends which form part of the nodule and the identity of its material with that of the flow-bands. the only difference being a certain amount of radial structure in the former, appear significant. Also the concentric structure, which is but feebly developed here and there, seems to show that it, like the radial growth, was developed after the present form was assumed, rather as a structure of secondary importance.

From the preceding remarks it is apparent that many pyromerides bear a relation to the enveloping rock similar to that which characterizes those fragments of a lava-flow which have resulted from flow-brecciation. They have distinguishing petrographical characters of their own, not identical with, often differing markedly from, the surrounding materials; they are connected with flow-movement in the rock by gradation into such bands as are characteristic of many lavas, and show occasionally contours which clearly indicate that part of the differentiated material was unable to accommodate itself to the strictly spheroidal form of the more perfect pyromerides.

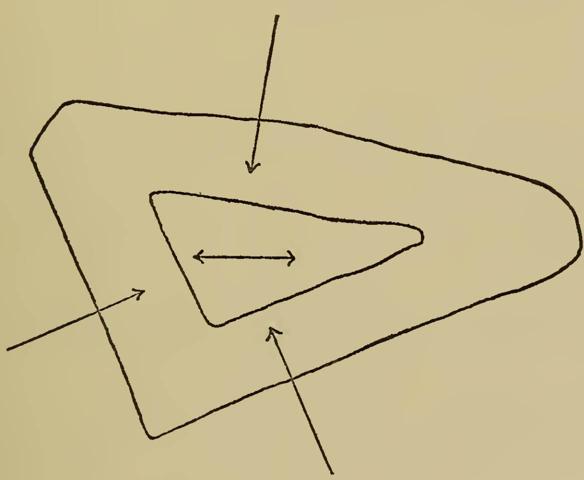
Turning from the form of the nodules to less evident structural peculiarities, it has been seen that the radial structure is always feebly developed, and that, in those cases[1] where a conspicuous indentation of the edge occurs, the direction of growth is normal to it. That such an appearance may be produced as a secondary structure in a fragment the contours of which are by no means spherical will be apparent from the following case. The rock from which the slide was prepared forms the lower part of the crags abutting on the more southerly side of the jetty at Boulay Bay. It is of the chocolate-brown colour commonly found, and shows many elongated fragments darker than the surrounding rock; the latter in itself does not differ materially from others in the neighbourhood. The fragments, which are sufficiently numerous to give both specimen and slide rather the appearance of an ash, are rounded or angular, similar to the lava which contains them, but still easily seen, more especially as they are for the most part characterized by flow-lines, which of course terminate abruptly. Closer observation shows that a radial structure has been set up, occasionally at one part only, but sometimes irregularly all over: obviously secondary, as in other

[1] That is, the radial structure does not define the edge of the pyromeride, but the edge of the pyromeride determines the direction of the radial growth.

parts the original flow-lines are generally found to persist. The latter are not sufficiently pronounced to prevent the secondary structure from being formed.

By incident light the unaltered part of the fragment appears brick-red, as is so commonly the case in these rocks; the radialized part, on the contrary, is a dull greenish grey, with golden-yellow polarization-tints.

Fig. 5.—*Diagram of fragment showing growth normal to its sides, the direction of which is indicated by the three arrows.*



× 24.

[The space enclosed by the inner triangle still shows the original flow-lines, the direction of which is indicated by the innermost arrow. The space external to the inner triangle is now occupied by the secondary growth.]

In some cases the fibrous growth, starting at right angles to the bounding-walls, has left no trace of the original, and the appearance is then less striking than when, proceeding uniformly inward, it has stopped short of effacement of the original flow-lines, leaving a central part in which these are still clearly visible, contained by lines parallel to, and equidistant from, those defining the fragment.

It is impossible to avoid the conclusion that this radial structure has arisen from the secondary heating-up to which the fragments have been subjected, and in this respect it is closely analogous to that described by Prof. Bonney from Arran.[1]

Prof. Cole,[2] in a paper based on a specimen of rhyolite brecciated by flow from Rocche Rosse, has described exactly the same phenomenon. He gives it as his opinion that 'spherulitic crusts will arise where fragments of obsidian, sufficiently consolidated for fracture, are subjected to renewed heating, or even to the slow passage of the residual heat from the lava-flow of which they form a part.'

[1] Geol. Mag. 1877, p. 506.
[2] Min. Mag. vol. ix (1891) p. 273.

IV. Pyromerides with relatively large Quartz-enclosures.

Figures (6–8) are given illustrating the relation existing between nodules and the contained quartz-masses from Boulay Bay.

It will be seen that they do not differ materially from those already described by many authors. The accompanying diagrams, however, show instances of quartz-enclosures from the harbour at Boulay Bay which deserve a few words, on account of the rather unusually elongated shape that they present.

They occurred in the pyromeride-bearing rock which has been above described as containing two constituents. Of these, one, purplish and viscous, has formed the nodules; the other, more fluid, the investing 'matrix.' It is with the former that these elongated quartz-masses are associated, a relation which seems significant as to the condition and circumstances under which it has solidified.

In these pyromerides typical contraction-cracks are often present, but between these and the irregular, comparatively large quartz-enclosures, often common also, are many intermediate shapes. Thus the quartz, though long in proportion to its breadth, and with crenated edges, seems too broad often for a contraction-crack, even though a general correspondence obtains between it and the nodule. The size of the latter seems of secondary importance: that is, the large pyromerides do not necessarily contain more quartz than the smaller, or *vice versa*. It is, however, sufficiently clear from the shape that these are gas-vesicles, and that they are not due to any selective action on the part of agents of decomposition; and it is also clear that, whatever force elongated the vesicles, it had ceased to operate before the formation of the pyromerides, for these are not elongated. Perhaps an explanation may be sought in the state of the rock before solidification. The matter in which the viscous pyromeridal material was placed was a more perfect glass. The former, with its associated vesicles, drawn out into irregular flow-bands or left as isolated clots by the action of flow in the latter, would, perhaps, when the whole came to rest, be enabled to draw itself together—like oil in water—assuming, with its enclosed vesicles (the pressure in which would by this time have diminished), more spheroidal outlines, those of the nodule naturally the more perfect.

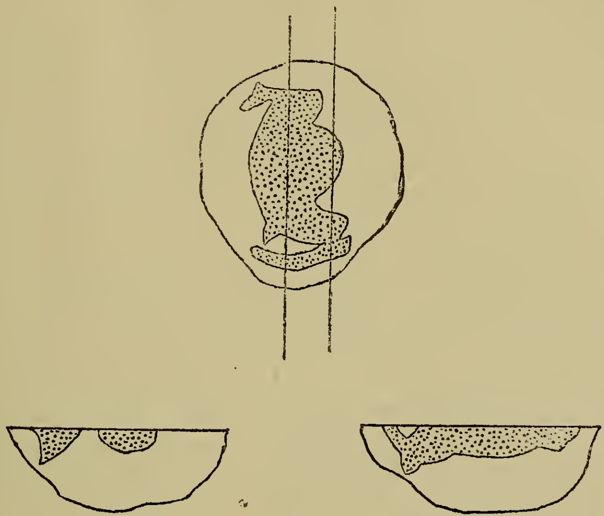
In conclusion I wish gratefully to express my thanks to Prof. Bonney for ever-ready help, and for the kindness which he has shown me during the preparation of these notes.

EXPLANATION OF PLATE VII.

Fig. 1. Part of cross-section of a fluxional band composed of pyromerides. The figure shows the structure of a pyromeride, and includes a contraction-crack concentric with the periphery, and showing recurved extremities. Numerous brecciation-veins traverse the section. The centre shows a somewhat different structure from the rest. In places it is composed of ill-developed spherulites (not included in the figure). Cliff north of jetty, Boulay Bay. $\times 9\frac{1}{4}$.

2. Pyromerides and enclosing perlitic rock, illustrating the difference in the nature of the two. The irregular shape of the former, as described in the text, is plainly shown. From beach in harbour, Boulay Bay. $\times 9\frac{1}{4}$.

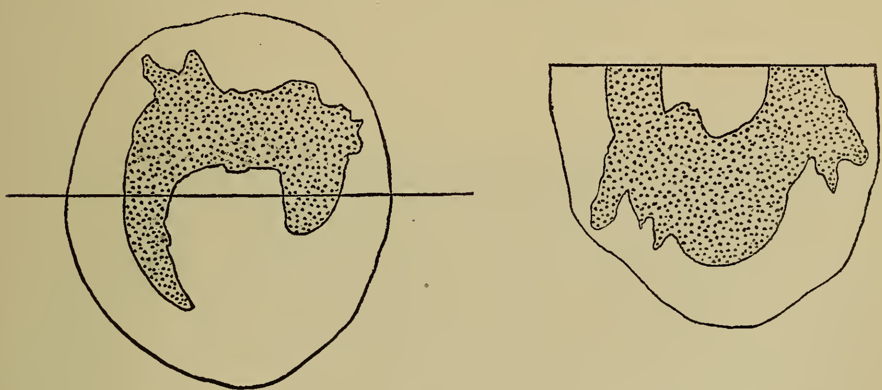
Fig. 6.—*Pyromeride showing shape of enclosed quartz-mass (dotted); from Boulay Bay.*



[Nat. size.]

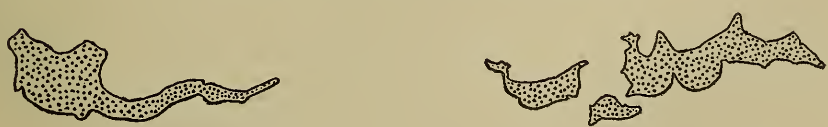
The two lower figures show the extension of the quartz in two planes at right angles to that of the upper figure.

Fig. 7.—*Pyromeride from Boulay Bay. (The right-hand figure represents a section taken across the left-hand one.)*



[Nat. size. As in the other figures, the dotted areas represent quartz.]

Fig. 8.—*Diagram of elongated gas-vesicles in pyromeridal rock. (From harbour of Boulay Bay.)*



[Slightly more than nat. size.]

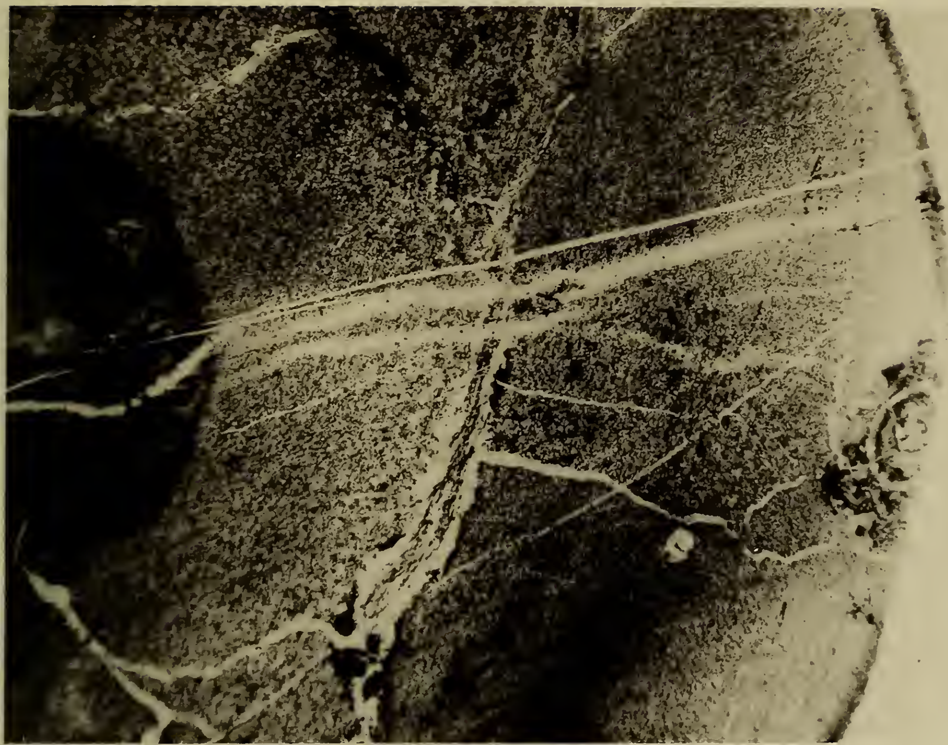
[$\frac{2}{1}$ nat. size.]

DISCUSSION.

Dr. J. W. GREGORY remarked on the resemblance between the sections exhibited by the Author and the hollow spherulites of Obsidian Cliff. He suggested that the infiltration of quartz into such hollow spherulites, which often consist of concentric, separated layers, would account for the formation of such pyromerides as those of Jersey. He thought that the characters of the Obsidian Cliff lithophyses could be best explained by the alteration of spherulites through their inclusion in a lava of later date than their original formation; and he noted the coincidence of the occurrence of brecciated obsidian in association with the lithophyses in the one case, and of brecciated felsite in association with the pyromerides of Jersey. He congratulated the Author on this interesting contribution to the literature of the coarsely spherulitic rocks.

Prof. BONNEY said that the Author had mentioned the obsidian from the Yellowstone Park, but inclined to the view that those spherulites were due to radial devitrification. At the same time it would be quite possible that the structure described by Dr. Gregory might also occur, for the Author considered the spherulites and pyromerides of Boulay Bay to have had different origins.

1.



2.

Pyromerides of Boulay Bay.

8. Exploration of Ty Newydd Caves, Tremeirchion, North Wales.

By the Rev. G. C. H. Pollen, S.J., F.G.S. (Read December 15th, 1897.)

[Abridged.]

[Plate VIII—Section.]

Contents.

I. Introduction.

In November 1896 a committee was formed, consisting of Dr. H. Hicks, F.R.S., our President, Dr. H. Woodward, F.R.S., with myself as secretary, to excavate some caves at Tremeirchion, very near the caves of Ffynnon Beuno and Cae Gwyn. These last were excavated by Dr. Hicks and Mr. E. B. Luxmore, and during part of the time by a committee appointed by the British Association in the years 1883 to 1888,[1] and it was hoped that the contents of the new caves might throw some additional light on the discoveries made there.

Our work is still far from complete, but Dr. Hicks, to whose authority I shall frequently appeal throughout this report, considers that the results already obtained are of sufficient interest to be brought before the Society.

In addition to organizing the committee of excavation, Dr. Hicks obtained two grants, from the Reserve Fund of the Royal Society and from the Government Grant Fund, to cover expenses. I am moreover indebted to him for much valuable advice and assistance, in examining the materials found, and even in visiting the cave in person.

I must also express my gratitude to Mr. A. Foulkes-Roberts, of Denbigh, for his very kind help in the prolonged negotiations that I have had with the tenants of Ty Newydd Cottage, after which I have named the cave. I must add that, since we first came to an understanding, the owner, Mrs. M. E. Griffiths, of Mold, has shown every disposition to assist me.[2]

Another portion of land, under which the cave runs, is the property of the Rev. E. J. Edwards, Vicar of Tremeirchion. He and his tenant, Mr. Edward Jones, placed the ground at my free disposal.

[1] A great number of papers have been published referring to these excavations. Prof. T. McK. Hughes, F.R.S., in Quart. Journ. Geol. Soc., vol. xliv (1888), pp. 112 *et seqq.*, gives references to papers published before that date. Dr. Hicks read a subsequent paper, which was published in the same vol. of this Journal, pp. 561 *et seqq.*

[2] [It is with great regret that I have now to state that Mrs. Griffiths died on Dec. 23rd, 1897, after only a few days' illness.]

Mr. P. P. Pennant, J.P., of Nantlys, also gave me full permission to make excavations in the valley below the cave, and to make a new section of the floor of Ffynnon Beuno cave, in order that we might compare the various materials there with those which we had dug out.

Finally, I cannot refrain from tendering my thanks to the other theological students of St. Beuno's College, who have actively assisted me with spade and pick. To one in particular, the Rev. E. R. Hull, S.J., I am indebted, not only for most energetic manual labour, but also for carefully measuring and preparing all the plans and sections brought before the Geological Society.

A view showing the exposed entrance to Ty Newydd Caves was given by Prof. T. McK. Hughes in the paper already mentioned.[1] No excavation was, however, undertaken at that time.

Owing to the proximity of Ty Newydd Cottage, we were unable to approach the cave from the exposed front, but we had to make a cutting and tunnel through the solid rock from the hillside above. This work occupied the whole winter of 1896–97, and it was not till March that we could begin the actual exploration.

Ty Newydd Caves are on the northern slope of a hill of Carboniferous Limestone called Y Graig or Graig Tremeirchion. This rock projects forward from the range of Denbighshire Grits and Wenlock Shales which form the north-eastern side of the Vale of Clwyd. Immediately to the east there are two hills 800 feet high, both less than a mile distant. The Graig, which is 595 feet high, is joined to these by a ridge which descends to 520 feet. On the other three sides there is an uninterrupted view across the Clwyd Valley.

The whole hillside and valley round the Graig are covered with Boulder Clay, containing frequent specimens of quartzite, pink granite, and other rocks which were recognized by Dr. Hicks as undoubtedly from the Lake District or Scotland. The Graig itself is almost bare rock, thinly covered with turf, under which, in all the hollows and pockets that we have explored, we have found scattered stones of Denbighshire Grit and other local material, very clearly striated, also some Arenig felstones, flint, quartzite, etc.

On the northern side there is a steep descent to a little brook, which flows at an elevation of 300 feet through Ffynnon Beuno Farm and the grounds of Bryn Bella. On the opposite side of the stream, and exactly facing Ty Newydd Caves, are the former excavations of Ffynnon Beuno and Cae Gwyn.

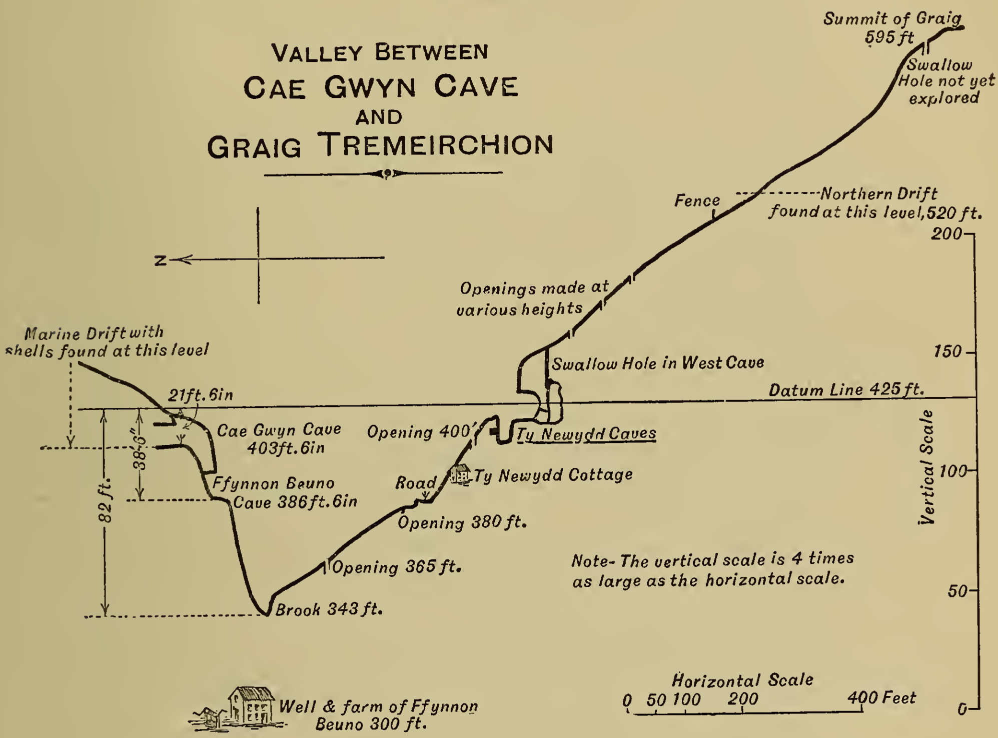
The entrance to Ty Newydd Caves is hidden from the valley by a wall of rock, the space between this and the caves having been quarried away about 50 years ago. In this wall there is a small cave running down towards the valley. This may be a continuation of our tunnel, but we have had no opportunity of examining it.

The present part of the cave exposed appears to be the back of a

[1] P. 132, fig. 7.

large chamber, 19 feet across and 12 feet high, of which the roof still projects some 7 to 10 feet. In some places stalactites adhere to the roof; an old man still remembers coming to the cave as a boy, and knocking off the 'icicles' to feed a limekiln which stood on the site of the present cottage. The eastern side of this chamber was occupied by a bank of drift extending 6 feet into the cavern and concealing the mouth of a cave, the 'Eastern Cave.' On the extreme west,

Fig. 1.



at a slightly lower level, was a second bank of drift which proved to be standing in the entrance of the 'Western Cave.'

For convenience of measurement we took a uniform datum-line, at 425 feet above the sea-level and 21 feet above the floor of Cae Gwyn Cave. The lower part of the front and all the cliff-face showed boring-holes of the former quarry-work.

The material found in the caves may be classified as follows:—

1. Disturbed material. This consists of large angular and subangular pieces of limestone, sometimes much fretted from long exposure to the wet drift, but frequently with fresh faces, presumably due to quarry-work. The matrix is a red sandy clay without lamination, similar to that in the smaller vertical fissures near the surface. This bed also contained many large broken stalactites and pieces of stalagmite up to 1 inch thick. It occurs only on the top of the bank in front of the Eastern Cave.

2. Sand. This is usually red from the presence of some clay, but occasionally yellow and nearly pure. It has no lines of stratification.

3. Gravel. This is for the most part clayey, and contains the following material:—

(*a*) Denbighshire Grit and micaceous shale—the ordinary stone of the gravel—dark olive-green or greenish-blue to pale greenish-yellow. When long exposed to wet it is very soft, with an outer coating of dark shining clay. Size: large grains to the size of a brick. The larger stones are much flattened, like those of Glacial Drift, but there are no striæ visible on the stones in the caves.

(*b*) Chert—frequent in the uppermost and lowest beds of gravel, rarer in the middle—white or pale yellowish grey, often containing Carboniferous chert-fossils; subangular; without striæ. Size: small grains to fragments 2 inches in diameter.

When we sent the first subangular specimens to Dr. Hicks, he was inclined to think that they might be very rude implements. But on subsequent examination of larger quantities it was considered that they were too doubtful to bring forward as evidence of man's handiwork.

(*c*) Vein-quartz. Abundant in some places and scarce in others, but confined to no special beds—white or pale yellow, with black irregular markings; much rounded; without striæ. Size: small grains to fragments $2\frac{1}{2}$ inches in diameter.

(*d*) Stalactites—only in large chambers—usually broken; of very coarse, crystalline structure; up to 6 inches in diameter.

(*e*) Stalagmite—confined to the upper beds—coarsely crystalline; $\frac{1}{4}$ to 1 inch thick, small fragments up to 5 inches square.

(*f*) Limestone—masses of every size occur in all the beds except the lowest gravel. In one part filling a swallow-hole, the material was chiefly angular limestone in sandy clay, with a few small grains of Denbighshire Grit and small patches of purple clay.

The top gravel in both caves is more sandy and contains stalagmite-fragments. The intermediate beds are often so largely mixed with red clay that the bed might rather be called gravelly clay than clayey gravel. The lowest bed contains most of the larger stones of Denbighshire Grit in irregular patches, but is otherwise very compact and fine.

None of the gravels show lines of stratification, the stones, where large or flat, being arranged according to the turns and eddies of the water in a confined space, rather than in any consistent layers.

4. The Brown laminated clay is in very fine layers of various colours, some being red, others yellow or black, the general mass being yellow when dry, and reddish-brown when wet. In

the latter state it is often hard to distinguish from the red clay next described. When at all dry it separates readily along the laminæ and gives a bright streak with the pick.

5. The Red plastic clay appears frequently to be derived from the last by partial removal of the sand; it then retains the lines of lamination, though obscurely, but does not split up. At other times it is browner in colour and free from lamination, and fills several of the larger horizontal fissures.

6. The Yellow stiff clay seems to be another modification of no. 4, from which all sand has been removed. It is very stiff, of a bright yellow colour, with scarlet bands, and readily splits up into thin layers. This bed only occurs as a lenticular mass in the Eastern Cave.

7. The Blue stiff clay does not occur in regular beds, but in larger or smaller irregular masses. It fills many of the horizontal fissures, where alone it is compressed into laminæ. It is very stiff, and in parts quite hard and nearly purple.

II. The Eastern Cave.

The Eastern Cave was concealed by a bank of drift which extended along one side of the exposed front. It was entirely protected by the overhanging roof, and was evidently undisturbed except for 1 or 2 feet at the top.[1] The bank was 6 feet high, with an open space of 5 feet between it and the roof. It rested on a floor of broken rock 422 feet above sea-level. Sections were taken at all the places marked with Arabic numerals on the accompanying map (fig. 2, p. 124).

The southern side consisted almost entirely of laminated clay. The lines of lamination were very wavy near the rock-wall—a result sufficiently accounted for by the trickling of water along the rock, gradually washing and dragging down that side of the bed. We could, however, trace continuous laminæ horizontally from south to north through the whole length of the bed, and also, on digging ack, we could follow the same lines with a slight north-easterly dip throughout the whole Eastern Cave.

The northern side of the external bank consisted of the same laminated clay alternating with beds of fine gravel, which thinned out towards the centre of the bank, and only reappeared as lenticular masses towards the south-east of the cave inside. Here they gradually merged into red plastic clay overlying the continuous laminated clay.

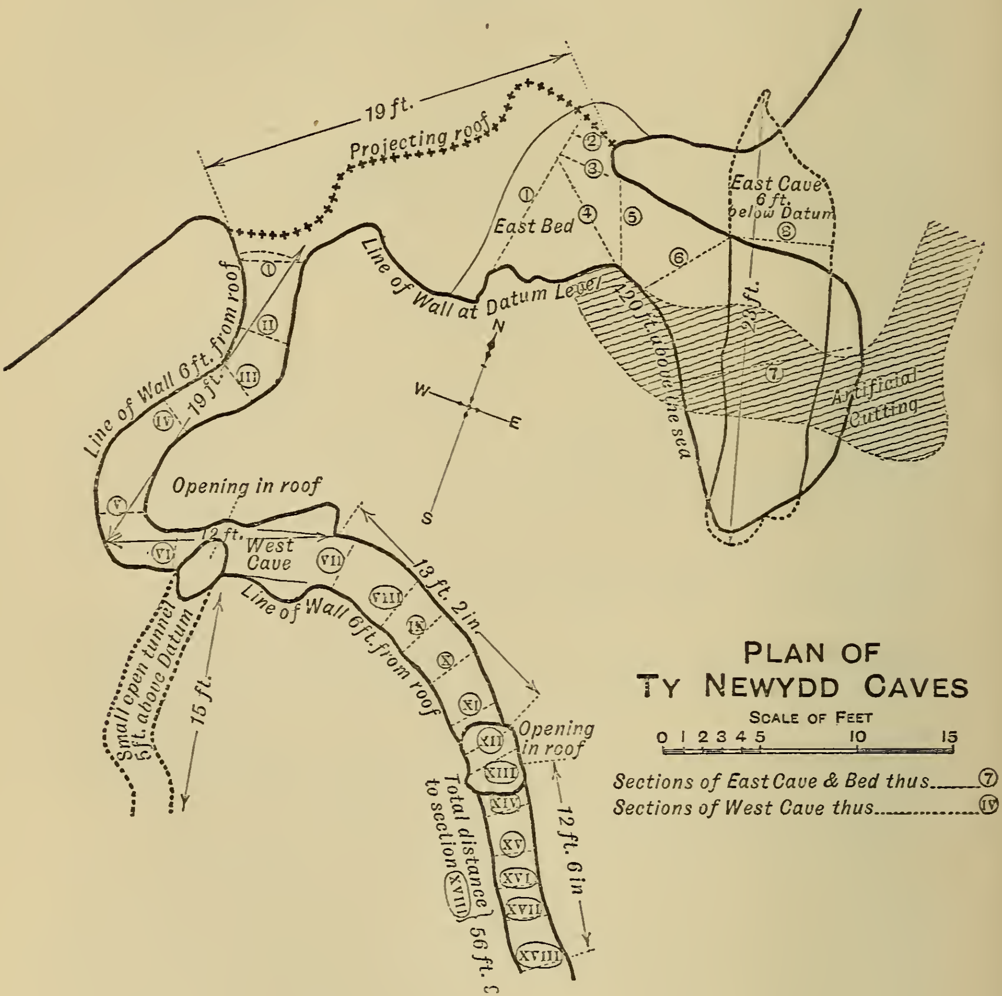
The lowest bed of gravel was coarser than those above, but did not extend into the cave. Of these gravels the upper one alone contained fragments of broken stalagmite averaging $\frac{1}{2}$ inch in thickness.

[1] There is a tradition that the body of a murdered pedlar was found here during the quarrying some 60 years ago. A box of gold coins and a red silk shawl! (the latter fondly remembered by the female inhabitants of the village), which were supposed to have been buried with him, have not yet been found.

On removing the whole bank a passage was found, 6 feet high and extending about 8 feet, when the floor stopped abruptly, giving admission to a cavern 23 feet long and 4 to 10 feet broad, at a much lower level.

The upper beds of the passage and cave were continuous with those that we had already excavated, while below appeared a bed of sand, which in the passage was largely mixed with blue clay, but

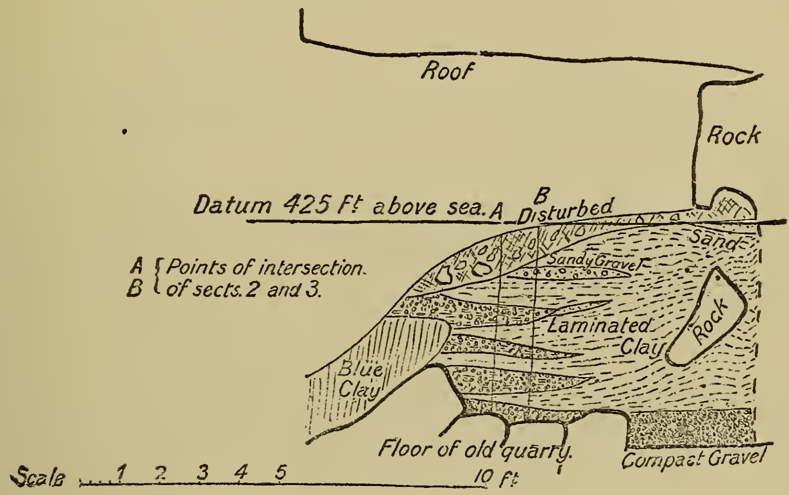
Fig. 2.



in the cave itself was almost pure and extends to an unknown depth. In the northern part of the cave, between the plastic and laminated clays, there was a lenticular mass of yellow clay described above, such as we have not met with elsewhere in the excavations.

The cave is enclosed on all sides by solid rock, and the only outlet must be below. We have excavated 8 feet below the level of the passage without finding a floor, and for the present we have ceased to explore further. In the walls of the passage and right round the cave there is an horizontal fissure 2 to 3 feet high, filled with blue clay. This we have not removed, as the roof appears to have no other support and is here much broken. There is, however, no fissure connecting with the surface, since we made an artificial tunnel through solid rock right across the roof of the cave (see plan, fig. 2).

Fig. 3.—*Section No. 1 in the Eastern Cave.*



The following are the measurements taken during the excavation: the positions can be seen in the plan (fig. 2, p. 124), in which the number of each section is given in Arabic numerals.

At the junction of Sects. 1 *&* 2.

	Ft.	ins.
Disturbed	1	0
Laminated clay	1	0
Clayey gravel		6
Laminated clay		6
Clayey gravel		4
Laminated clay		2
Clayey gravel		2
Laminated clay		2
Clayey gravel		4
Laminated clay		3
Coarse gravel		3

Junction of Sects. 1 *&* 3.

	Ft.	ins.
Disturbed	1	0
Sandy gravel		6
Laminated clay	1	0
Clayey gravel		6
Laminated clay		4
Clayey gravel		6
Laminated clay		2
Clayey gravel		8
Laminated clay		3
Coarse gravel		3

Junction of Sects. 4 *&* 5, *at mouth of Eastern Cave.*

	Ft.	ins.
Sand		6
Plastic clay	1	0
Sandy gravel		4
Sand		3
Laminated clay	1	10
Blue clay	1	0

Middle of Sect. 6. 6 *feet in passage of Eastern Cave.*

	Ft.	ins.
Sand		6
Sandy gravel		4
Plastic clay		7
Clayey gravel		3
Laminated clay and gravel	1	6
Blue clay and sand	1	10

Middle of Sect. 7. Southern portion of Eastern Cave.

	Ft.	ins.
Sand		6
Laminated clay		4
Plastic clay and gravel	2	11
Clayey gravel	1	5
Laminated clay	1	11
Sand ... over	6	0

Middle of Sect. 8. Northern portion of Eastern Cave.

	Ft.	ins.
Plastic clay	3	0
Yellow clay	1	5
Laminated clay	5	0
Sand ... over	3	0

III. The Western Cave.

The Western Cave is a fissure-tunnel extending a considerable distance into the hillside, with its roof more or less parallel to the slope of the hill at a distance of 16 to 20 feet, but this distance diminishes as we proceed farther.

Before we began our excavation, a body of laminated clay was visible on the extreme west of the mouth, running parallel to the side. This, aided by some larger stones from the gravel and a small oblique patch of clay, gave the whole bed the appearance of dipping almost vertically. On cutting back, however, to an undisturbed face, it was seen that there was a distinct horizontal stratification, and the laminæ along the wall were found to be of a different appearance and texture from those met with elsewhere, being probably due to material washed down from the other beds, and deposited in the space left by shrinkage of the whole mass. Similar beds of sand, clay, or gravel were found at intervals in many parts of the cave.

Under the mouth, at a height of 414 feet above sea-level, there was a large block of stone extending into the cave some 7 feet. As we were unable for the present to remove this, we made our floor to the same level, only once sinking a shaft 3 feet deeper into the gravel at a distance of 7 feet from the mouth. The true floor of the cave has not been found in any part of the excavations.

The succession of beds in the cave was as follows :—

1. Sand, usually 1 foot deep in the part nearest the mouth, but much deeper under the two vertical openings to be described later. Beyond the second opening the sand appears to increase rapidly. At 65 feet from the mouth it is over 6 feet deep.

2. Clay, laminated in part, especially near the vertical openings, but becoming plastic in other parts, very variable in thickness. It is, however, traceable as a more or less distinct bed throughout, though interrupted.

3. Sandy gravel. This stratum, from 4 to 12 inches in thickness, is a most characteristic bed. Although the proportion of sand and clay in its composition varied, it could always be recognized by the presence of broken stalagmite $\frac{1}{4}$ to $1\frac{1}{2}$ inch or more thick, and also of subangular chert, which was abundant in this and the lowest gravel, but absent from the intermediate beds.

4. Plastic clay and clayey gravels. These were met with in very variable beds or masses, especially in the first 40 feet

excavated. Beyond this distance the gravel becomes more homogeneous and compact, being merged into the lowest compact gravel. At 32 feet from the mouth, the combined thickness of the clays and clayey gravels was $5\frac{1}{3}$ feet.

5. Compact gravel. This is the lowest bed that we have excavated, and it extends throughout the whole cave, with a fairly level surface, about 420 feet above sea-level, though it is higher immediately over the large stone at the mouth. It is characterized by the presence of subangular chert, but beyond 40 feet from the entrance we could no longer find any clear line separating it from the upper clayey gravel.

At 24 feet from the mouth, and again at $44\frac{1}{4}$ feet, there were vertical openings in the roof of the cave, reaching to the surface. The first of these was free, except for a heap of stones below, and one or two large stones and a little soil above. The sides were very little worn by water, and it gave every sign of being comparatively recent. The second opening was, however, larger and with rounded sides. It was filled with drift right up to the surface.

Below the top soil, here very thin, there was a rough gravel containing local stones, together with several quartzites and felsites identified by Dr. Hicks as hailing from the Snowdonian area. We also found a flint-pebble which, according to the same authority, can have come only from some northern source.

At $5\frac{1}{4}$ feet from the surface this gravel was succeeded by a bed of sandy to clayey gravel composed almost entirely of subangular limestone-fragments, with a few small grains of the local grits and patches of blue clay. This bed was 17 feet thick. Below these came the ordinary succession which we had found throughout, and this continued right across the opening, though slightly disturbed by the deposit which had evidently fallen in through the swallow-hole at a subsequent date to the general filling-in of the cave.

At 46 feet 10 inches from the mouth, and almost under this swallow-hole, $18\frac{1}{3}$ feet below the subangular limestone-deposit (that is, $6\frac{1}{2}$ feet below our datum), we found a much-worn fragment of tooth, which has since been identified at the Jermyn Street Museum by Mr. E. T. Newton, F.R.S., as part of a lower molar of rhinoceros. Unfortunately the species could not be determined with certainty.

Throughout the whole cave large blocks of limestone from the roof and sides were met with in the upper beds, but the lower portion of the walls had remained in place until we removed the contents of the cave.

Turning now to the longitudinal section (Pl. VIII), I must first point out that, although the general idea is correct, in some cases we had to choose which beds to represent or omit, as they frequently separate vertically (see fig. 4, p. 129). In each case we have taken the measurements from the highest point of the roof.

In the entrance is seen a large block of limestone below, which is the only sign of a floor with which we have met, even if it can truly be said to represent a floor. We hope to be able in the course of next year to excavate at a lower level, and if possible to find the true floor of the tunnel. Up to sect. IV[1] the sequence is quite clear, and in the upper beds to sect. VI also, but the middle and lower beds were too confused to follow exactly.

From sect. VI to sect. VII we despaired of taking sections which would fairly represent the beds, owing to the presence of large blocks of limestone and extreme dampness. The upper laminated clay and gravel were alone measured accurately. The succession of the other strata is correct, but I cannot say that they are strictly to scale. We can also connect all the beds here with those which extend beyond sect. VII, except the second sandy gravel. This most probably unites with the upper bed at sect. VII, and both continue together, but it may have become more clayey and been merged in the clayey gravel below, since this contains a few pieces of stalagmite in its upper part. A possible explanation would be that all the sandy gravel and laminated clay were originally against the roof of the cave, and that the beds have gradually settled down, the present top part being retained in position by two projecting shoulders of the walls. The sand, on this supposition, would have been introduced later through the shaft above.

This opening is 16 feet 2 inches high from the roof of sect. VI, but the top is not the original surface, as several feet have been quarried away quite recently.

At a height of 5 feet from sect. VI, on the south side of the shaft, there is a small gallery, open for 15 feet, but too narrow to explore further. There was about 1 foot of mixed clay and sand on the floor, but no lamination or stratification was visible in this bed.

From sect. VII onward every line represents a distinct bed, which was not only measured at the subsequent sections, but was also followed up carefully from one point to another.

In all this portion of the cave there are many large blocks of limestone, especially in the upper strata. I have not figured these, as they did not prevent us from following up the various strata.

Beyond sect. XI there is a second opening in the roof. This is 21 feet high. It is filled with a bed of gravel, of a different character from any with which we have met before, composed of angular limestone in sand or clay, with a few minute grains of Denbighshire Grit here and there, and some small patches of blue clay. The top part, for $5\frac{1}{3}$ feet, had some larger stones with very distinct glacial striæ, and they include some erratics from the Snowdon district.

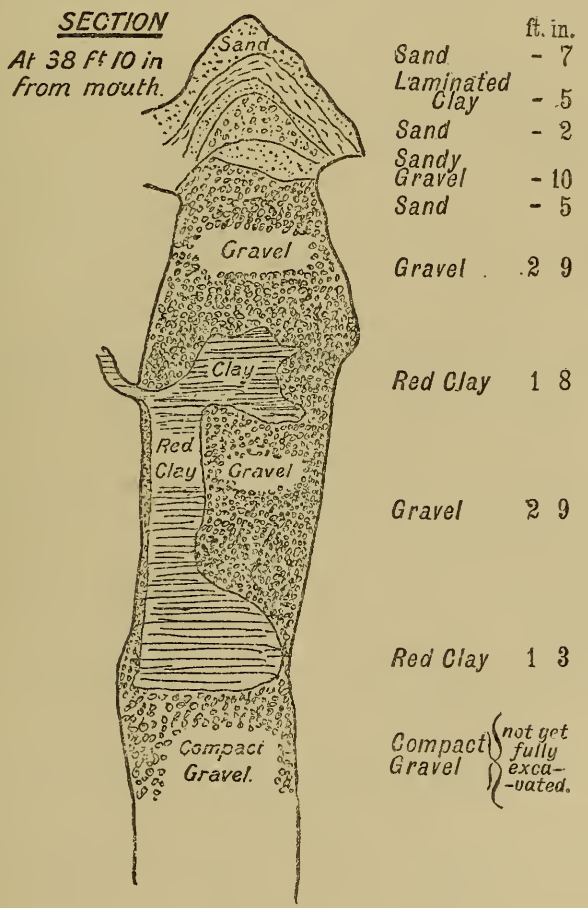
The laminated clays and gravels all pass under the shaft, and are found quite distinct on the farther side, though there has evidently been some confusion immediately below the opening.

[1] The Roman numerals indicate the various transverse sections taken.

[The position of the rhinoceros-tooth is indicated at sect. XIV, at the end of the compact gravel excavated when the drawing was made. The excavation has since been continued to the same level as far as sect. XVIII, but no other fossils have been discovered.

The roof beyond sect. XVIII continues at approximately the same slope as between the two openings, and as the ground outside is more nearly level, we are approaching the surface. The material excavated beyond the last point shown in the drawing (Pl. VIII) is almost pure sand, at least 5 feet thick at a distance of 10 feet from sect. XVIII.]

Fig. 4.—*Section X in the Western Cave.*



The various measurements were all taken from the highest point in the roof above each section, and the distance above or below datum refers to this point. Sections XII and XIII were measured from the surface over the second swallow-hole. A few of these measurements are appended (see p. 130), and their position can be found on the plan (fig. 2, p. 124) and longitudinal section (Pl. VIII).

Sect. I.—3 *inches below datum, at mouth of Western Cave.*

	Ft.	ins.
Sand	1	0
Plastic clay		6
Sandy gravel		3
Plastic clay		4
Laminated clay		3
Clayey gravel		11
Plastic clay		5
Compact gravel	5	4
Blue clay		6

Sect. VI.—1 *inch above datum, and* 24 *feet from mouth.*

	Ft.	ins.
Sand	2	0
Sandy gravel	1	3
Clays and gravel	2	6
Clayey gravel		10
Plastic clay		6
Compact gravel	2	11

Sect. VII.—4 *feet above datum, and* 33 *feet* 2 *inches from mouth.*

	Ft.	ins.
Sand	2	0
Sandy gravel	2	5
Clays and gravels	4	10
Compact gravel	3	3

Sect. X.—8½ *feet above datum, and* 38 *feet* 10 *inches from mouth.* (*See fig.* 4, *p.* 129.)

	Ft.	ins.
Sand		7
Laminated clay		5
Sand		2
Sandy gravel		10
Sand		5
Clayey gravel	2	9
Plastic clay	1	8
Clayey gravel	2	9
Plastic clay	1	3
Compact gravel	4	2

Sect. XII.—31½ *feet above datum* (i. e. *surface*), *and* 44⅓ *feet from mouth.*

	Ft.	ins.
Gravel with northern and western erratics	5	3
Gravel of angular limestone	17	0
Laminated clay		10
Sand		5
Sandy gravel	1	6
Clayey and compact gravel	7	6

Sect. XIV.—24 *feet above datum, and* 46 *feet* 10 *inches from mouth.*

	Ft.	ins.
Gravel of angular limestone	12	2
Sand		2
Sandy to clayey gravel	1	5
Plastic clay	3	3
Compact gravel[1]	13	6

[1] In the lowest part of this section the tooth was found.

Sect. XVII.—18 *feet* 8 *inches above datum, and* 53 *feet* 7 *inches from mouth.*

	Ft.	ins.
Sand	2	0
Gravel of angular limestone	4	5
Sandy gravel	1	7
Laminated clay		5
Clayey gravel		4
Laminated clay		8
Clayey gravel		3
Sand		2
Laminated clay		4
Compact gravel	15	0

IV. Connexion with the Neighbourhood and Ffynnon Beuno Caves.

Besides making the excavations in the caves, we also dug holes in the hillside above, in the valley below, and in the floor of Ffynnon Beuno Cave.

Above us we found 1 to 2 feet of top soil and roots containing many scattered stones of striated Denbighshire Grit, vein-quartz, and Snowdonian erratics. Beyond the fence to the west there are cultivated fields over which small boulders are scattered, the larger having been gathered into heaps in the hedge. A few minutes' search of either heaps or smaller stones was sufficient for obtaining many specimens of granite and felsite. I sent a collection of these to Dr. Hicks, who replied :—'There are undoubted northern fragments,—granite, quartzite, and some peculiar felstones; these probably came from the Lake District, though some may have had a still more northerly home. Others, grits and felstones of various kinds, might have come from the Welsh mountains, west of the Vale of Clwyd. They resemble rocks found *in situ* in the Snowdonian area, Arenig, etc.'

In the valley we made three excavations, at 24, 40, and 60 feet above the brook. They all showed 1 to 2 feet of top soil, under which was a Boulder Clay composed chiefly of local material, but with many erratics. The material, as a whole, was quite different from anything that we found in the caves. In each case this rested directly on the rock. The highest of the three excavations struck the vertical face of the limestone, and in the lowest corners there appeared to be fewer erratics than above, but I could not distinguish two separate beds.

We also made a new shaft in the floor of Ffynnon Beuno Cave, near the position marked as section 2, in the plan given by Dr. Hicks in his paper on that cave, which was read before the Society, and published in this Journal.[1] The following is Dr. Hicks's description of the section :—'The surface-loam (1), about 1 foot in thickness, contained a few bones of sheep, etc. . . . Under about 6 inches of a breccia (2) made up of angular fragments of limestone, the reddish cave-earth (3) containing the remains was found. . . . Under the reddish cave-earth was found a yellowish band, not stalagmitic, but yet more coherent than the cave-earth, and seeming, from its appearance, to indicate that it had been the floor of the den. Under this was a gravelly material (4) made up mainly of fragments derived from the hills above, and containing no bones.'

This gravel Dr. Hicks only tested at intervals, but did not remove. When we examined an undisturbed place, we found that the yellow-clay layers were very similar to those in the Eastern Cave, except that there was no continued lamination, but the whole mass crumbled into small flakes. The gravel was much like our sandy gravel, but without pieces of stalagmite.

[1] Vol. xlii (1886) p. 5, fig. 2, & pp. 6, 7.

V. Conclusions.

Our excavations have not as yet provided us with certain evidence on many of the questions that have been raised by the cave-explorations of the Vale of Clwyd. Three points are, however clearly established:—

1. The material in the Ty Newydd Caves, and in the lower part of Ffynnon Beuno and Cae Gwyn is of purely local origin. Of this we can speak with confidence, as the question was before us from the beginning; we have, therefore, examined all the gravels with minute care, and all stones of whose origin we did not feel certain were forwarded to Dr. Hicks.

2. This local deposit is of earlier date than the Boulder Clay with western and northern erratics. This was sufficiently proved by the occurrence of the granites and felsites on the hillside at a much higher level than the caves. All doubt on the subject is, however, now removed by our having found the two beds actually superimposed in the second vertical shaft.

3. The occurrence of the rhinoceros-tooth shows that there was a land-surface, and a climate capable of supporting such large mammalia, either before or during the period when the cave was being filled.

EXPLANATION OF PLATE VIII.

Longitudinal section of Western Cave, Ty Newydd, on the scale of about 9 feet to 1 inch.

Discussion.

The President said that, having visited the cave during the explorations, he could bear testimony to the unusual care and assiduity with which the work had been conducted. The material as it was being removed was most carefully examined, and measured sections were constantly taken. After the disturbed material at the entrance had been removed, it was found that the deposits, in a more or less stratified condition, extended inwards, and that the various bands could be distinguished throughout. The most important fact, however, was the finding that the deposit in the cavern, which was entirely of local origin, was overlain in one of the fissures by a drift consisting mainly of Western and Northern erratics. The cavern was undoubtedly in existence and had been filled with the deposit before the ice from the Snowdonian district, or from the North, had reached this area. Mr. Strahan, in his excellent memoirs on this area, had pointed out the boundaries where the Western and Northern drifts commingled, and had shown that it was impossible to make any important subdivisions in them. The results now obtained confirmed the views held by the speaker with regard to the deposits in the Ffynnon Beuno and Cae Gwyn Caves, and the time of their occupation by the animals and by man. He hoped that the Author and his friends at St. Beuno's College would continue their excellent work, and that funds would again be granted to enable them to complete the exploration. Meanwhile he heartily congratulated them on the valuable results already obtained.

Sir HENRY HOWORTH said that the facts and conclusions of the paper completely supported the view for which some geologists had fought for many years, namely, that the so-called Glacial Drift lies over the beds containing the so-called Pleistocene beasts and Palæolithic man, and not below it. One additional fact in support of this view occurred to him. The contents of the cave pointed very clearly to the waters which conveyed them in having been of a torrential character. This was shown by the size of the stones, by the shifted beds of clay, sand, and gravel with cross-bedding, etc. If the drift with foreign stones, which occupies the bottom of the valley and the hill-tops, occupied the country when the torrential water flowed over it and carried its contents into the cave, it was impossible to believe that some of these foreign stones should not have found their way in too. The complete absence of these foreign stones from the contents of the cave seemed to him to be conclusive that the drift with foreign stones was distributed over North Wales after the cave was filled with its stratified contents.

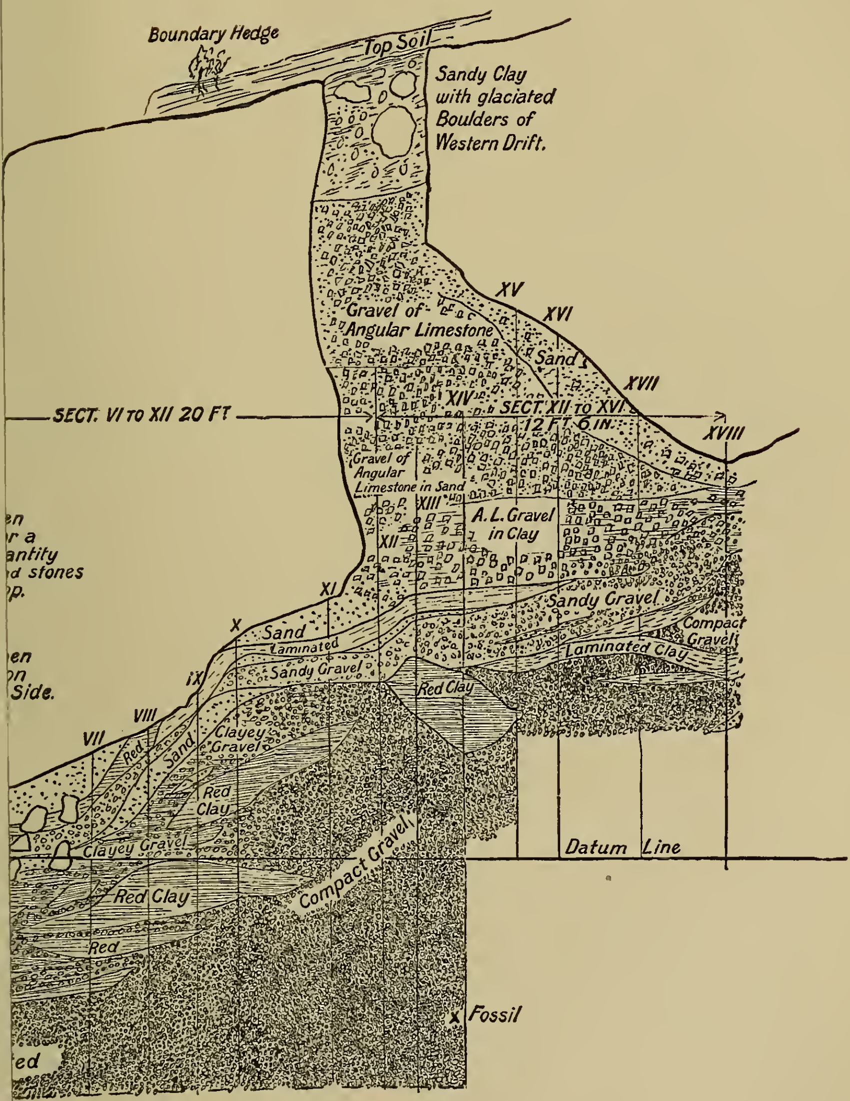
Mr. CLEMENT REID thought that the Author had conclusively proved that the in-filling of the cave took place before the last glaciation of the district. He was not prepared to accept the cave-deposits as pre-Glacial, as suggested by the President, for the Cae Gwyn fauna is thoroughly Pleistocene.

Mr. STRAHAN remarked that the district abounded in underground water-channels communicating with the surface by swallow-holes and other openings. The cave described by the Author seemed to be such a channel, filled with torrential gravel and sand, in which the fragment of tooth occurred as a pebble. That it was so filled in pre-Glacial times was proved by the total absence of material foreign to the district. An inter-Glacial episode would not explain the circumstances; the contents of the cave must have been formed before any of the drift with erratics, which is now so abundant, reached the neighbourhood. He complimented the Author on the extreme care with which the investigation was being conducted.

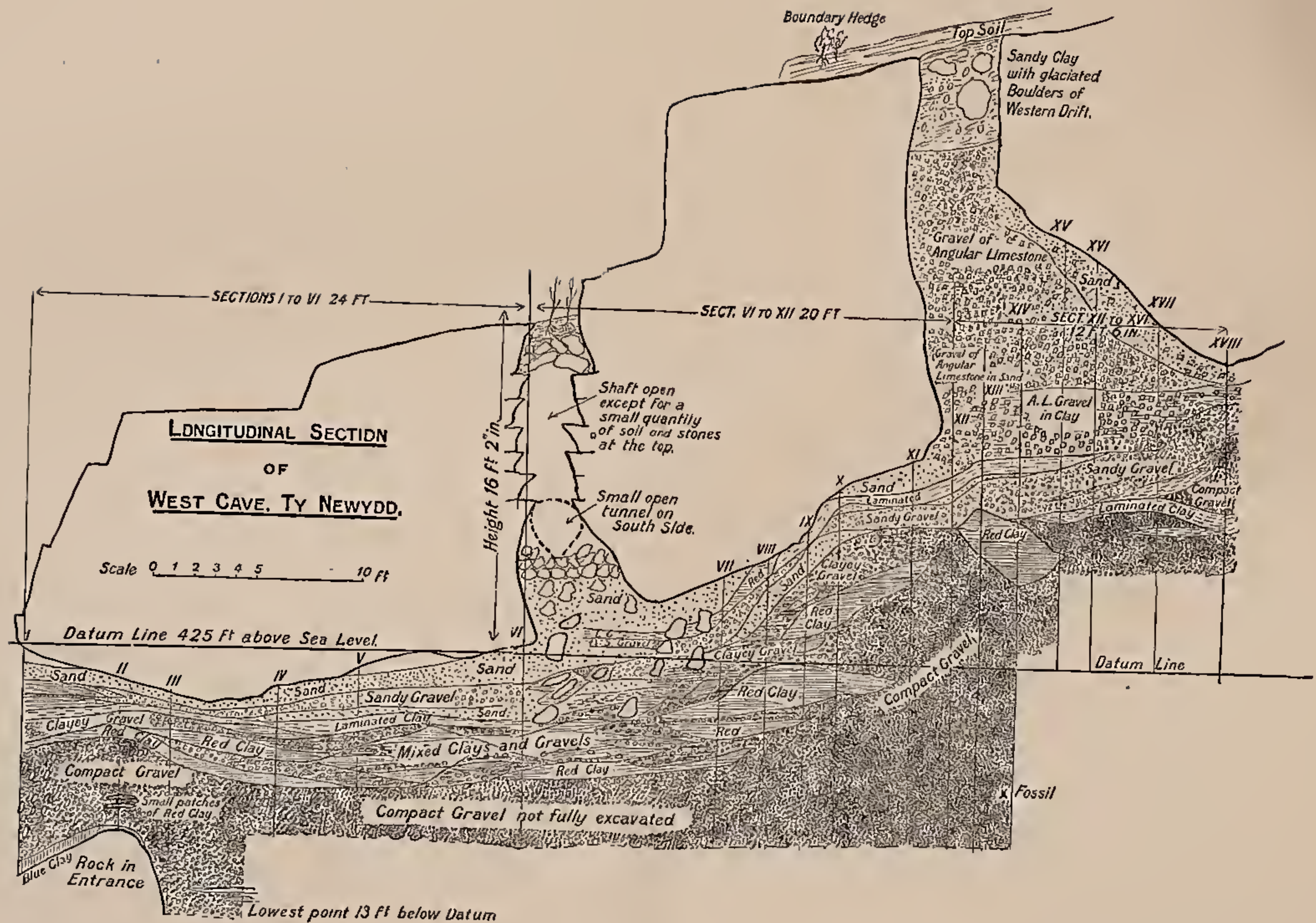
Mr. MARR pointed out that the deposit of materials yielding a definite fauna in caverns before the last glaciation of North Wales and the North of England seemed now to be satisfactorily established: as the result of the work by Mr. Tiddeman in Victoria Cave, Settle; by the President in the caverns adjoining those described in this paper; and now by the Author of the paper just read. The evidence was cumulative; but he (the speaker) believed that, had the question of the age of man been left out of account, the evidence long ago brought forward by Mr. Tiddeman would have been generally accepted.

Mr. A. E. SALTER was interested to find that the lower and older gravels of the fissure consisted of local material only, and that above them a drift occurred containing far-travelled erratics, because he found the same occurrence in the South of England. In the Thames Valley, for instance, the oldest gravels, as at Shooter's Hill, are purely local, while those of later age contain Glacial materials. He had observed a similar succession in Devon and Dorset.

The Author, in reply, expressed his gratitude for the kind reception which had been given to his paper. He had no theories to defend, but had endeavoured to put the simple facts before the meeting and to let these tell their own tale. He had spoken of Pleistocene mammalia, because the fossil found was in the same state of preservation as those in the Ffynnon Beuno Caves, which are generally called Pleistocene. In answer to Mr. Reid, he said that stones of Denbighshire Grit of a fair size occur throughout the cave. The main point established was the occurrence of a local drift which contained fossils, and was earlier than the drift with erratics.



Boundary Hedge
Top Soil
Sandy Clay with glaciated Boulders of Western Drift.
XV
XVI
Gravel of Angular Limestone
Sand
XVII
XIV
SECT. VI TO XII 20 FT
SECT. XII TO XVI 12 FT. 6 IN.
XVIII
Gravel of Angular Limestone in Sand
XIII
A. L. Gravel in Clay
XII
XI
Sandy Gravel
X
Sand
Laminated
Compact Gravel
Laminated Clay
Sandy Gravel
IX
Red Clay
VIII
VII
Red
Sand
Clayey Gravel
Red Clay
Clayey Gravel
Compact Gravel
Datum Line
Red Clay
Red
Fossil



Longitudinal Section
of
West Cave, Ty Newydd.
Scale 0 1 2 3 4 5 10 Ft
Boundary Hedge
Top Soil
Sandy Clay with glaciated Boulders of Western Drift.
Gravel of Angular Limestone
Sections I to VI 24 Ft
Sect. VI to XII 20 Ft
Sect. XII to XVIII 12 Ft 6 In.
Height 16 Ft 2 In
Shaft open except for a small quantity of soil and stones at the top.
Small open tunnel on South Side.
Gravel of Angular Limestone in Sand
A. L. Gravel in Clay
Sandy Gravel
Laminated Clay
Compact Gravel
Red Clay
Sand
Laminated
Clayey Gravel
Datum Line 425 Ft above Sea Level
Datum Line
Sandy Gravel
Mixed Clays and Gravels
Compact Gravel
Small patches of Red Clay
Compact Gravel not fully excavated
Fossil
Blue Clay
Rock in Entrance
Lowest point 13 Ft below Datum

9. *The* Bala Beds *and* Associated Igneous Rocks *of* Lambay Island, Co. Dublin.

By C. I. Gardiner, Esq., M.A., F.G.S., and S. H. Reynolds, Esq., M.A., F.G.S. (Read December 1st, 1897.)

[Plate IX—Map.]

Contents.

I. Introduction.

Lambay Island lies off the East Coast of Ireland, some 10 miles north of Dublin, the nearest point on the mainland being in the district of Portraine, where there occurs an inlier of Bala rocks which we have already described.[1]

The name of Lambay is probably familiar to geologists from the occurrence there of the 'Lambay porphyry,' a very handsome and striking rock, described in detail by Von Lasaulx[2] and mentioned in many geological and petrological works.[3]

It was with the intention of investigating the occurrence of this rock in the field, and at the same time of seeing whether the other rocks exposed on the island were of a similar nature to those at Portraine, that we visited the island.

The only detailed account of the geology of Lambay appears to be in the explanatory memoir to Sheet 102 of the Geological Map of Ireland, published in 1861. Homogeneous and porphyritic trap-rocks are mentioned, catching up in places masses of slates and grits which they have baked and hardened. Ashes were also found, while limestone and graptolitic shales gave evidence that some of the rocks of the island were of Bala age.

On looking at the map of the island it will be seen that a large part of it is drift-covered, but from the exposures which occur it is obvious that the greater part of Lambay is formed of igneous rocks, the sedimentaries occurring in detached masses of no very great extent, and, except in the case of the limestone, they yield little fossil evidence from which their age can be determined. It will be most convenient to describe first the sedimentary and then the igneous rocks.

[1] Quart. Journ. Geol. Soc. vol. liii (1897) p. 520.
[2] Tscherm. Min. u. Petrogr. Mitth. vol. i (1878) p. 419.
[3] See, among others, Teall's 'Brit. Petrogr.' 1888, p. 248; Harker's 'Petrol. for Students,' 1895, p. 106.

II. The Sedimentary Rocks.

At the north-western corner of the island, in Saltpan Bay, is an exposure of brown fissile slates, faulted, along its western edge, against an andesite, but apparently overlain conformably to the east by igneous rocks; for though at this junction, which can be seen at sea-level, near Calico Hole, the slates appear somewhat crushed, the line cannot be taken as a fault.

Exactly similar slates are to be seen in the road north of the Castle, about $\frac{1}{4}$ mile south-west of Saltpan Bay, and, though the intervening country is drift-covered, it is probable that the two sets of exposures are in the same bed of slate, as is suggested in the Survey Memoir (p. 49).

Similar slates are exposed in Broad Bay, the next bay to the west of Saltpan Bay, and they run across the inner end of Scotch Point, being seen on its western side. The ashes forming Scotch Point underlie these slates conformably.

No other sedimentary rocks are to be seen on the western coast of the island, but on the south-western side, in Talbot's Bay, patches of green and red slates occur, several yards in length and breadth, entirely surrounded by the dark green andesite which here forms the coast. In places these slates are baked by the igneous rock, and at one spot they contained *Orthis biforata*. Bands of grit and tuff occur with the slates, the tuff-bands containing fragments of grit, slate, and ash.

The middle of Talbot's Bay is cut out in black and green slates showing much contortion and containing bands of purplish grit. These beds are so utterly unlike the brown slates exposed in Saltpan Bay and near the Castle that we cannot fall in with the suggestion in the Survey Memoir that they are 'evidently a portion of the same Silurian slates.'

The Talbot's Bay slates are, however, extremely like those exposed in Carnoon Bay to the south-east, the coast between the two bays being formed of a coarse tuff or agglomerate. The Carnoon Bay slates are black and purple in colour, and contain a tuff-band somewhat similar to that which occurs in Talbot's Bay.

To the south many small patches of red and green slates and fine ashes are exposed, caught up in the andesite, which here forms the coast-line, the smaller inclusions being baked and porcelainized, the larger ones showing no signs of alteration.

The largest and most important mass of sedimentary rocks that occurs in the island forms the summit of Heath Hill, and occupies the shore-line from Kiln Point to Seal Hole.

To the north-east these rocks are bounded by a fault, which can be seen at the top of the cliff on the northern side of Seal Hole. At Kiln Point, to the south, the junction is seen to be an unfaulted one, the limestone overlying the igneous rock, and here the former rock shows evidence of alteration by the andesite. This alteration is visible both in a hand-specimen and under the microscope, the limestone becoming thoroughly crystalline and the shaly partings porcelainized, while the igneous rock becomes much more finely granular.

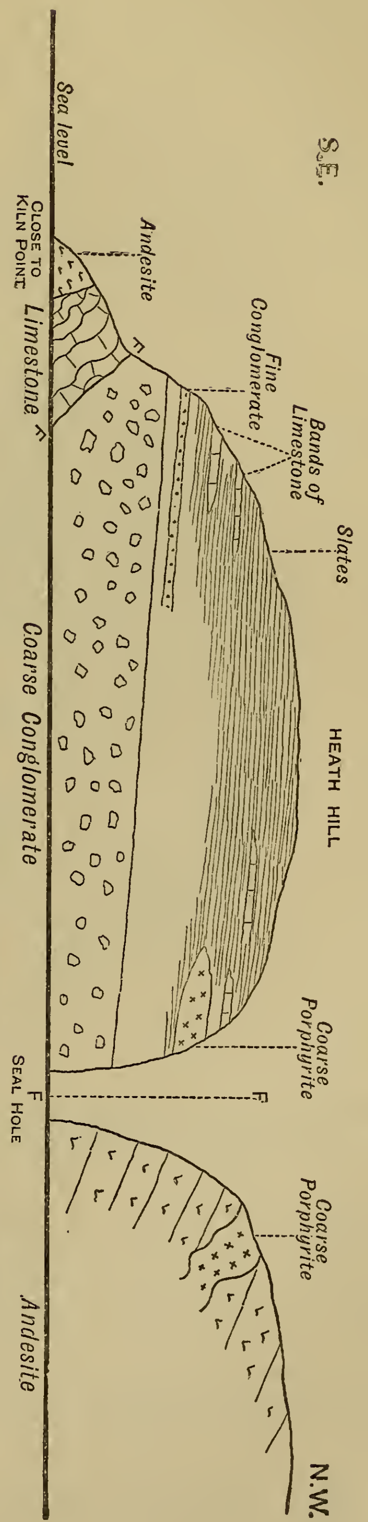
The corals, chiefly *Favosites* sp., which are found in the limestone are not obliterated by the alteration in it, but are to be seen to within an inch or two of the igneous rock. From this limestone we also obtained *Halysites catenularia*, Linn.

The limestone is covered by a conglomerate formed of large and small blocks, the larger of which sometimes reach 6 feet in diameter and are usually rounded, while the smaller blocks are frequently angular.

The matrix is sometimes calcareous and contains small, perfectly-preserved corals, but is more usually a black shale in which small angular fragments of rocks are irregularly scattered, so that it resembles an ash in appearance. The included blocks are usually of limestone, very often fossiliferous (*Favosites* sp., *Halysites catenularia*, Linn., *Heliolites megastoma*, M'Coy ?, and *Rafinesquina expansa*, Sow., small var., having been obtained), and of andesite; but blocks of black earthy shale, green slate, grit, conglomerate, calcareous ash, and coarse porphyrite also occur.

A section of this rock showed fragments of various andesites, one a rock formed of parallel acicular felspars in a much altered matrix, another a fresh mica-andesite, a third a vesicular andesite, all embedded in a matrix formed of fragments of crystals, quartz, and iron-ores.

Fig. 1.—Section of Heath Hill, from near Kiln Point through Seal Hole.



[Horizontal scale: 12 inches = 1 mile. Vertical scale greatly exaggerated. The shales dip S.S.W.]

The conglomerate shows signs of faulting and is covered by slates and impure limestones, which, as will be seen from the map (Pl. IX), form the whole of Heath Hill. The dip of these beds is about 60°–50° S.S.W. at various points of the hill. From them we obtained *Calymene* sp.; *Illænus* sp.?; *Remopleurides* sp.; *Trinucleus* sp.; *Tiresias* sp.[1]

Just above Seal Hole, on the north side of the hill, a small plug of coarse porphyrite is seen cutting into the slates, which do not appear much altered by its intrusion. The occurrence of this rock here is noted in the Survey Memoir (pp. 48, 49), where it is represented

Fig. 2.—*Conglomerate from Kiln Point.*

× 18.

[The section shows a fragment of a mica-andesite on the right, and on the left the matrix of the conglomerate, in which small quartz-fragments and pieces of felspar and felspathic rocks are found.]

in the section given as a mass resting on slates and covered by no deposit, and it is supposed to be a remnant of a mass which 'entirely embedded the conglomerate and shales.' As, however, the mass of igneous rock is entirely covered and surrounded by slates, it appears to us to be of the nature of an intrusion.

At Raven's Well, on the north side of the little valley leading down to Seal Hole, brown and grey slates, sometimes of a very ashy nature, are seen dipping at 60° S.S.W., and the faulted junction of

[1] These, and the other fossils which we obtained from the island, have been identified for us by Mr. F. R. Cowper Reed, M.A., F.G.S. A list of fossils found on Lambay Island is given in the Survey Memoir, pp. 11 & 12.

these beds with the andesites is seen, as mentioned above, in the cliff on the north side of Seal Hole.

The coarse conglomerate is visible at sea-level, a little way to the north-east of this fault-line, and also at the top of the cliff along the coast due east of the Bell Rock.[1]

With the occurrence of a thrust-conglomerate on the mainland immediately opposite at Portraine, the question of the origin of the Lambay Conglomerate is one which naturally arises. That earth-movements have affected the conglomerate and the limestone-bands at Kiln Point is obvious from the faults in the former and the curvature of the latter which are to be seen there; but the junction of the conglomerate and the igneous rocks never has the appearance of a thrust-plane. The limestone, which is altered by its contact with the igneous rock, is bent, and the conglomerate is faulted against it; there is no resemblance, however, between the crushed material along the fault-line and the gradual formation of the conglomerate at Portraine.

The beds immediately above the conglomerate are not seen, but a very short distance up the hill-side occurs a fine conglomerate of well-rounded pebbles of limestone and andesite sometimes an inch long, in a calcareous matrix, and this is covered by the slates of Heath Hill. None of these show any such crumpling as might be expected if the mass had been thrust over the underlying igneous rocks, and the limestone at its base had been crushed and broken up into the conglomerate. At Portraine the tough grits which have been thrust over the underlying limestones are very obviously curved, and similar, if not more pronounced, curvature might be expected in the Heath Hill slates had they been acted on by similar forces, as they would have been more readily affected. The occurrence of the fine conglomeratic bands above the coarse bed also points to the latter being an ordinary conglomerate, for if it had been laid down close to the shore (as appears probable from the size and angularity of its blocks) when the shore-line had increased its distance from this spot, we should expect the materials brought thither to be smaller and better rounded.

The constituents of the coarse conglomerate have been mentioned already, and among them, it will be seen, are lumps of black earthy shale. These contain obscure traces of graptolites, and are absolutely uncrushed; but if the conglomerate were formed by earth-movements, which had broken up hard limestone-bands and mixed their fragments up with pieces of igneous and other rocks, it would be imagined that blocks of such a soft nature as these black shales would have shown some signs of the stresses to which they must have been subjected.

The matrix of the conglomerate shows no signs of crushing either in the field or under the microscope, but appears to be of a somewhat

[1] On the very top of Heath Hill occur a large number of well-rounded blocks of various rocks, gneiss, quartzite, felstone, andesite, fossiliferous limestone, grit, etc.; but this deposit does not in any way resemble the Kiln Point Conglomerate, and is very probably a Glacial drift.

ashy type. Small detached corals occur here and there throughout the rock.

It appears, therefore, that this conglomerate is not a thrust-conglomerate, but resembles rather the ashy conglomerate of the northern end of the Portraine section. They both have an ashy matrix, and both contain blocks of much the same nature. The limestone-blocks on Lambay Island are more fossiliferous than those at Portraine, and are shown to be of the same age as the Bala Limestone of the mainland.

The bed is a fairly coarse deposit, and, though many of the blocks are well rounded, one occasionally meets with corals (not attached to any piece of rock) in a comparatively fresh condition, and with angular blocks. This points to the derivation of some of the material from close at hand, but some of the blocks may have been rounded on land and then not moved far from the shore before being finally entombed.

Summary of the Sedimentary Rocks.

The sedimentary rocks of Lambay Island are therefore seen to be chiefly of the nature of slates and limestones, and to be contemporaneous with some of the igneous rocks of the island. On the north-west the slates have yielded no palæontological evidence of their age, while but little is forthcoming from those on the south-western side. All these slates occur in the neighbourhood of deposits of ashes or tuffs, and may have been laid down during intervals of comparative quiescence, when the neighbouring volcano was inactive or pouring out its lava in other directions, while the ordinary agents of denudation were cutting down its cone and distributing the fragments thereof to a distance. That advancing streams of lava occasionally caught up some of the mud from the sea-floor and baked it appears from the red shales of Carnoon Bay, while the intrusion of coarse porphyry on Heath Hill into the slates shows that igneous activity had not ceased after the deposition of those beds, the baking of the limestone at Kiln Point leading the observer to the same conclusion.

III. The Igneous Rocks.

These may be divided for purposes of description into (*a*) the fragmental rocks, (*b*) the andesitic rocks, and (*c*) the coarse porphyrite.

(*a*) The Fragmental Rocks.

These consist of rocks of every degree of coarseness, from fine ashes to coarse tuffs. There are two localities where they occur over areas of large extent, namely at Scotch Point and along the coast between Talbot's Bay and Carnoon Bay. Between the Castle and Broad Bay there occur several exposures in a tuff-band which runs roughly north and south, while small exposures of ashes associated with the igneous rocks occur here and there throughout the island. Such are the bed between Knockbane and Calico Hole, and the patch between Trinity Well and Raven's Rock, these beds appearing to have been due to small outbursts which scattered fragments of pumiceous and compact andesitic rocks over the top of the lava-flows at various points.

The Scotch Point ashes are of medium grain, and in a hand-specimen show rounded and subangular fragments of andesitic rocks, dark- and light-green in colour. A microscope-section shows angular and rounded fragments of felspathic rocks in which all the felspars are replaced by calcite, and many of the fragments are exceedingly vesicular. In many places blocks of coarse porphyrite are to be seen, often very amygdaloidal and probably of the nature of volcanic bombs, while dykes of a similar coarse rock are seen cutting the ashes here and there.

The other large patch of ground in this corner of the island occupied by pyroclastic rocks is between the Castle and Broad Bay. It is separated from the Scotch Point ashes by a mass of coarse porphyrite, a drift-covered region, and the outcrop of slates mentioned above (p. 136). Here the ash-bed rests on what is apparently an andesite containing large rounded blocks of amygdaloidal coarse porphyrite; this, in its turn, is underlain by a band of coarse porphyrite, which can be traced for some 300 yards in a north-and-south direction. But the microscope shows that the supposed andesite is really andesitic ash, and at the northern end of the exposure occur well-marked bands of fine ash, striking roughly south-west and dipping at about 80° S.E.

The occurrence in these ash-beds of bomb-like portions of coarse porphyrite points to the near presence during their formation of the coarse rock in the liquid state, and we may well imagine a series of explosions drilling a hole through the andesitic flows and forming a passage for the uprise of the porphyrite: the ash-beds being chiefly formed of fragments of the shattered andesites, but including portions of the uprising rock which were blown out from it at intervals.

On the south-western coast of the island, between Talbot's Bay and Carnoon Bay, is exposed a fairly coarse tuff or agglomerate, numerous exposures of the same rock being found for some distance inland. It ends off against much-crumpled slates in Talbot's Bay, the actual junction being a faulted one, while in Carnoon Bay a few finer tuffs and slates, dipping east at a high angle, intervene between the coarse tuff and the crumpled slates. The coarse bed is largely composed of rounded and angular blocks of slate and fine andesite, but blocks of coarse porphyrite also occur, generally rounded and very amygdaloidal. This mass of agglomerate may very possibly mark the spot where a volcanic neck was drilled through the sea-floor which was formed of the slates of Talbot's Bay and Carnoon Bay.

Owing to insufficient exposures, it is difficult to say decidedly whether these three masses of ash and tuff are to be regarded as marking the positions of old vents, or as being merely beds of ashes formed by the scattering over the sea-floor of fragments which were shot out from some vent in the vicinity.

(*b*) The Andesitic Rocks.

As will be seen by reference to the map (Pl. IX), much the greater part of the island is formed of rocks of an andesitic nature. In a hand-specimen some of them show small porphyritic felspars, and some are difficult to class, as they appear to be intermediate between the andesites and the coarse porphyrite.

At certain spots the andesites include angular blocks of igneous rock, sometimes in large numbers, as on Lambay Head and in the cliffs at the mouth of Thornchase Valley; while at other spots fine and coarse breccias occur among them, as above Freshwater Bay near Gillap. The inclusions in the rock at the mouth of Thornchase Valley are noted in the Survey Memoir.

The andesites as a rule show no augites, but examples of augite-andesite occur. The rock at Kiln Point is a hypersthene-andesite, the hypersthene being now replaced by bastite. One of the inclusions in the andesite at Carrickdorrish shows numerous porphyritic crystals; these cannot be determined with certainty, owing to the alteration which has gone on, but they are very probably altered olivines. Some of the inclusions at the mouth of Thornchase Valley show augites, though the enclosing rock does not appear to have any.

As shown in the map, the chief exposures of augite-andesite are close to the top of Knockbane, close to Raven's Rock, west of Flint Rock, and on Lambay Head.

The Lambay Head augite-andesite is a very well-marked rock rnnning along the crest of the Head towards Pilot's Hill, its large augites being readily seen on its weathered surfaces. In a hand-specimen this rock shows a dark green, somewhat horny-looking groundmass, in which small felspars are sparingly scattered and large porphyritic augites occur, the largest one seen measuring 9 mm. in length. A microscope-section of this rock shows a fairly prominent, highly altered groundmass, in which are many short, broad felspars, now entirely replaced. The porphyritic felspars are also entirely converted into a quartz-mosaic, but the porphyritic augites are very fresh, and occur in granular aggregations; magnetite is present, while chlorite and epidote have come in as secondary minerals.

The augite-andesite which occurs close to the top of Knockbane has a fine, compact, somewhat horny groundmass, purple in colour, containing numerous ill-defined patches of a green colour (generally rounded in outline), and small black patches are also to be seen. The microscope shows the groundmass to be now formed of secondary minerals, quartz, iron-ores, and calcite, while the porphyritic felspars which it contains are also entirely altered. Augites are represented by a brown decomposition-product, which here and there encloses cores of the original undecomposed mineral.

Running east-south-east from the steep cliff known as Raven's Rock, and traceable for some 350 yards, is a third well-marked band of augite-andesite. The rock, when fresh, is of a dark-green colour ; small green felspars are with difficulty to be made out, the most obvious constituents of the rock being large black augites, measuring as much as 6 mm. in length, and showing well-marked cleavage; the groundmass of the rock is fine-grained. The microscope shows a groundmass of felspar-microlites, augite-granules, magnetite, hæmatite, and chlorite ; in it are small porphyritic felspars, now entirely replaced, and large augites.

Going east-south-east from Raven's Rock, the last exposure of this augite-andesite is close by a wall running north and south, after which no exposures are to be seen for some distance. Almost due east of the last exposure, however, near the wall, occurs a small area of exposures, most of which are in a rock with a fine purple groundmass containing bright yellow-green, rather small, porphyritic felspars and large black augites, sometimes 9 mm. long. Other exposures are in a green-and-purple rock with a fine-grained groundmass, containing a few small porphyritic felspars and numerous vesicles.

About 450 yards due west of the summit of Flint Rock occurs a small exposure of a greenish rock with a fine groundmass, no distinctly porphyritic felspars, but with large black augites, sometimes 7 mm. long. This rock resembles markedly the augite-andesites of Lambay Head and Raven's Rock; but, as the ground between Flint Rock and Knockbane is much covered with drift, it is impossible to tell whether there is any extensive occurrence of the rock between the two hills.

Though augites occur in some of the other andesites, they are found very seldom, and the above-mentioned type of rock, containing abundant augites, was found nowhere else on the island.

The remaining andesites call for very little remark. They are generally of a very normal type of fine-grained andesite; porphyritic constituents are rarely visible in a hand-specimen, but under the microscope they are all seen to contain porphyritic plagioclase-felspars, now much replaced, and frequently the twinning is wholly obliterated. Flow-structure is to be seen at times in the groundmass, which is composed of small felspar-microlites and decomposition-products, such as quartz, calcite, chlorite, and epidote, while either magnetite, hæmatite, or ilmenite is generally present. A far from uncommon porphyritic constituent of these rocks is apatite, which occurs in the usual needles, giving straight extinction, while bastite-pseudomorphs after hypersthene occur in the Kiln Point andesite.

The alteration that has gone on in these rocks is very great, and the resulting formation of secondary minerals most marked. In some cases the production of epidote and quartz has been the result following on the destruction of the porphyritic felspars ; in other cases calcite has come in, and more or less spherical masses of calcite occur (see fig. 3, p. 144), the concentric shells of calcite being separated by shells of hæmatite, while in other cases chlorite occurs abundantly.

There are a few instances, however, where the groundmass shows the structure known as 'micropoikilitic.' Mr. Alfred Harker, in his paper on 'The Gabbro of Carrock Fell,'[1] and Mr. F. R. Cowper Reed, in his notes on 'The Geology of the Country around Fishguard,'[2] notice this structure, the former in lavas metamorphosed by the gabbro, the latter in felsites which he considers metamorphosed. In the last-named paper a very full account of previous notices of this structure, which seems generally to have been seen in felsitic rocks, is given. On Lambay Island, however, it occurs in andesitic rocks and in the coarse porphyrite. It is to be seen in five of the slides which we have had cut; three of these

Fig. 3.—*Vesicular andesite from Freshwater Bay.*

× 18.

[The rock is very much altered, calcite and other minerals having come in with the alteration. In the vesicles the calcite often assumes a spherical arrangement, as shown in the figure, the spheres of calcite being separated by spherical shells of hæmatite.]

are from andesites, and two from the coarse porphyrite. Two of the slides from the andesites are cut from rocks close to the junction with the limestone at Kiln Point. This rock in a hand-specimen is seen to have an appearance somewhat different from that of the usual fine andesite of the island, being more compact and horny, and the sections show the alteration of the rhombic pyroxene which they contain and of the groundmass, the small felspars in which have to a large extent disappeared, ragged-edged plates of quartz having been formed, giving rise to the micropoikilitic structure.

[1] Quart. Journ. Geol. Soc. vol. l (1894) p. 311.
[2] *Ibid.* vol. li (1895) p. 149.

The other example of this structure in a fine andesite is in a rock some 200 yards south-west of Kiln Point.

In these three slides, though the alteration of the groundmass has gone on to so great an extent, the porphyritic felspars are remarkable on account of their freshness.

Here and there the andesites are amygdaloidal, and occasionally as much as half the rock consists of amygdules; this is especially well seen in a rock obtained from a spot about halfway between Heath Hill and Bishop's Bay.

The inclusions noted as occurring at the mouth of Thornchase Valley and on Lambay Head are also to be seen along the cliffs between Bishop's Bay and Sunk Island Bay, and on Sunk Island itself, while the island of Carrickdorrish also shows them all over its surface. They were very possibly blown on to the surface of the andesites, and gradually incorporated in them, or they may have been portions of the rocks which formed the vents through which the andesites rose to the surface.

(*c*) The Coarse Porphyrite.

The last type of rock remaining for description is the coarsely porphyritic rock, well known as the 'Lambay porphyry,' and described by Von Lasaulx both macro- and microscopically.[1] This writer mentions that it has been described as an amphibolite-greenstone, as a quartzless orthoclase-porphyry, and as a diabase-porphyry, and pronounces in favour of the last name.

From the map (Pl. IX) it will be seen that the coarse rock occurs in very many places on the island, but in only a few does it extend over a large area, the rock being more usually found in small unconnected patches.

The coarsest variety was found in a small exposure on the seaward face of the point forming the south-western edge of Sunk Island Bay. Here the groundmass is green in colour and very compact, while large green platy felspars, sometimes as much as 23 mm. broad, are present in great abundance, showing repeated twinning. Calcite occurs in little rounded masses, possibly filling vesicles or replacing augites. More usually, however, the porphyritic felspars are smaller; thus in the exposure between the Coastguard Station and Scotch Point the groundmass is also green and compact, but the felspars are not more than 11 mm. broad; here augite is a fairly abundant porphyritic mineral, crystals of this mineral measuring as much as 6 mm. in length. In the mass occurring round Trinity Well the porphyrite has a compact purple groundmass; the porphyritic felspars are numerous, and run up to 12 mm. in length, being green and platy like those described above. Amygdules are fairly common in this rock, being formed of calcite or of calcite and chlorite.

The long strip of coarse rock exposed along the base of the hills

[1] Tscherm. Min. u. Petrogr. Mitth. 1878.

east of the Castle is of the same type as the mass near Trinity Well, and seems to be intruded along the junction of the andesites and slates.

The two exposures of the porphyrite, one of which forms the conical hill at the south-western end of Pilot's Hill, and the other Flint Rock and part of Bell Rock, resemble one another exactly. The groundmass is more prominent than in most of the coarse rocks, and of a grey-green colour, while the felspars are thinner than the usual porphyritic felspars; they are about 7 mm. long, and show a markedly parallel arrangement. On the northern slopes of the conical hill, mentioned above as forming the south-western end of Pilot's Hill, the coarse rock is extremely amygdaloidal. The amygdules, formed of calcite, weather out into round masses, sometimes 17 mm. long, and occasionally form by far the largest portion of the rock. This very amygdaloidal porphyrite is also seen on the northern slopes of Flint Rock.

Another peculiarity of the coarse rock of these two exposures is the presence of a large number of included fragments. These are of very irregular shapes, angular in outline, and generally blue or purple in colour; they are consequently very obvious in the faces of rock exposed. They vary much in size, the largest one seen being about 12 inches long; they all have a somewhat striped appearance, break with a fairly perfect conchoidal fracture, and appear somewhat porcelainized. In fact, they look like baked ashes, and under the microscope they are seen to be fine ashes which have undergone considerable alteration.

The base of the mass which forms part of Pilot's Hill was seen in the cliff just above sea-level; it was slightly amygdaloidal, enclosed blocks of andesite, and rested on an andesitic breccia, beneath which came a red amygdaloidal andesite.

It appears, therefore, from these two exposures of the coarse rock that we have evidence of the actual outflow of the porphyrite, for we can see the brecciated surface of the underlying andesite in the sea-cliffs, the slightly amygdaloidal base of the porphyrite (which caught up and enclosed portions of the rock beneath it), and its extremely amygdaloidal nature along the northern slopes of the two exposures, while the closer grain and appearance of the rock also mark it out from the other coarse porphyrites of the island.

The other exposures of the rock are small in extent, though numerous, and show the porphyrite penetrating the finer andesite in dykes of various lengths. Here and there they accompany exposures of breccia, which seems to point to explosive action having caused, or having assisted in causing, the opening in the andesites, which was afterwards filled with the coarser rock.

Two sections from the coarse porphyrite show a micropoikilitic structure in the groundmass. One of these is from the edge of the Trinity Well mass, and the other from a small exposure of the rock south-west of Heath Hill. In one of these the freshness of the porphyritic felspars, as was the case with the andesites showing micropoikilitic structure, is remarkable.

The coarse porphyrite, therefore, usually occurs in dykes or sills, but it is also found as an extruded mass on Flint Hill and Pilot's Hill.

With regard to its mineralogical constitution, we have nothing to add to Von Lasaulx's account. We have recognized porphyritic felspars allied to labradorite, much decomposed, in a groundmass of lath-shaped felspars and augite-granules. Calcite, epidote, magnetite, pyrites, and sphene also occur.

IV. Conclusions.

From the observations recorded herein, it seems plain that in Bala times Lambay Island was close to a centre of vulcanicity. A vent could not have been very far distant, and its flanks must have extended close to the districts of Lambay and Portraine.

The main extrusions of lava were of a very normal type of andesite, augite- and hypersthene-andesites being, however, represented to a small extent on the island, while the coarse Lambay porphyrite was injected into these andesites, and must occasionally have reached the surface. That some of the lavas flowed beneath the sea seems probable from the occurrence among them of beds of slate, while that the period of igneous activity had not ceased when the sedimentary rocks of Heath Hill had accumulated is shown by the intrusion of the coarse porphyrite into the slates of that hill, and the baking of the limestone at its eastern edge.

The palæontological evidence is scanty, but, such as it is, it points to the sedimentary rocks being of the same age as the Portraine beds, namely, Upper or Middle Bala.

Hence, in Bala times, there was an immense outpouring of andesitic rocks in this district, while explosions shot out fragments which formed ash-beds at various places, and cracks in the andesites were filled with a coarsely porphyritic rock, which also here and there welled up to the surface. Meanwhile limestones and shales were being deposited round the volcano, and were in part subjected to the ordinary agents of denudation. Fragments of the igneous rocks and of these upraised sedimentaries were rolled down to the shore and piled up to form a massive conglomerate, which, as it sank beneath the waves of the Bala sea, was covered by calcareous mud; and therewith the history of Lambay Island in Bala times is brought to a close.

In conclusion we would offer our best thanks to Mr. W. W. Watts, for the assistance which he has so kindly given us; to Mr. F. R. Cowper Reed, for naming our fossils; and to the authorities of the Geological Museum in Dublin, for the generosity with which they have afforded us every facility for examining the collections of rocks and fossils in their possession.

PLATE IX.

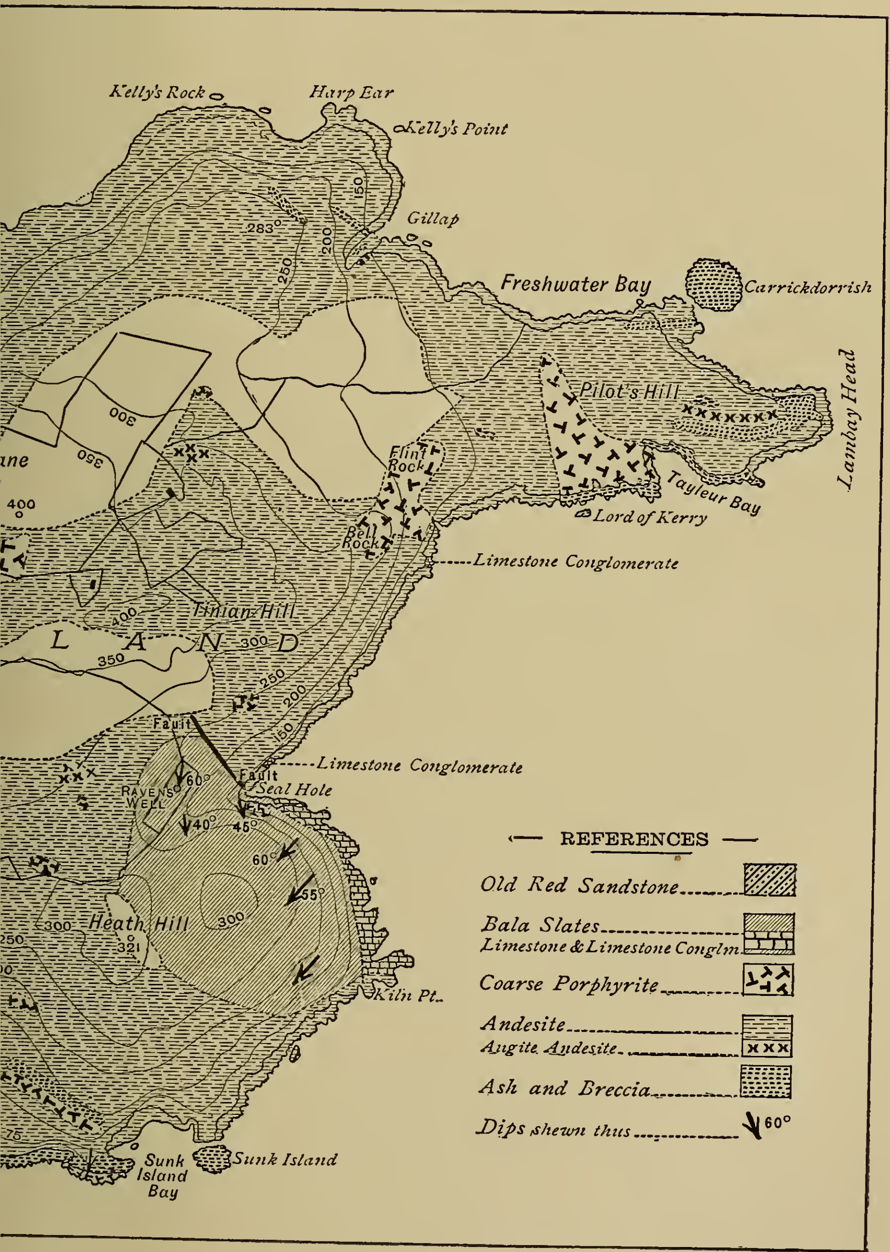
Geological Map of Lambay Island, on the scale of 4 miles to the inch.

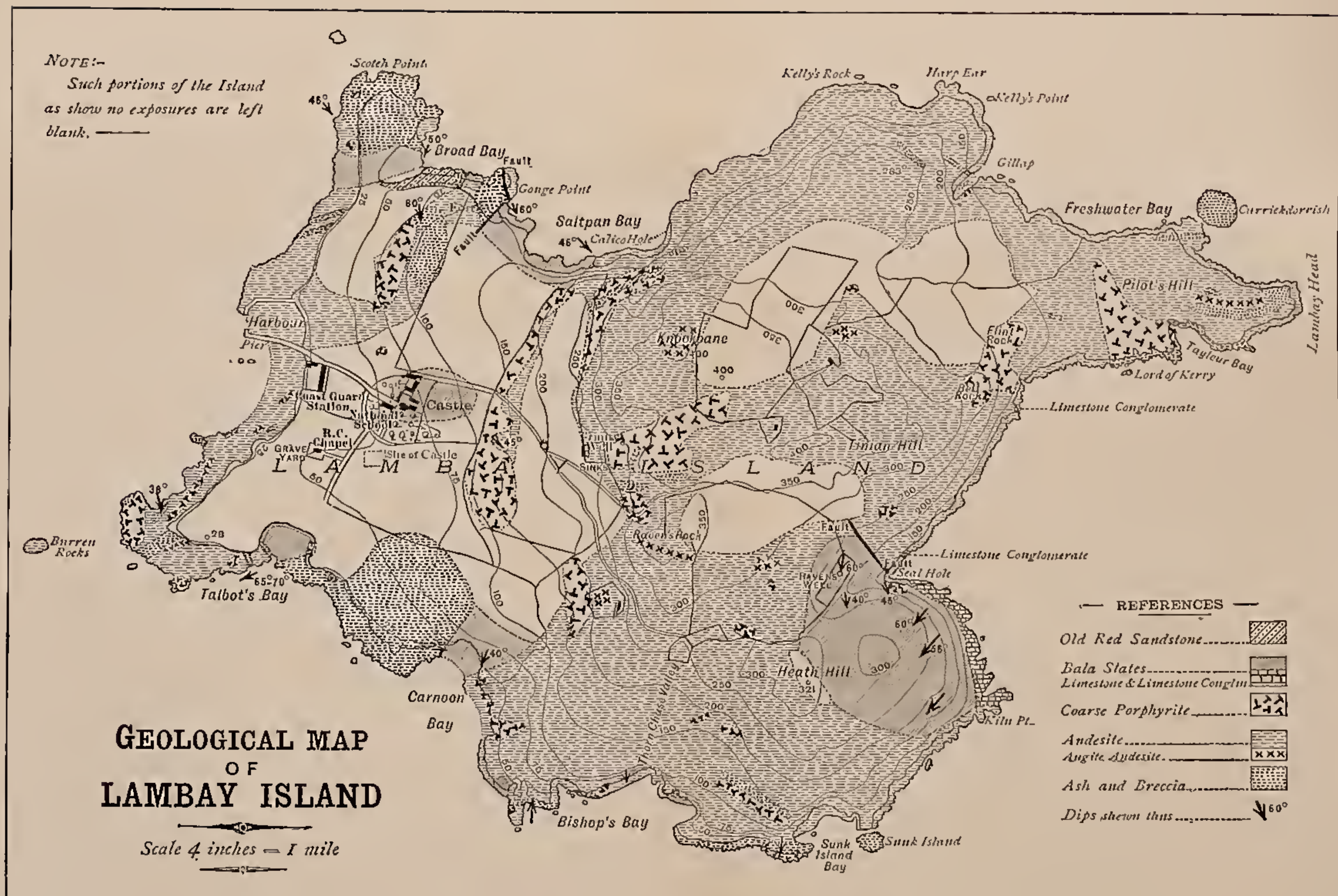
Discussion.

Mr. W. W. Watts congratulated the Authors on the excellent work that they had done. He was not quite convinced by the arguments which he had heard as to the outpouring of parts of the Lambay porphyry in the form of lava.

Mr. G. W. Lamplugh asked whether the Authors had found any pebbles of the porphyrite in the Old Red Sandstone, as he believed that Mr. McHenry thought the point of importance.

Mr. Gardiner, in reply to the last-named speaker, stated that no pebbles of the coarse porphyrite had been noticed by the Authors in the Old Red Conglomerate which occurred on the island.


Kelly's Rock
Harp Ear
Kelly's Point
Gillap
Freshwater Bay
Carrickdorrish
Lambay Head
Pilot's Hill
Flint Rock
Bell Rock
Tayleur Bay
Lord of Kerry
Limestone Conglomerate
Tinian Hill
L A N D
Fault
Limestone Conglomerate
Ravens Well
Seal Hole
Heath Hill
Kiln Pt.
Sunk Island Bay
Sunk Island
REFERENCES
Old Red Sandstone
Bala Slates
Limestone & Limestone Conglm.
Coarse Porphyrite
Andesite
Augite Andesite
Ash and Breccia
Dips shewn thus 60°


NOTE:-
Such portions of the Island as show no exposures are left blank.
GEOLOGICAL MAP OF LAMBAY ISLAND
Scale 4 inches = 1 mile
REFERENCES
Old Red Sandstone
Bala Slates
Limestone & Limestone Conglm
Coarse Porphyrite
Andesite
Augite Andesite
Ash and Breccia
Dips shewn thus
Scotch Point
Broad Bay
Fault
Gorge Point
Saltpan Bay
Calico Hole
Kelly's Rock
Harp Ear
Kelly's Point
Gillap
Freshwater Bay
Carrickdorrish
Lambay Head
Pilot's Hill
Tayleur Bay
Lord of Kerry
Limestone Conglomerate
Harbour
Pier
Castle
Coast Guard Station
R.C. Chapel
Grave Yard
Site of Castle
L A M B A Y I S L A N D
Knockbane
Raven's Rock
Raven's Well
Seal Hole
Heath Hill
Kiln Pt.
Burren Rocks
Talbot's Bay
Carnoon Bay
Bishop's Bay
Sunk Island Bay
Sunk Island

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[No. 214 will be published on May 2nd next.]

[The Editor of the Quarterly Journal is directed to make it known to the Public, that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

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Vol. LIV. MAY 2nd, 1898. **No. 214.**
PART 2.

THE

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SESSION 1897–98.

1898.

Wednesday, May 4–18
" June 8–22

[*Business will commence at Eight o'Clock precisely each Evening.*]

10. *On the* Occurrence *of* Chloritoid *in* Kincardineshire. By George Barrow, Esq., F.G.S. (Read January 19th, 1898.)

[Communicated by permission of the Director-General of H.M. Geological Survey.]

In the neighbourhood of Drumtochty, near Fordun, I found numerous fragments of a green schist, which are characterized by white or yellowish spots. On closer examination these specimens disclose numerous minute, dark, glistening crystals, which are fairly evenly distributed. Several of these were picked out with the point of a knife, when they proved to be hard and brittle. Placed on a sheet of white paper, the crystals were seen to be rudely hexagonal and dark green by transmitted light. Their characters and mode of occurrence suggested that they were chloritoid, or 'brittle-mica,' and subsequent investigation has proved that this is their true nature.

The rock containing them was first met with *in situ*, at the entrance to the little gully at the head of Friar Glen Burn, near Drumtochty Castle. The section here shows a highly chloritic green grauwacke, becoming gradually finer in texture, and passing into the spotted green schist containing the chloritoid, which may be conveniently called the 'chloritoid-rock.' A few inches of grey, almost metallic-looking schist succeeds this, and farther on is a rather yellow schist, with small crystals of brown mica. This passes gradually into a schistose pebbly grit of the arkose type: that is, the pebbles are embedded in what was originally a fine arkose matrix, as distinguished from the chloritic matrix of the green grauwacke. This sequence of rocks is easily recognized, and we have now succeeded in finding it in a number of localities along a narrow belt of ground nearly 22 miles long, extending from the coast north of Stonehaven nearly to the North Esk, keeping always some little distance north of the Highland Fault. The various localities will be indicated on the Geological Survey 1-inch maps, sheets 66 and 67, to be shortly issued.

Of these other exposures, the two most interesting are the section seen in the Cowie Water, close to Urie House, and that on the coast, 2 miles north of Stonehaven (Red Man, on the 1-inch map). These are practically identical, and in both we note a thin film of grey schist in contact with the coarser part of the green grauwacke. In this film occur the largest crystals of chloritoid that have been found hitherto in this district; but they are very sparsely scattered through the schist. With this exception, the chloritoid seems to be restricted to the green band lying between the two grits referred to above. This band varies much in appearance, and judging from the amount of metamorphism that it has undergone, it may be a slate, phyllite, or fine schist.

It is in the fine schist alone that the chloritoids are visible in hand-specimens; their presence was, however, suspected in the slate and fine phyllite, both from the nature of the section exposed and from the fact that, even in the slate, the white spots are still big enough to recognize with a hand-lens. Microscopic examination proves that they are present in great number, but the crystals are extremely small and ill defined, tending to occur in groups. In fact they are almost identical with the ottrelite described by Mr. W. M. Hutchings[1] as occurring in a slate near Tintagel. As the containing rock becomes more crystalline, both the chloritoids and the spots tend to become larger, till in the schist in Friar Glen Burn we see numerous dark-green glistening crystals, often as large as a pin's head, and white spots as big as peas. In some of the specimens of this type the microscopic sections show a perfect gradation from the largest to the smallest crystals, and clearly prove that the mineral in the slate is the same as that more commonly seen in this schist. Without this graduated series one could not have been sure of this identity.

Description of the Rock.

The chloritoid-rock is in all cases a typical 'felt' of white mica and chlorite, associated with a considerable amount of quartz, but very little felspar. The larger chloritoid-crystals are either irregularly-shaped plates or flakes, giving a mere suggestion of prismatic outline, or lath-shaped, with jagged ends—obviously the plate seen edgewise. Binary twinning is almost always shown by the latter under the microscope (see figure, p. 154); polysynthetic twinning is distinctly rare. When the crystals fall below a certain size they never show any twinning.

The spots are numerous, and so full of inclusions of the minerals of the rock-matrix that at times their boundaries can be made out only under crossed nicols, when they form areas of very low double refraction. Very small chloritoid-crystals (one might almost say 'specks,' they are so small) occur sometimes in this spot-material, but they are not common. The real nature of this material we have been unable to determine; the optical properties are ill defined, probably because it seems very liable to decompose. A considerable amount of it was obtained after treatment with hydrochloric acid, and proved to be composed chiefly of silica, iron, and alumina. The field-evidence leaves little doubt that the spot-material represents a stage in the formation of staurolite, but this cannot be actually proved.

One other feature of the chloritoid-rock may be worth noting here. In common with most of the finer sediments of the Highlands, originally rich in chlorite, this band contains a great number of schorl-crystals. As in the case of the chloritoid and the spots, the crystals increase in size as the rock containing them becomes more coarsely crystalline.

Optical Properties and Hardness of the Mineral.

The binary twins show strong pleochroism; when the shorter diagonal of the prism is at right angles to the trace of the twin-face

[1] See Geol. Mag. 1889, p. 214.

or base the colour is pale green or greenish-yellow, varying considerably with the thickness of the section; when parallel to the twin-face the colour is the very characteristic, clear indigo-blue. The double refraction is not high; it seems to be distinctly lower than that of hornblende, though, according to the tables of minerals, it should be slightly higher. On mounting some of the isolated and broken-up crystals in balsam, the high refractive index is well seen. Besides this, we now note the rapidity with which the strength of the pleochroism diminishes as the fragments become thinner—an important point, as it explains the very different aspect, especially so far as colour is concerned, of the minute crystals seen in the slate and the larger ones of the schist. That the mineral possesses a fairly well-marked basal cleavage is at once obvious, for almost all the fragments are lying on their basal plane. Here and there we find traces of a prismatic cleavage, the angle being a little over 60°. It is never distinct enough to permit of accurate measurement. Indeed, the comparative absence of any such cleavage is really of more value for purposes of identification than the fact that obscure traces of it may be met with occasionally. Examining suitable flakes, we may note:—

$a = \alpha =$ olive-green.
$b = \beta =$ deep indigo-blue.
$c = \gamma =$ pale green-yellow.

The mineral is positive, and shows the oblique emergence of a positive bisectrix.

The above characters show that, optically, it is a typical chloritoid.

Its hardness may be expressed by the statement that it will just scratch glass, and will not scratch fresh microcline. An ordinary knife will not scratch it, but, owing to the inclusions being often chlorite and white mica, the knife will frequently appear to do so, when in reality it is scratching only the softer material.

Chemical Composition.

The preparation of a sample sufficiently pure for chemical analysis has given great trouble, and taken much time. As the sections show, not only do the crystals contain many inclusions, but the edges are very jagged, and the enveloping material, largely chlorite and white mica, is felted into these jagged edges. Further, it was found that the material of the white spots was heavier than the densest solution either of cadmium borotungstate or of methylene iodide. After repeated trials, a large quantity nearly pure was obtained by the following process:—Several pounds of the rock were powdered up sufficiently small to pass through fine muslin. The powder was placed in a large enamelled-iron developing-dish, and water from a tap was allowed to fall slowly onto it. By this means more than two-thirds of the material was got rid of, without any appreciable loss of the mineral sought. The residue was placed in a weak solution of hydrochloric acid and heated over a steam-bath for some hours—in fact till it ceased to tinge the acid solution yellow.[1] It was again elutriated under the tap, and the residue, after drying, passed through a borotungstate solution of sp. gr. 2·9. This practically eliminated nearly all the quartz and white mica, except such as adhered to the chloritoid. The residue was now passed under a powerful electro-magnet, which picked up the chloritoid and dropped nearly all the white-spot material. (This it will not do unless the material has been first strongly acted upon by acid, and a large part of the iron removed.) Some of the white material was still taken up by the magnet, but examination showed that its surfaces were greatly etched and corroded. About 2 grammes of the now nearly pure chloritoid was gently ground in an agate mortar, washed, and dried. The powder was placed in a concentrated solution of cadmium borotungstate, and now the etched surfaces of white material, owing to their air-retaining nature, floated much longer than the chloritoid, which was drawn off almost pure. An analysis was made of this material and is given below. It is so nearly identical with that given by Barrois, to show the composition of the large crystals from the schist in the Ile de Groix, that the two are printed side by side:—

	Kincardine.	Ile de Groix.
SiO_2	26·00	24·90
Al_2O_3	40·05	40·36
FeO	19·50	26·17
Fe_2O_3	5·05	
MgO	2·88	2·54
Loss on ignition	6·00	6·23
Total	99·48	100·20

It will thus be seen that, both optically and chemically, the mineral here described is substantially identical with that analysed by Dr. Barrois from the Ile de Groix. But there is a great difference between the rocks containing the mineral, for the chloritoid in the foreign specimen occurs in a decomposed sillimanite-gneiss, and, as our experience from Kincardine would lead us to expect, the crystals are large in proportion to the very high metamorphism that the nature of the rock suggests. In a specimen kindly supplied to me by Dr. Barrois one crystal weighed 2 grammes. Curiously enough, films of the rock-matrix traverse these crystals in exactly the same manner as do minute threads in the exceptional crystals obtained on the Kincardineshire coast; and further, both show polysynthetic twinning. The part played by this mineral seems fairly evident. Owing to the exceptional composition of the containing rock, it entirely replaces the characteristic brown mica so abundant in the Highland schists. Indeed, in a single slide from the margin of the rock, we may find alternate films, one of which contains

[1] After this prolonged heating the flakes were examined carefully, to make sure that they had not been acted on by the acid. The four analyses that have been made of the mineral in different stages of purity show this quite clearly, for in two cases acid was not employed; yet these two correspond exactly with the others, allowing for more impurity.

biotite to the exclusion of chloritoid, while the adjacent film contains chloritoid to the exclusion of biotite. To a certain extent the sillimanite-gneiss from the Ile de Groix shows the same characteristic. The rock is greatly decomposed, but there does seem to have been a little brown mica in it; still, the total amount must be quite insignificant when compared with the great quantity of chloritoid present in the large crystals. In ordinary sillimanite-gneisses biotite is one of the chief constituents. It will be interesting to learn to what extent biotite is similarly replaced in other areas.

Variation in Composition of the Chloritoid.

Examining the list of analyses of this mineral given by Dana, one is struck by the fact that no two of them have the same composition, and consequently either the mineral must vary much in composition, or else the extreme difficulty in eliminating impurities has led to a belief in a variation that does not exist. Is not the latter the more reasonable supposition? Four analyses[1] of the Kincardineshire mineral have been made from specimens varying in purity. The first gave nearly 1·5 per cent. of alkalies, and the last merely a trace. On completing the first analysis it was seen that a large quantity of white mica must be adhering to the jagged edges of the chloritoid, but the microscope fails to make this at all clear. Obviously, it was quite improbable that an appreciable amount of alkali would be present. At intervals during the last 3 years efforts have been made to rid the mineral of impurity. This I have practically succeeded in doing, with the result that the chemical composition proves in reality to be substantially identical with that of the mineral from the Ile de Groix. As the crystals in this rock are so large that a practically pure sample can be obtained in an hour, we may fairly regard it as the standard or type.

Had not the above efforts to obtain pure material been made, I should simply have added one more to the list of chloritoids having exactly the same optical properties, but with a very variable composition. Now, if we turn to the paper by A. Renard & C. de La Vallée Poussin,[2] we see that the fine crystals from Serpont are actually figured. This figure shows that the mineral is permeated with quartz, so disseminated through it that the quartz must be very difficult to eliminate. If our suggestion that the chief variations in composition are really due to impurity be correct, then the Serpont specimen should show an abnormally high silica percentage (41·65). This is exactly what it does, and Dana lays special stress on this point, using this high silica-percentage to justify a different name for the mineral from that of chloritoid having the composition given by Barrois and myself. The identity of all three minerals, so far as optical properties go, is rendered clear by the careful descriptions given in the paper referred to above. By sedulously noting the composition of the matrix in which these minerals are embedded, and especially the material in contact with

[1] Mr. W. M. Hutchings kindly made the second for me.
[2] 'Note sur l'Ottrélite,' Annal. Soc. Géol. Belgique, vol. vi (1879) p. 51.

it, whether it be quartz, white mica, or chlorite, or any other mineral, we see, on turning to the published analyses, that the nature of the enveloping material will largely account for the supposed differences in composition. Briefly put, I would suggest that chloritoid, ottrelite, etc., possessing the optical properties of the mineral here described, have really the same composition—if we could only obtain pure material to work upon.

The Presence of Manganese.

In the Kincardineshire specimen and in some crystals sent to me by Dr. Barrois a special examination was made for manganese, and a very small quantity (·02 per cent.) was found to be present in both. In some analyses of ottrelite the manganese is present in considerable quantity, as much as 8 per cent. in one case.

In conclusion I have to thank Dr. Barrois for courteously sending me a specimen of the Ile de Groix rock, and Prof. Bonney for the loan of his slides. My thanks are also due to my colleague Mr. Teall for the loan of the slide of the rock from Ottré, and for kind assistance in the preparation of this paper.

Postscript.

[The appended figure shows the form and mode of occurrence of the common binary twins. The crystal is immediately in

Chloritoid from Friar Glen Burn, Kincardineshire.

× about 80. Crossed nicols.

contact with minutely intergrown white mica and chlorite along a considerable part of its margin. Great difficulty was experienced in getting rid of this marginal material, and a considerable quantity of nearly pure chloritoid has to be taken, in order to prepare a small sample pure enough to give a true analysis. Fortunately the presence of white mica as a source of impurity can be instantly detected by the alkalies shown in the analysis. Neither potash nor soda occurs in any of the chloritoids, and so long as either was present in appreciable quantity the analysis could not give the true composition of the mineral. The four analyses showed the steady decrease of this source of impurity. I regret to say that the record of the first has not been kept, as it was obviously made with impure material. Mr. Hutchings has kindly supplied the account of the second. The lime present in Nos. II. and III. is probably contained in the white-spot material, which was not separated entirely except from the last sample analysed.

	I.	II.	III.	IV.
SiO_2		31·40	30·00	26·00
Al_2O_3		37·38	36·10	40·05
FeO		18·81	18·57	19·50
Fe_2O_3			5·03	5·05
CaO		2·80	2·00	......
MgO		3·05	3·02	2·88
K_2O	} 1·5	0·38	} 0·50	Trace.
Na_2O		0·65		
H_2O		5·45	5·00	6·00
		99·92	100·22	99·48

G. B.—February 4th, 1898.]

Discussion.

Sir Archibald Geikie said that, although he rose in obedience to the President's call, he did not feel that he had sufficient personal acquaintance with the subject of the paper to warrant him in offering any criticism. He was glad of the opportunity, however, of welcoming a paper of this kind in the meeting-room of the Geological Society. Those whose memories carried them back 30 or 40 years would remember how completely the field-geologists of this country had then thrown over the practical aids of chemistry and petrography. Such a contribution as that to which the Society had just listened it would have been almost impossible for any of those men to produce, admirable observers as they were. Mr. Barrow had shown that, besides being an excellent surveyor in the field, he was also a skilled chemist and trained petrographer. He was engaged in working out the structure of some of the most difficult country in the Central Highlands, and devoted himself also with the most praiseworthy enthusiasm to the study of the chemical and mineralogical characters of the rocks which he encountered. His work had thus a special value, for it united a grasp of broad questions of tectonic geology with a laborious devotion to the investigation of the minutest features in the composition and internal structure of the rocks.

Lieut.-Gen. McMahon congratulated the Author and also the Society on the paper just read. The chemical analyses of minerals in days before the systematic application of the microscope to geology had often led to erroneous results, because minerals very commonly enclosed endo-minerals differing materially in chemical composition from themselves, the resulting analyses being thus vitiated. The future of chemical mineralogy depended on chemists making sure, by preliminary microscopical and optical tests, that they were really dealing with a homogeneous and pure mineral. The correct definition of mineral species depended on the combination of the petrological and chemical methods. These methods the Author appeared to have combined in his own person.

The President and Mr. Teall also spoke, and the Author replied.

11. Sections *along the* Lancashire, Derbyshire, *and* East Coast Railway *between* Lincoln *and* Chesterfield. By C. Fox-Strangways, Esq., F.G.S. (Read January 5th, 1898.)

[Communicated by permission of the Director-General of H.M. Geological Survey.]

[Plate X.]

The portion of this railway between Lincoln and Chesterfield, which has lately been opened for traffic, traverses the country in a nearly east-and-west direction; and, consequently, crosses at right angles to the strike all the formations from the Lias to the Coal Measures in succession. At its eastern end, owing to the general flatness of the country, there are not many deep cuttings; the strata are, therefore, not well exposed, and a considerable thickness of beds is not seen at all. West of the Trent the ground is more hilly, and cuttings are numerous; but the finest exposures are in the higher ground, along the outcrop of the Magnesian Limestone and Coal Measures near Bolsover and Chesterfield, where some very interesting sections occur.

Commencing at the junction with the Great Northern Railway, about 1½ mile west of Lincoln, the new railway crosses the level ground covered by the alluvium and gravels of the little rivers Till and Witham, which, according to a boring at the junction, have a thickness of about 20 feet. They appear to be rather more extensive than shown on the Geological Survey map, reaching about a mile westward to the foot of the slightly rising ground on which Skellingthorpe stands.

At the station here about 6 feet of gravel (composed of pebbles and flints) is seen resting on Liassic clay; but the latter has not been excavated, and no fossils were found to indicate to what horizon in the Lias this clay belongs. At Old Hag Wood, a shallow cutting shows Lias Limestone crowded with *Gryphæa incurva* and small gasteropoda. Beyond this the Lias keeps to the surface to beyond the county boundary, but does not extend so far west as shown on the Survey map, being covered east of Harby Station by sand with pebbles and flints.

West of Harby the line crosses the great sandy flat which extends for a distance of about 3 miles, to the foot of the rising ground near Clifton. The lower part of the Lias and Rhætic is entirely concealed by this sand, and there is no indication of their outcrop at the point crossed by the line, the first evidence of the beds beneath being at the lane about ½ mile east of Clifton Station, where an excavation shows 3 feet of grey marls overlying red marl. This section has the appearance of being at the base of the 'Tea-Green Marl,' but it is a long way west of the outcrop as laid down on the Geological Survey map, and without a further examination of the country bordering the line no definite statement can be made as to that point.

At Clifton Station the Red Marl comes on in force, and is seen in the deep cutting across the rising ground between North and South Clifton. On the western side of this ridge a thick deposit of blown sand creeps up the hill, thinning out over the summit; but at the railway it does not come over onto the eastern slope as shown in the Survey map. At the point where the level of the rails cuts the surface the sand is from 5 to 6 feet thick.

Beyond this ridge the line crosses the broad expanse of the Trent alluvium. Of this a detailed section, of which the figure in Pl. X is a reduced copy,[1] shows the variations in the beds. The piers of the viaduct go down from 25 to 30 feet through alluvial deposits, and from the section it will be seen that they consist principally of loam resting on a varying thickness of sand and gravel. At about 400 or 500 yards west of the present river the horns of red deer were found at a depth of 25 feet. This is near the margin of what appears to be an old course of the River Trent.

At Fledborough Station there are cuttings in Red and Grey Marl with skerry[2] which continue for 3 or 4 miles, till the Great Northern Railway is reached at the Dukeries Station. The cuttings along this part of the line being sloped down, the sections are not very clear, but judging from the general appearance of the country bordering the line one must conclude that there cannot be much drift or superficial beds of any sort on this side of the Trent. Field-ponds and other shallow excavations all show solid strata. At the Dukeries Station the grey and white flaggy sandstones of the Keuper, which come out from beneath the Red Marls, are well exposed in the Great Northern Railway, and along the junction-line connecting the two railways. The beds have a slight dip to the south-east, and are very flaggy, with bands of marl. They probably represent the easterly extension of the Tuxford Stone, which was formerly much worked around that place; but the beds here are not strong enough to be of any value. A deep well sunk at this point shows the character of the strata that lie below.

In the following section there is not more than 51½ feet of strata that can be classed with the Lower Keuper Sandstone or Water-stones. This is considerably less than the usual thickness assigned to these beds, but it appears to correspond very well with what is seen of them in the Kirton cutting mentioned subsequently. The gypsiferous marls and sandstone shown in the upper part of the boring are very conspicuous in the cutting at Tuxford Station, where the thick lenticular masses of gypsum stand out prominently from the sides of the sloped-down banks. Beds of marl and skerry continue

[1] The figures in Pl. X, which considerably add to the value of this account, are based on drawings which Mr. R. Elliott Cooper, the engineer of the railway, has very kindly given me. The horizontal section is reduced from the original drawing.

[2] 'Skerry' is the name usually applied in this district to the thin layers of marly sandstone.

for about 2 miles west of the station; but there are no sections to indicate the junction with the Lower Keuper Sandstone, which, however, does not appear to run up this valley so far as it is shown on the Geological Survey map.

Well-section near Tuxford.

In the triangle between the Lancashire, Derbyshire, and East Coast Railway, the Great Northern Railway, and the Junction-line connecting these two.
(Section communicated by Mr. R. Elliott Cooper.)

	Feet.	Inches.
1. Red and blue marl	25	0
2. Hard blue stone and gypsum	3	0
3. Blue stone and red marl	3	0
4. Hard blue rock	5	0
5. Blue marl and hard layers	3	6
6. Hard blue rock	2	0
7. Red-and-blue marl and gypsum	156	6
8. Fine sandstone	3	0
9. Red sandy marl and gypsum	41	6
10. Hard sandy rock		9
11. Red-and-blue marl and gypsum, sandy	26	9
12. Red sandy marl	10	0
13. Sandy red-and-blue marl and gypsum	8	6
14. Red sandy marl	3	0
15. Hard sandy rock and thin veins of gypsum	8	9
16. ,, ,, ,,	3	0
17. Sandy red-and-blue marl and gypsum	4	9
18. Sandstone	5	6
19. Red and blue sandy rock	3	0
20. Red sand-rock	8	6
21. Red sandy marl	15	0
22. Fine sandstone	3	0
23. Red sandy marl	10	6
24. ,, ,, and gypsum	1	6
25. ,, ,,	5	6
26. ,, ,, and gypsum	5	0
27. ,, ,,	5	6
28. Hard sandy rock		6
29. Red sandy marl and gypsum	1	6
30. Sandy marl and layers of sandstone	2	6
31. Red sandy marl	1	6
32. Red and blue sandy marl	7	0
33. Blue sandy marl	29	0
34. Light-coloured sandstone	11	0
35. Sand and pebbles	1	6
36. Light and brown sand	8	6
37. Red sandstone	19	6
38. Red sand	43	0
39. ,, and pebbles	153	6
	650	0

Water-level 54 feet from surface. The ground has since been lowered 6 feet, making the depth of the boring from the present level 644 feet and the water-level 48 feet.

South of Kirton there is a deep cutting in the sandstone and marls of the Waterstones, which becomes more sandy towards

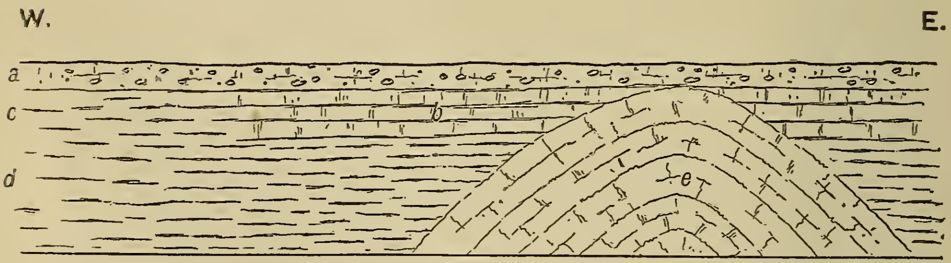
Boughton Station, where a thick bed of pinkish sandstone crops out.

At the foot of the escarpment formed by these hills the line enters on the great dip-slope of the Bunter Pebble Beds, but there is no section in them till we get within a mile of Ollerton, where a long cutting shows soft current-bedded sandstones with a few pebbles, which gradually become more massive and contain the pebbles arranged in distinct lines. Cuttings in similar beds continue at intervals for the next 5 miles, the best sections being at Ollerton Station, south of Broomhill Grange, and at Bradmer Hill. At the second of these there are a number of small faults hading west, which give the beds a peculiar jointed appearance.

The Lower soft Red and Mottled Sandstone of the Bunter, which crops out at the foot of the escarpment formed by the Pebble Beds, occupies a breadth of about a mile between the last cutting and Warsop; but as the railway is carried on an embankment there are no sections in the rock.

West of Warsop Station the line crosses the great dip-slope of the Magnesian Limestone, the first section reached being at the junction with the Midland Railway near Parson's Wood. Here there is an interesting exposure, of which a sketch is given below, showing the Permian Marls and Upper Limestone resting unconformably against a boss of the Lower Limestone. The disturbance of the Limestone before the marls were deposited is very striking.

Fig. 1.—*Section at Warsop Colliery Junction, near Sookholme Lodge, showing Permian Marl and Limestone resting unconformably on Lower Limestone.*



a=Red sandy clay, with some pebbles and limestone-fragments.
b=Thin flaggy limestone. *c*=Marly clay.
d=Red marl. *e*=Massive limestone.

[Height of section=about 10 feet.]

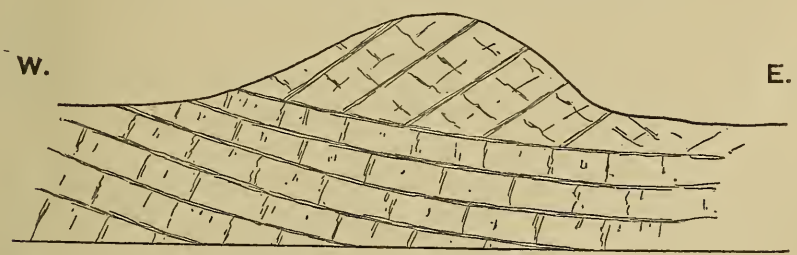
These marls are seen again immediately west of Parson's Wood, where there appears to be some disturbance in the beds, thin beds of contorted limestone being mixed up with the marl. The marls continue as far as the Midland Railway (Mansfield and Worksop branch), as is correctly shown on the old Geological Survey map, but they cannot be of any great thickness, as the cuttings in the lower railway are entirely in limestone.

In this district the Permian beds consist of a lower and upper limestone with intervening marls. The basement-breccia, which occurs farther south, does not appear to be present here; at least it is not recorded in the shafts of the tunnel illustrated in Pl. X (vertical sections). The Lower Limestone is by far the most important division, the Middle Marls being merely a thin stratum, while the Upper Limestone is represented only by the thin flaggy limestone seen near Parson's Wood.

At Langwith Junction there are deep cuttings in the Magnesian Limestone, both along the main line and in the Clown branch, as well as in the Midland Railway below, which well show the false-bedded character of the rock and how much it obscures the true dip of the beds. About ½ mile from the station, opposite Upper Langwith, there is a well-marked anticlinal axis, at which the dip of the beds turns over to the west, and about ¼ mile beyond this, at the last bridge in the cutting, the limestone is cut off by a fault running in a north-westerly direction, which brings down the red sandy marl on the west side. This section, which is just on the steep side of the valley, is interesting from there being about 5 feet of rubble in the upper part, which has slipped down when the hill was higher, and distinctly turned over the edges of the surface-beds of marl.

The line now follows the valley of the River Poulter for about a mile, there being no sections till the deep cuttings in the Magnesian Limestone near Scarcliff are reached, where the beds dip from 2° to 5°, and in some cases as much as 10° to the east. The false-bedding is here very marked, the upper part of the cutting being in some places quite unconformable to that below, and dipping at a high angle in the opposite direction.

Fig. 2.—*Section in Scarcliff cutting, showing marked false-bedding, amounting to unconformity, in the limestone.*

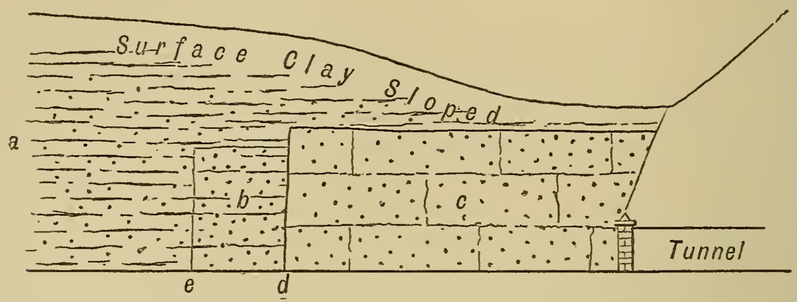


[Height of section = about 30 feet.]

Between Scarcliff and Bolsover the line crosses the Permian escarpment by a tunnel nearly 1½ mile in length, the shafts of which afford a good insight into the thickness of the beds. (See Pl. X, vertical sections.)

The maximum thickness of the Magnesian Limestone met with in the shafts was 61 feet; but this is probably not nearly the full thickness of that formation, a considerable amount of the upper beds having been denuded away. The lower part of the shafts, and nearly the whole of the tunnel itself, is in the Coal Measures. These latter are high up in the series, and it is evident that they do not contain coal-seams of any value. It also appears from these sections that the upper part of the Coal Measures is, at this depth, not stained red by the Magnesian Limestone, as usually observed along the outcrop of this junction, a staining which gave rise to the supposition that these uppermost beds were of Permian age.

Fig. 3.—*Section at the western end of Bolsover Tunnel.*



a = Sandy shales, sloped.
b = Sandy shales, rather harder and more sandy, vertical face.
c = Massive sandstone.
d = Line of fault, nearly vertical.
e = Apparent line of fault. The semblance is probably due to *b* being left vertical, while *a* is sloped.

The western mouth of the tunnel shows a little shale over massive sandstone, which a little farther on is faulted against sandy shales. This fault runs in an east-and-west direction very obliquely to the railway, and is nearly vertical, but may have a slight hade to the north. (See fig. 3.)

About 400 yards from the tunnel-mouth there is 5 feet of coaly shale and coal dipping 2° east; and at the station-yard an impure coal-seam is seen, 3 feet thick, dipping 8° south-east. This is probably the seam indicated on the Geological Survey map at Castle Lane, and the highest seam shown on the Hor. Sect. Sheet 18, which is stated to have been worked about 3 miles farther north.[1]

After crossing the Doe Lea Valley, soft rubbly and flaggy sandstones are seen at the junction with the Midland Railway; and a little farther on the deep cutting at Long Duckmanton shows sandstones and shales dipping at angles from 4° to 6° east, with a seam of coal about 1 foot thick, which crops out at the bridge, with another thin seam about 10 feet below this. At the summit near the centre of this cutting there is an irregular boss of sandstone which seems to be let into a hollow in the shales, so abrupt are the terminations on either side. This sudden ending-off of the Coal Measure sandstones against the shales appears to occur rather frequently in this district, and another instance will be noticed subsequently.

[1] Expl. of Hor. Sect. Sheet 61, p. 5.

At the station called Arkwright's Town, on Duckmanton Moor, the beds appear to be considerably disturbed, probably by the fault (shown on the Geological Survey map) which crosses the line at this point, but as the banks are now partially walled up the section is not clear. Immediately west of this station commences the most complete section to be seen along the whole line, which, including the cuttings and tunnel, has a length of 1½ mile. The beds, which are seen here in one continuous section, represent the Middle Coal and Iron Series, the most valuable part of the Derbyshire Coalfield, and as they dip from 18° to 20° east of the tunnel, and from 10° to 15° west of it, there must be a thickness of between 1000 and 2000 feet of strata exposed at this place. The following section illustrates the approximate thickness of the beds between the station and the tunnel:—

Section between Arkwright's Town Station and Duckmanton Tunnel.

	Feet.	Inches.
1. Alternations of sandstone and shale (with coal-seam 1 ft. 4 in.)	100	0
2. Shale with smutty coal	15	0
3. Flaggy sandstone	15	0
4. Shales with ironstone and coal	30	0
5. Sandstone	4	0
6. Shales with ironstone and coal	30	0
7. Sandstone	6	0
8. Shales	25	0
9. Coal	2	6
10. Sandstone	30	0
11. Dark shales with some coal	35	0
12. Shales and thin ironstone	25	0
13. Sandstone	20	0
14. Dark shales with ironstone	30	0
15. Shales with thin sandy bands	40	0
16. Sandy shales	20	0
17. Dark shales	30	0
18. Shales	8	0
19. Sandstone	2	6
20. Sandy shales	20	0
21. Coal	1	0
22. Shale	1	0
23. Coaly shale and coal	6	0
24. Shale and ironstone	10	0
25. Sandstone passing into shale above and below	1	0
26. Laminated shales with thin coal	15	0
27. Irony shale and sandstone ......10 0 to	12	0
28. Shales	12	0
29. Sandstone	8	0
30. Finely laminated shale with ironstone	12	0
31. Shales and ironstone-nodules ......30 0 to	40	0
32. Sandstone with ironstone-nodules ......10 0 to	15	0
33. Dark shale	15	0

According to the map, the outcrop of the Top Hard Coal is crossed close to the station, but it is not seen, unless some smut near the stationmaster's house represents it.

The most conspicuous seams of coal are Nos. 9 and 23, which crop out east and west of Deepsick Lane Bridge respectively; the latter of these is probably the Soft Coal, but without surveying the neighbouring country it is impossible to identify the named seams. This interesting section may be further continued by the following account of the measures passed through in the tunnel, these latter being nearly consecutive with those above:—

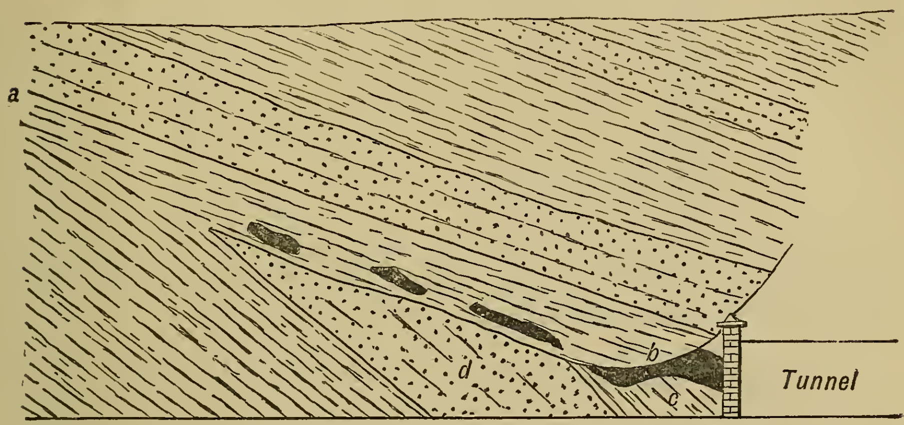
SECTION OF STRATA PASSED THROUGH IN DUCKMANTON TUNNEL.

(*Estimated from a drawing to scale by Mr. R. Elliott Cooper.*)

	Ft.	in.
1. Hard rock		9
2. Shale and ironstone	14	10
3. Hard rock	1	6
4. Shale and ironstone	11	6
5. Ironstone		9
6. Shale and ironstone	10	2
7. Measures 1 6 / 8. Ironstone 1 0 / 9. Coal 3 6 } Heading.	0	6
10. Black fireclay	11	0
11. Hard bind	10	10
12. Clunch	1	3
13. Bind		6
14. Clunch	1	0
15. Bind		6
16. Clunch		9
17. Bind	2	0
18. Clunch	3	0
19. Bind		10
20. Clunch		6
21. Bind	3	5
22. Clunch	1	4
23. Bind	2	0
24. Clunch	2	5
25. Bind	1	10
26. Rock	7	10
27. Bind	1	0
28. Clunch	6	10
29. Bind	18	0
30. Coal-seam. DEEP HARD COAL	6	0
31. Black fireclay	11	0
32. Rock-seam	4	0
33. Shaly bind	3	0
34. Rock	1	6
35. Shaly bind	21	0
36. Coal ... 2 0 / 37. Clay ... 1 0 / 38. Coal ... 9 } PIPER COAL	3	9
39. Fireclay	4	0
40. Softish shaly bind	29	0
41. Rock	1	6
42. Shale	2	6
43. Rock	1	9
44. Bind	16	0
45. Coal	1	6
46. Fireclay	5	0
47. Shale	6	4
48. Coal	3	0
49. Very hard black fireclay	20	0
50. Rock	4	4
51. Bind and shale	2	8
52. Rock	3	0
53. Very hard bind	16	0
54. Coal-seam. TUPTON COAL.	3	0
55. Fireclay	3	0
56. Rock	1	0
57. Shale	5	0
58. Cannel Coal	1	0
59. Bind	17	0
60. Clunch	3	0
61. Hard bind with ironstone.	98	0
62. Coal	3	0
63. Black fireclay, very hard.	15	0
64. Coal	2	6
65. Hard bind	46	0
66. Fireclay	3	0
67. Coal-seam. BLACK SHALE COAL	6	0
68. Ironstone with siliceous pebbles.		

In this tunnel, all the measures down to the Black Shale Coal were crossed; the positions of the Deep Hard Coal, the Piper Coal, the Tupton Coal, and the Black Shale Coal are very clear, but the numerous beds of Ironstone Rake which occur in this series do not appear to have been recognized by the men. The Black Shale Coal, which is better known as the Silkstone Coal, crops out at the western mouth of the tunnel, and is cut off by a fault or slip of some kind which has produced the peculiar arrangement of the strata shown in fig. 4; but, owing to the present state of the cutting, it is difficult to make out what really occurs.

Fig. 4.—*Section at the western end of Duckmanton Tunnel, showing the curious break-up of the coal-seam on the northern side.*



a=Shales, sandy shales, and sandstones.
b=Coal, about 6 feet thick at the tunnel: this thins out westward, and breaks up into patches.
c=Clay and shale.
d=Sandstone, thinning out westward.
[On the south side of the cutting the coal is represented by one small patch.]

Close to the top of the tunnel-arch there is a fault, as shown in the figure, but there is no trace of it beneath the large coal-seam. The fault on reaching the coal-seam appears to have developed into a lateral thrust, which has drawn out the coal in a long tongue to the west, and broken it up into a series of isolated patches that extend for 50 yards or more. These patches being high up in the nearly vertical cutting, it is not easy to examine them carefully, and one does not feel sure as to the true interpretation of this very curious section. As this cutting is near the foot of a rather steep escarpment, it is possible that no true fault exists, but that we have here the section of a very considerable landslip.

Within 1200 yards of the tunnel-mouth the line crosses no less than six faults, showing the broken nature of the strata hereabouts. The rocks consist of alternations of sandstones, shales, and thin coals, with thick shale in the upper part and massive sandstone at the bottom. The dip decreases gradually from 15° at the tunnel till the great anticlinal axis, which traverses this part of the coal-field, is reached. This axis is crossed at 800 yards from the tunnel, and forms a fairly flat arch in the thick beds of sandstone and shales, which is beautifully shown in the deep cutting that occurs at this point.

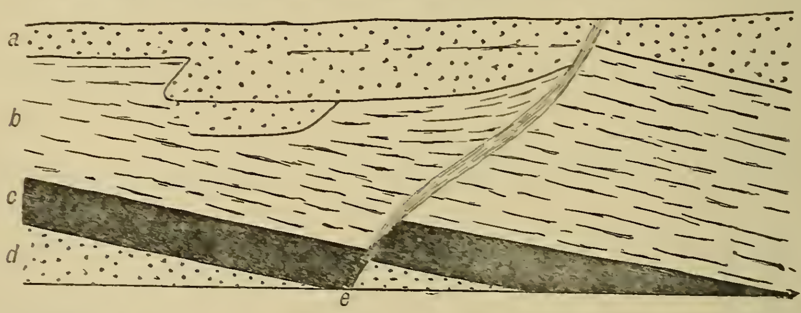
Beyond this the inclination of the beds turns over to the west, and the dip gradually increases to as much as 25° at Hady Lane, where the outcrop of the Black Shale Coal with the Ironstone series above it is again reached. The following details of the coal were measured at this spot:—

SECTION AT HADY PLANTATION.

	Feet.	Inches.
Shale with many bands of ironstone.		
Coal	0	3
Shale	2	6
Coal	2	8
Shale	2	10
Coal	1	3
Shale	1	10
Coal	1	8
Shale	1	0
Coal with a parting	3	0

In the cutting between here and Spital two coal-seams are seen, the uppermost of which is about 6 feet in thickness; it is intersected by a small fault, as shown in the accompanying figure:—

Fig. 5.—*Section in cutting west of Hady Plantation.*



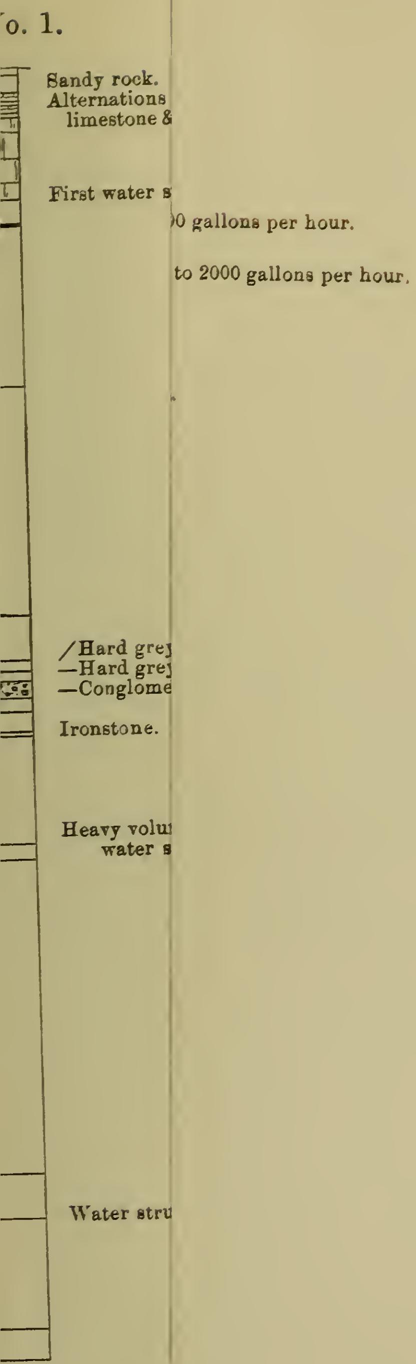
a = Sandstone, which passes very abruptly eastward into shale.
b = Shales.
c = Coal-seam, 6 feet in thickness.
d = Sandstone rising in a great floor on the other side of the cutting.
e = Fault, with easterly downthrow a little less than the thickness of the coal.

The bed of sandstone in the upper part, on the east side, ends off very abruptly in the same manner as that noticed at Long Duckmanton. This appears to be a peculiar feature in these Coal-Measure sandstones. It is very different from ordinary thinning out, and is probably due to the effect of strong currents during the deposition of the beds.[1]

The dip here has turned round more to the south, causing very extensive slips on the northern side of the railway. In fact, nearly all the upper beds have slipped over the basement-sandstone shown in the figure, so that the dip-slope of this bed now forms the surface of the cutting on the northern side.

From this point the line passes over a lofty embankment into the town of Chesterfield, and no more sections are exposed.

[1] An illustration of a similar instance is given in the Geol. Surv. Memoir on the Yorkshire Coalfield (figs. 5 & 6, p. 16), only in the present case the shales are not inclined.


o. 1.
Sandy rock.
Alternations
limestone &
First water s
)0 gallons per hour.
to 2000 gallons per hour.
/Hard gre
—Hard gre
—Conglome
Ironstone.
Heavy volu
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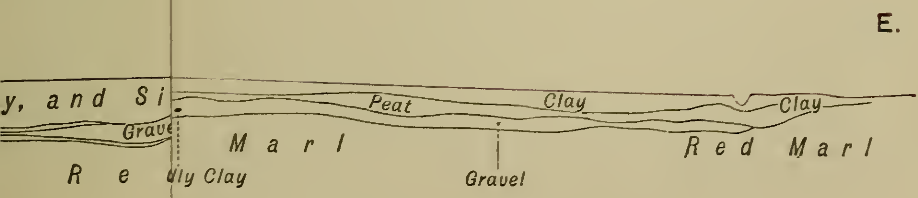
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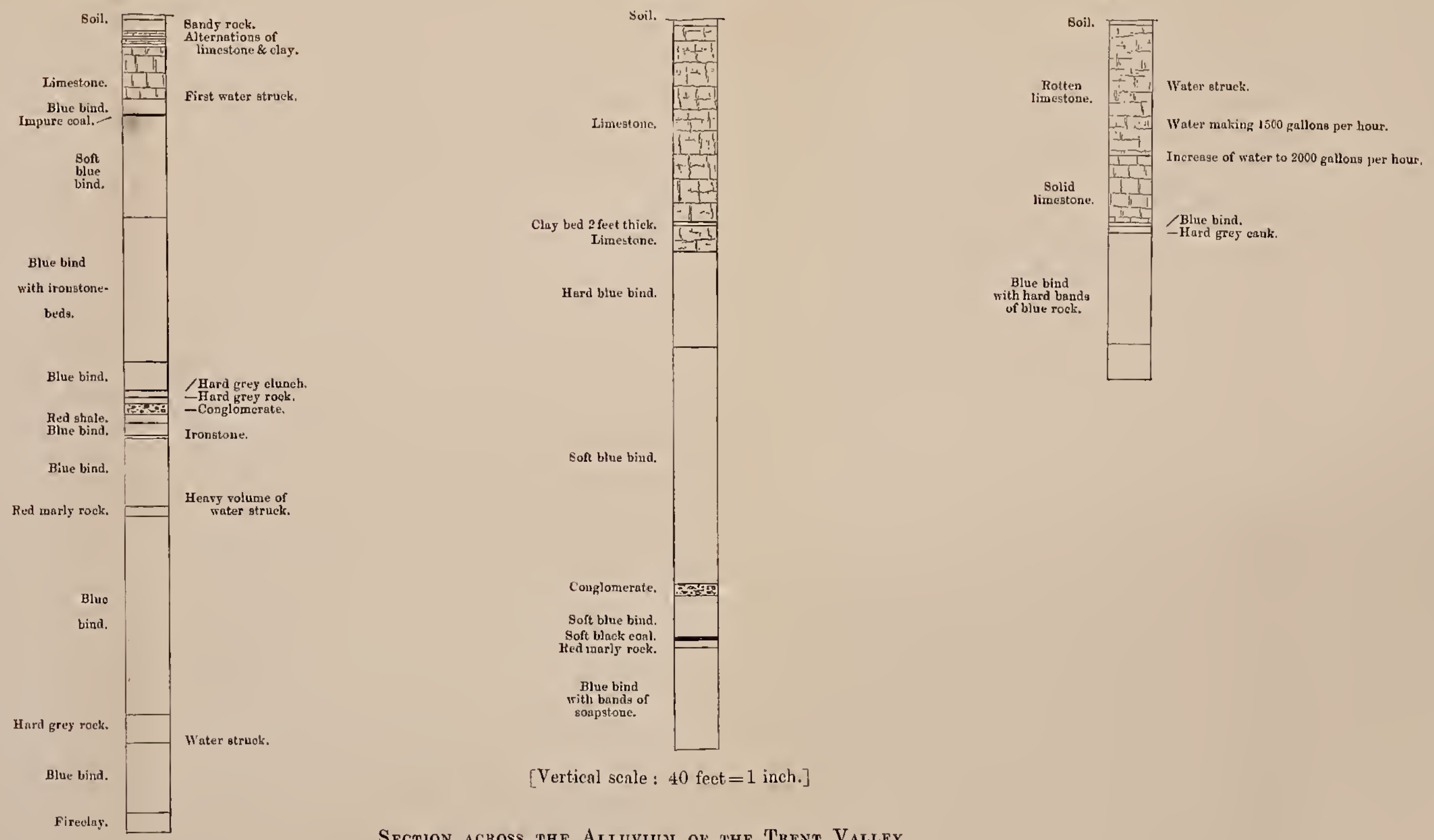
Vertical sections of strata in the Shafts of Bolsover Tunnel.

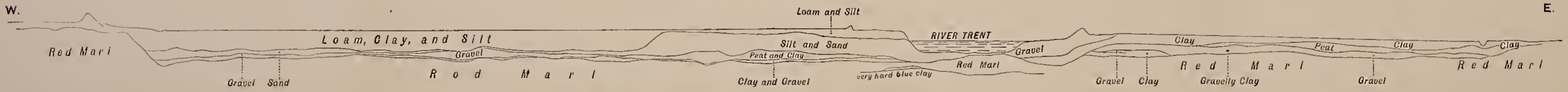
(From a drawing by Mr. R. Elliott Cooper.)



[Vertical scale: 40 feet=1 inch.]

Section across the Alluvium of the Trent Valley.

(Reduced from a drawing by Mr. R. Elliott Cooper.)



[Horizontal scale: 192 feet=1 inch; vertical scale: 96 feet=1 inch.]

The course of this railway being along its whole length nearly at right angles to the strike of the beds, renders it very favourable for geological investigation. The finest cuttings are undoubtedly those in the Coal Measures at the western end, but the Magnesian Limestone and the Bunter Pebble Beds also afford very fine sections. The absence of Glacial deposits is another very interesting feature. Not a trace of genuine Boulder Clay has been seen along the whole line, which traverses a distance of nearly 40 miles across the centre of the country.

EXPLANATION OF PLATE X.

Sections in Bolsover Tunnel and section across the alluvium of the Trent Valley, the vertical scale of the former being 40 feet=1 inch, and of the latter 96 feet=1 inch. The horizontal scale of the Trent Valley section is 192 feet=1 inch.

Discussion.

Prof. Hull pointed out how the district traversed by this railway was of especial interest for several reasons: (1) for the remarkable regularity in the succession of the formations from the Oolites down to the Permian; (2) as being a storehouse for the coal-supply of the future; and (3) as containing in the New Red Sandstone of Sherwood Forest the most important water-bearing formation in that part of England. He referred to the deep borehole put down some years ago by the Corporation of Lincoln at Scarle, which appears to have been situated close to the line of railway described by the Author, and was intended to prove the presence of coal. Commencing at the base of the Lias, it passed through all the formations to the base of the Magnesian Limestone Series at a depth of 2030 feet, and entered some peculiar strata, which he (Prof. Hull) believed to be representative of the Upper Coal Measures of the Manchester district; these are not present in the Derbyshire Coalfield, owing to overlap by the Permian beds.

Mr. Harmer, alluding to the question of the important change produced by infiltration, hoped shortly to lay before the Society evidence to show that the difference between the two principal and seemingly self-evident divisions of the Coralline Crag of East Anglia was more apparent than real, and that the so-called 'Polyzoan Rock' forming the upper part of that formation was, in fact, only an altered condition of the shelly sands of the lower part.

The Rev. J. F. Blake said that, although there might not be any drift along the particular line described by the Author, there was plenty a little way to the south. On the hills near Mansfield there were large boulders of ash like that of the Lake District, and a little south of it masses of Borrowdale syenite and Iron Crag lava, or what looked like them. He had called it the 'volcanic' drift. The gravels also that capped the Pebble Beds were largely composed of the Permian limestone occurring at lower levels on the west, and farther east were found Liassic fossils from the east; so that the drift had come from the north-west and east.

He also enquired whether the Marl Slates and the Permian breccias were found in the section. He considered that the phenomena, which the Author referred to a landslip, illustrated very well on a minute scale what happened when a thrust-plane was produced.

Mr. Lamplugh thought that, with regard to the Glacial deposits, the field-evidence on both sides of England showed that during the maximum glaciation, the chief accretive and radiant centres of the ice-sheet lay over the basins of the North and Irish Seas, the comparatively low topography of the surrounding land being practically obliterated. Under these conditions the rarity or absence of drift-deposits in the area described by the Author might readily be explained, since this part of England would lie between, or near, the margin of the two great ice-lobes.

The President and Mr. Whitaker also spoke.

The Author, in reply, said that the beds described in the Trent valley are alluvial and not Glacial. With regard to the absence of drift, not being acquainted with the surrounding country, he could only speak for the railway-section. The section figured near Parson's Wood very much resembles an unconformity, but the exposure is not extensive enough to allow of a definite expression of opinion.

2. *On a* Quartz-rock *in the* Carboniferous Limestone *of* Derbyshire. By H. H. Arnold-Bemrose, Esq., M.A., F.G.S. (Read February 2nd, 1898.)

[Plates XI & XII.]

Contents.

I. Introduction.

The object of this paper is to give a detailed description of a rock consisting essentially of quartz, which occurs in the Mountain Limestone of Derbyshire. It is not a quartzite in the ordinary meaning of the word—that is, a sandstone indurated by the deposit of interstitial quartz or by the recrystallization of the detrital grains into a clear mosaic, though sometimes a specimen may be found simulating the latter structure. It belongs rather to the second division of quartzite suggested by Mr. Rutley,[1] namely, that of an infiltration or metasomatic quartzite; in other words, it is a silicified limestone. The term 'quartz-rock' will, therefore, be applied to it in this paper.

Often associated with the quartz-rock is a quartzose limestone. This is a fossiliferous limestone containing a large number of quartz-crystals, which may be easily seen with a lens when the rock is wet.

I first noticed the quartz-rock when commencing my study of the Toadstone some years ago. Near the village of Bonsall, the footpath from Ember Lane to Pounder Lane passes a bold outcrop of hard rock, locally known as the 'Top Lift.' A thin section from it was prepared, and on examination was found to consist of quartz-grains. Until about 2 years ago it lay in my cabinet. Since 1894 I have been engaged during my spare time in re-mapping the Toadstone and in trying to differentiate successive horizons in the limestone in order to decipher, if possible, the history of the volcanic eruptions in Derbyshire. In doing this I have met with the quartz-rock in various localities. Its presence in the limestone rendered the task of tracing the horizons in that rock more difficult. It was therefore thought necessary to find its relations to the limestone. With this object in view, I revisited every part of the limestone-region where I remembered that I had seen any similar rock, and examined a large number of thin sections. Though every outcrop may not have been seen, sufficient has been done to prove that the

[1] 'On the Origin of certain Novaculites and Quartzites,' Quart. Journ. Geol. Soc. vol. l (1894) p. 380.

quartz-rock is neither distributed universally throughout the limestone series nor restricted to certain beds in it. There is, on the other hand, sufficient evidence to show that it occurs irregularly in the limestone, and is found most plentifully in two small areas: the southern, near Bonsall, and the northern, near Castleton. In the southern area it occurs in the limestone-beds below the second Toadstone of Masson, and therefore 400 feet at least below the top of the limestone, while in the northern area it occurs in the cherty beds near the top of the series.

The presence of the quartz-rock in the northern area was mentioned in the Geological Survey Memoir of North Derbyshire, and some of its aspects in the field were briefly described, but no systematic attempt appears to have been made to ascertain its origin, and there is no mention made of its microscopic structure. The quartz-rock in the southern area does not appear to have been described. It will be dealt with first in this paper, because I had finished working at it before I examined the northern district.

II. The Southern Area.

This small area, immediately east of the village of Bonsall (6-inch map 34, N.W.), is situated between Bonsall on the west, Ember Farm on the east, Pounder Lane on the north, and Ember Lane on the south. The quartz-rock occurs plentifully in the walls in isolated and irregularly-shaped bosses, and in large blocks on the surface of the ground. Sometimes this rock, in common with the ordinary and dolomitized limestone of the surrounding district, is traversed by veins of fluor. The quartzite, quartzose limestone, and the ordinary limestone were mapped by me on the scale of 25 inches to a mile. The limestone dips generally to the east, at an angle of from 15° to 20°, below the lava which forms the summit of Masson Hill. On the south is the agglomerate of Ember Lane, and on the east the large mass of ophitic olivine-dolerite, which at present I consider to be either a sill or the remains of a volcanic neck, since it cuts across the limestone-beds.

An examination of the map shows that the quartzite and quartzose limestone are not confined to one horizon, but occur as bosses in the limestone at various horizons. The following outcrops will be described:—

(*a*) The 'Top Lift.'
(*b*) The 'Old Chert-quarry.'
(*c*) 100 feet north of (*b*) and in the same field.
(*d*) Field north of, and adjoining the preceding field.
(*e*) Field east of, and adjoining Pounder Lane.
(*f*) Moorlands Lane.

(*a*) The 'Top Lift.'

The footpath from Ember Lane to Pounder Lane passes on the left a bold, irregularly-shaped mass of rock (the 'Top Lift'), which is totally unlike the limestone of the district. A number of detached blocks cover part of the slope on its north-western side. The rock is of a dark colour; its surface is often rough, and contains a number of small holes. It shows no sign of stratification, very hard, breaks with a glistening fracture, and has a crystalline structure. In a hand-specimen it somewhat resembles a fine-grained quartzite.

Five specimens were collected, and thin slices were examined. No. 8,[1] sp. gr. 2·51, in ordinary light, is a granular rock, with black or dark brown material, probably hæmatite, between the grains. Between crossed nicols it appears as an aggregate of quartz-grains, the majority of which are elongated in the direction of the least axis of depolarization. They vary in size from less than ·02 × ·01 mm. up to ·04 × ·12 mm. They have no crystalline outline, but closely interlock and penetrate each other. The rock is not formed of detrital grains cemented together by secondary quartz, but appears to have originated by the crystallization of the quartz *in situ* in such a manner that adjacent grains have prevented their neighbours from assuming crystalline boundaries. Some of the grains contain calcite.

No. 420 is very similar, except that it contains a large quartz-grain measuring 1·25 × ·75 mm., and including smaller grains in it.

No. 421, sp. gr. 2·60, has a similar structure. Several large grains of quartz contain calcite. Small pieces of fluor fill a few spaces between the quartz-grains. Vacant places in the section are probably due to the fluor which filled them being broken out in grinding.

No. 422, sp. gr. 2·57, is similar to the preceding, but contains a larger proportion of fluor. One cube of this mineral is seen embedded in and penetrating three adjacent quartz-grains. The quartz which penetrates, and is enclosed in, the irregular masses of fluor in most cases possesses crystalline outline, giving either hexagonal cross-sections, remaining extinct under crossed nicols, or those nearly parallel to the axis extinguishing with their length, and terminated at each end by the pyramidal faces. No. 423, sp. gr. 2·53, has a similar structure.

(*b*) 'The Old Chert-quarry.'

About 600 feet north of the 'Top Lift' is an old quarry marked 'Chert-quarry' on the 1-inch Geological Survey map. This is probably the 'Stubben' white chert or limestone-quarry mentioned by Farey.[2] An almost vertical face of rock, about 13 feet high, is exposed, in which no chert is seen. The face consists mainly of a quartz-rock of the 'Top Lift' type, passing in places into a quartzose limestone, which is often traversed by thin veins of quartz and sometimes of calcite. The quartz-rock was not examined microscopically, because it was obviously similar to the 'Top Lift' rock.

[1] These numbers refer to the thin slices examined under the microscope.
[2] 'General View of the Agriculture & Minerals of Derbyshire,' vol. i (1811) p. 273.

Nos. 533 & 534, 2 inches below 533. The base is of a cloudy or crystalline calcite, through which the quartz-crystals are irregularly distributed. Numerous small veins or strings of quartz traverse the slice. The grains are often smaller than the separate crystals. The veins have a structure similar to that of the quartz-rock, and often run a tortuous course. A foraminifer replaced by calcite is penetrated by a quartz-crystal.

No. 747, about 4 feet below 534, is a foraminiferal limestone partly replaced by calcite. Quartz-crystals are scattered through the slice, and sometimes penetrate a foraminifer. The slice is traversed by several small veins, which consist of separate quartz-crystals, and a quartz-aggregate similar to the quartz-rock. The grains vary much in size and often interlock. The outer crystals are arranged in various positions with regard to the boundary of the vein.

No. 748, about a foot below 747. The base consists of cloudy or crystalline calcite, without any trace of organisms. The quartz sometimes is in separate crystals, but most commonly in aggregates or groups irregularly distributed. The component grains vary in size. A vein of crystalline calcite traverses the slice.

(*c*) 100 feet north of (*b*) and in the same field.

About 100 feet north of the chert-quarry and in the same field is an outcrop, measuring about 6 feet in length by 5½ feet in height, consisting of quartz-rock and quartzose limestone.

No. 428, sp. gr. 2·54, consists of fluor and quartz, the latter predominating. In some parts of the thin slice the individual quartz-crystals are embedded in fluor, and in other parts fluor is absent. The last-named mineral is irregularly distributed, has a faint violet tint, possesses traces of cleavage, and always remains extinct between crossed nicols.

No. 539, 3 feet to the right of 428. No. 427, 6 feet ditto. No. 536, 2 feet below 428. No. 426, 2 feet below 537.	These four specimens are similar, and consist of quartz in a cloudy or crystalline calcite.

The quartz is sometimes in idiomorphic crystals, which give a hexagonal cross-section, but is more often in groups of crystals which have interfered with one another's growth. Many of them contain zones of calcite, which in some cases mark the previous boundaries and in others are parallel to the present boundaries of the crystal.

No. 427 contains a large quartz-crystal with three zones of calcite. Small portions of two of the hand-specimens were dissolved in dilute hydrochloric acid. The residue of No. 426 consisted entirely of crystalline quartz, often in groups or clusters of crystals. Few of the separate crystals had perfect crystalline boundaries. The largest was ·5 × ·15 mm. The residue of No. 427 was similar and contained fragments of fluor. The crystals of quartz varied in size from ·70 × ·20 mm. to ·15 × ·05 mm. In some parts of the rock-face the calcite has weathered out, and the quartz-crystals remain loose, but just coherent. Where the rock is much weathered they may be separated by the finger.

No. 535, 2 feet below 536, consists almost entirely of quartz-rock. A finer mosaic occurs in a small vein which traverses the slice. Fluor fills small spaces between some of the quartz-grains, and follows part of the course of the vein, not continuously, but in a series of disconnected portions.

(*d*) Field north of, and adjoining the preceding field.

In the field immediately north of that in which the old chert-quarry is situated there is an interesting exposure of the quartz-rock. The upper portion consists of a small escarpment of ordinary limestone dipping into the hill in a north-easterly direction.

Passing over a few yards of grass we come to a bed of limestone, which contains a few quartz-crystals (No. 430). Under this is about 6 feet of quartz-rock (No. 529). The upper boundary with the limestone is nearly horizontal, the lower is of an undulatory or wavy outline, the quartz-rock sending down two V-shaped wedges into the limestone below (Nos. 528, 431); the lower portions of this are covered with grass, from which a few pieces of quartz-rock project. The lower limestone, close up to and under the quartz-rock, contains a large number of quartz-crystals. These form about 50 per cent. of the rock, and are easily visible under a lens when the rock is wetted. There is, therefore, a close association between the quartz-rock and the quartzose limestone.

No. 529 consists almost entirely of quartz-grains, closely interlocking and fitting together, and generally elongated. A few have a hexagonal outline, and remain extinct between crossed nicols. Some of them contain a small quantity of calcite. The other constituent is fluor, which is very small in amount, and occupies spaces between the quartz-crystals.

No. 430 (the limestone above the quartz-rock) contains shell-fragments and a few foraminifera. The quartz-crystals are not numerous. They are idiomorphic, and combinations of the prism and double pyramid. The majority are clear, but some contain a small quantity of calcite.

No. 528 (6 inches below the lower boundary of the quartz-rock) is similar to the preceding, but contains a greater number of foraminifera, one of which is penetrated by a quartz-crystal.

No. 431, about 7 inches below the quartz-rock, is a limestone, containing few foraminifera and numerous quartz-crystals with sharp outlines. Some of them include a small quantity of calcite. Several small veins or strings of quartz traverse the slide in such a manner that the quartz-crystals are sometimes aggregated along tortuous lines, which are not always continuous, but interrupted. One of these bifurcates, and the branches run together again after a short course. In these veinlets the quartz-crystals often penetrate one another or are arranged in clusters, the structure of which is like that of the quartz-rock. The separate crystals have no apparent connexion with the veins, but are irregularly distributed throughout the remainder of the slice. A little lower down the rock contains no quartz in some places, and no residue when dissolved in acid.

No. 749, below the limestone from which No. 431 was taken. In a hand-specimen, this appears to be either the junction of the quartz-rock with limestone, or, what is more probable, a vein of quartz-rock in the limestone. The greater part of the thin slice consists of quartz-rock, which differs from that of the ordinary type by the presence of a few small patches of crystalline calcite between the quartz-grains. There is a fairly sharp line of division between this and the other portion of the slice. The latter contains much more calcite and larger quartz-grains, which are often idiomorphic crystals. It is traversed by two small veins of quartz roughly parallel to the junction-line. Some of the quartz contains calcite. There are traces of fluor present.

(*e*) Field east of, and adjoining Pounder Lane.

In the field immediately east of Pounder Lane are several large bosses of dark quartz-rock which often contains veins of fluor. At the top of the field are two escarpments of ordinary limestone dipping 15° in an easterly direction. Lower in the series may be seen ordinary limestone-beds on the same horizon as quartz-rock and quartzose limestone with quartz-veins. Lower still, close to the lane, are several bosses of quartz-rock and limestone arranged nearly parallel to the lane and on one horizon. Above the escarpment are limestone-beds dipping in the same direction: these are probably on the same horizon as the quartz-rock described above.

The quartz-rock often contains holes as big as a man's fist. They are no doubt due to the weathering out of lumps of quartzose limestone. Portions of the latter are often embedded in the quartz-rock. In places the carbonate of lime has weathered out, leaving loose quartz-crystals, which are easily washed away. The various stages of this process may be seen.

No. 547 is a quartz-rock, of the Top Lift type, containing fluor in detached pieces and in plates which include quartz-crystals, reminding one of ophitic structure. The quartz-grains are generally elongated, but do not possess crystalline outline.

No. 425, sp. gr. 2·65, a few inches from No. 547. Quartz-crystals in calcite. The quartz generally possesses a crystalline outline, often giving hexagonal cross-sections. Sometimes a hexagonal section at right angles is seen embedded in, or on the edge of, a section parallel to the axis, showing that the two penetrate each other at right angles. In places the quartz-grains form an aggregate resembling the quartz-rock. The crystals often contain calcite. The residue consists entirely of quartz-crystals or clusters of the same. The size of the crystals varies from ·5 × ·15 mm. to ·15 × ·05 mm. Two often penetrate each other at right angles, forming a penetration-twin.

No. 434, sp. gr. 2·64, about 1 foot from No. 425. A foraminiferal limestone, containing numerous quartz-crystals in bipyramidal prisms. Some of these contain a small quantity of calcite, which in one case is arranged zonally. Many of the foraminifera are penetrated by quartz-crystals, which fact proves that the quartz is later than the organisms and therefore of secondary growth. The residue consists entirely of quartz-crystals, which sometimes penetrate each other at right angles. They vary in size from ·80 × ·20 mm. to ·10 × ·0375 mm.

No. 745, a few feet from No. 434, is a piece of white limestone surrounded by and embedded in the darker quartz-rock. It consists of foraminifera, fragments of organisms, and a small quantity of crystalline calcite. Very few quartz-crystals are present. The residue consists of quartz-crystals, which vary in size from ·30 × ·10 mm. to ·10 × ·025 mm.

No. 744, about 20 feet from No. 434, but on the opposite side of it to No. 745. This is from a small outcrop of limestone, which is a few feet from one of the quartz-rocks, and separated from it by grass. It is a limestone containing foraminifera and other organisms. There is a large number of quartz-crystals present. The residue consists entirely of quartz-crystals, varying in size from ·80 × ·20 mm. to ·15 × ·05 mm. Two often penetrate each other at right angles.

The preceding specimens are from about the same horizon, assuming the rock originally to have had the same dip as the ordinary limestone above it in the same field.

The following are from a higher horizon:—

No. 741. A foraminiferal limestone, with very few quartz-crystals and fragments of organisms. One foraminifer is pierced by a crystal of quartz. The small amount of residue consists only of quartz-crystals, always separate, varying in size from ·40 × ·125 mm. to ·05 × ·025 mm.

No. 742, near No. 741. A foraminiferal limestone, with few small quartz-crystals and some crystalline calcite. The residue consists of quartz-crystals, varying in size from ·25 × ·05 mm. to ·05 × ·0125 mm., and two or three small fragments of a non-crystalline material.

No. 743, 20 feet from No. 742, is similar to it, and contains shell-fragments. The residue consists of quartz-crystals, varying in size from ·20 × ·05 mm. to ·04 × ·01 mm., and a few small pieces of brown opaque material.

(*f*) Moorlands Lane.

In Moorlands Lane, near its junction with Moor Lane, about 1 mile north-west of Bonsall, is a small quarry in which the quartz-rock has been worked.[1]

[1] This is probably the white chert or china-stone quarry mentioned by Farey, 'General View of Agric. & Minerals of Derbyshire,' vol. i (1811) p. 274.

No. 599 is a quartzite of the Top Lift type. A few small veins of quartz run through the section. Some of the grains have a crystalline outline, and contain rough zones or inclusions of calcite. A similar rock was also found between Uppertown and Bonsall, and near Brightgate.

III. The Northern Area.

Specimens were examined from the following localities:—

(*g*) Pindale.
(*h*) Bathamgate.
(*j*) Brock Tor.
(*k*) Oxlow Rake.
(*l*) Doveholes.

(*g*) Pindale.

In about half-a-dozen fields which lie west of Pindale, and between Dirtlow Rake and Bradwell Moor Farm (6-inch Map 10, S.W.), the ground is fairly well covered with isolated blocks and masses of quartz-rock. A few isolated blocks of similar rock are found along the south side of Oxlow Rake, which is a continuation of Dirtlow Rake. At the head of Pindale they often contain nodules of chert.

No. 592, sp. gr. 2·52, quartz-rock, north side of Pindale, is a fine-grained rock, consisting of quartz with a dark-coloured material filling the spaces between the crystals. Under a 1-inch objective the crystals are much elongated, and give lath-shaped sections like felspars; but they are not twinned, and always show straight extinction. Their boundaries are not crystalline, but their edges are often notched like the teeth of a cog-wheel, due to penetration or interlocking of adjacent crystals.

No. 593, sp. gr. 2·50, is very similar to No. 592, and the same description will suffice. The block contains chert-nodules. A nodule from another block contained part of a fossil shell.

From the manner in which these blocks lie about on the grass, it is impossible to make out their relation to the limestone-beds. But on the opposite side of the valley of Pindale there is a boss of rock which is on the same horizon as the limestone a few yards away, and which in its occurrence and microscopical structure is very similar to the Pounder Lane rock.

This outcrop was carefully worked over, hammer in hand, all chips broken off being subjected to the lens. Five specimens were selected, and thin slices were prepared from them.

No. 586, sp. gr. 2·60, consists of quartz and fluor. The latter mineral occurs in irregularly-shaped patches, enclosing small prisms of quartz terminated by pyramids, and reminding one of ophitic structure. It has an uneven violet colour, and contains many cleavage-lines, which meet at angles varying from 63° to 78°. The greater portion of the slice is composed of quartz, the crystals of which interlock.

No. 587, 2 inches below No. 586, is a piece of limestone enclosed in the quartz-rock, and gradually shading off into it. Several encrinite-stems are seen in a hand-specimen. Under the microscope the base is mainly crystalline calcite, with no traces of organisms—except an encrinite-stem which contains a crystal of quartz. The quartz-crystals have regular boundaries, and occur singly or in groups or clusters.

No. 588, sp. gr. 2·63, 2 yards below No. 587, is a quartzose limestone. It contains traces of organisms, probably sections of shells which are partly replaced by masses of quartz-crystals and single crystals, and also a section of an encrinite-stem.

No. 589, sp. gr. 2·63, 2 yards below No. 587. A foraminiferal limestone. The quartz occurs mostly in separate crystals, which have well-defined crystalline boundaries. A characteristic of this slice is the great number of foraminifera which contain and are penetrated by quartz-crystals, clearly indicating that the quartz is secondary and later than the organisms, and is in fact a replacement of them. There is very little of the aggregate of quartz-grains as seen in the two previous slices. The residue, after solution in hydrochloric acid, consists entirely of quartz-crystals; these vary in size from ·60 × ·09 mm. to ·07 × ·02 mm.

No. 590, on the same horizon as the preceding and a yard or so distant, sp. gr. 2·587. Limestone containing foraminifera, oolitic grains, and shell-fragments. Some of the organisms are penetrated by quartz-crystals. The quartz occurs also in groups or bunches of crystals, which, under polarized light, form a mosaic, and in the residue occur as a bundle of quartz-crystals, the pyramidal points projecting outward in every possible direction. The residue is quartz only, in bunches and separate crystals, the latter varying in size from ·32 × ·06 mm. to ·03 × ·01 mm. A few chert-nodules were seen in some of the quartz-rock on this side of the valley. The rock weathers black, and often contains blue fluor. It shows no traces of bedding. The softer parts weather out, leaving a vesicular or pitted surface, similar to that of the Pounder Lane rock. Some lower beds, a short distance down the Dale, consist of limestone with partings and nodules of chert containing casts of encrinite-stems.

(*h*) Bathamgate (6-inch Map 15, N.E.): about 800 feet south of Moss Rake.

The quartz-rock occurs in isolated blocks at the western end of the Rake.

Nos. 577, 580, sp. gr. 2·50. These are similar in structure to the Top Lift quartz-rock.

No. 578, sp. gr. 2·47. This and No. 579 differ from the specimens previously described. The rock consists mainly of large quartz-grains forming a granitic structure, with smaller ones of sometimes hexagonal outline embedded in, and filling spaces between them. It might be described as an intimate mixture of granitic and microgranulitic (Michel-Lévy) quartz.

No. 579. The grains vary much in size, and many of the larger among them are elongated. Zonal inclusions are frequent, and are in several cases arranged in the form of a regular hexagon or a section of the prism with pyramidal terminations, though the grain itself possesses no crystalline outline. In the former case the grain remains extinct between crossed nicols, in the latter it extinguishes with the axis of the prism. These facts show that the grains are not a secondary growth around detrital quartz, but that they originally had a crystalline outline, and then interfered with each other's growth: that they were in fact idiomorphic, and then became allotriomorphic. The structure is a combination of the granitic (with a tendency for some grains to become elongated in the direction of the axis of the prism) and the microgranulitic.

(*j*) Brock Tor (6-inch Map 9, S.E.), immediately north of Moss Rake.

This rock is similar to that of Bathamgate, both in the field and under the microscope.

(*k*) Oxlow Rake (6-inch Map 9, S.E.).

The few isolated blocks near this Rake are quartz-rock of the Top Lift type.

(*l*) Doveholes (6-inch Map 15, N.W.). Old Quarry near Bull Ring.

I have not been successful in finding any quartz-rock in this quarry, but a small quantity of the limestone in one place contains numerous quartz-crystals. They appear to be local, and the quartzose limestone shades off quickly into the ordinary white limestone. Two thin sections were examined.

No. 443, sp. gr. 2·65, is a limestone with few foraminifera and a large number of quartz-crystals. The quartz often contains calcite in zones, but more often in irregular patches. The two are sometimes blended, as if the quartz were in the act of crystallizing round a portion of the adjacent calcite. Where the quartz is surrounded by fibrous calcite, it often contains inclusions of the latter mineral arranged roughly parallel to the fibres.

No. 444 consists of calcite, with possibly a few traces of foraminifera, and many quartz-crystals. The quartz often contains calcite. The residue consists of quartz-crystals, varying in size from ·35 × ·10 mm. to ·10 × ·025 mm.

It is interesting to contrast the microscopic structure of the foregoing rocks with the chert and the 'siliceous limestone' near

Bakewell, described in the Geological Survey Memoir of North Derbyshire, 2nd ed. (1887) p. 166.

Under the microscope the chert-nodules consist of a cryptocrystalline quartz-mosaic, with flecks of calcite distributed through it. The 'siliceous limestone' consists of a microcrystalline quartz-mosaic, often passing into cryptocrystalline structure which contains small patches of the former. The threads of silica consist of a mosaic of clear quartz-grains, without any crystalline outline, and not elongated. They traverse a cryptocrystalline quartz.

This siliceous rock is probably a replacement of limestone by silica, which has not crystallized out like that in the quartz-rock described in the former part of this paper. It is more allied to chert.

IV. The Quartz-rock is a Limestone which has been replaced by Crystalline Quartz.

It is well known that quartz-crystals occur in limestone: some references will be found in Mr. Wethered's paper.[1] It does not appear, however, that the crystals have been previously found in large quantities. Out of 30 lbs. of limestone from Caldon Low dissolved by Mr. Woodcroft, 3 ounces only of quartz-crystals were obtained.[2] In the thin sections of limestone which I have examined from other parts of Derbyshire the quartz-crystals are seldom present, while in the limestone in contact with the quartz-rock they often form half, or a greater portion of the thin slice.

In 1881 Lang described a quartzite which consisted of interlocking grains of quartz. In one locality it contained fossils.[3]

In the following year Groddeck described a silicified Devonian coralline limestone, which under the microscope consisted of a very fine-grained mass of quartz.[4]

In 1887, in the Geological Survey Memoir of North Derbyshire, the Pindale blocks were mentioned, and the following explanation was given of their origin:—'At the head of Pindale they distinctly occur as a bed in the limestone, and the vast number of loose blocks seem to have been left by the removal of the limestone round them. They seem to have been a very cherty limestone, or in some cases a bed of chert with patches of limestone. As a result of aqueous metamorphism the limestone was removed, and its place taken by a white sand, resulting from the decomposition of chert' (p. 130).

In 1890 Loretz drew attention to some loose quartz-blocks in the district of Schwarzburg, which he described as due to the silici-

[1] 'On Insoluble Residues obtained from the Carboniferous Limestone Series at Clifton,' Quart. Journ. Geol. Soc. vol. xliv (1888) pp. 194, 195.

[2] W. J. Sollas, 'On the Flint-Nodules of the Trimingham Chalk,' Ann. & Mag. Nat. Hist. ser. 5, vol. vi (1880) pp. 445–447.

[3] 'Ueber Sedimentär-Gesteine aus der Umgegend von Göttingen,' Zeitschr. deutsch. geol. Gesellsch. vol. xxxiii (1881) p. 217.

[4] 'Zur Kenntniss des Oberharzer Culm,' Jahrb. d. k. preuss. geol. Landesanst. 1882, pp. 59–62.

fication of Plattendolomit, the various stages of which were seen from the carbonate up to the fully altered rock. At another locality he found a similar quartzite containing *Productus horridus*, and considered it to be an alteration-product of Zechsteinkalk.[1]

In 1892 Mr. Griswold described a soft Ouachita rock, in which he considered that the calcite was decomposing and being replaced by quartz, and also a spotted chert which was probably an oolitic limestone, the grains of which were being replaced by silica.[2]

Two years later, Mr. Rutley, in a paper read before this Society, suggested that certain quartzites were originally limestones, now replaced by silica; and, in the discussion which followed, Prof. Hull expressed the opinion that better evidence of so remarkable a change would be required before that author's views could be accepted.[3]

Last year Sir Archibald Geikie described a specimen of silicified limestone from County Meath, in which he said that new quartz had grown in optical continuity with and around grains of grit, and that it was originally a gritty oolitic limestone, wherein the calcite had been replaced by quartz, and the silica had been introduced in solution.[4] By the kindness of Prof. Watts I saw the specimen, and examined a thin slice of it under the microscope. It appeared to me very similar to the Derbyshire rock, but more decomposed, and may have had a similar origin.

In the Derbyshire rocks which form the subject of this paper one cannot help noticing the intimate association that exists between the quartz-rock and the quartzose limestone. In some localities the quartz-rock alone is found, the softer rocks having been entirely removed from around it by denudation, or the junction being covered. But in other places (except in Doveholes Quarry), wherever the quartzose limestone occurs, there we find the quartz-rock. A quartz-vein generally has the quartzose limestone adjoining it on either side, and lumps of quartzose limestone are often found in the quartz-rock, and shading off into it. There is, in fact, a gradual passage from the quartz-rock, through the quartzose limestone, to an ordinary limestone, which contains few, if any, crystals of quartz. In the quartzose limestone the quartz occurs not only in individual crystals, but also in aggregates of crystals, which have the same structure as the quartz-rock.

Quartz, therefore, is present in the limestone under discussion as numerous separate crystals, in groups of crystals, and on a larger scale as veins and bosses of quartz-rock. The difference is merely one of degree, and we are, I think, justified in ascribing a common origin to the quartz in the quartzose limestone and in the quartz-rock.

1 Zeitschr. deutsch. geol. Gesellsch. vol. xlii (1890) p. 371.

2 Ann. Rep. Geol. Surv. Arkansas for 1890, vol. iii (1892), 'Whetstones & Novaculites of Arkansas.'

3 'On the Origin of certain Novaculites & Quartzites,' Quart. Journ. Geol. Soc. vol. l (1894) pp. 377-392.

4 Ann. Rep. Geol. Surv. U. K. for 1896 [1897], p. 58.

The quartz-rock is not a sandstone or a gritty limestone altered by the growth of crystalline quartz around and in optical continuity with the original quartz-grains, but on the contrary is due to a growth of quartz around what were originally isolated crystals of the same mineral. The evidence for this opinion is the presence of zonal calcite in the grains which now form a quartz-mosaic, and the absence (which by itself would not be conclusive) of anything like detrital quartz-grains either in the rock itself or in the surrounding limestone, or in any of the residues examined.

The quartz has not been formed from chalcedonic silica, otherwise we should expect to find some traces of it in a thin section or in the residues. The latter consist only of crystalline quartz. Mr. Wethered found in the limestone at Clifton that amorphous and chalcedonic silica and crystalline quartz frequently occurred in the same fragment.[1]

The presence of chert in the quartz-rock at the head of Pindale and of part of a foraminifer in the similar rock of Pounder Lane, and the frequent penetration of organisms by quartz-crystals in the quartzose limestone, are, I think, evidence that the quartz in these rocks is a replacement of the limestone. We may therefore assume that, just as the separate crystals and small groups of crystals of quartz have replaced parts of the organisms in the limestone and also small portions of the limestone itself, so the quartz-rock has replaced larger portions of limestone.

In some places, such as Pindale and the Top Lift, the whole of the limestone and quartzose limestone have been weathered away, leaving the quartz-rock in bosses or loose blocks. In other places patches of the softer rocks are left, which show the gradual transition from the quartzite to ordinary limestone.

V. The Origin of the Quartz.

Mr. Wethered reduces the possible modes of origin of the quartz-crystals in the Carboniferous Limestone Series at Clifton to four.[2]

The crystals in the Derbyshire rock are obviously not detrital. I have already shown that they are not due to secondary crystallization around detrital grains of quartz, and that they are not the result of the crystallization of chalcedonic or amorphous silica. There is left only the fourth case, which is that of simple crystallization of silica out of a siliceous solution. This is the origin suggested by Prof. Sollas for the small quantity of quartz-crystals often found in limestone, and it is, I consider, the origin of the quartz in the quartz-rock and the quartzose limestone.

There is room for speculation as regards the source of the silica. It may have been derived from siliceous organisms in the limestone, or more probably from deep-seated thermal waters containing silica in solution.

[1] Quart. Journ. Geol. Soc. vol. xliv (1888) p. 194.
[2] *Ibid.* p. 195.

The irregularly-shaped bosses and the veins of quartz-rock, and the juxtaposition with them of the quartzose limestone, are results which might be expected if the silica was derived from thermal waters. This theory would also explain both the origin of the silica and the removal of the limestone which it has replaced.

EXPLANATION OF PLATES XI & XII.

Plate XI.

Map of the district north-east of Bonsall, on the scale of 12½ inches=1 mile, showing the distribution of the quartz-rock and the quartzose limestone.

Plate XII.

(The figures are photographed by the author from the microscope, the first five in polarized light and between crossed nicols, the sixth in ordinary light.)

Fig. 1. Quartz-crystals in fluor. Pindale (*g*). Traces of cleavage-planes of the latter mineral are seen in the dark portion of the figure. Thin slice No. 586. (See p. 176.)

2. Quartz-rock. Top Lift (*a*). The quartz-grains are elongated in the direction of the principal axis, and extinguish with their length. They do not possess crystalline outline, but closely interlock. Thin slice No. 420. (See p. 171.)

3. Quartz-rock, Pindale (*g*). Similar to fig. 2, but of a more finely-grained structure. Thin slice No. 593. (See p. 176.)

4. Quartzose limestone. Chert-quarry, Masson (*b*). Part of a tortuous vein of quartz in a base of cloudy calcite. Thin slice No. 534. (See p. 172.)

5. Quartzose limestone. North of Chert-quarry (*c*). Quartz-crystals containing calcite-zones. A large quartz-grain is seen with zones marking successive stages of growth. Thin slice No. 427. (See p. 172.)

6. Quartzose limestone, Pindale (*g*). A foraminiferal limestone showing an organism pierced by a quartz-crystal. Thin slice No. 589. (See p. 177.)

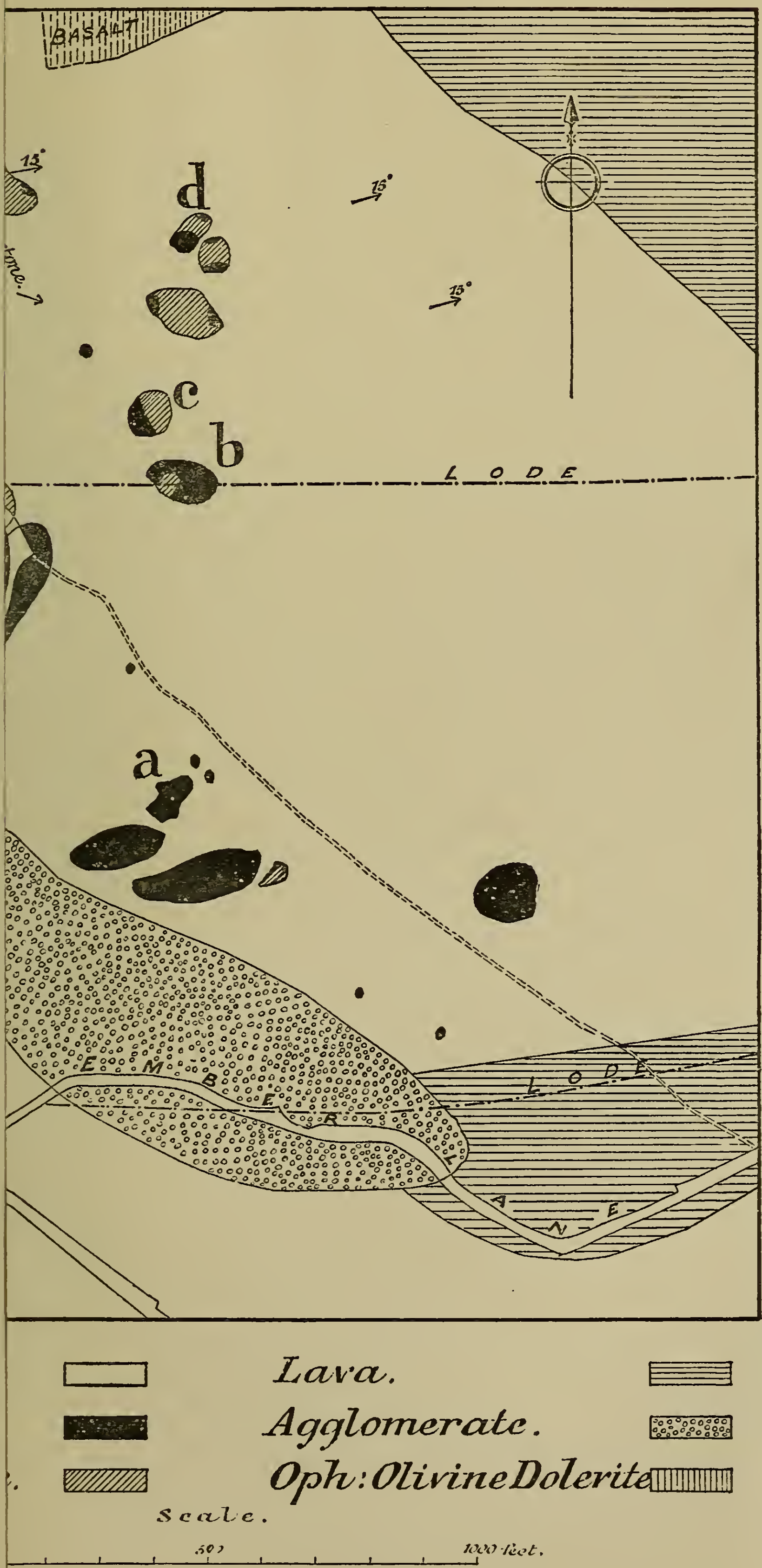
Discussion.

Prof. Bonney said that he thought the Author had quite made out his case. The chert in the Carboniferous Limestone was perhaps a stage in the same direction; the Upper Greensand at Ventnor was converted in a similar way into chert, and the Portland oolite was locally converted into chert. It would be interesting to know whether the process now described was by transference of silica from organisms, or was from thermal springs, as was probably the case in the Stotfield sandstone near Elgin.

Prof. Watts said that he had observed several cases of the growth of quartz-crystals in limestone, though the process had never gone quite so far as the extreme cases mentioned by the Author. Instances from the South and Centre of Ireland and from the Purbeck Limestone indicated some widespread cause, rather than the local one hinted at by the last speaker. He paralleled the action with the dolomitization of limestones in Ireland, South Wales, and the Isle of Man: cases in which dolomite-crystals ate

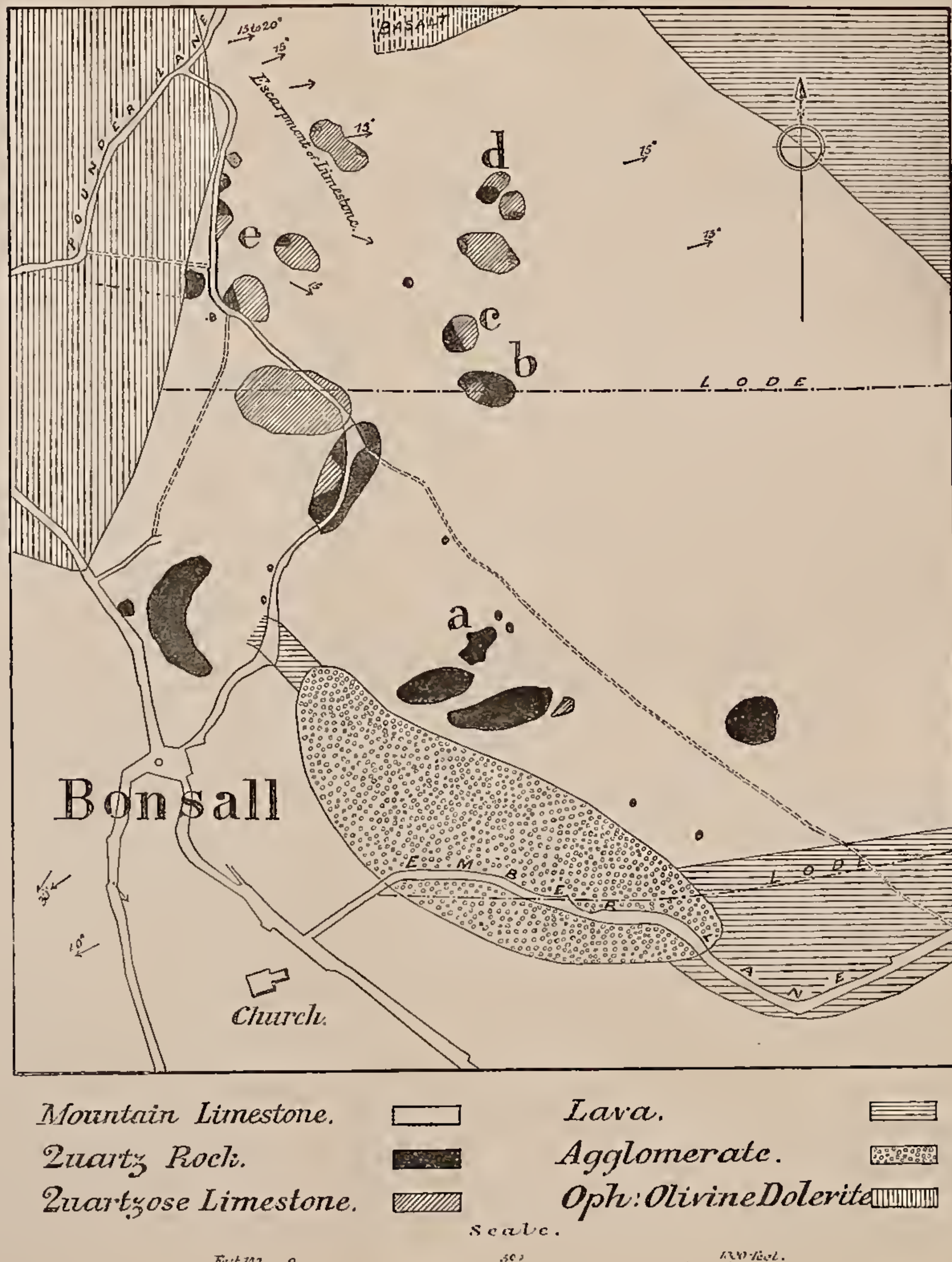
[B]ONSALL

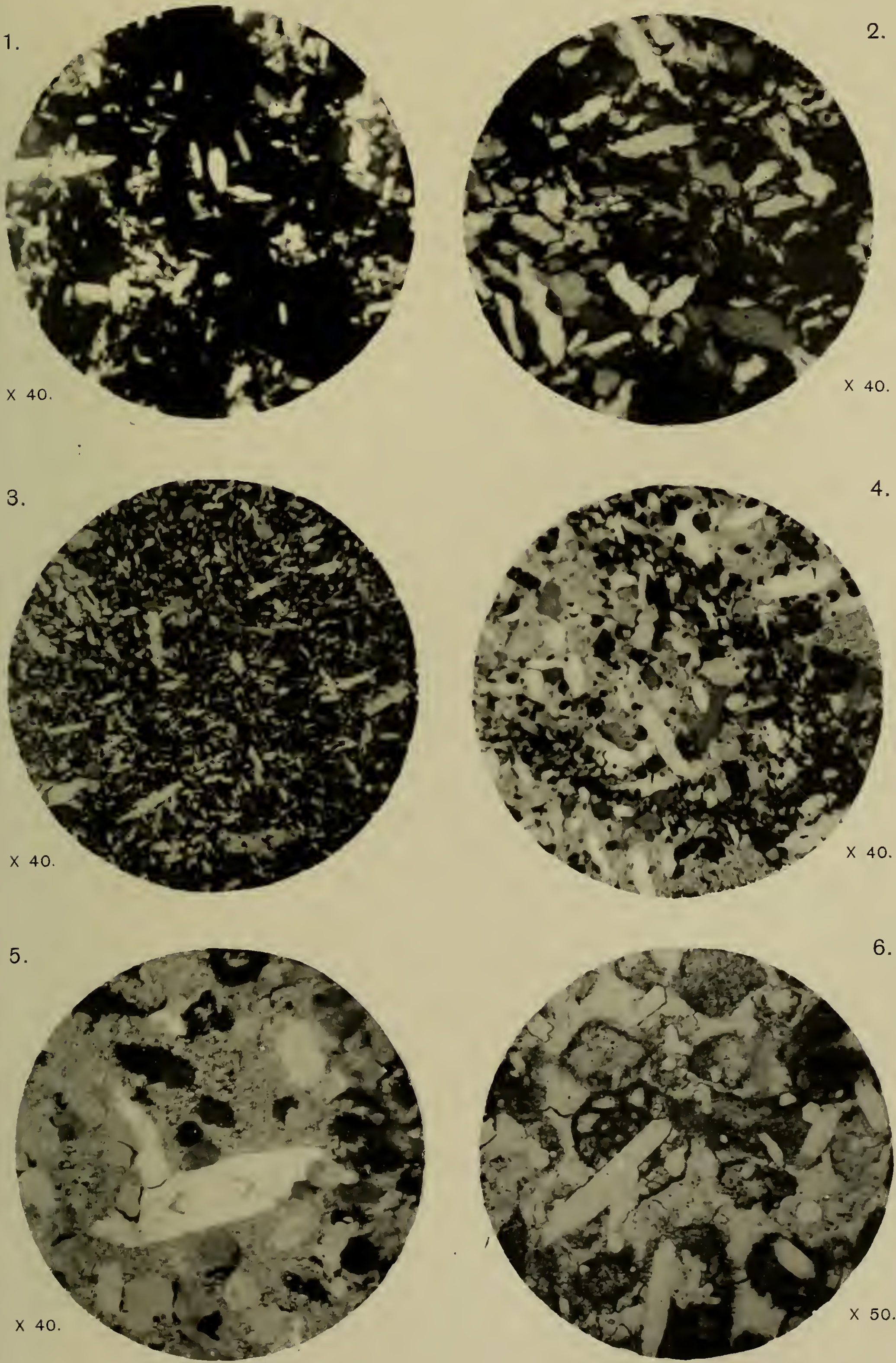
[Q]uartz Rock & Quartzose Limestone.



Map of District N.E. of Bonsall

Shewing distribution of Quartz Rock & Quartzose Limestone.





Quartz-Rock and Quartzose Limestone
from Derbyshire.

up the oolitic limestones, destroying both their structures and organisms, and absorbing their impurities, which in some instances retained their original arrangement, but in others became grouped parallel to the outlines of the crystals of dolomite.

Mr. Strahan expressed his admiration of the slides and specimens exhibited by the Author, and of the conclusive proof which they afforded of his argument. The dolomitization of oolitic Carboniferous Limestone in South Wales, referred to by the previous speaker, seemed to be due to a similar process of alteration, the replacing mineral in both cases appearing first as perfect isolated crystals, scattered through unaltered limestone regardless of the organic structures. By a gradual increase in numbers such crystals finally replaced the original constituent, and completely obliterated all organic structure. The source of the carbonate of magnesia, however, was no less obscure than that of the silica. Some of the Carboniferous Limestones of North Wales contain doubly-terminated crystals of quartz, but not in such abundance as in the cases now described. Galena also, in the neighbourhood of a lead-vein, occurs as isolated crystals embedded in solid unaltered limestone.

The Rev. H. H. Winwood also spoke.

The Author replied that the microscopic structure of the quartz-rock differed entirely from that of chert; and that the insoluble residue of the quartzose limestone consisted of quartz-crystals, and contained no chalcedonic or amorphous silica.

13. *On some* Gravels *of the* Bagshot District. By Horace W. Monckton, Esq., F.L.S., F.G.S. (Read January 19th, 1898.)

In 1891 I brought before the Society a paper on the beds of gravel which occur on the hills and in the valleys of the district south of the Thames between Guildford and Newbury. In that paper I drew particular attention to the composition of the gravel, and showed that gravel of a very uniform character extends in some cases over a considerable area (in one case over a length of nearly 10 miles), whereas other gravels in the near neighbourhood have different and yet curiously persistent characteristics. These peculiarities seemed so difficult to explain, on any theory which attributed the formation of the gravels to the action of the sea, that I arrived at the conclusion that they were river-gravels—their peculiarities of composition depending upon the geological structure of the drainage-areas of different rivers.

Sir Joseph Prestwich appears to have been inclined to the same conclusion. He says, writing in 1890 :—

'As the channels of the early streams became deeper and larger, and the Lower Greensand more exposed, the mass of débris carried down increased, and the proportion of chert and ragstone became greater. It was then that were formed the extensive plateaux of gravel of the Chobham and Frimley Downs, and of the other hills we have named in Berkshire, Hampshire, and Surrey.'[1]

With this I quite agree, but in the next paragraph Sir Joseph says, 'We are without a clue as to whether fluviatile or marine action had to do with their origin'; but, he continues, 'It is not improbable that they are in part of subaerial origin.'

In 1883 the Rev. Dr. Irving suggested an estuarine origin for the highest plateau-gravels of the area with which I am dealing,[2] and in 1890 he expressed the opinion that their origin was fluviatile, though, if I understand him rightly, he attributed the formation of gravels at lower levels to marine action—'the work of floating ice . . . in the old Thames Straits.'[3]

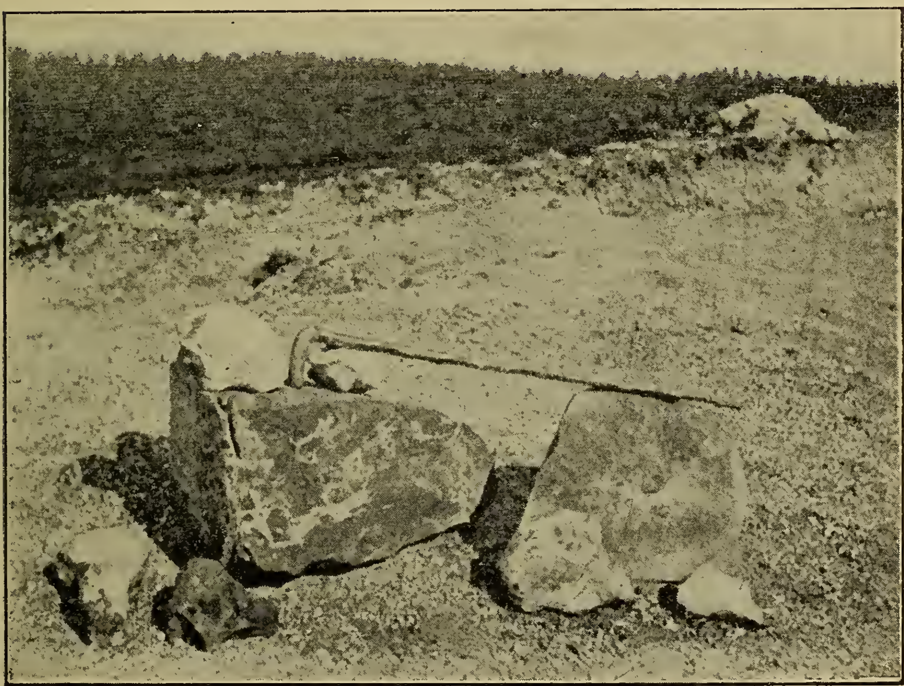
It would seem, therefore, that I have the support of both Sir Joseph Prestwich and Dr. Irving as to the fluviatile origin of the highest-level gravels, and the evidence of composition on which I largely rely was not brought forward by those authors, though both agree that the materials came from the south and south-east. I think, therefore, that I may safely say that on this point I am on fairly sure ground.

All are, I think, agreed that the low-level gravels of the Thames Valley are of fluviatile or at least of subaerial origin, and I have failed to find evidence which points to the presence of the sea in this area at any time during or since the deposition of the highest gravels, that is, those of Upper Hale, Aldershot, and of the North Downs.

[1] Quart. Journ. Geol. Soc. vol. xlvi, p. 173.
[2] Proc. Geol. Assoc. vol. viii, p. 143.
[3] Quart. Journ. Geol. Soc. vol. xlvi, p. 562.

Since I wrote the above-mentioned paper, I have examined the stones on various modern beaches, and have noticed that stones of whatever shape soon become rolled to pebbles on a sea-beach. I may mention the beach of Fécamp in Normandy. The cliffs there are lofty, they are composed of Chalk with a great deal of flint, and yet angular flints are quite rare on the beach. Now, the gravels of the district with which I am dealing are largely composed of flints, which, though they show signs of the action of water, are far more angular and irregular in shape than those of the sea-beaches which I have examined. Some of the flints, indeed, show so little sign of wear that I am tempted to doubt whether they could have been transported to their present position without the aid of ice.

Fig. 1.—*Easthampstead Plain, Gravel Hill: sarsen with rootlet-tubes; large flints very little rolled or waterworn.*



[Level: 400 feet above Ordnance datum.]

Large unwaterworn or very little waterworn flints occur in the gravel at Shoppenhangers Farm, Maidenhead, 110 feet above Ordnance datum; at the Hockett, Cookham Dene, 351 feet above Ordnance datum; at Caversham, and other localities. But there is Chalk at the present surface of the ground in close proximity to these places, and the flints may have travelled only a short distance.

This cannot be said, however, of the flints found in the gravel of Easthampstead Plain, 400 feet above Ordnance datum; and I have a photograph (fig. 1) showing six large flints which have certainly not been much rolled or waterworn. These I found in a pit at Gravel Hill, one of the northern spurs of the plateau of the Easthampstead Plain, and ½ mile east of the Easthampstead Cæsar's Camp. The two large blocks in the photograph (fig. 1, p. 185) are sarsens. I have seen similar flints in other pits on this plateau—at Wagbullock Hill, for instance.

These flints are stained of the brown colour, which, according to Sir Joseph Prestwich,[1] shows that they have not been derived directly from the Chalk, but from an older drift. At no time, however, have they been much waterworn, and the older drift must, I should suppose, have been somewhat of the nature of Clay-with-flints.

The Chalk-outcrop nearest to Gravel Hill is 7½ miles a little W. of N., but the gravel is shown by its composition to have come from the south or south-east, and the nearest Chalk at the surface on that side is 10½ miles distant, close to Tongham. These flints must therefore have travelled 10½ miles, and of course may have come from a still greater distance. Now Sir Charles Lyell, speaking of the South Hampshire gravel, says, 'The occasional occurrence of unrolled chalk-flints in the gravel, in places where they must have travelled 12 miles from their nearest source, also implies the aid of ice-action.'[2]

Sir Charles Lyell also considered the presence of large angular sarsens enveloped in gravel as evidence of ice-action,[3] and this evidence we find on the Chobham Ridges plateau; but perhaps I may be allowed to deal with the sarsens in some detail.

Mr. W. H. Herries has described some blocks of white sandstone which he saw in the large pit at St. Ann's Hill, Chertsey;[4] and I have seen such blocks there unwaterworn, and no doubt from Lower Bagshot Beds.

Sir Joseph Prestwich considered that the greater number of the sarsens scattered over parts of the South of England were from the Reading Beds, and with this I think most of us agree; he, however, also records sarsens from the Bagshot Beds, though he says that he has never seen them in sandpits or roadside-cuttings.[5]

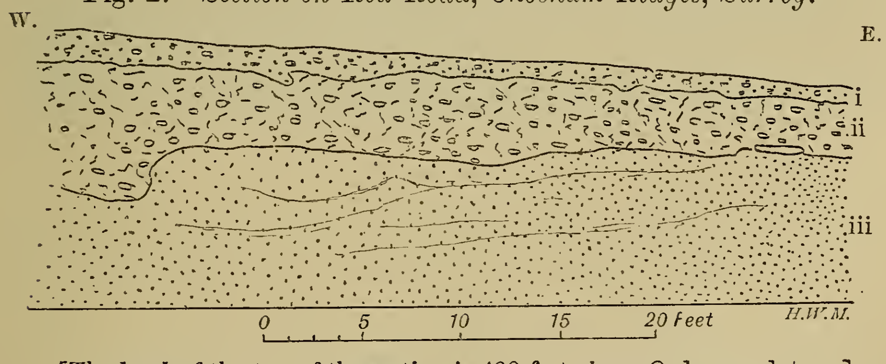
Mr. W. H. Herries says that he has 'never seen a sarsen-stone in the Upper Bagshot Beds themselves,' and that the example at St. Ann's Hill already referred to is 'the only instance of stone resembling sarsen-stone' that he has seen in the Bagshot Beds.[6] Nor have I ever seen a sarsen *in situ* in undisturbed Bagshot Sand; and, with the exception of the St. Ann's Hill specimen, I never remember seeing a sarsen which had not been more or less weatherworn or waterworn.

[1] Quart. Journ. Geol. Soc. vol. xlvi (1890) p. 156.
[2] 'Antiquity of Man,' 4th ed. (1873) p. 222.
[3] *Ibid.* pp. 182, 221.
[4] Geol. Mag. 1881, p. 171.
[5] Quart. Journ. Geol. Soc. vol. x (1854) p. 129.
[6] *Op. jam cit.* p. 174.

On July 3rd, 1897, when with the Geologists' Association at Woking, I was shown a sarsen in a sandpit, which was described by the workmen as having been in the sand. The sandpit is at a place called Betsford on the Geological Survey map, Sheet 8, and Whitstreet on the new Ordnance 1-inch Survey map, Sheet 285. The sarsen was about 4 feet in longest diameter, and had been waterworn. The sandpit is in Lower Bagshot Beds. Unfortunately the sand had all been worked away from above the sarsen, but the adjoining part of the pit seemed to me to show signs of 'run of the hill' and of re-arranged Bagshot Beds, and I suspect that the sand which had been dug from over the sarsen was not Bagshot Beds *in situ.* It is not unusual to find sarsens in sand near the surface of the ground, unaccompanied by gravel. Several were dug up when making a new football-ground at Wellington College, and I have kept two specimens. They are somewhat waterworn, and no doubt have been let down from their original position during the course of denudation of the sand around them, as was long ago suggested by Mr. Whitaker.[1] Of course, these furnish no evidence of ice-action.

In his admirable 'History of the Sarsens,' Prof. T. Rupert Jones[2] mentions some 'very fresh sarsens' (by which I understand, stones only a little waterworn) on Crawley Hill, a spur from the Chobham Ridges plateau. He describes them as at the bottom, or almost at the bottom, of gravel, and resting, or nearly resting, on the Upper Bagshot; and all authors agree that this is a very usual position in which to find sarsens. I have noted a section which illustrates

Fig. 2.—*Section on Red Road, Chobham Ridges, Surrey.*



[The level of the top of the section is 400 feet above Ordnance datum.]

The plateau of Chobham Ridges extends to the west, and the valley is east of the section.

i = White (discoloured) sand and gravel of irregular thickness, up to 1 foot.

ii = Gravel of subangular flints, flint-pebbles, Lower Greensand chert and ragstone, and small quartz: 6½ feet thick at the western or plateau-end; 2 feet at the eastern or valley-end.

This is Southern Drift of the Chobham Ridges plateau. A sarsen 2¼ feet × 3 inches is shown at the eastern end of the section.

iii = Yellow sand: the lower part is Upper Bagshot Beds *in situ*, the upper part is the sand of the Upper Bagshot re-arranged; 10 feet exposed.

[1] 'Geol. of Middlesex, etc.,' Mem. Geol. Surv. 1864, p. 72.

[2] Wilts Arch. & Nat. Hist. Soc. Mag. 1886, p. 122.

this remarkably well. It is a cutting on a road, named Red Road on the 6-inch map, on the east side of Chobham Ridges. The cutting extended from the 400-foot contour-line down to a level of 360 feet above Ordnance datum.

This section (fig. 2, p. 187) is of especial interest, because it extends from the surface down into the Upper Bagshot Beds and shows:

1st. The irregular base of the gravel, which, it will be seen, thickens towards the plateau.

2nd. The position of a sarsen lying flat at the bottom of the gravel.

3rd. The re-arranged sand under the gravel passing down into the Bagshot sand *in situ*. I was unable to decide as to the precise line between the re-arranged bed and the Bagshot bed. In the upper part of the sand there was an irregularly stratified appearance, which was entirely absent in the lower part of the section, and which I have never seen in the Upper Bagshot Beds. This is indicated by faint lines in fig. 2.

I have a number of notes of sarsens, large and small, which I have seen in gravel-pits. Most of them were at, or close to, the bottom of the gravel, and resting wholly or partly upon sand; though it was in most cases not possible to say with certainty whether the sand was Bagshot *in situ*, or had been re-arranged. I have taken photographs of some of these sarsens, and I propose to offer copies to the Society for reference.

There are some pits on the top of Chobham Ridges, close to the Royal Albert Asylum, and at a level of 400 feet above Ordnance datum, in which sarsens may be usually seen.

In one place I noted three sarsens close together, the largest 1 foot 5 inches in breadth. They were under $5\frac{1}{4}$ feet of gravel, which was very irregularly stratified and much contorted in places.

I noted in another place a section showing:—

1. Gravel with very irregular stratification	5 feet
2. Sandy gravel with current-bedding	2 feet,

and I have often seen a similar state of things in the gravels at Hayes, Dawley, etc., that is, well stratified below and irregularly stratified or contorted above.

In a pit a little south of the last mentioned, near the Royal Albert Asylum, the gravel is thinner (3 to 5 feet) and the sarsens are more easily uncovered. They are flat waterworn stones; the largest that I have seen measured 11 × $7\frac{1}{4}$ feet × 1 foot 11 inches. On one occasion I counted twenty-five stones in this pit, each over 3 feet in length.

I took some photographs of this pit, one of which is reproduced as fig. 3 (p. 189), and in it several sarsens are shown. They had not, I think, been moved since they were uncovered: the gravel had merely been worked away from above them, and the edge of the working is seen in the photograph behind the sarsens.

As I have said, there is nothing to show that the sand on which these stones rest has not been re-arranged. I could find no sign of fossil shells in the sarsens, so they may be a consolidated part of a re-arranged bed, and I have no doubt that some sarsens are consolidated gravel. I exhibit two specimens. The first, a fragment weighing a little over 500 grammes, was given to me by Prof. Rupert Jones, F.R.S., and contains subangular flints, flint-pebbles, and small quartz-pebbles. The second is a fragment of a pebble (145 grammes) and contains small chips of flint: I found it in gravel on the east side of Chobham Ridges, 300 feet above Ordnance datum.

Fig. 3.—*Gravel-pit with numerous sarsens, Chobham Ridges,* 406 *feet above Ordnance datum.*

I do not suggest that the presence of sarsens at the bottom of the gravel is any evidence of ice-action; but I now come to a case where the stone is actually in the gravel, and where it seems to me that floating river-ice would account for the state of things now to be seen.

The pit which I wish next to describe is on Jackpond Hill, one of the western spurs of Chobham Ridges. The level is 360 feet above Ordnance datum.

In April, 1891, I noted that this pit showed 5 to 6 feet of orange-coloured and red unstratified gravel. On July 19th, 1897, I visited the pit and found a better section open, showing that in parts the gravel is roughly stratified, but it also showed a great deal of contortion. In one place I saw a sarsen in the gravel, and was able to photograph it. As it was partly buried, I cannot say what its full size was, but the exposed part measured $3 \times 1\frac{1}{2}$ feet. It lay with an inclination to the south-east.

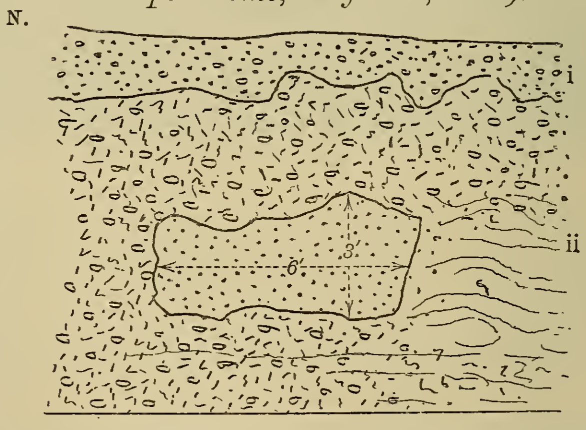
Below the stone 4 feet of sandy gravel was exposed (bottom not reached), and this was irregularly but distinctly stratified. Above the top of the stone there was $2\frac{3}{4}$ feet of gravel and surface-earth. The gravel above and at the sides of the stone showed scarcely any sign of stratification. There can thus be no doubt that this large stone was moved during the deposition of the gravel, but though waterworn it retains its angular form to a great extent, and it seems to me that the position of this sarsen, together with the contortions in the gravel, furnishes evidence of the presence of ice in the river by which the gravel was laid down.

For many years gravel has been worked for roads at Penny Hill, near Bagshot. The level is 400 feet above Ordnance datum, and the hill is practically part of the Chobham Ridges plateau. The sections frequently show that the gravel is to a great extent of an unstratified and mottled character. In August last I saw a small sarsen, 2 feet from the surface of the ground and $2\frac{1}{2}$ feet from the bottom of the pit, the whole side of the pit being formed of gravel with scarcely a sign of stratification.

The Rev. Dr. Irving has described a completely unstratified gravel at this same level (400 feet above Ordnance datum) at Broadmoor, which is on a part of the plateau of the Easthampstead Plain, and evidently contemporaneous with the gravel that I have been describing on the adjoining Chobham Ridges plateau. Dr. Irving suggests that it may be a glacial deposit of Pliocene age.[1]

Through the kindness of Prof. Rupert Jones, F.R.S., I am able to reproduce a sketch (fig. 4) taken by himself in 1863, which represents an irregularly-shaped block of brown sand 6 × 3 feet in gravel. Prof. Rupert Jones considers that this block was probably frozen when embedded in the gravel, and that it is consequently evidence of the presence of ice in the waters by which the gravel was deposited.

Fig. 4.—*Section in Windsor Ride Gravel-pit, Camberley (reproduced, by permission, from a drawing made on the spot by Prof. T. Rupert Jones, May 24th, 1863).*



i = White (discoloured) sand and gravel, with a black irregular line at the bottom.
ii = Gravel.

On the same plateau as these examples are numerous instances of well-stratified current-bedded gravels. We have therefore examples of stratified, contorted, unstratified, and mottled gravel, all on the same plateau, and all, I should say, of the same age. Moreover, these features are present in gravel at all sorts of levels,

[1] Quart. Journ. Geol. Soc. vol. xlvi (1890) p. 561, note.

from that of the Chobham Ridges plateau down to the level of the Thames.

Sarsens, too, are found in gravels of very various levels. In August 1897, I saw one in a pit 292 feet above Ordnance datum, close to a ford over the Wishmoor Stream on Olddean Common. Its size was $3\frac{1}{2} \times 3\frac{1}{2} \times 1\frac{1}{2}$ feet. It was tilted to the south, above it was 4 feet of gravel, and there was a little gravel under the northern end, while the southern end rested on sand. The stone was somewhat waterworn, but still of a decidedly angular shape. The gravel was roughly but distinctly stratified, and in fact resembled, so far as I could see, the sarsens and gravel which I have been describing, more than 100 feet higher in level.

In my paper of 1891 (Quart. Journ. Geol. Soc. vol. xlviii, 1892, p. 42) I described sarsens in the middle of gravel at about this same level, namely, 300 feet above Ordnance datum.

I am inclined to look upon the gravel of Snelsmore Common, north of Newbury, and 400 feet above Ordnance datum, as practically contemporaneous with the gravel of the plateau of the Bagshot district, and also of fluviatile origin. I was, therefore, interested to hear Mr. H. B. Woodward ask at a meeting of this Society whether some of the plateau-gravels near Newbury might not be of Bagshot age.[1] This remark seemed of especial interest to me, as I consider the Chobham Ridges plateau-gravel coeval with the Farnham plateau-gravel, in which flint-implements have been found.

But, first as to Snelsmore Common, I have noted small sarsens in the gravel not lying horizontally, but more or less on end; perhaps this may indicate the action of river-ice.

Section at Snelsmore Common, near Newbury, 400 *ft. above* O.D.

1. Stiff reddish clay with stones ...... 2. Gravel, subangular flints, and pebbles, small sarsens on end	3 ft. 4 in.
3. Coarse sand, yellow, orange, greenish, and white	1 ft. 6 in.
4. Gravel, like bed 2	3 ft.

There are small pebbles of quartz up to $\frac{1}{4}$ oz. in weight, but they are rather rare. In some places the gravel is well and evenly stratified, and in others it is unstratified.

I pass now to the Farnham gravel, which I did not describe in my paper of 1891. The highest of the Farnham gravels caps an elongated plateau, with a level of from 360 to 380 feet above Ordnance datum. It runs in a north-easterly and south-westerly direction, and is about 5 miles south-west of the Fox Hills plateau, which is at practically the same level above the sea (350 to 390 feet above Ordnance datum).

On the Geological Survey map the Farnham plateau is mapped as

[1] Quart. Journ. Geol. Soc. vol. liii (1897) p. 437, discussion.

'River- and Valley-Deposits,' whereas the Fox Hills plateau is mapped as 'Hill-gravel and Sand of doubtful age and origin.' I believe that both are river-gravels of about the same age, and I do not quite appreciate the reason which has led to different colours being used for them on the Geological Survey map.

The gravel of the plateau at Farnham is in places 25 feet or more thick. As a rule, there is little or no sign of stratification, the gravel consisting of a mass of stones closely packed together, but in places where the gravel is sandy it is seen to be well stratified. I took a photograph of a part of one pit, where the stratification was particularly well shown on a north-and-south face, about ½ mile south-west of St. Thomas's Church.[1]

The gravel consists mainly of flint. Flint-pebbles occur, also pebbles of ironstone, some Lower Greensand chert, and a little quartz. The gravel rests partly on Folkestone Beds and partly on Gault, and the Chalk-flints may have come from the north, west, or south-west, probably from older gravels or Clay-with-flints. The cherty fragments doubtless came from the Hythe Beds, which now crop out some 4 miles south of the plateau.

On the south-eastern side of the plateau there is a small valley, and on the opposite side patches of gravel occur at about the same level, which are mapped 'Hill-gravel,' etc. I have, however, no doubt that they are river-gravels practically contemporaneous with the Farnham gravel; it is interesting to note that the proportion of chert is larger, and that there are few or no flint-pebbles from the Tertiary pebble-beds (I saw only poor sections, so cannot speak with certainty as to the proportions), which is what one would expect from their situation.

There are two terraces of gravel on the north-west of the Farnham plateau, one at a level of about 300 feet above Ordnance datum, and the other about 250 feet. The upper terrace, 12 feet or more thick in places, consists mainly of brown subangular flints, and the sections that I have seen do not show much sign of stratification. This may be of the same age as the gravel at Ash, in which there is a large pit 285 feet above Ordnance datum. It shows a good section of 6 feet of yellow and reddish gravel, much contorted, though with little other sign of stratification. But this was only a local feature, for in the large pit north of the road and at the same level the gravel is well stratified. This terrace is probably connected with the river which deposited the gravels at Great Bottom Flash, Mitchet Lake, etc. It seems to me clear that these extensive terraces on the side of the Fox Hills must owe their origin to a river with a drainage-area extending much farther south than that of the modern Blackwater, and I therefore suggest that the terraces of Farnham owe their origin to the same river.

This flat, or slightly sloping, expanse of gravel of Mitchet Lake bears a curious resemblance to the gravel-flats at the top of the

[1] The photograph is no. 1324 of the Brit. Assoc. Committee Geol. Photogrs.

plateaux above it, and to the gravel-covered flats near the Thames below. Now, my point is that all are river-gravels, and the question arises, if I am right in this view, is there anything to show that the sea invaded this district at any time between the deposition of the oldest and the newest gravels?

Dr. Irving has brought forward an example of contorted stratification at a level of 240 feet above Ordnance datum near Wellington College, and he attributes the contortions to 'the action of bergs or floes of ice which floated in the waters that then filled the valley up to about this level.'[1] Mr. Hudleston has, however, attributed a very similar example of contortion to a sliding mass of névé or indurated snow.[2]

On the whole, therefore, I venture to submit that we have no evidence of the presence of the sea in this district during the Drift period. There is, however, as I hope I have shown, ample evidence of ice-action, and this evidence is more or less present in the gravel at all levels, so that I am led to think it probable that the gravel of this part of England practically coincides in age with the duration of the Glacial Period—using that term in a wide sense, so as to include the period where indications of approaching cold appear in (or even before the date of) the Cromer Forest Bed.[3]

Discussion.

Mr. Clement Reid asked why the gravelly sarsen-stones exhibited might not be of Eocene date. They were discovered loose on the surface, but were similar to gravelly sarsens undoubtedly of Reading and Bagshot ages found in Dorset. Was there any known instance of the formation, in this country, of a siliceous conglomerate in a deposit newer than the Oligocene? With regard to the transportation of large angular masses of flint and sarsen, he remarked that when the gravels of the Chobham plateau were being deposited, the area must have been dominated by land of considerably greater height within a short distance. Perhaps slow soil-cap movement, like that of Patagonia, may have helped to transport the blocks down gentle slopes. It seemed scarcely necessary to postulate the action of river-ice at that height.

Mr. Whitaker said that all agreed that great unworn flints could not have been rolled down by streams for any great distance. He had seen flint-pebbles in East Kent made in a chalk-pit, artificially and very expeditiously, by washing in puddle-pits. As to sarsen-stones, there was no need to invoke very distant transport, as they may come from various Tertiary deposits. It was very singular that in the Chalk tract of the London Basin sarsens occur to the greatest extent in that part where, from the westerly thinning of the London Clay, the Bagshot Beds come within little vertical

[1] Proc. Geol. Assoc. vol. xi (1890) p. clx.
[2] Quart. Journ. Geol. Soc. vol. xlii (1886) p. 169 & fig. 8.
[3] H. B. Woodward, 'Geol. of England & Wales,' 2nd ed. 1887, p. 481.

distance of the Chalk, which suggests that a large portion of the sarsens come from the Bagshot Beds. He had seen in the Hampshire Basin sarsens with large masses of Bagshot Sand enclosed in gravels. As to the gravels near Farnham, there was no intrinsic evidence as to what they were, and he did not regard the Survey classification in this matter as final. He would certainly not class any of them as Bagshot. The expression 'plateau-gravel' merely implies that the deposit occurs at a high level, but nothing further. The materials of which these gravels are composed seem to come more from the south than from any other direction. When flint-implements are found in gravels, he would be inclined to call these 'river-gravels.'

Mr. R. S. Herries admitted the occurrence of sarsen-stones in the Woolwich and Reading Beds, but did not think that there was any well-authenticated instance of a sarsen-stone being found entirely in the Bagshot Beds in the Bagshot district. In this district the sarsens often occur on the top of the Bagshot Beds, or partly embedded in them, but always where there is or has been overlying gravel, and the speaker thought that they belonged to the gravel and not to the Bagshot Beds.

Mr. A. E. Salter had noticed sarsens near the mouth of the Thames at Sharnell Street and Cobham, the Medway Valley near Aylesford, St. George's Hill near Weybridge, and embedded in the gravels at Lee-on-the-Solent, the position of which in every case could be explained by the hypothesis advanced by the Author. He was particularly struck by the remarks on 'redeposited Bagshot,' and thought it extremely probable that the sands at Netley and Headley Heaths on the North Downs were of this character. At the former place the presence of a sarsen quite close to one of the sections, at an altitude of over 600 feet above Ordnance datum, and in all probability derived from the superincumbent gravel, lends support to this idea.

Mr. W. H. Shrubsole said that he would mention two facts, of small importance by themselves, which might be worth consideration in connexion with other information. One was that he had often seen fine-grained 'sarsen-stones' *in situ* at the base of the brick-earth, resting on Chalk, in East Kent; and the other fact was that, about 20 years ago, he found a large quantity of irregular fragments of igneous rocks, differing greatly in size, embedded in the upper part of the Lower Bagshot Sand at Mill Hill, Sheppey. They were examined by competent petrologists, and pronounced to be an assemblage which in all probability had been transported from Scandinavia. His own opinion at the time was, and still is, that ice had been the transporting agent.

Mr. O. A. Shrubsole had noticed contortions and irregularities in the gravel of this district, but did not offer an opinion as to the cause which has produced them. He had also obtained from it flints of the kind claimed to be implements of an early type.

The Author, by permission of the President, read the following note which he had received from Dr. Irving, who was unable to be present:—

'Does this—"*in situ*"—mean in the position in which they were formed *qua* rock? If so, very interesting. If not, a loose use of the phrase for the purpose of technical science. No doubt some ice and snow at times carried stones. Compare my note (Quart. Journ. Geol. Soc. vol. xlvi, 1890, p. 561 note) on the gravel in the pit at Broadmoor, 400 feet O.D., a snow-wash, such as I have often seen and walked over in the gullies of the high Alps, very likely. Many angular flints are the result of rupture by frost in their present locality. Conditions vary; laws of Nature are constant.'

The Author, for himself, thanked the various speakers for their remarks, critical and otherwise; but as there was another paper to follow, he would refrain from a detailed reply. Many of the questions opened up in the course of the discussion were of the highest interest, and to some extent were dealt with in the paper.

14. *Some* New Carboniferous Plants, *and how they contributed to the* Formation *of* Coal-Seams. By W. S. Gresley, Esq., F.G.S. (Read February 23rd, 1898.)

[Abstract.]

The Author, in a paper published in abstract in the Society's Quarterly Journal for May 1897 (vol. liii, p. 245), argued that certain brilliant black laminæ in coal, and similar materials found among some mechanical sediments of the Coal Measures, pointed to the former existence of an aquatic plant. In the present communication he describes structures in the pitch-coal laminæ of bituminous coal and in the glossy black layers of anthracite which he believes to be indications of two other kinds of plants, and states that he has examined structures which may be due to some other kinds of vegetation.

Discussion.

Mr. Strahan admired the persistence with which the Author brought forward his views on these so-called coal-plants, and regretted that there was not better evidence of the origin ascribed to them.

Dr. Hicks and Dr. Hinde also spoke.

15. Cone-in-Cone: Additional Facts *from* Various Countries. By W. S. Gresley, Esq., F.G.S. (Read March 23rd, 1898.)

[Abstract.]

Examples of flinty stone in the 'fire-clay series' of the Ashby coal-field exhibit 'areas of conic structure lying unconformably.' In the same stratum of shale are large masses of the same flinty rock, more or less coated with conic structures, which appear to have been formed out of layers of shale and ironstone. The bending-up of the shale above the nodules and down below them, the close but unconformable covering of Permian breccia, and the staining of the whole section suggests, if indeed it does not demonstrate, to the Author that the growth of the cone-in-cone took place subsequently to the deposit of the Permian breccia. Several American and other examples are described, and a series of conclusions are appended to the paper.

Discussion.

Mr. Clement Reid and Mr. Strahan spoke.

16. Contributions *to the* Glacial Geology *of* Spitsbergen. By E. J. Garwood, M.A., F.G.S., & J. W. Gregory, D.Sc., F.G.S. (Read February 2nd, 1898.)

[Plates XIII–XIX.]

Contents.

I. Introduction.

On June 17th, 1896, the tercentenary of the discovery of Spitsbergen by Barentz, we first sighted the western coast of the great island, the unknown interior of which Sir Martin Conway's expedition had been organized to explore. The sea was strewn with floes, which barred direct approach to the shore, and the incidents of the passage through the ice helped us to realize that we were 13° north of the Arctic Circle, far within the area which, according to a once popular theory, was formerly buried beneath a massive cap of ice. But the first near view of the land was calculated to destroy whatever faith we might have had in the former existence of a north polar ice-cap. For the sharp, serrated ridges of Mount Starashchin (see Pl. XIX, fig. 2) and Dodman Den, which guard the entrance to Ice Fiord, indicate that Western Spitsbergen has not at any recent time been wholly submerged beneath an ice-cap.[1] Confluent series of glaciers occur in Spitsbergen at the present day, and form the so-called 'inland ice-sheets.'[2] One such can be seen to the north of Ice Fiord, rising gradually from the shore to the sky-line; while on the plateau south of the fiord are smaller, disconnected glaciers. Hence, during the passage up Ice Fiord, between the great ice-sheet to the north and the scattered glaciers to the south, through the ice-floes among which the steamer carefully threaded its way, and past the huge piles of ice heaped along the shore, we were impressed by the fact that Spitsbergen is an exceptionally favourable locality for the study of glacial geology; for the three main ice-agents may be seen there working side by side.

The literature upon Spitsbergen is voluminous; but the main object of this paper is to record our actual observations upon the points which seem to us to bear especially on glacial problems. It is therefore unnecessary to refer at length to the previous literature on the glaciation of Spitsbergen. We need only point out that the first satisfactory descriptions of the Spitsbergen glaciers are those of Martins[3] and Durocher[4]; that reference to the work of the numerous Swedish expeditions and an account of the views of Baron von Nordenskiöld will be found in Leslie's[5] summary of that distinguished explorer's voyages; that many valuable observations as to the action of coast-ice have been recorded by Mr. James Lamont,[6] F.G.S., and Col. Feilden,[7] and that an admirable account of many of the western glaciers has been given by the late Gustav Nordenskiöld.[8] Mention must finally be made of the careful measurement of the rate of movement in a Spitsbergen glacier by MM. de Carfort & Lancelin,[9] and of the figures of the King's Bay glaciers published

[1] The same conclusion has been previously advanced for other Arctic areas, such as Alaska, North-eastern Labrador, Northern and Southern Greenland. We have noted Prof. Tarr's objection to this view; but his suggested explanation of the facts advanced by Chamberlin appears to us quite insufficient—in Spitsbergen at least. See R. S. Tarr, Bull. Geol. Soc. Amer. vol. viii (1897) pp. 252–256.

[2] It is well to explain here the sense in which we use the word 'ice-sheet': we mean simply a sheet of ice. Those ice-sheets, such as that of Greenland, which completely bury the interior of a country, and in which the ice itself forms the watershed, we refer to as 'ice-caps.'

[3] Ch. Martins, 'Observations sur les Glaciers du Spitzberg comparés à ceux de la Suisse et de la Norvège,' Voy. en Scandinavie, etc. sur la corvette la *Recherche*, Géogr. Physiq. vol. i (1845) pp. 138–192.

[4] J. Durocher, 'Sur les Glaciers du Spitzberg comparés à ceux des Alpes,' *op. cit.*, Géogr. Physiq. vol. i (1845) pp. 320–349.

[5] A. Leslie, 'The Arctic Voyages of Adolf Erik Nordenskiöld, 1858–1879,' London, 1879.

[6] Jas. Lamont, 'Notes about Spitzbergen in 1859,' Quart. Journ. Geol. Soc. vol. xvi (1860) pp. 428–444; 'Seasons with the Sea-Horses,' London, 1861.

[7] H. W. Feilden, 'A Subaqueous Moraine,' Glac. Mag. vol. ii (1894) pp. 1–5.

[8] G. Nordenskiöld, 'Redogörelse för den Svenska Expeditionen till Spitsbergen, 1890,' Bihang k. Svenska Vet. Akad. Handl. vol. xvii, pt. ii, no. 3 (1892), 93 pp., 6 pls. & map.

[9] R. de Carfort & Lancelin, 'Étude sur le Mouvement des Glaciers dans la Baie de la Recherche,' pt. vi of 'Voyage de la *Manche* à l'île de Jan Mayen et au Spitzberg,' Paris (1894), pp. 116–124, pl. xxi.

by Hamberg [1] in 1894. The last-named author first called attention to the three most striking characters of the Spitsbergen glaciers, namely:—the false-bedding and lamination of the ice, the irregular distribution of the intraglacial material, and the wall-like termination of the glaciers. Some of these features may be discerned in Mr. B. Leigh Smith's admirable photographs, of which no published account has been issued, although a set of them is available for reference in the Map-room of the Royal Geographical Society.

Nothing, however, had been done in Spitsbergen comparable to the masterly studies of the Greenland glaciers which we owe to Prof. Chamberlin [2] and his colleagues, to Drygalski,[3] and to the contributors to the 'Meddelelser om Grönland.' We had the opportunity of studying in Spitsbergen the same types of glacier-structure that have been so admirably described and so beautifully illustrated by Prof. Chamberlin, whose series of memoirs forms the most important contribution to glacial geology during recent years.

It is unnecessary to say much about the stratigraphical geology of Spitsbergen; but, as we are bound to refer to the possible analogy between the geographical structure of that country and of Greenland, a few lines on the subject may be conveniently inserted. Spitsbergen itself (excluding North-east Land and the islands adjacent thereto) consists of two parts. There is an extensive eastern plateau formed of Devonian, Carboniferous, Triassic, and Cretaceous strata, which are in the main horizontal, and are in places penetrated by intrusive igneous rocks; and there is a lofty western mountain-chain formed of pre-Devonian granites, gneisses, and schists, which are in places associated with uplifted members of the sedimentary series.

We are glad of this opportunity of thanking Sir Martin Conway, whose careful preparations ensured the success of the expedition, and whose keen scientific interests led him continually to alter his plans so as to give us the fullest possible opportunity for our work. It was, moreover, a great advantage for us to be able to discuss difficulties with a mountaineer and a geographer who has so intimate a knowledge of Alpine and Himalayan glaciers. References to the localities and an account of the conditions under which our work was done will be found in Sir Martin Conway's book.[4]

[1] Axel Hamberg, 'En Resa till Norra Ishafvet Sommaren 1892,' Ymer, vol. xiv (1894) pp. 25–61 & pl. i.

[2] T. C. Chamberlin, 'Glacial Studies in Greenland,' pts. i–x, Journ. Geol. (1894–97): pt. i, *op. cit.* vol. ii (1894) pp. 649–666; pt. ii, *op. cit.* (1894) pp. 768–788; pt. iii, *op. cit.* vol. iii (1895) pp. 61–69; pt. iv, *ibid.* pp. 197–218; pt. v, *ibid.* pp. 469–480; pt. vi, *ibid.* pp. 565–582; pt. vii, *ibid.* pp. 668–682; pt. viii, *ibid.* pp. 833–843; pt. ix, *op. cit.* vol. iv (1896) pp. 582–592; pt. x, *op. cit.* vol. v (1897) pp 229–240.

[3] E. von Drygalski, 'Grönlands Gletscher und Inlandeis,' Zeitschr. Ges. Erdk. Berlin, vol. xxvii (1892) pp. 1–62.

[4] 'The First Crossing of Spitsbergen,' London, 1897.

II. The Glaciers and their Action.

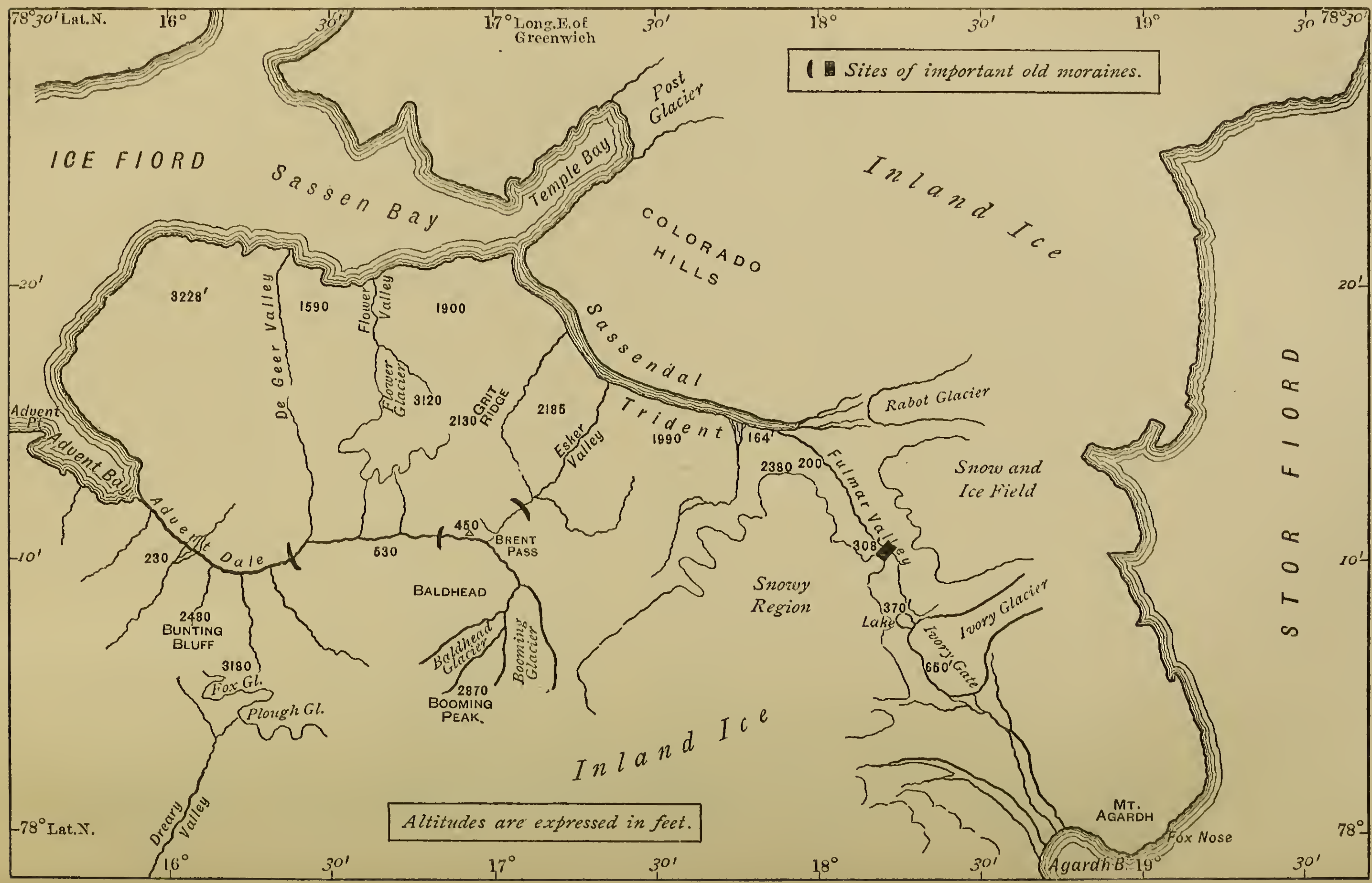
Precipitation in Spitsbergen is probably greatest along the western mountain-chain, for the winds from the south-west have crossed the comparatively warm waters carried northward by the Gulf Stream, and thus arrive laden with moisture. The snow that falls on the seaward face of the mountain-range has a ready escape down the steep slope to the sea; but, although the eastern plateau is intersected in every direction by deep valleys and branching fiords, the snow that falls on it has no such easy outlet: the snow therefore accumulates, until it forms either glaciers of the 'Piedmont' type or 'inland ice-sheets.'

The extent of the ice in Spitsbergen has been exaggerated: it has been stated, for example, that 'the interior of Spitsbergen at presents consists of an immense ice-plateau, from 1500 to 2500 feet in height, which has its issue into the sea by means of the glaciers, which everywhere on the coasts protrude into the sea.' It had, however, been proved by the Swedish expeditions, and especially by that under Prof. Nathorst & Baron de Geer in 1882, that some parts of the interior are free from ice. Belts of land break up the inland ice into three main sheets, as was shown very clearly by Lieut. Byström's map,[1] issued in 1896. We saw but little of these great ice-sheets, as we made no attempt to cross them. For, though they are of great interest from their probable resemblance to the ice-sheets that once covered some parts of the British Isles, yet their geological action can be better studied upon their margins than upon their surface; in a march across them probably little could be seen of the processes that take place within or below them.

In addition to these 'inland ice-sheets' there are in Spitsbergen glaciers of the ordinary Alpine type. They agree with those of Switzerland in most respects. They flow from high collecting-grounds until they melt away or are otherwise destroyed. They carry down upon their surface lateral and median moraines, and their ends are often surrounded by terminal moraines. But two differences between the glaciers of Switzerland and Spitsbergen were soon apparent. The former are the outlets of extensive snow-fields, and the material of which they consist passes from snow into ice through the stage of névé. But many of the Spitsbergen glaciers do not drain snow-fields, and their material passes directly into the condition of névé-ice and glacier-ice. Thus, at the head of nearly every glacier-pass that we crossed (for example, Fox Pass, Bolter Pass, Flower Pass), we found no true névé or gathering-ground of snow. In some cases such glacier-ice may have been formed by avalanches; but at least in one case this explanation is inadmissible, and we were forced to the conclusion that under Arctic conditions snow may be converted into ice without pressure, and that the existence of glaciers does not necessarily postulate the existence of great snow-fields.

[1] H. Byström, 'Öfversiktskarta öfver Norra Polartrakterna,' Stockholm, 1896.

Fig. 1.—*Map of a portion of Spitsbergen, based on that published by Sir Martin Conway.*



But the most important difference between Arctic and Alpine glaciers is seen in the character of their respective terminal fronts. Most Swiss glaciers end with a tapering snout. Some of those in Spitsbergen (such as Flower Glacier, Baldhead Glacier, etc.) do the same; but the majority end in a vertical cliff of ice, of the type for which Lieut. Lockwood's apt name of 'Chinese wall'[1] is generally adopted. This name is appropriate owing to two characters: the face is vertical, and sometimes overhangs at the top like the machicolations of a mediæval fortress; secondly, the intraglacial material is arranged in lines like the layers of mortar in a wall.

The vertical faces of these Arctic glaciers have been suggested by Chamberlin[2] as largely due to the low angle at which the sun shines upon them. This no doubt assists in the formation of these 'Chinese walls,' for when the sun is low on the horizon it tends to cut the opposite face of the glacier backward by vertical ablation, instead of reducing its thickness by ablation over the whole upper surface. But the position of the sun is not the only factor, and we doubt whether it is a very important one, for the rays of the sun when it is near the horizon have comparatively little melting-power, compared with those which come from the zenith. Moreover, glaciers facing in the same direction and in the same neighbourhood sometimes end with tapering snouts, and sometimes with Chinese walls. (See Pl. XVII, fig. 1.)

Our first impression on seeing a glacier with a wall-termination was that this arrangement was due to the glacier being in a state of advance: and, so far as we could see, glaciers ending in snouts were either receding or stationary, while those with Chinese walls were always advancing.

The formation of the overhanging cornice appears to be due to the rapid forward movement of the uppermost layers of ice. This may be aided to some extent by the melting backward of the lower, dirt-bearing layers, owing to their greater absorption of heat; but in the case of at least some of the Spitsbergen glaciers, the influence of this factor must be quite insignificant.[3]

Glaciers with these Chinese walls are more instructive than those with snouts, and we therefore propose to describe one in some detail. The first view of such a glacier (see Pl. XIII, fig. 1) shows that it is composed of a lower part charged with débris, and an upper part in which the ice is pure and white. We almost instinctively proceeded at once to the foot of the ice-cliff to search for 'ground-moraine.' But the included material in the lower

[1] A. W. Greeley, 'Three Years of Arctic Service,' vol. ii (1886) p. 34, & app. p. 28, figs. 3 & 4.

[2] T. C. Chamberlin, 'Glacial Studies in Greenland,' pt. vi, Journ. Geol. vol. iii (1895) p. 566.

[3] Its action has been invoked to help to explain vertical glacier-faces by Reid, and overhanging faces by Salisbury and Chamberlin. See H. F. Reid, 'The Mechanics of Glaciers,' Journ. Geol. vol. iv (1896) p. 926; R. D. Salisbury, 'Salient Points concerning the Glacial Geology of North Greenland,' Journ. Geol. vol. iv (1896) p. 782; and T. C. Chamberlin, 'Glacial Studies in Greenland,' pt. ix, Journ. Geol. vol. iv (1896) p. 591.

layers of the glacier, where not hidden by ice-talus, is so abundant that we found it in places impossible to draw any sharp line of separation between the glacier and the beds on which it rests. We found, in fact, a gradual passage from ice charged with morainic material into subglacial morainic material which has been saturated with water and frozen hard. We soon learnt that the idea of a 'ground-moraine' as a moraine formed beneath the sole of a glacier was not in accordance with the facts of Spitsbergen geology, for most of the glaciers there have no soles. But we learnt to regard the whole of the débris-bearing layers of the glacier as the representative of the ground-moraine, for they act as it was supposed to do.

How the lower layer of the glacier becomes charged with débris was shown most clearly by sections at several of the glaciers which we examined, especially the Ivory Glacier, near Agardh Bay, and Booming Glacier at the head of Advent Dale. The photographs reproduced in Pl. XV, fig. 2, & Pl. XVI, figs. 1 & 2, as also the diagram on p. 204, illustrate the main stages in the process. As a glacier moves most quickly where it meets with least resistance, the upper layers flow forward more rapidly than those near the base. Accordingly, in a glacier which ends with a cliff-like face, the upper layers ride forward over those below, until they overhang as a projecting cornice. As the cornice is pushed still farther forward, masses of it break away and fall to the foot of the cliff. There they accumulate as an ice-talus bank, which in time becomes so large as to check the advance of the lower layers of the glacier. If the talus-bank is too heavy to be pushed forward, the glacier is forced to ride over it. The ice, therefore, that was originally the uppermost layer of the glacier will then form the base, and be in turn forced to rise upward over later talus-banks that accumulate in front of it. As the process is continuous, the glacier advances by an 'overrolling' motion, the top layer falling to the bottom, and then working upward over other fallen masses.

The use of the word 'overrolling' is open to the objection that it suggests a very flexible or viscous character of the ice. Some of the most conspicuous features of these glaciers, such as their false-bedding, their differential flow, their apparently rapid advance and the readiness with which they expand into radial fans, suggest that their ice is far more mobile than that of the Swiss glaciers. But further acquaintance with the Spitsbergen glaciers led us to change this opinion, especially in the case of the débris-laden strata of ice. Closer examination showed that the false-bedding was due to shearing. As the glacier presses against its talus-bar, bands of ice are driven forward and ride across the lower layers along thrust-planes. Thus Pl. XVII, fig. 2, shows part of the upper face of Booming Glacier: the face is broken into two by a narrow platform. This ledge marks a band rich in débris, above which is one of the thrust-planes. Smaller shearing-planes occur all through the débris-laden portion of the glacier. Hence the mechanical movement of the lower sections of the glacier appears to be due to a

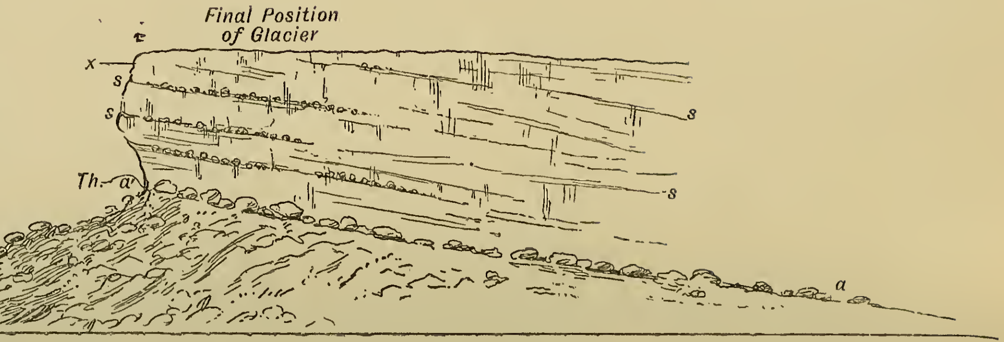
Fig. 2.—*Diagram showing the travel of material carried up an inclined plane, and ultimately deposited in front of a glacier.*

CW = Chinese wall.

a = Raised beach-material : pebbles, driftwood, whalebones, and shells.

a' = The same dragged up the slope, when frozen into the sole of the glacier.

b = Terminal moraine on ice-talus. ss=Shear-planes. Th=Thrust-plane. x=Spot at which shells and beach-pebbles were found.



series of shearing-planes, owing to the pressure of the ice behind, rather than to a viscous yielding or to the action of continuous fracture and regelation.

The overrolling advance of the glaciers affords a simple explanation of the origin of the débris-bands and intraglacial material with which the lower part of the glacier is so richly charged. Let us consider the case of a glacier passing over loose materials, such as a raised beach. The ice-blocks which form the talus are generally irregular in shape, and as they fall with some force their projecting corners are driven into the ground. The blocks are further hammered in by the fall of others upon them. When the glacier flows over the talus, the latter is probably first crushed and then re-solidified, during which some of the underlying earth must get frozen in with the ice. When this basal layer of ice works upward, it carries with it the material which it has picked up from the valley-floor. This process being continually repeated, the whole of the lower part of the glacier becomes charged with débris, which, if no other factor came into play, would at length be distributed in layers throughout the whole thickness of the glacier.

Such débris-bands have been described by Chamberlin from the glaciers of Northern Greenland; he, however, records them only from quite the lower part of the glacier. His observations agree with the view that has been often expressed, to the effect that the intraglacial drift of the ice-sheets of North America and North-western Europe was entirely limited to the basal layers. In some of the Spitsbergen glaciers, however, the intraglacial material, though most abundant in the lower part, is scattered throughout nearly the whole thickness, as in the Plough Glacier (Pl. XIII, fig. 1).

That the intraglacial drift is picked up from off the valley-floor and raised through the glacier was shown in one case by the nature of the material. The terminal lobe of the Ivory Glacier, which occupies part of Agardh Dale, flows over a plain of recently-upraised sea-floor, whose surface is thickly covered with water-worn pebbles and mud. Scattered throughout this deposit occur numerous shells, with driftwood and fragments of whalebone. We found fragments of the shells of *Saxicava rugosa*, *Mya truncata*, etc. in some abundance in the lower débris-bands of the glacier, and on the lower slopes of the terminal moraine; at higher levels, the shells are scarcer and more fragmentary. We found one fragment at the height of 400 feet, and that we did not find any still higher was probably due to the hurried nature of our search.

It may be suggested that these marine remains found in the moraine were derived from some old raised beach, which is situated at a level higher than that at which we found them. The highest raised beach that we could find in the traverse from Sassen Bay to Agardh Bay was not more than 200 feet above sea-level. We found no trace of any raised beach in the upper Fulmar Valley between the great morainic bar and the northern face of the Ivory Glacier. In the lower Fulmar Valley we found traces of raised beaches, but we doubt whether they reached the 300-foot level (see fig. 3, p. 206). The highest terraces that we could see on the sides of

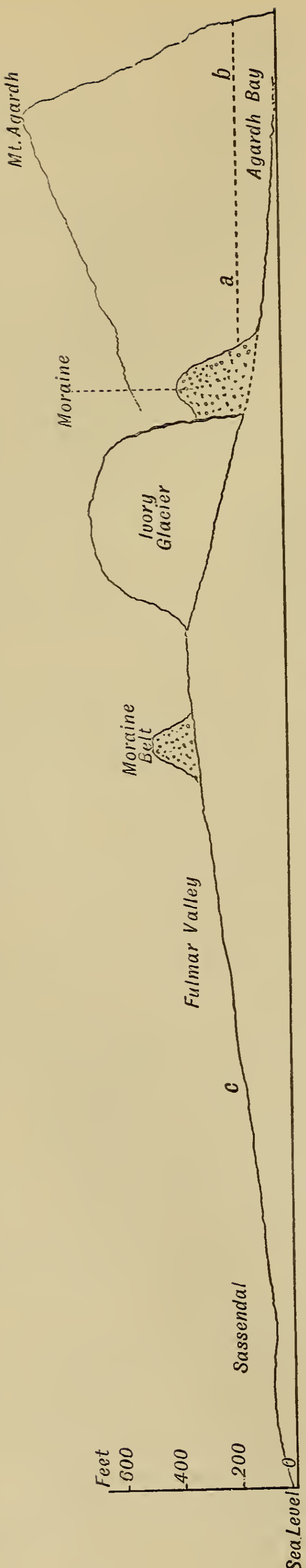


Fig. 3.—*Section along the valley-floor from Sassendal to Agardh Bay.*

a–b = Approximate position of the highest raised beach in Agardh Bay.
c = do. of the highest beach-deposits in Sassendal.

Agardh Dale were certainly at a lower level than this; hence the shell-fragments occur at least 200 feet above any raised beach in the immediate neighbourhood. If the case rested on shell-fragments alone, the negative evidence would perhaps be inconclusive[1]; but the bulk of the moraine and the intraglacial material consists of waterworn pebbles and similar beach-material; among it we found, moreover, fragments of whale-bones and driftwood. Raised beaches on the flanks of a valley would not have yielded sufficient material: the quantity is so enormous that it can have come only from some thick deposit, such as that formed in an up-silted bay. We could see no sign of any high-level beach-deposits whence the material could have been derived.

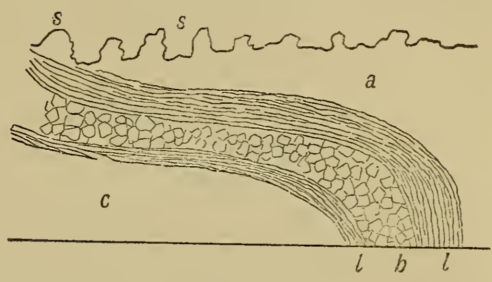
Considering, therefore, that the glacier certainly passes over beach-material, which it can be almost seen to enclose and elevate, we have no hesitation in attributing the present elevation of the shells to uplift by the glacier rather than to derivation from hypothetical deposits, the existence of which at the height required is improbable.

The upward flow of layers of glacier-ice was, however, proved in another way. Fig. 4 is a diagrammatic sketch of part of the eastern side of Booming Glacier, about ½ mile from its lower end. A seam of ice-breccia is seen to run obliquely across the section from top to bottom. If the glacier were flowing like an ordinary stream in an unobstructed channel,

[1] Seagulls, for instance, carry shells to their nests. Some cases of the occurrence of shells at high levels may be thus explained.

then this band of ice-breccia would cut right across the lines of flow. The stratification of the glacier at this point is clearly due to deposition, for the breccia has certainly not been formed by crushing along a plane within the glacier. The section shows therefore that the movement of the ice is oblique to the main axis of the glacier.

Fig. 4.—*Part of the eastern side of Booming Glacier.*



a=Ordinary granular ice.
b=Ice-breccia. *l*=Laminated ice.
c=Black massive ice. *s*=Séracs.

The differential movement in the Spitsbergen glaciers that we have been previously considering must be too limited in lateral range to account for any commingling of boulders from different sources. The differential movements caused by the deformation of the ice during its flow may be considerable in amount both vertically and longitudinally. But the lateral movements thus produced must be small. Glacial geologists long ago explained[1] the intermixture of boulders from various localities by the assumption that the ice at different levels below the same point on a glacier may be moving in different directions. That this supposed action does take place, and on a large scale, is, we think, proved by the following case. It is further of interest as an illustration of the spasmodic nature of the alternate advance and retreat of Spitsbergen glaciers.

The terminal face of Booming Glacier is at present advancing, whereas nearer its source the glacier is diminishing, apparently owing to a diminution in the snowfall at its head (see Pls. XVIII & XIX). The upper surface of the glacier is saucer-shaped, being higher at the margin than in the middle, so that it appears as though the ice, in flowing forward, were climbing upward. But we doubt whether this be the true explanation: it seems more probable that the central depression has been formed by subsidence, owing to the melting and solution of the lower layers of the ice. It is, of course, possible that the ice has actually been forced to rise up a slope of moraine, much as water is heaped up round the margin of a lock into which a powerful current is flowing. Chamberlin[2] has described cases among the North Greenland glaciers in which the downward slope is not uniform in direction, but is interrupted by depressions sometimes so great as to lead to a reversal in the flow of the supraglacial streams. These reversed slopes, however, compared with the ice-fields on which they occur, form only minor undulations, and the glacier may be riding over obstructions in the

[1] See, for example, J. G. Goodchild, 'The Glacial Phenomena of the Eden Valley,' Quart. Journ. Geol. Soc. vol. xxxi (1875) p. 69.

[2] T. C. Chamberlin, 'Glacial Studies in Greenland,' pt. x, Journ. Geol. vol. v (1897) p. 231.

manner of the car of a switchback. But the upward slope on the margin of Booming Glacier is so great, in proportion to the length of that glacier, that we cannot reconcile the ascent of the ice with any theory of glacial flow. We are therefore driven to regard the depression in the middle of this glacier as due to recent shrinkage. Some of the tributaries to Booming Glacier have not been affected by the diminished snowfall which has led to the decrease of the main stream. Thus a glacier that flows down from the Baldhead has continued to advance, and is now spreading out over the ice-stream by which it was once dammed back and absorbed. A point in the middle of Booming Glacier, which at one time only received material from the sources of the main stream, now receives a supply from the source of the tributary. If Booming Glacier increases in size, it will again block the lateral glacier, and all the morainic material along its middle line will come from the peaks at its head. Hence, in the deposits of the glacier there would be a layer with boulders from the west, interstratified between layers in which all the material came from the south.

III. The Deposits of the Glaciers.

The deposits of the Spitsbergen glaciers may be conveniently divided into four groups:—

(1) Normal moraines of the Swiss type.
(2) Moraines formed of intraglacial material.
(3) Moraines formed of redeposited beach-material.
(4) Glacial gravels.

(1) Normal Moraines of the Swiss type.

This division includes moraines formed of material that has been carried on the surface of glaciers. The boulders of these supraglacial moraines are mainly angular, irregular, and unscratched; they generally occur in ill-assorted material, which is coarse and granular, and in which arenaceous material predominates. A few rounded and some scratched boulders occur, but the proportion is not greater than in an ordinary Swiss moraine.

Moraines of this character are common in the Spitsbergen uplands. As examples, we may cite some of those on the flanks of Booming Glacier, one in Esker Valley on the north-eastern side of Brent Pass, and the moraines at the northern foot of Mount Nordenskiöld.

The moraines agree in their general characters with those of existing Swiss glaciers, and there is accordingly no need to describe them.

We may refer, however, to a case of the formation of crescentic moraines by the Grit Ridge Glacier. A lateral glacier in the valley is depositing a series of crescentic terminal moraines on the surface of the main glacier. These moraines are being carried forward by the main stream, and when that melts they will be deposited along one side of its valley. The direction of the moraines of this tributary will be different from that of the deposits of the main glacier; and the moraines will be probably deposited at the foot of the left bank of the valley, some distance below the tributary at the mouth of which they were formed. The occurrence of small terminal moraines along the sides of a valley has been recorded in England and Greenland, and variously explained.

(2) Moraines formed of Intraglacial Material

are more important and interesting. The main characters of these deposits are that the materials are subangular and rounded; while scratched and polished pebbles and boulders are abundant. The coarser constituents are scattered through a fine-grained matrix, which is often well laminated, and may be false-bedded: this matrix is frequently argillaceous. Lenticular masses of clay in sand, or of sand in clay, are often present. The moraine may be either well stratified, or there may not be a trace of stratification in it.

The most striking difference between moraines of this group and those of the Swiss type is the much greater percentage of rounded and striated boulders. Thus, in the supraglacially-formed moraines of Booming Glacier, it often needed some search to find a striated boulder. The following list shows the character of the intraglacial material, represented by a small heap lying in front of the face of Booming Glacier:—

	Boulders.	Pebbles.
Rounded and striated	27	6
Angular and subangular and striated ...	7	0
Angular, but not striated	12	10
Rounded, but not striated	3	3

The matrix was a tough clay. The proportion of pebbles was smaller than usual, for in some heaps they were more numerous than the boulders.

Moraines of intraglacial material are common in Spitsbergen around existing glaciers. They often form the basis of old moraines, the surfaces of which are covered by a layer of supraglacial morainic material. Our interest in these moraines was at once roused by their remarkable resemblance in composition to Boulder Clay. On the broad plain at the foot of Booming Glacier we found some square miles of a tough mud containing boulders and pebbles; it only needed to be dried and hardened in order to form an ideal Boulder Clay. Clearly this deposit had been laid down by land-ice, but not as a tip-heap at the end of a glacier. As the glacier gradually melted away, the materials scattered through it were deposited upon the valley-floor. Sections cut by streams through the deposits showed them to be sometimes laminated with remarkable regularity, forming clays of the type named by Goodchild 'gutta-percha clays.'

These deposits are not always regularly stratified, for they may be laid down in contorted masses. An instance of the formation of such contorted drifts was afforded by the Reiper Glacier, in which the basal layers of ice and the débris-bands were contorted by lateral pressure. On the melting of the ice, its included material is evidently dropped into false-bedded and contorted layers.

(3) Moraines formed of redeposited Beach-material

occurred in most of the principal valleys at the point where the glaciers had at one time entered the sea. There is one in Advent Dale, below the junction with De Geer Valley. But the moraine of this group to which we devoted the most careful examination is situated along the south-eastern face of Ivory Glacier. That moraine forms a series of conical hills of gravel, composed almost entirely of pebbles and sand; a few boulders occurred in it, and there were numerous broken shells, blocks of driftwood, and fragments of whalebones. As a rule the deposit was unstratified, but in places the streams that flowed from the face of the glacier had re-sorted some of the material.

In this Ivory Glacier moraine, although most of the materials have come from shore-deposits, land-ice is alone responsible for their present arrangement. But where a glacier has reached the sea, water plays a more important part and the materials are stratified. At Cape Lyell there are the remains of an old moraine in which the materials are stratified and very false-bedded: the deposits appear to have been arranged by tidal action at the foot of the glacier. The well-developed stratification of the beds on the western side of the great moraine in Advent Dale was probably similarly produced.

Mr. Lamont[1] has described a moraine in Deeva Bay, and Col. Feilden another at the head of Green Harbour, both of which may belong to this group. Feilden calls the latter a 'subaqueous moraine,' and says 'I have no doubt that this moraine was formed under water.'[2] But in a second description of the moraine he adds that the beds do not show any sign of stratification;[3] and we must confess to a doubt, as to whether mixed materials can be deposited on a large scale in shallow water, and exposed to the strong tides of a Spitsbergen fiord, without showing some 'sign of stratification.'

(4) Glacial Gravels.

One of the most remarkable observations made by Nansen during his traverse of Greenland was the insignificant part which water

[1] Jas. Lamont, 'Notes about Spitsbergen in 1859,' Quart. Journ. Geol. Soc. vol. xvi (1860) p. 431.

[2] H. W. Feilden, 'A Subaqueous Moraine,' Glac. Mag. vol. ii (1894) p. 4.

[3] *Id.*, 'Notes on the Glacial Geology of Arctic Europe & its Islands, Pt. II,' Quart. Journ. Geol. Soc. vol. lii (1896) p. 740.

appeared to play in the economy of the ice-sheet. He found no stream flowing over the surface of the ice, and accordingly scouted the idea that kames and eskers could have been formed in channels upon the surface of the ice-sheet. The observations of other explorers have, however, shown that the conditions of the ice-sheet at the time of Nansen's march must have been exceptional. Jensen, for example, has published views of streams flowing over the surface of the ice-cap.[1]

We were not surprised therefore to find that the Spitsbergen glaciers are intersected by river-channels, sometimes so deep as to be impassable for the sledges, and that numerous streams discharge from the terminal face of the glaciers. The stream that we examined most carefully was one on Flower Glacier, the course of which we followed during an ascent of Mount Lusitania. The channels both of the stream and its tributaries were generally quite free of débris. In fact all the supraglacial streams flowed with such velocity that they kept their channels quite clear, except of an occasional boulder. Whether subglacial streams deposit débris along their courses we could not of course directly see. But their velocity, so far as could be judged from the behaviour of the streams at the mouths of their tunnels, is probably even greater than that of the superficial streams. The latter flow in open channels, whereas the subglacial streams are forced through pipes, the size of which is no doubt kept at the minimum by the weight of ice upon the roof. It is only natural, therefore, that the power of the subglacial currents should be great, and it is not likely that deposits would be formed beneath them.

We at least found no trace of gravel-deposits resembling eskers formed either in subglacial or supraglacial streams. The moraines of the Ivory Glacier were in places kame-like in form, but they were certainly not formed subglacially. On the plain at the foot of Booming Glacier is a small esker-like ridge, but it is very low, and there is no available evidence as to its formation.

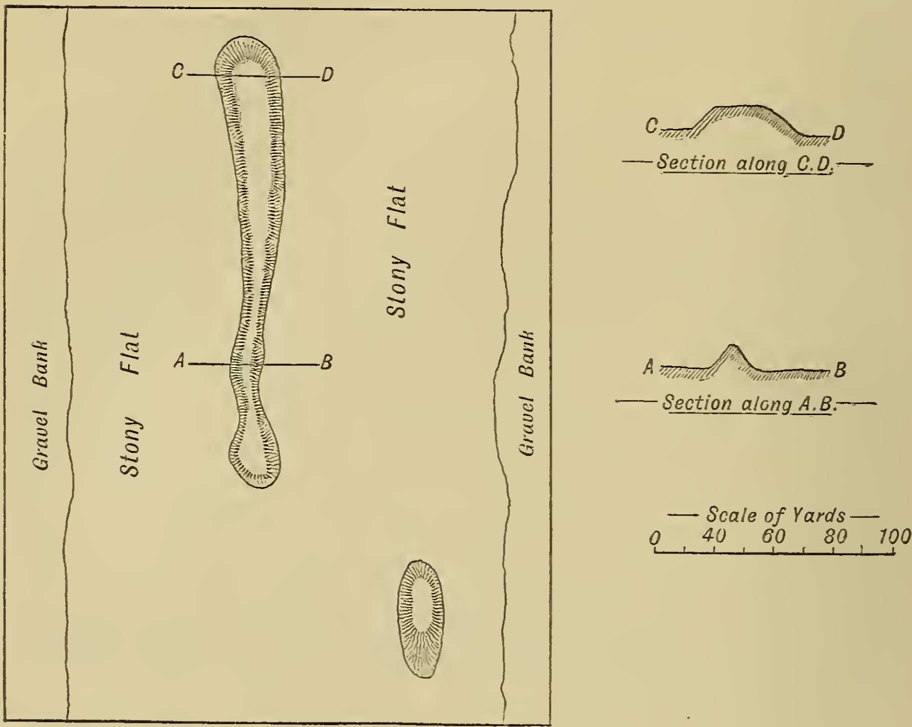
We were, however, so fortunate as to find a fairly typical esker in a position which left no doubt as to its origin. It occurred along the floor of a valley which descended from Brent Pass to the Sassendal. The valley is marked on Sir Martin Conway's map as the Esker Valley (fig. 1, p. 201).

The esker is about $\frac{1}{2}$ mile in length, and its course is slightly sinuous. It varies in width at the base from 15 to 40 yards. Its upper end is semi-cylindrical in transverse section, but at the north-eastern end its summit is flattened into a platform 25 yards wide. The summit of the esker is almost horizontal, but the height of the ridge gradually increases from 20 to 35 feet owing to the slope of the valley. The esker rises from a flat, which at the time of our visit was ice-covered; a stream flowed across the plain on each side of the esker. Beyond the flat a terrace of gravel, similar to

[1] J. A. D. Jensen, 'Expeditionen til Syd Grönland i 1878,' Medd. om Grönl. vol. i (1879) p. 61 & pl. iii.

that which forms the esker, runs along each side of the valley at the same height. (See fig. 5.)

Fig. 5.—*Sketch-plan and sections of the esker-like gravel-ridge.*



An examination of the valley in which this interesting gravel-ridge occurs leaves no doubt as to its mode of origin. At one time the mouth of the valley was blocked by a ridge of Carboniferous cherts which converted the middle part of the valley into a lake-basin. The streams filled this basin with gravel washed from the great terminal moraine in the upper part of the valley. Later on, the Esker Valley river cut through the chert-bar, and then the streams began the erosion of the gravel-plain. The esker has been left in the angle between the stream which comes from Brent Pass and a tributary which drains the southern slope of the Trident.

This explanation, of course, does not apply to all eskers. The reasons given by Prof. Sollas [1] for rejecting this origin of Irish eskers are conclusive for most cases. But, as Mr. J. B. Woodworth [2] reminds us, 'the term esker is applied in common usage to deposits having at least slightly different modes of origin,' and 'each esker should be diagnosed on its own merits.'

[1] W. J. Sollas, 'A Map to show the Distribution of Eskers in Ireland,' Sci. Trans. R. Dubl. Soc. ser. 2, vol. v (1896) p. 786.

[2] J. B. Woodworth, 'Some Typical Eskers of Southern New England,' Proc. Boston Soc. Nat. Hist. vol. xxvi (1894) p. 219.

IV. Marine Ice and its Action.

Spitsbergen offers exceptional opportunities for the study of the geological action of marine ice, owing to its extensive shore-lines, its deep fiords, its numerous exposed islets, the powerful currents in the surrounding seas, and the rapid elevation which the land has recently undergone. Nevertheless, the results of the undoubted agency of marine ice are not very conspicuous.

The direct geological action of sea-ice is, so far as we could learn, of four kinds :—

(1) The transportation of material.
(2) The contortion of shore-deposits.
(3) The formation of small ridges and boulder-terraces above sea-level.
(4) The striation, rounding, and furrowing of rocks.

(1) The Transportation of Material.

The three main types of sea-ice may all act as transporting agents. Many of the blocks that floated down Ice Fiord were black with moraine-matter, with which they had been charged when part of a glacier. The ice-floes formed by the freezing of sea-water, though at first quite pure, are driven ashore by wind or tide, and there pick up a load of beach-material. In the case of the ice-foot the base is charged with fragments of the beach, while its upper surface is covered by the talus that falls upon it from the cliffs.

Ice of all three kinds is sometimes stranded, and when it melts away it deposits its load upon the shore. That this method of transportation of material must take place is obvious, and it has been repeatedly recorded. We need only remark that we saw many patches of boulders and pebbles, which were far distant from their place of origin. Along the shore of Ice Fiord, between Advent Bay and the head of Sassen Bay, there are boulders of gneiss from the north-west of Spitsbergen, and heaps of Old Red Sandstone from the head of North Fiord and Klaas Billen Bay.

(2) The Contortion of Shore-deposits.

Ever since the boat-voyage of Dease & Simpson in 1837, along the northern shores of British North America [1], it has been well known that the stranding of pack-ice has a very powerful action on shore-deposits.

The first result of this disturbance is the contortion of the layers of beach-material, though this cannot be seen clearly until streams have cut sections through the deposits. As one example, we may cite a case observed at Fox Point on Cape Lyell, on the southern shore of Bell Sound.

The disturbances produced by stranding floes are not limited to the spot actually struck by the ice, but frequently extend for some

[1] P. W. Dease & T. Simpson, 'An Account of [their] recent Arctic Discoveries,' Journ. R. Geogr. Soc. vol. viii (1838) p. 221.

distance up the beach. The shore-deposits are often frozen hard, and weighted by a load of ice and snow; hence the pressure of the stranding ice results in a greater lateral movement of the materials than would happen if the beds were loose and incoherent, or were free to yield by increasing in thickness.

A second result of the stranding of floating ice is the formation of bars at the entrance to bays. The bays often remain frozen over until much later in the season than the open fiords or sea. Thus Advent Bay was almost entirely covered by fast ice early in July, when Ice Fiord contained only loose drift-ice. Advent Bay is situated at an angle in Ice Fiord, where the shore, after a long east-and-west course, makes a bold sweep to the north-east. The prevailing winds blow up the fiord, and they accordingly drive the ice along the stretch of straight shore-line, and pack it into the angle by Advent Bay. As the ice grinds along the shore it pushes the beach-material eastward, until it has formed a bar which juts out for a third of the distance across the bay. The bar has been strengthened by the accumulation of river-borne sediment in the dead water behind it, and by the packing of shore-material by stranding ice in front. Most of Advent Point is now above sea-level, but its low, flat surface shows that it has been at one time cut down by marine denudation. At Lomme Bay is a similar bar, of which an admirable photograph has been taken by Mr. Leigh Smith; the bar in this case is narrower than that at Advent Bay, so that stranding ice can ride across it, and plane down the ridges formed whenever the bar is pinched by heavy pack-ice.

The height on the shore to which action of sea-ice extends is, however, comparatively small. We were unable during our short stay to determine the maximum height to which ice can rise; for on a coast undergoing such rapid elevation as that of Spitsbergen it is impossible to distinguish between the action of ice forced up from the sea at its present level and that of ice which grounded when the land was lower. The crews of the Norwegian sloops, whose experience of the Spitsbergen coasts has been gained in many seasons and under different conditions, all agreed that the coast-ice rarely rises more than about 40 feet above sea-level. Mr. Martin Ekroll, who wintered on the east coast of Spitsbergen and carefully observed glacial action, gave 60 feet as the highest level to which he had seen ice pushed above the sea.

(3) Shore-ridges and Boulder-terraces.

Series of raised beaches at different levels are common in Spitsbergen, and associated with these are two features which may be noticed, as due to the action of shore-ice.

Between the main raised beach-lines occur numerous small wavy ridges, which often resemble the ridges between plough-furrows. A few days' observation on shore supplied a simple explanation of their mode of origin. At the end of June the shore of Ice Fiord was bounded by a belt of fast ice; as it melted, a channel of water was formed between it and the shore. When the temperature fell to freezing-point, this water, being practically quite fresh, was frozen. Owing to the resistance of the ice-belt, the newly-formed ice could expand only on the landward side; as the young ice presses against the shore, it pushes the beach-material before it into ridges. These are often somewhat irregular in their course, for the water freezes into hexagonal masses, and the ridges necessarily acquire the angular course of the margin of the ice that forms them.

A second characteristic feature of a beach moulded by shore-ice is the occurrence of lines of large, rounded, or subangular stones, in form strikingly like those of the East Anglian Boulder Clay. They are pressed together so closely and regularly as in some cases to resemble a terrace of masonry or a pavement of cobbles. The first beaches of this type that we met with were at Cape Starashchin. The shore is steep, and is broken into a series of platforms; the faces of the platforms are almost entirely free from boulders, while the terraces between are often paved with closely-packed boulders. Subsequent observation and dredging between tide-lines showed that these peculiar congregations of boulders were due to stranding ice, which had pushed the boulders before it to just above sea-level, and left the beach between tide-lines quite clear.

A good illustration of similar boulder-terraces on Rolfsoe, near Hammerfest, is given in the atlas to the voyage of the *Recherche*.[1] Baron von Nordenskiöld [2] has described similar boulder-accumulations in Nova Zemlya; he calls them 'stone ramparts,' and gives the same explanation as that at which we had independently arrived. The 'boulder-pavements' on the shores of the American lakes, which have been admirably described and figured by Prof. J. W. Spencer,[3] may be mentioned in this connexion; but they are different both in aspect and origin.

These peculiar lines of boulders are probably not easily destroyed, and thus they may sometimes be useful as a test of shore-action. Campbell [4] has described a beach near Dunrobin in Sutherland, composed of 'terraced piles of boulders which do not seem to be moraines,' but which may be an example of this form of ice-action. Campbell himself suggested that it was probably due to the ice-foot.

(4) The Striation, Rounding, and Furrowing of Rocks.

We had few opportunities of observing the action of shore-ice on rocky shores, as our camps during the early period of our visit were on wide raised beaches. But that shore-ice can both scratch and polish rocks we had abundance of indirect proof. The same results

[1] 'Voyages en Scandinavie . . . . sur la corvette la *Recherche*,' Atlas géologique, pl. vii.

[2] A. E. Nordenskiöld, 'The Voyage of the *Vega* round Asia & Europe,' vol. i (1881) p. 188.

[3] J. W. Spencer, 'Ancient Shores, Boulder-pavements, & High-level Gravel-deposits in the Region of the Great Lakes,' Bull. Geol. Soc. Amer. vol. i (1890) pp. 71–86 & pl. i.

[4] J. F. Campbell, 'Frost and Fire,' vol. ii (1865) p. 155.

are produced by land-ice, and we saw no means of discriminating between the striæ produced respectively by glaciers and floating ice. We were therefore interested to hear from Mr. Martin Ekroll that, in his opinion, furrows are formed only by the latter agent. The furrows he regards as always due to fragments of floes which have been thrown up on their sides; the whole weight of the slab of ice then presses directly upon the surface below. The edge of the ice becomes charged with rock-fragments from the beach, and as it is driven forward it cuts into the rock-surfaces like the edge of a file, instead of polishing them like its face.

Mr. Lamont[1] has previously described a glacial furrow on one of the islands of Stor Fiord, and given good reasons for thinking that it was formed by floating ice; the furrow, however, in that case was not cut in solid rock.

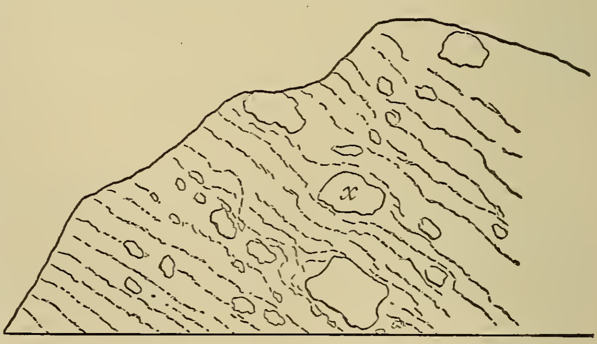
V. Traces of Former Glaciation.

The literature upon Spitsbergen abounds in references to the former greater extension of some of the existing glaciers. But there has been a complete agreement as to the absence of any signs of a pre-Pleistocene glaciation. Sedimentary rocks belonging to the pre-Devonian, Devonian, Carboniferous, Triassic, Jurassic, Cretaceous, and Palæogene systems are abundant; but, as Baron von Nordenskiöld tells us, 'at least we in vain, in the various rocks of that island, searched for stones furrowed by the action of ice, or boulders, or other beds resembling the glacial deposits of the present age.'

We were, however, so fortunate as to discover two cases of apparent glacial deposits in the Spitsbergen series. The oldest is a bed of a massive conglomerate at Fox Point, which belongs to the Hekla Hook series. The best section is exposed in a small headland, and shows some 50 feet thickness of the series.

The matrix is comparatively fine-grained, and has acquired by pressure an imperfect foliation. (See fig. 6.) Scattered through the groundmass are huge boulders, of which the largest was 5 feet high and 7 feet long. The boulders are roughly rounded, and the surfaces are sometimes marked by indefinite groovings, but we were unable to find any definite striæ. The boulders consist of a miscellaneous collection of granites and gneisses, none of which have at present any outcrop near the locality where the deposit occurs.

Fig. 6.—*Diagram of the Hekla Hook glacial beds, Bell Sound.*



x=Boulder 5 feet high and 7 feet long.

[1] Jas. Lamont, 'Seasons with the Sea-Horses,' 1861, p. 204.

The matrix is often contorted, and the fine beds are crushed and bent as they pass round the huge boulders. This crushing and the imperfect cleavage are, no doubt, due to subsequent earth-movements. But the deposit is not a crush-breccia, and the boulders are foreign to the locality. The general aspect of the deposit is strikingly like that which a moraine would probably adopt if solidified, uptilted, and subjected to extreme pressure. The age of the deposit is probably the same as that of the old glacial conglomerate on the Varanger Fiord described by Reusch and Strahan.

On the northern face of Bunting Bluff, in beds which are of late Mesozoic or early Kainozoic age, one of us found another apparently glacial deposit. It contained huge boulders of granite and other rocks foreign to the locality; some of these showed scratches which are probably glacial in origin.

At the mouth of Bell Sound, we found another case of the occurrence of polished boulders scattered through a matrix of fine materials. This bed is Lower Kainozoic; but the boulders were all well rounded, and they were never more than a foot in diameter. The evidence in this case is less satisfactory, but the action of floating ice would afford the most ready explanation of the characters of the deposit.

VI. Some General Conclusions.

In the preceding pages we have tried to limit ourselves to a simple statement of facts, only classifying our observations and introducing such theoretical suggestions as to justify their record. We now propose to refer very briefly to the bearing of some of the facts on the problems of glacial geology.

(1) Land-ice *versus* Sea-ice.

In view of the long controversy between the advocates of land- and floating ice, we sought for some test by which to distinguish the action of these agents. But we could find no character by the use of which it would be possible to decide whether a given deposit had been formed by glaciers or by floating ice. Both forms of ice round rocks, cut striæ, and deposit heaps and ridges of contorted and false-bedded material. The mere presence of marine shells is useless, for they are transported and uplifted like any other material with which a glacier has to deal.

True boulder-paved terraces and shore-ridges can perhaps be formed only by shore-ice; but recognition of the latter would be impossible after denudation of the deposits had taken place; and cases have been described in which the action of a glacier on a moraine crowded with boulders has formed a pavement closely resembling those of the boulder-paved terraces.[1]

We found nothing being formed that would consolidate into a good Boulder Clay like those of Northern England except on land.

[1] W. Upham, 'Irregularity of Distribution of the Englacial Drift,' Bull. Geol. Soc. Amer. vol. iii (1892) p. 136.

On the other hand, we found nothing among the morainic beds exactly like the Cromer Till and the Essex Boulder Clay. And given a supply of suitable materials, we see no impossibility in the formation in a quiet bay of a subaqueous deposit that would be indistinguishable from a boulder-clay.

The determination as to which of two types of ice has formed a particular deposit must therefore be left to the general probabilities of each case.

(2) The Transmarine Passage of Glaciers.

The rapidity with which glaciers are destroyed when they enter the sea seemed to us a feature of some importance in connexion with the suggested passage of an ice-sheet from Scandinavia into England. Hammer's[1] careful observations upon the Jakobshavn Glacier have given exact data as to the solution of glacier-ice by sea-water at low temperatures: he found that in the winter, when the sea-water was at a temperature below $-1°$ C., ice submerged beneath it diminished 200 times as quickly as when exposed to air of the same temperature. It is therefore not surprising that no case is known of the passage of a glacier across any belt of sea, as the old Scandinavian Glacier is assumed to have done.

It may be urged that an elevation of 250 feet would convert most of the North Sea into dry land; but the Norwegian Channel, the highest ridge across which lies 140 fathoms deep, would still be left. To drain it, an elevation of 1200 feet would be necessary. Even if this great rise had taken place, the channel would still serve as a serious obstacle to the passage of Scandinavian land-ice to the south-west; for, as Prof. Bonney[2] has pointed out in an unanswered enquiry in 'Nature,' the ice would tend to flow down the valley to the north.

The value of another objection to the theory was impressed upon us during the voyage along the Norwegian coast. Some of the Lofoten Islands and smaller islets to the south have unglaciated contours. Their jagged summits must have risen above the ice, like the nunataks on the borders of the Greenland ice-cap. In some places at least, the Scandinavian ice cannot therefore have extended much farther west than the present coast-line. This argument has been repeatedly advanced, and the evidence in its support has been clearly summarized by Sir H. H. Howorth.[3]

[1] R. R. J. Hammer, 'Undersögelser ved Jakobshavns Isfjord og nærmeste Omegn i Vinteren 1879–1880,' Med. om Grönl. vol. iv (1883) pp. 34, 36, 64, & 265.

[2] T. G. Bonney, 'The Scandinavian Ice-sheet,' Nature, vol. xlix (1894) pp. 388–389.

[3] H. H. Howorth, 'The Glacial Nightmare & the Flood' (1893), vol. ii, pp. 703–710; 'On the Erratic Boulders & Foreign Stones of the Drift-deposits of Eastern England,' Geol. Mag. 1897, p. 155. For arguments in support of this view from a different line of consideration, see A. M. Hansen, 'The Origin of Lake-basins,' Nature, vol. xlix (1894) pp. 364–365.

(2) The Uphill Flow of Glaciers.

With regard to the cause of glacier-movements we have no fresh information. We found nothing inconsistent with the view that the flow is due to the action of gravity alone. The one apparent case of uphill advance with which we met may be as easily explained by local subsidence of the upper part of the glacier, owing to diminished snowfall, as by assigning climbing powers to the ice.

We do not deny that ice may sometimes surge upward when meeting obstacles in its path, a fact which probably explains such local variations in the level of a glacier as those described by Bonney[1] and Kendall[2] on the Gorner Glacier, by Chamberlin[3] and Wright[4] in Greenland, or the slight upbending of a thin glacier-snout over a moraine as recorded in the case of the Glacier de Zigiore Nuove by Sherwood.[5]

In the case of Greenland a great upward movement of ice is often assumed, on the ground that ice formed in the interior has to climb over a marginal mountain-chain. Thus Prof. Crosby[6] tells us that 'it is the general belief of geologists that if Greenland were divested of its ice-cap it would exhibit continental relief—elevated margins and a depressed interior.' This view of the geographical structure of Greenland appears improbable. Geologically Greenland is very similar to Spitsbergen. It very likely consists of a high plateau of sedimentary deposits supported on a great block of Archæan rocks, which are exposed round the margins. The hypothesis that there is a great depression in Central Greenland is not one upon which it is safe to base an argument.

(4) The Uplift of Material and Land-ice.

Nevertheless we found evidence, which we regard as conclusive, of the upraising of materials in glaciers. We can see no other satisfactory explanation of the occurrence of shells, whalebone-fragments, and driftwood in the Ivory Glacier moraines at an elevation greater than that of any raised beach known in the district. The bearing of this fact on the origin of the British high-level, shell-bearing drifts is obvious; but that question is also affected by the character of the earth-movements now taking place in Spitsbergen. The archipelago is now undergoing elevation, part of which at least must be positive, since the rate of movement varies horizontally. Thus the highest terraces we saw were those at Cape Starashchin, which slope downward towards the east. The

[1] T. G. Bonney, 'Ice-blocks on a Moraine,' Nature, vol. xl (1889) p. 391.

[2] P. F. Kendall, 'Geological Observations upon some Alpine Glaciers,' Glac. Mag. vol. ii (1894) p. 121.

[3] T. C. Chamberlin, 'Glac. Stud. Greenland,' Journ. Geol. vol. v (1897) p. 231.

[4] G. F. Wright & W. Upham, 'Greenland Icefields,' 1896, p. 95.

[5] W. Sherwood, 'Glaciers of Val d'Hérens,' Nature, vol. xlvii (1892) p. 174.

[6] W. O. Crosby, 'Englacial Drift,' Amer. Geol. vol. xvii (1896) p. 225.

terraces at the mouth of the Sassendal similarly descend to the south-east.

The elevation was most rapid on the south side of Ice Fiord, especially near its mouth, which is the line of greatest recession of ice. This coincidence is in harmony with Baron de Geer's[1] theory that depression and elevation have been often determined by the formation and disappearance of an ice-load.

Hence the weight of an ice-cap on Snowdon might itself lead to a depression of the area. This would lessen the height up which the Moel Tryfaen shells would have had to be uplifted by a glacier on the one theory. But, on the other hand, it would weaken the argument against the marine origin of the Moel Tryfaen sands based on the absence of evidence of submergence in other districts.

We therefore express no opinion as to the origin of these drifts, as we see no impossibility either in the local subsidence of the Snowdon area or in the uplift of the shells by land-ice.

(5) The Flow of Glaciers.

The internal processes in a glacier by which this uplift of material by ice is possible are intimately connected with the flow or advance of the glacier-ice. The mechanical processes are of three kinds.

There is first a simple flow like that of the Swiss glaciers, which takes place mainly in the upper layers which are free from intraglacial material. The ice in these upper layers appears more flexible than that of Switzerland, for the ice in the terminal cornice is often bent and curved. The greater flexibility may perhaps be due to the larger size of the glacier-grains, some of which are enormous. Some of them, in a block which had fallen from Booming Glacier, were 4 inches in diameter. These were much larger than any we had seen in Switzerland; and the biggest that we remember recorded thence were some found by Forel on the Aletsch Glacier, which were as much as 3 inches in diameter.

The nature of the ice-movement in the lower débris-laden portions of the glacier appeared to be very different from that of the upper part, for the ice behaves as if it were rigid and inflexible. The mere existence of vertical 'Chinese walls' shows that the ice is not capable of rapid change of shape. The advance of the ice is effected not by a flow like that of a viscous substance, but by a continual series of deformations, like a rock which is yielding under great strains. The ice is crushed and fractured, and successive slices are thrust forward along shearing-planes. A certain amount of melting and regelation also takes place, but these processes are much less important than in the case of Alpine glaciers or of the layers free from débris.

A third type of advance occurs in cases where the upper layers

[1] G. de Geer, 'Quaternary Changes of Level in Scandinavia,' Bull. Geol. Soc. Amer. vol. iii (1892) p. 67; 'On Pleistocene Changes of Level in Eastern North America,' Proc. Bost. Soc. Nat. Hist. vol. xxv (1892) pp. 459, 473–474.

of the glacier move more rapidly than the lower; the glacier then progresses by an overrolling movement, banks of ice-talus being formed in front, which are subsequently overridden and again incorporated in the glacier.

(6) The Transport of Material.

All the material carried by the glacier was either supraglacial or intraglacial. At least, we saw no sign of the dragging forward of subglacial moraine matter.

The supraglacial material is mostly angular, and agrees in general characters with that of Swiss supraglacial moraines. The main differences are that the erratics are usually smaller and the matrix more argillaceous, both of which are due to the nature of the rocks of the country and not to the glacial agencies.

The material carried intraglacially is very abundant, and forms the principal constituent of the Spitsbergen moraines. As is known to be the case in Greenland, and as is assumed to have been the case in the North American ice-sheet,[1] the material is mainly scattered through the lower layers of the ice; but there are cases in which it occurs throughout the whole thickness of the glacier. The material may be uniformly scattered through the ice, but it is generally collected along lines or into lenticular masses. It varies in amount from a thin dust, which slightly discolours the ice, to moraine-stuff which is simply held together by a small proportion of ice. We have referred to this material as intraglacial, instead of as 'englacial,' owing to the varying meaning given to the latter term. It was first proposed in 1883 by Chamberlin[2], who then used it in contra-distinction to 'supraglacial' to include all 'the material embraced *within* the glacial ice.' Later on, however, Prof. Chamberlin limits the term to the material in the upper layers of the glacier. Thus he[3] remarks:—'The term *englacial*, as here used, does not include such materials as may be lodged in the basal stratum of the ice and brought down to the actual bottom by basal melting.' Hence, Prof. Chamberlin would exclude from the category of englacial drift by far the larger proportion of the material which we include in 'intraglacial' drift; for we include therein all materials included in the ice between the surface and sole of the glacier.

Other authors, such as Mr. Warren Upham[4]—the most energetic recent champion of the importance of 'englacial' drift,—use the term in a wider sense than either of the definitions just quoted. The difference in terminology no doubt increases the apparent difference of opinion as to the importance of intraglacially-carried

[1] W. Upham, 'Englacial Drift,' Amer. Geol. vol. xii (1893) pp. 38–39.

[2] T. C. Chamberlin, 'Preliminary Paper on the Terminal Moraine of the Second Glacial Epoch,' Ann. Rep. U.S. Geol. Surv. no. iii (1883) p. 297.

[3] T. C. Chamberlin, 'The Nature of the Englacial Drift of the Mississippi Basin,' Journ. Geol. vol. i (1893) p. 60.

[4] W. Upham, 'Irregularity of Distribution of the Englacial Drift,' Bull. Geol. Soc. Amer. vol. iii (1892) pp. 134–148.

material. Our observations certainly support the views of those who—like Mr. Goodchild, Mr. Upham, and Prof. Crosby—have attributed great importance to it. The distinction between supraglacial and intraglacial material is no doubt arbitrary, for débris may easily pass from one class to the other: the lowering of a glacier's surface by ablation must increase the supraglacial, at the expense of the intraglacial material.

The separation of intraglacial from subglacial material appears to us far less definite; and the six criteria suggested by Mr. Upham [1] are inapplicable in Spitsbergen. As we have previously remarked (p. 203), there is a very gradual passage from intraglacial to subglacial moraine-matter, although a sharp separation between them is often assumed, as, for example, by Upham.[2] The melting of an ice-sheet probably takes place on the lower as well as on the upper surface, and this may lead to some intraglacial material becoming subglacial. We agree, therefore, with Crosby [3] when he argues that there is 'no definite distinction between subglacial and englacial till, because, broadly speaking, it has all been englacial.'

We have especially quoted Mr. Upham as the latest champion of the importance of intraglacial material; but we have not forgotten that this view was upheld in this country many years previously by Mr. J. G. Goodchild [4] in his remarkable paper on 'The Glacial Phenomena of the Eden Valley and the Western part of the Yorkshire-Dale District.' We were constantly reminded during our study of the Spitsbergen glaciers of his protest against regarding Glacial Drifts as a ground-moraine, and of his explanation of their deposition by the quiet melting-away of an ice-sheet charged with rock-fragments. This paper was written 23 years ago; but the views expressed therein as to the transport and deposition of glacial beds agree more nearly with the glacial phenomena seen in Spitsbergen than those of any other contribution that we know to British glacial geology.

(7) Glacial Gravel-hills.

As in the case of recent observers in Greenland,[5] we saw no sign of the formation of eskers in either supraglacial or subglacial channels, or by streams flowing through ice-cañons. The only eskers that we found must have been formed by torrential action at

[1] W. Upham, 'Criteria of Englacial & Subglacial Drift,' Amer. Geol. vol. viii (1891) p. 377.

[2] *Id.*, 'Englacial Drift,' Amer. Geol. vol. xii (1893) p. 38.

[3] W. O. Crosby, 'Englacial Drift,' Amer. Geol. vol. xvii (1896) p. 222.

[4] Quart. Journ. Geol. Soc. vol. xxxi (1875) pp. 55–99, pl. ii; and 'On Drift,' Geol. Mag. 1874, pp. 496–510. The former paper is reprinted, with additions and explanations, in Trans. Cumb. & Westmorl. Assoc. no. xii (1887) pp. 111–167.

[5] For example, R. D. Salisbury, 'Salient Points concerning the Glacial Geology of North Greenland,' Journ. Geol. vol. iv (1896) p. 809. An esker was described by Kornerup at Arsalik near Holstenborg, 'Geologiske Iagttagelser fra Vestkysten af Grönland (66° 55′–68° 15′ N. Br.),' Meddel. om Grönl. vol. ii (1881) pp. 192–193, 245.

some distance from the edge of the ice. None of the river-channels that we saw either in or on the ice contained much débris.

In this connexion we may mention that a few drumlin-like mounds were met with, but not in such a position as to throw any further light on their formation.

(8) Differential Flow in Glaciers, and the Striation of Intraglacial Material.

Differential flow occurs in glaciers on a small scale, owing to the movement along shearing-planes; and one consequence of this appears to be a striation of the materials carried in the glacier. Prof. Russell[1] has recently pointed out that ice charged with débris must be more rigid than pure ice otherwise of the same character. When, therefore, a block composed of alternate layers of clean and débris-charged ice is subjected to pressure, it will yield more readily along the pure layers, and thus at once cause a differential flow. The pure layers are not absolutely free from débris, but usually contain some scattered pebbles, which will be dragged forward across the face of the débris-charged layer, causing mutual abrasion of the rock-fragments. Only by some such process can we account for the striation and rounding of the intraglacial material in some Spitsbergen glaciers.[2]

(9) The Evidence for Interglacial Periods.

The advance and retreat of the Spitsbergen glaciers are very irregular, and appear to be often due to quite local climatic changes. Ground from which ice has receded soon becomes covered with vegetation and inhabited by reindeer and foxes. The latter animals make caches of dead reindeer-meat as a supply for the winter, for we found heaps of bones which can have been collected only by foxes. The remains of plants and bones may thus readily become interstratified between beds of glacial drift by a further local advance of the ice.

We found moreover, in several places, a growth of plants on mud-hills covering sheets of 'fossil ice.' Owing to the protection of the overlying débris, the ice was melting very slowly; but as it dwindles in mass, numerous slips take place in the mud-hills, leading to the burial of the plants in a very admirable preserving medium. A future examination of these beds would probably show a remarkable interstratification of true glacial deposits with clays containing fossil plants and reindeer-bones.

[1] J. C. Russell, 'The Influence of Débris on the Flow of Glaciers,' Journ. Geol. vol. iii (1895) p. 823.

[2] The striation of boulders carried intraglacially has been suggested by Kendall, Glac. Mag. vol. ii (1894) p. 45. But the angularity of most of the Swiss intraglacial débris is a further indication of the simpler character of the movements in the ice there. The fact has been used by Chamberlin, Bull. Geol. Soc. Amer. vol. v (1894) p. 85, as an argument against the uplift of material in glaciers.

(10) Glacial Erosion.

The Spitsbergen fiords have been often quoted as due to the erosive action of ice. But, as we hope to show in describing the structural geology of Spitsbergen, the fiords are the direct consequence of earth-movements. There is no evidence of the fiords having been even considerably enlarged by glacial action. So far as our observations extended, they support the views of those geologists—notably Prof. Bonney[1]—who have denied to glaciers more than a limited abrasive power.

(11) Glacial Periods as a Result of Epeirogenic Movements.

The theory that glacial periods have been formed as a consequence of epeirogenic uplifts receives no support from the glacial history of Spitsbergen. Throughout Kainozoic times Spitsbergen seems to have been part of a great land-area. In the Pleistocene period there came a depression, which appears to have coincided with the maximum glaciation of the country; for there is no trace of marine shells in the late Kainozoic, except after the time of the greatest extension of the glaciers. Moreover, the gradual elevation that is still taking place has been coincident with a general retreat of the glaciers; for the cases of local advance are not sufficient to outweigh the general evidence of a considerable recent decrease in the extent of the Spitsbergen ice-fields.

EXPLANATION OF PLATES XIII–XIX.

[All the Plates, except Pl. XV, fig. 1, & Pl. XIX, fig. 2, are reproduced, by kind permission of the Council of the Royal Geographical Society, from blocks in their possession.]

Plate XIII.

Fig. 1. Stratified morainic material in ice, Plough Glacier.
2. Contorted morainic material in ice of Reiper Glacier.

Plate XIV.

Fig. 1. Formation of crescentic moraines, Grit Ridge.
2. Terminal moraine, Ivory Glacier.

Plate XV.

Fig. 1. Moraine of Ivory Glacier.
2. Ivory Glacier, overriding terminal moraine.

Plate XVI.

Fig. 1. Further advance of Ivory Glacier, overriding terminal moraine.
2. Westernmost view of Ivory Glacier, ice advancing.

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[1] T. G. Bonney, 'Do Glaciers Excavate?' Geogr. Journ. vol. i (1893) pp. 481–499. For a recent summary of the literature on the subject, with a verdict adverse to the erosive theory, see G. E. Culver, 'The Erosive Action of Ice,' Trans. Wisc. Acad. Sci. vol. x (1895) pp. 339–366.

PLATE XVII.

Fig. 1. Terminal fronts of Booming and Baldhead Glaciers.
2. Ice-talus formed from advancing upper layers, Booming Glacier.

PLATE XVIII.

Fig. 1. View showing the raised edge of Booming Glacier.
2. Booming Glacier, looking up.

PLATE XIX.

Fig. 1. Upper portion of Booming Glacier, showing the centre sagging away from the side of the valley.
2. View of Starashchin Ridge.

DISCUSSION.

Sir MARTIN CONWAY called attention to the fact that the whole of the oval terminal dome of the Ivory Glacier—3 miles wide, 2 miles long, and about 400 feet thick—had been formed by the advance of the glacier from the neighbouring side-valley to the north since Von Heuglin's visit to Agardh Bay in 1870. The moraine-hills (220 feet above the level of the raised beach below) had therefore all been formed within that short interval. Referring to the advance of some of the Spitsbergen glaciers and the retreat of others, he pointed out that the glaciers which terminate with an ice-cliff in shallow bays, if they do not advance over the moraines deposited by them in the water, must cut themselves off from the water by a ring of terminal moraines. Instances of glaciers thus cut off, and of others thus advancing into the sea, were observed by the 1897 Expedition.

Prof. BONNEY enquired whether Dr. Gregory had been able to establish any relation between the height to which a glacier had lifted material and that from which it had descended. He doubted whether much striation of pebbles would go on in the ice, but said that in Switzerland the number of striated pebbles increased as the moraine became more distant from the present end of the glacier. He also asked whether the beach-material was found to rise from the north towards the south, that is, in the direction of movement of the glacier. He thought the paper a most important one.

The Rev. EDWIN HILL said that now for the first time we are given an intelligible theory of how moving ice may pick up materials and raise them high above its floor. The advance as described seemed analogous to that of a wave breaking on a beach, or a 'bore' advancing up a river. The uplifting action required a good deal of thought to attain a clear conception of its cause. The talus would doubtless be incorporated in the advancing mass and, he thought, might not much impede it, but the theory seemed complete, and independent of this. Such ice as that described neither ploughed nor eroded, contrary to common views, nor did he hear anything of intercrossing streams. A medial hollow might follow from sub-glacial melting, but what was the cause of advance if the rear were lower than the front? He had never listened with more interest to any paper.

Mr. P. F. Kendall said that the paper would mark a distinct epoch in British glacial geology. Hitherto, one body of geologists had attributed the drift-deposits of Britain to the agency of land-ice, while another had invoked the agency of the sea. The latter had argued that glaciers cannot move uphill, that they cannot transport materials from lower to higher levels, that glaciers cannot gather up materials over which they are moving, and that even if they could pick up shells they would grind them to powder. The Authors have shown that the glaciers of Spitsbergen were actually doing each of these things. In his experience of the Alps he had never failed to find a profusion of scratched stones, and had observed in front of the Gorner Glacier actual striated pavements of well-glaciated boulders showing the 'forced arrangement' described by Hind. The ability of glaciers to striate englacial materials seemed to be indicated by the fact that, on the surface of the Findelen Glacier, scratched stones had been found (by himself and others) which were being liberated by melting from a gravel-filled crevasse. He had ascribed the striations to chafing in the crevasse by differential movements of the ice. The sharp splintered peaks referred to by the Authors need not imply that they had never been overridden by ice. Mr. G. H. Barton had described similar appearances in the Nugsuak peninsula, where, however, the occurrence of boulders and other indications showed that, though the rocks had been beneath the ice, rapid shattering by frost had destroyed the rounded glacial contours.

Mr. Marr also spoke.

Dr. J. W. Gregory expressed gratitude for the reception of the paper. With regard to the points raised in the discussion, he said that Mr. Kendall's Swiss case of the striation of intraglacial material was noticed in the paper. They had considered the probable destruction of glaciated contours by frost, and Prof. Tarr's suggestions as to the preservation of jagged outlines under an ice-sheet; but they could not understand the sharp boundary between glaciated and non-glaciated slopes, except on the view that the latter had stood out above the ice. They had seen cases of differential movement in glaciers on a great scale, the ice at different levels travelling in different directions. The forward advance of the end of Booming Glacier in spite of the shrinking of the upper part is probably due simply to gravity, the glacier resting on a slope. He agreed with Mr. Hill that the retardation of the advance of the lower layers of the glacier by the talus-bar is unessential, nevertheless he thought that this retardation did take place.

Mr. Garwood, in reply to Prof. Bonney, pointed out that, owing to the radial spreading-out of the Ivory Glacier where it debouches onto the flat estuary in Agardh Bay, nothing but the terminal front is visible. In reply to Mr. Hill he observed that, although the Authors did not rely at all on the retardation of the lower layers of the ice by the accumulated talus for the formation of the vertical fronts, nevertheless they considered that this talus would probably assist in that formation.

With regard to the question of the excavating power of an advancing glacier, he thought that the very mode of advance of Arctic glaciers, as described in the paper, militated strongly against any appreciable action of this kind.

Commenting on the contrast between the angular contour of the higher ground and the curved slopes below, he pointed out that the extremely rapid weathering so clearly taking place at the present day must long since have removed most of the more obvious signs of glaciation, if these had been impressed on the high ground in former times.

He described a deposit of glaciated fragments of granite and diabase occurring on the plateau of Sticky Keep in the Sassendal, at a height of 1200 feet above the floor of the valley. These rocks must have been removed from the north, and have crossed the Sassendal, unless we assume the formation of the valley subsequently to the transport of the boulders. In his second visit to the island last summer, he had obtained evidence confirmatory of this, which he hoped to have the pleasure of laying before the Society at an early date.

17. NOTE on CLIPPERTON ATOLL (NORTHERN PACIFIC). By REAR-ADMIRAL Sir WILLIAM J. WHARTON, R.N., K.C.B., F.R.S., Hydrographer to the Admiralty. (Communicated by Sir ARCHIBALD GEIKIE, D.Sc., LL.D., F.R.S. Read March 9th, 1898.)

[PLATES XX–XXII.]

IN the eastern part of the Northern Pacific, in lat. 10° 17′ N., long. 109° 13′ W., and 600 miles away from the nearest point of the continent of North America, is a small, lonely atoll called Clipperton. It has never been properly surveyed, but was in 1840 sketched by Capt. Sir E. Belcher, R.N.

Its lagoon, 2 miles in diameter, was then open to the sea in two places, both shallow. The remainder of the ring surrounding it was a few feet above water, forming two flat, bare, crescent-shaped islands. It was the haunt of innumerable sea-birds, as might be expected from its solitary position, and it is doubtless to these birds that the fact that no scrap of vegetation exists is due.

Since the date of Sir E. Belcher's visit the entrances have been closed by piled-up coral-sand, the ring is complete, and the lagoon is cut off from the influx of ocean-waters, except by infiltration.

So far, Clipperton Atoll only resembles many other islands of similar type and position, but there is one point which distinguishes it, so far as I know, from all other atolls, and that is the existence on one part of the ring of a mass of rock about 60 feet in height. Some atolls have an island somewhere near the centre of the lagoon, but none, as this, on the ring itself.

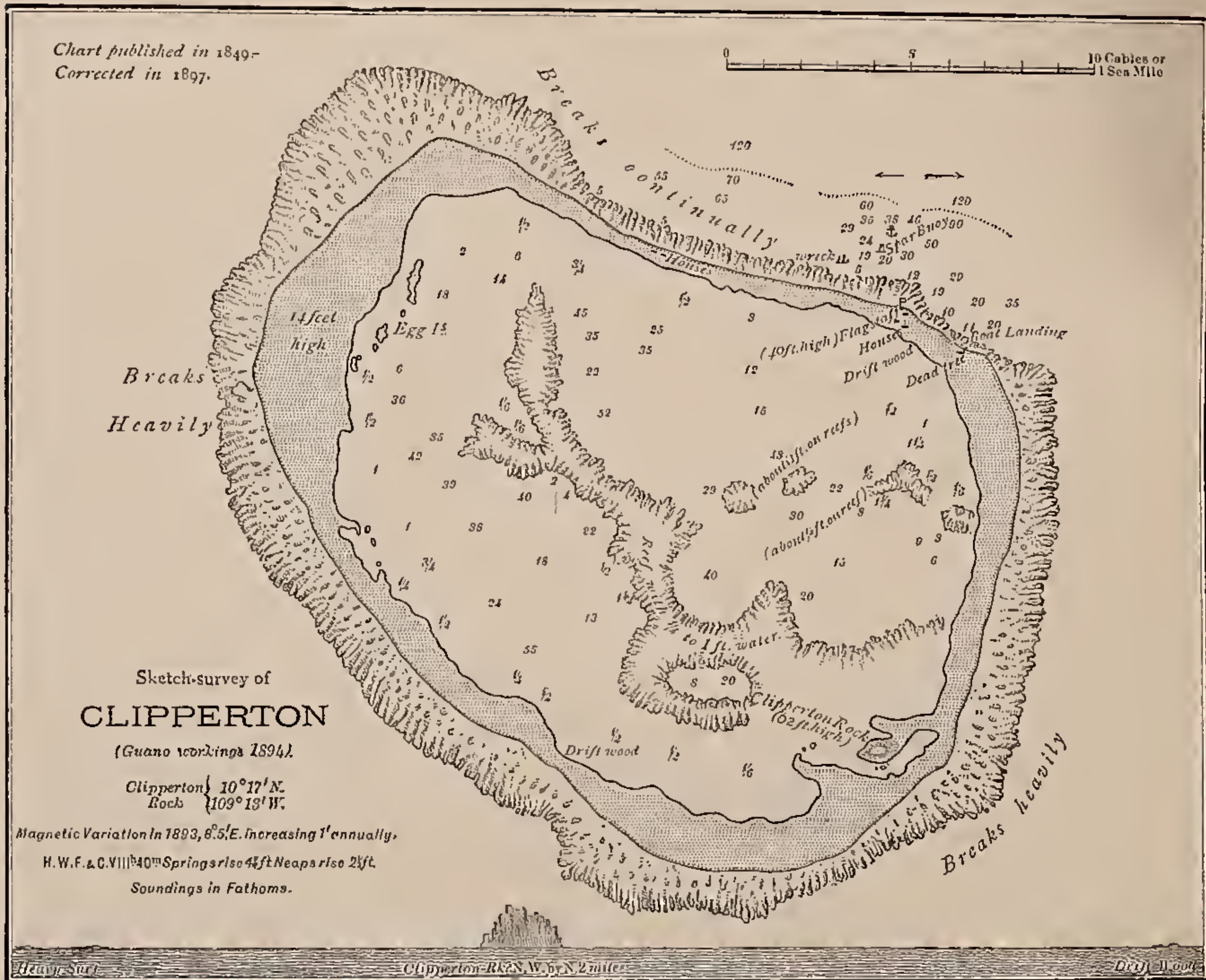
I have long wished to know the geological character of this rock, but it is only lately, by the kindness of Mr. J. Arundel, who visited the island in connexion with its guano-deposits, which have been for some time worked, that I have obtained specimens of it. Mr. Arundel, in sending me the hand-specimens, stated that the rock was composed of volcanic material and coralline limestone mixed, and on receiving them I imagined that he had, except in one case, sent me specimens of the calcareous rock only.

I sent the specimens to Sir A. Geikie, who showed them to Mr. Teall, and I believe that their first impression was similar to my own. They found, however, that the pale specimens did not effervesce with acid, and could not therefore be unaltered coral-rock, while the only dark specimen contained porphyritic felspars in a finely crystalline base which they surmised to be some variety of trachyte or andesite. Mr. Teall's subsequent investigation, submitted to the Society together with the present Note, brings to light a remarkable change in the structure and composition of the apparently calcareous specimens, which have proved to be all of the same trachytic origin.

The position of this undoubtedly volcanic mass is of great interest. By no theory of the formation of atolls can the survival of a portion

REDUCED FROM THE ADMIRALTY CHART.

e seen 4 or 5 leagues away.]



MAP OF CLIPPERTON ATOLL, REDUCED FROM THE ADMIRALTY CHART.

[The rock may be seen 4 or 5 leagues away.]

Fig. 1.—*Stratified morainic material in Ice-plough Glacier.*

Fig. 2.—*Contorted morainic material in ice.*

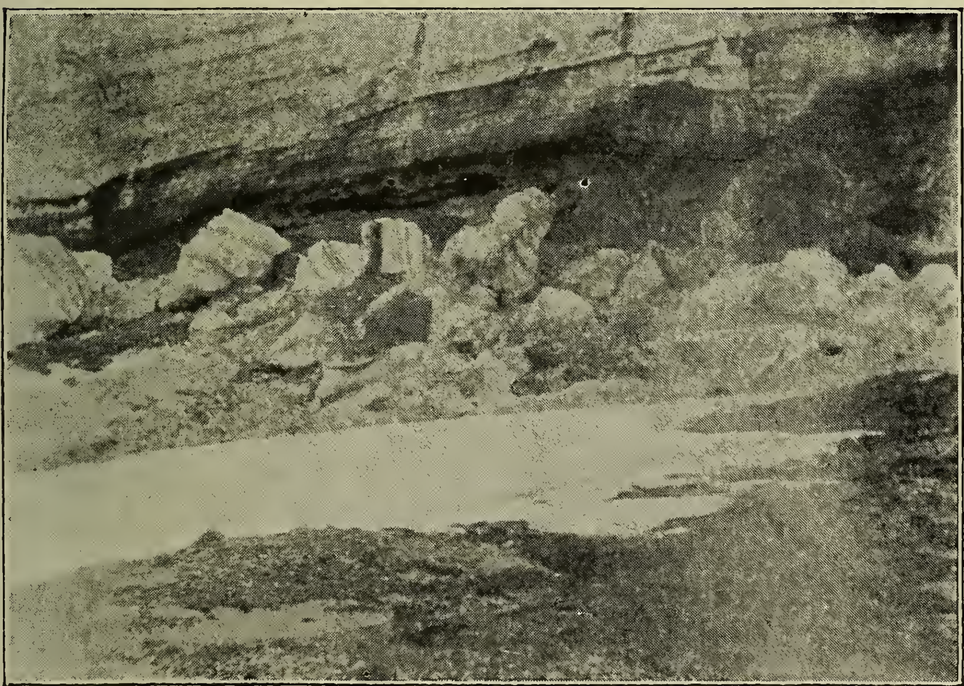


Fig. 1.—*Formation of crescentic moraines, Grit Ridge.*

Fig. 2.—*Terminal moraine, Ivory Glacier.*

Fig. 1.—*Moraine of Ivory Glacier.*

Fig. 2.—*Ivory Glacier, overriding terminal moraine.*

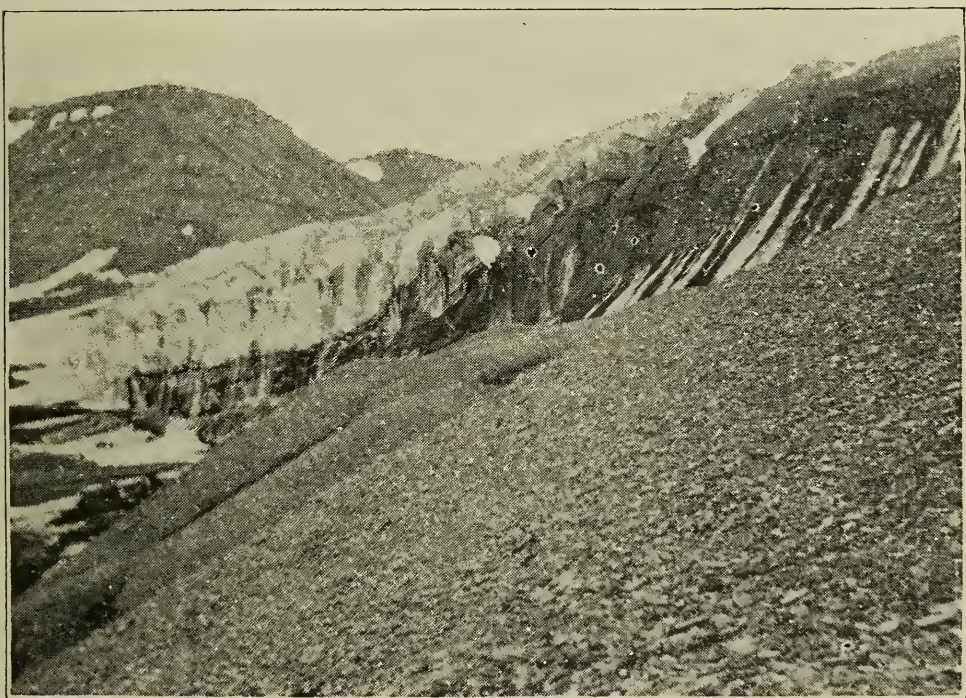


Fig. 1.—*Further advance of Ivory Glacier, overriding terminal moraine.*

Fig. 2.—*Westernmost view of Ivory Glacier, ice advancing.*

Fig. 1.—*Terminal fronts of Booming and Baldhead Glaciers.*

Fig. 2.—*Ice-talus formed from advancing upper layers, Booming Glacier.*

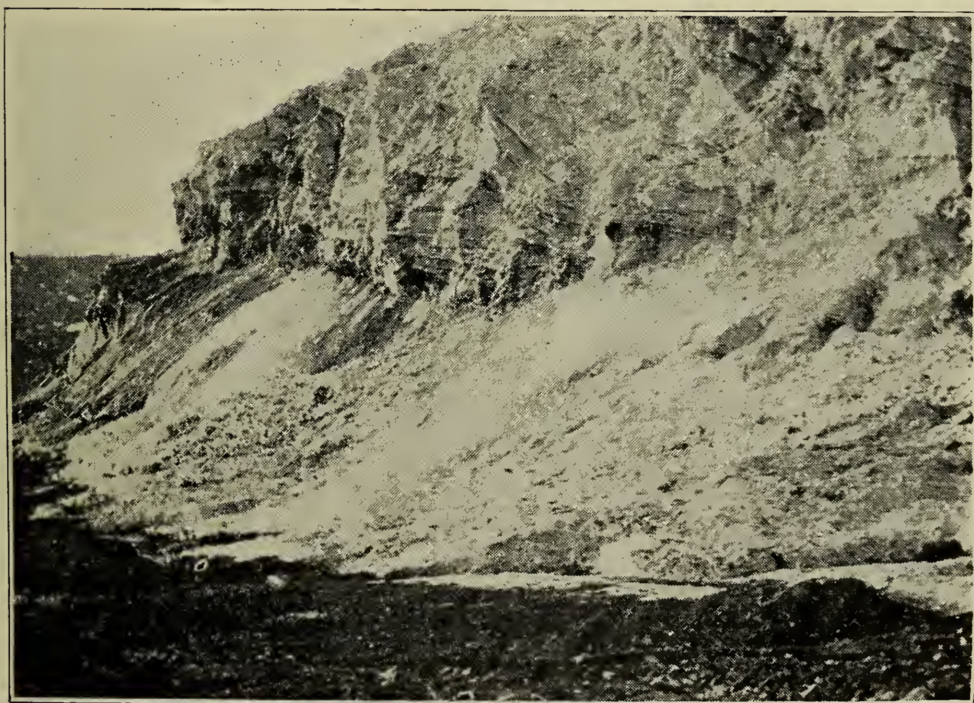


Fig. 1.—*View showing the raised edge of Booming Glacier.*

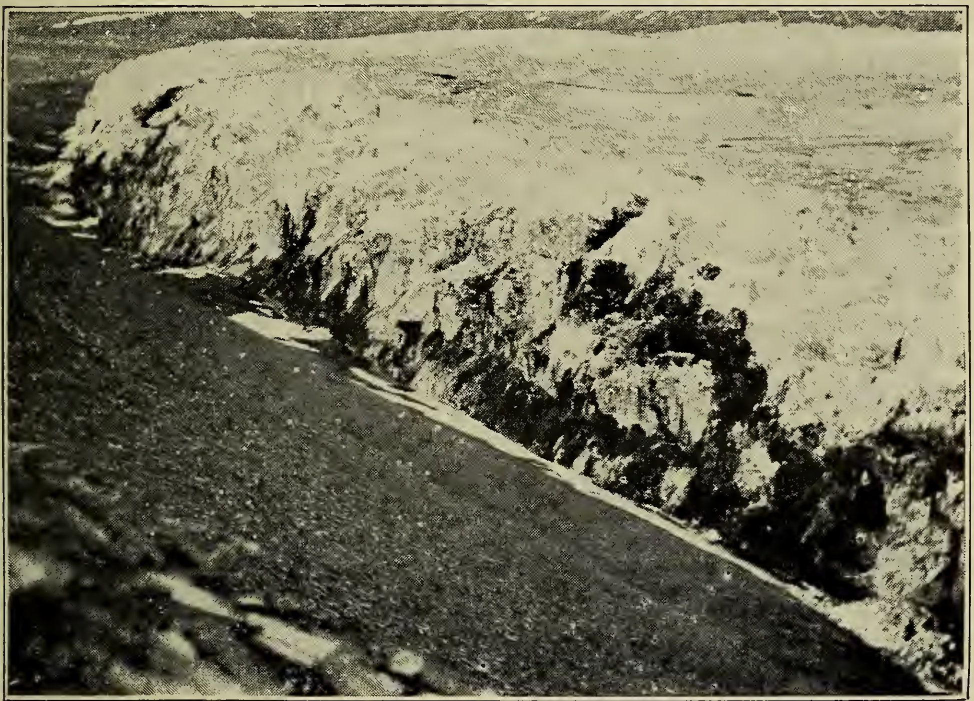


Fig. 2.—*Booming Glacier, looking up.*

Fig. 1.—*Upper Portion of Booming Glacier, showing the centre sagging away from the side of the valley.*

Fig. 2.—*Starashchin Ridge* (*Spitsbergen*).

Rock on Clipperton Atoll, looking north-west.

Near View of Rock on Clipperton Atoll.

of the volcanic base on the rim alone be explained. If the island has sunk, why is it not, as in all other cases, in the lagoon?

If the coral circle has grown up on the flanks of the original volcanic mound, the same difficulty presents itself. Unfortunately we know nothing of the depths around; and it is only on the somewhat vague soundings of the lagoon by the captain of a merchant vessel that the plan is based, showing that the depths there are very considerable, amounting to 50 fathoms.

If this be so, it adds another peculiarity to the atoll, for in no known case is so great a depth found in so small an atoll.

On this point Mr. Arundel writes as follows:—

'After taking soundings in a perfectly round hole in the lagoon, which looks very much like an old crater, and where we obtained as much as 20 fathoms (a man named Antone claims to have got soundings at 26 fathoms), we started to the north-western side of the island. On the way from the circular basin, we took another sounding in what looked like a deep part, but only obtained 11 fathoms.'

The true greatest depth is thus doubtful; but even 20 fathoms is deep for so small an atoll.

The only solution which presents itself to me is that we here have the rare case of coral forming on the lip of a volcanic crater, one part of which alone, perhaps the plug, has resisted the action of the sea, which has worn the rest of it down to the limits of wave-action.

It will be remembered that the great explosion of Krakatoa resulted in the blowing away of a large part of the island situated above the hollowed-out interior, but that the margin of the actual vent remained on one side of the deep hole thus formed.

A similar incident, leaving a plug on one side of the crater-hollow, might explain the Clipperton Rock.

EXPLANATION OF PLATES XX–XXII.

Plate XX.

Map of Clipperton Atoll, reduced from the new Admiralty chart.

Plate XXI.

View of the rock on Clipperton Atoll, looking north-west. (From a photograph.)

Plate XXII.

Nearer view of the same rock. (From a photograph.)

18. *A* Phosphatized Trachyte *from* Clipperton Atoll (Northern Pacific). By J. J. H. Teall, Esq., M.A., F.R.S., V.P.G.S. (Read March 9th, 1898.)

[Plate XXIII.]

The following remarks are based on five rock-specimens from Clipperton Atoll, referred to by Admiral Wharton in his description of that island.

One is a dark brown rock composed of porphyritic crystals of glassy felspar and a compact groundmass; the others are white or cream-coloured, and in some of these the same porphyritic felspars as in the first-mentioned rock may be observed. The examination of a series of microscopic sections shows that the rocks are all more or less altered trachytes.

The brown rock is the least altered. It consists of phenocrysts of sanidine (Pl. XXIII, fig. 1) set in a groundmass of microlitic felspars and brown interstitial matter. No ferro-magnesian minerals are recognizable. The conspicuous phenocrysts of sanidine are, as a rule, comparatively free from inclusions; but the rock contains also some patches of felspar, which are so crowded with inclusions of a brown substance that the felspar-material forms only a small portion of the compound mass.

An analysis of this rock yielded the following somewhat surprising result:—

SiO_2	54·0
P_2O_5	8·4
Al_2O_3	17·9
Fe_2O_3	4·4
CaO	1·4
K_2O	4·5
Na_2O	5·0
Loss on ignition	3·8
	99·4

The phosphoric acid is present in the brown substance, which evidently represents, in a more or less altered form, the interstitial matter of the original trachyte.

The microscopic sections of the white or cream-coloured rocks all show the structure of a trachyte. In some specimens the phenocrysts of sanidine have been more or less preserved, while the groundmass has been replaced by isotropic secondary material; in others the phenocrysts have disappeared, and their places have been wholly or partially filled up with the same secondary substance. It is evident, therefore, that a trachyte has been attacked by some chemical process, and that a pseudomorph of the rock has been formed.

The secondary substance, when examined with a high power, often shows concentric or agate-like modes of aggregation; and, as the silicification of acid and intermediate igneous rocks is by no means an uncommon phenomenon, it was thought at first that the white rocks were merely silicified trachytes. A chemical examination at once disposed of this idea. The most altered rock possesses the following percentage composition :—

SiO_2 (2·8) and matter insol. in HCl	5·0
P_2O_5	38·5
Al_2O_3	25·9
Fe_2O_3	7·4
Loss on ignition	23·0
	99·8

Thus 95 per cent. of the rock is a hydrated phosphate of alumina and iron, somewhat allied to the so-called redonite from the island of Redonda, in the West Indies.[1]

The appearance of a microscopic section of this rock is represented in Pl. XXIII, fig 2. The outlines of one of the porphyritic felspars are clearly seen, but the original substance has been replaced by the phosphate, which shows the peculiar agate-like structure above referred to. The groundmass has also been replaced by the same material.

To complete the chain of evidence, an intermediate specimen, in which the phenocrysts were comparatively unaltered and the original structure of the groundmass was well preserved, was partially analysed. It contained 43·74 per cent. of silica, 17 per cent. of phosphoric anhydride, and gave 12·3 per cent. loss on ignition.

The three specimens above described illustrate very clearly the progressive substitution of phosphoric for silicic acid, and the introduction of water :—

	I.	II.	III.
SiO_2	54·0	43·7	2·8
P_2O_5	8·4	17·0	38·5
Loss on ignition	3·8	12·3	23·0

A comparison of the whole series of microscopic sections proves that the phosphatizing process first attacks the interstitial matter, then the microlitic felspars of the groundmass, and last of all the porphyritic sanidines.

The chemical analyses show that the change is accompanied by the removal of silica and alkalies, and by the introduction of phosphoric acid and water. This change has probably been effected by solutions of alkaline phosphates, principally ammonium phosphate, and other compounds derived from the droppings of sea-birds.[2]

[1] C. U. Shepard, Am. Journ. Sci. vol. xlvii (1869) p. 428, and vol. l (1870) p. 96.

[2] Some additional specimens from Clipperton have been received from Admiral Wharton. They are portions of coral-rock more or less phosphatized.

Since the above was written my attention has been called to an important series of papers[1] by M. Armand Gautier on the phosphatic deposits of the 'Grotte de Minerve.'

This cavern is situated in the valley of the Cesse, in Hérault, at the junction of the Nummulitic Limestone and Devonian. The walls and roof are of limestone; the floor is formed of a Quaternary deposit, containing mammalian remains and resting on the Devonian. At a depth of 3 or 4 metres from the surface a yellowish rock is met with, containing 50 per cent. of the phosphates of lime and alumina. During his excavations in this cavern M. Gautier found a vein of a white, pasty substance, composed almost entirely of a hydrated phosphate of alumina (P_2O_5, Al_2O_3, 7 H_2O), for which he proposed the name 'minervite.' He considers that this substance has been formed by the action of ammonium phosphate arising from the decomposition of organic matter, on clay or hydrargillite. In support of this view he shows that precipitated alumina can be wholly converted into a phosphate having the composition of minervite, by the action of a solution of ammonium phosphate, and that kaolin can, in the same way, be partially changed into a similar phosphate. He refers to the deposits of Alta Vela, Redonda, and Commandeur (French Guiana), and concludes that they have been formed in a similar manner.

Owing to the kindness of Mr. J. Hort Player, I have obtained specimens of the phosphates of Redonda and Connétable (French Guiana). Those from Redonda are brown or buff-coloured porous rocks, some of which clearly show the structure of an andesite. There can be no doubt that some, if not all, of the Redonda phosphate has been formed from an andesite in the same manner as that of Clipperton has been formed from a trachyte.

The specimens from Connétable, a small island near Cayenne, do not show igneous structure. They are whiter than the specimens from Redonda, and closely resemble some portions of the Clipperton rocks in which the igneous structures have disappeared.

We may, therefore, conclude that the formation of phosphates of alumina and iron is by no means an uncommon occurrence when guano is deposited on igneous rocks.

EXPLANATION OF PLATE XXIII.

Fig. 1. Altered trachyte from Clipperton Atoll, showing phenocrysts of sanidine set in a groundmass of microlitic felspars and brown interstitial matter. In the central lower portion of the slide is an example of the felspar crowded with brown inclusions.

2. Highly altered trachyte, showing the replacement of felspar by phosphate with concretionary structure, and the groundmass replaced by a similar material, but without concretionary structure.

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[1] 'Formation des Phosphates naturels d'Alumine et de Fer,' Comptes Rendus, Acad. Sci. Paris, vol. cxvi (1893) p. 1491. See also other papers in the same volume on pp. 928, 1022, and 1171.

Fig. 1.

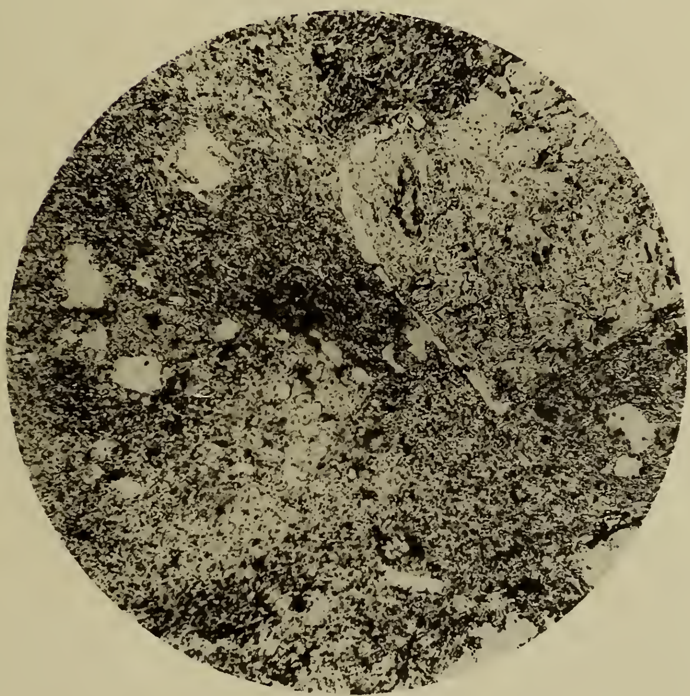

Fig. 2.

Phosphatized Trachyte from Clipperton Atoll.

Discussion (on the two preceding Papers).

Prof. Clowes stated that, as a chemist, he felt much interested in Mr. Teall's paper. He assumed that the Author intended it to be understood that a double decomposition took place between the ammonium-phosphate solution derived from the guano and the insoluble aluminium silicate of the rock; in that case, ammonium silicate would pass away in solution, and no deposition of silica would take place in the rock. From a chemical standpoint, the Author had fully proved an extremely interesting case of chemical metamorphosis. It reminded the speaker of a somewhat analogous instance of chemical change, which he discovered in conjunction with Prof. Blake some years since in the neighbourhood of Nottingham. There a rock containing barium carbonate had apparently undergone change into barium sulphate, by the action of water containing calcium sulphate; this change was known to take place, but in the above instance the change lacked the satisfactory proof given by the present Author.

Dr. Blanford said that he could not agree with Admiral Wharton that the facts as stated are incompatible with subsidence. Neither a volcanic crater with a distinct rim, nor a lava-flow, such as the phosphatized trachyte appeared to have been originally, could be of submarine origin; nor was it probable that either originated on a level with the surface of the sea. It was more likely that both crater-rim and lava were formed above the sea, and had been depressed.

Mr. Clement Reid asked what climatic conditions held on this island—was it a rainless area, or one with alternate rainy and dry seasons?

Capt. Stiffe observed, with reference to the question of climatic conditions raised by the previous speaker, that he believed deposits of guano could be accumulated only in a comparatively rainless district, as in rainy localities the guano would be washed away as quickly as deposited.

Prof. Hull and Mr. Bauerman also spoke.

Sir A. Geikie, in reply to the remarks made by previous speakers, said that he unfortunately possessed no information regarding the meteorology of Clipperton Atoll. He could see no reason why a volcanic crater should not be formed below the surface of the sea; but the Clipperton crater may have been of the same explosive origin as that of Santorin, and its solitary rocky peak may be the only remaining visible fragment of its rim. With regard to the supposed impossibility of lavas having flowed under the sea, he could only observe that no facts in the geological history of Britain were more abundantly proved than that from the earliest Palæozoic periods the vast majority of the volcanic eruptions in our region have been submarine, and that they have included the outflow of lava, the solid, unbroken sheets of which are now found intercalated between strata full of marine organisms.

Mr. Teall also replied.

19. *The* Eocene Deposits *of* Devon. By Clement Reid, Esq., F.L.S., F.G.S. (Read March 23rd, 1898.)

[Communicated by permission of the Director-General of H.M. Geological Survey.]

In a paper read before this Society in 1896 I gave a short description of the Eocene Deposits of Dorset, and remarked that 'It is noteworthy that the new evidence discovered in the western end of the Hampshire Basin strongly supports the idea that the pipeclays of the Bagshot Series are derived from the weathering of the Dartmoor Granite, and that the Bovey Tracey outlier, so like the deposits around Bournemouth, is, as maintained by Mr. Starkie Gardner, of the same age and deposited in the same basin, though in Devon Eocene rest directly on Palæozoic rocks.'[1] Since these words were written I have had occasion to re-examine the Bovey basin on behalf of the Geological Survey, with the result that light can now be thrown on several obscure points in the geology. As my notes on the Bovey area will complete the general description of the western end of the Hampshire Basin, it will be useful to lay before the Society the results, especially as much detailed work remains to be done and it will be at least 3 years before any general memoir can be published.

In the year 1875, when Mr. H. B. Woodward was revising the geology of the Bovey basin, and I was engaged in mapping the Greensand and plateau-gravel of Haldon, we were much exercised as to the age and relationship of the deposits, but then had no clear evidence to permit us to go contrary to the received ideas, though Mr. Woodward published a paper in which he gave reasons for reducing the low-lying Greensand outliers to two small and doubtful patches, at Haccombe and Combe. He also suggested that the plateau-gravel of Haldon might be of the same age as the marginal gravels of the Bovey Valley, considering both as 'Drift' and regarding the latter—erroneously, I think—as overlying the Tertiary pipeclays.[2] Since that time I have mapped the greater part of the Tertiary strata of the Hampshire Basin, and have been drawing nearer and nearer to the Devon area which I examined more than 20 years ago. Dorset brought out some quite unexpected resemblances between the undoubted Bagshot Series and the so-called Miocene of Bovey, placing me in a position to read the new evidence without difficulty as soon as there should arise an opportunity of revisiting the latter area.

In the summer of 1897 I revisited Devon. Commencing at

[1] 'The Eocene Deposits of Dorset,' Quart. Journ. Geol. Soc. vol. lii (1896) p. 494.

[2] 'Notes on the Gravels, Sands, and other Superficial Deposits in the Neighbourhood of Newton Abbot,' Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 230.

Great Haldon, the plateau-gravel, which here reaches a height of over 800 feet, was re-examined. This gravel turned out to be almost identical in composition with that of Black Down in Dorset. It, also, is mainly composed of large boulders of 'annealed' or toughened Chalk-flint, weathered to a considerable depth and often containing Upper Chalk fossils. Mixed with these is much Greensand chert, with radiolarian chert and veined Palæozoic grits like those so conspicuous farther east. At Haldon Palæozoic rocks are somewhat more common, in larger pieces, less worn, and Purbeck rocks are naturally absent; in other respects the Haldon and Dorset gravels are of identical composition and appearance, containing similar seams of white clay and rough quartz-sand. The alteration of the large Chalk-flints to the core is an important point, for in Pleistocene deposits the contemporaneous weathering seldom extends to a greater depth than $\frac{1}{8}$ inch. Eocene deposits, on the other hand, always show a curious change in the pebbles, which, even if only exhibiting conspicuous weathering to a moderate depth, are annealed and toughened to the centre. The composition, general character, and position of the Haldon gravels all point to their being of the same age as the gravels in Dorset which, for reasons already given,[1] I consider to belong to the Bagshot Series.

The reference of the high-level gravel of Haldon to the Bagshot Series naturally raises in a new form the question of the supposed Upper Greensand age of the gravels surrounding the Tertiary basin of Bovey at Combe, Milber Down, Wolborough, and Staple Hill. Combe lies about 2 miles west of Little Haldon, and about the same distance north of Kingsteignton. On the high road $\frac{1}{4}$ mile south of Combe Hill Cross a pit has been opened for road-material and sand; it shows :—

	Feet.
Coarse gravel of well-rounded large Chalk-flints, toughened and weathered to the centre; much small quartz; Palæozoic grits, coarse and fine; radiolarian chert (common), and red jasper (one pebble); greenstone and ash; Greensand chert (one large block).	12
Buff-coloured sand with much schorl................................	3

The occurrence of rolled Chalk-flints and Greensand chert makes it impossible that the gravel can be of Cretaceous age; the sand also corresponds in character with that associated with the lignite of Bovey, not with the Cretaceous sand of Haldon. The deposit agrees closely with the gravel capping Haldon, except that, resting on Palæozoic strata, and lying west of most of the Cretaceous deposits, the proportion of old rock in the gravel is considerably greater.

The supposed outlier of Greensand at Milber Down yields similar results, for the pits all contain varying quantities of Chalk-flint

[1] *Op. jam. cit.* pp. 491, 492.

and Greensand chert. Towards Haccombe numerous large blocks of Greensand chert are obtained; but close examination shows that these are waterworn masses, not blocks weathered out of solid Greensand. The same locality yields large Chalk-flints. Here again the supposed Cretaceous gravel is evidently the gravelly base of the Tertiary deposits.

West of the Aller Brook similar gravels are found close to the Waterworks Reservoir in Newton Abbot. The pit exhibits 13 feet of coarse gravel interstratified with whitish sand, the gravel being mainly composed of Chalk-flints, with a few large blocks of Greensand chert, some Culm Measure grit, and many quartz-pebbles. This gravel, and that seen in the large pit close to Wolborough Church, are clearly marginal deposits dipping sharply beneath the pottery clays which lie a short distance towards the south-east.

About 3 miles north-west of Newton Abbot lies the most westerly of these supposed Cretaceous outliers. Several large sand-pits have been opened near Lower Staplehill, and one of these shows a clear section of the gravel resting at a high angle on Devonian slates and passing beneath the lower beds of the pipeclay. The gravel at this point is largely composed of quartz, veined grit, radiolarian chert, and igneous rock, but I also found in it several masses of Greensand chert, and two rolled Chalk-flints like those of Haldon. Thus the whole of the supposed low-lying Greensand outliers contain derivative masses of Chalk-flint, and are of Tertiary age.

With regard to the age of the pipeclay and lignite of Bovey, it is difficult yet to speak with confidence. Mr. Starkie Gardner has pointed out that the flora is probably of Bagshot age, not Miocene as stated by Heer, and the resemblance of the deposits and of their flora to the undoubted Bagshot of Dorset is most striking. Still one cannot yet say that the botanical evidence is conclusive, for the species are few and greatly need re-examination. Other fossils are almost entirely absent.

The general conclusions arrived at from my recent work in Devon and Dorset are therefore:—1st, That the supposed littoral Cretaceous rocks near Dartmoor are Eocene, and that no trace of a Cretaceous shore-line is there visible. 2nd, That, as has been for some time maintained, the Bovey Beds are Eocene, not Miocene. 3rd, That the high-level plateau-gravels of Haldon, like those of Black Down in Dorset, and probably those also of the Cretaceous hills between the two districts, are of Lower Bagshot date, and mark the course of the old Eocene river.

Discussion.

Mr. A. E. Salter regretted that the Author had not illustrated his paper by sections and specimens of the very interesting and varied constituents of the gravel-deposits described. He had visited the deposits at Moreton, Hardy's Monument, Great and Little Haldon, etc., and felt bound to say that his observations did not allow him to agree with the Author as to their Eocene age. A careful study of the high-level gravels in the Thames and Hampshire Basins, together with those of Dorset and Devon, had led the speaker to suggest in a recent paper that the Black Down (near Weymouth) and Haldon gravels, together with the Westleton Drift as seen north of London, were due to Pliocene or older streams flowing in various directions from Dartmoor. He asked the Author to cite a section in the Bovey district where these gravels were to be seen underlying the Bovey clays and not merely inferred to do so. On Little Haldon the gravels in one place rest upon an uneven surface of white pipeclay.

Mr. Harmer, referring to the previous speaker's remarks, believed that the correlation of some of the gravels of the South of England with those of Westleton, which are composed almost entirely of flint, rested on a very slender foundation; but he felt inclined to fall back upon an opinion once expressed by a distinguished Fellow of this Society, that the beds at Westleton are not Westleton Beds.

Mr. R. S. Herries asked whether the Author made the statement, that the gravelly deposits passed under the Bovey Beds, from personal observation. He was glad to hear that the Author confirmed Mr. Starkie Gardner's views as to the Eocene age of the Bovey Beds.

Mr. Strahan said that the Author's identification of the gravels at Bovey seemed to depend upon the same sort of evidence as that of the Dorset outliers. These outliers had been found to correspond in character to gravels which could be actually seen passing beneath undoubted Eocene strata. That they could be of the same age as the Westleton Shingle, as suggested by a previous speaker, was disproved by the fact that they shared in the flexures which affected the Chalk and which were certainly older than the Westleton Shingle. He enquired whether it was not a fact that, of the gravels attributed to a Bagshot age, some lay at Bovey at a much lower level than others on Haldon.

The President said that he had been asked by Mr. H. B. Woodward, who was unable to be present, to state his opinion as follows:—

He (Mr. H. B. Woodward) was quite prepared to accept the Author's grouping of the older gravels at Newton Abbot. When working in that neighbourhood he had been perplexed by these deposits and had regarded them as Drift, partly because the coarse boulder-gravels which occurred there looked more like Drift than anything else; and partly because these deposits were met with at various levels in the Bovey Basin, and appeared to overlie the undoubted Bovey clays and lignites, which are confined to the basin as if deposited in an old lacustrine area. Moreover, the coarse flint-gravels occurred on the high grounds bordering the basin: so that (as he had remarked in his paper read before the Society in 1876) there seemed to be some connexion between these

Bovey gravels and the plateau-gravels which cap the Greensand heights of Devon.

Now that the Author had identified Bagshot Beds on Haldon, these anxieties and difficulties were removed; and the only question that remained was in reference to the likelihood of faulting, to account for the relative positions of the several deposits.

Prof. Judd also spoke, and the Author replied.

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[No. 215 will be published next August.]

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[With Four Plates, illustrating Papers by Mr. A. J. Jukes-Browne, Mr. F. A. Bather, and Miss G. L. Elles.]

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TO BE HELD AT BURLINGTON HOUSE.
Session 1898–99.

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Wednesday, November 9–23
„ December 7–21

1899.

Wednesday, January 4–18
„ February (*Anniversary*, Feb. 17th) 1–22
„ March 8–22
„ April 12–26
„ May 10–24
„ June 7–21

[*Business will commence at Eight o'Clock precisely each Evening.*]

20. *On an* Outlier *of* Cenomanian *and* Turonian [*equivalent to* Lower *and* Middle Chalk] *near* Honiton,[1] *with a* Note *on* Holaster altus, *Ag.* By A. J. Jukes-Browne, Esq., B.A., F.G.S. (Read March 23rd, 1898.)

[Communicated by permission of the Director-General of H.M. Geological Survey.]

The existence of an outlying tract of Chalk in the parish of Widworthy, near Honiton, has been known for many years, but no description of it has ever been published, although it is the most westerly inland tract of Chalk in England: the only more westerly patches being those on the coast.

It was known to Dr. Fitton,[2] who mentions the occurrence of a particular stone called grizzle by the quarrymen 'in a large pit or quarry at the bottom of the Chalk, near Sutton and Widworthy,' remarking also that 'it contains green particles, and does not burn to lime.'

The outlier of Chalk is marked on De la Beche's geological map published by the Geological Survey in 1845. In 1874 the district was re-surveyed by Mr. Ussher for a new edition of the Survey map,[3] but he found that the quarry referred to was disused and overgrown.

My object in visiting the locality last year was to ascertain whether the succession of beds was similar to that on the coast, in which case the Chalk would be Middle Chalk (Turonian), and the Lower Chalk would be represented by quartziferous limestone and calcareous sandstone; or whether it included anything like the more ordinary kind of Lower Chalk, such as occurs at Membury and Chard.

The geographical position of this tract is about 4½ miles south-west of Membury, 3 miles east of Honiton, and about 7 miles from the coast near Beer Head. It occupies high ground, from 400 to 500 feet above the sea.

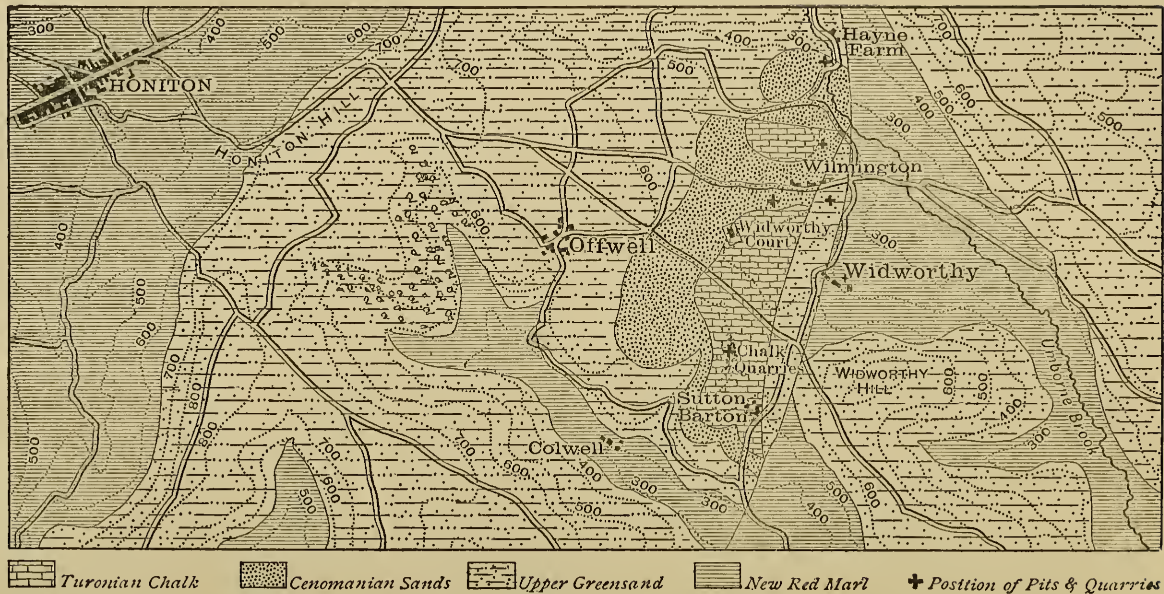
The Sutton quarries are ½ mile south-west of Widworthy Church, and are very large excavations, one pit being 50 or 60 feet deep, but entirely overgrown by grass and copsewood, so that hardly any chalk was visible at the time of my visit. In the most northerly pit, however, was a small exposure of hard calcareous sandstone; and, on making enquiries, I learned that this calcareous sandstone was the grizzle, but that the best stone, and that for which the quarries were formerly worked, was a freestone in the Chalk.

[1] [There is no Lower Chalk as chalk near Honiton, and the present writer uses the term Cenomanian for the arenaceous beds which appear to be the equivalents of the Chalk Marl in this part of Devon, and to correspond with the zone of *Ammonites Mantelli* in the West of France; see Quart. Journ. Geol. Soc. vol. lii (1896) p. 171.—April 22nd, 1898.]

[2] Trans. Geol. Soc. ser. 2, vol. iv, pt. ii (1836) p. 234.

[3] This re-survey has not yet been published.

Fig. 1.—*Geological map of the country south-east of Honiton.*



[Reproduced, by permission, from the new Geological Survey map.]
Scale: 1 inch = 1 mile.

This freestone has been used in the construction of Widworthy Court, Widworthy Barton, Sutton Barton, and other houses in the neighbourhood, so that specimens of it were easily obtainable. An inspection of them showed that the stone resembled Beer Stone so closely that I felt sure that the bed was a continuation of the stratum exposed at Beer. As a building-stone it is evidently quite as good as Beer Stone, the external angles of the stones in the buildings above mentioned being as sharp as when dressed by the mason.

Wishing to see the stone in place, I had part of the lower face of the quarry near the old lime-kiln cleared. This disclosed about 18 feet of hard chalk containing *Inoceramus mytiloides* and many pieces of *Inoceramus*-shell; at the bottom was a mass of hard shelly stone; but this was not in place, and appeared to be a block of inferior freestone left on the floor of the quarry. It was evident that much labour would be required to lay bare a face that would show the full thickness of the stone.[1]

The following information respecting the quarry was obtained from Mr. Daniel Hooper, a mason living at Offwell, who had been employed at the quarries when they were last worked, between 40 and 50 years ago. He said that the succession of beds was as follows, but the thicknesses are only approximate:—

	Feet.
7. Flint-rubble at the top	4 to 6
6. Soft white chalk	10 to 30
5. Hard chalk	about 20
4. Freestone	„ 5
3. Soft chalk with green grains	„ 5
2. Hard cockly chalk	„ 2
1. Grizzle at the bottom.	

The grizzle was not worked in his time. The freestone, or at any rate the best part of it, was about 5 feet in thickness; and the chalk above, both the hard and the soft, was burnt for lime.

The soft white chalk, of which a foot or two can be seen at the top of the quarry, most probably belongs to the zone of *Terebratulina gracilis*. No. 5 is evidently the chalk which was exposed by my excavation, and which, with the freestone, clearly belongs to the zone of *Rhynchonella Cuvieri*.[2] From the evidence of the section described hereafter near Wilmington it is probable that No. 2 is the base of this Middle Chalk or Turonian, and that the grizzle is the rock also exposed at Wilmington.

In order to show that the freestone occupies exactly the same

[1] The quarries were visited in 1894 by Mr. Rhodes, the fossil-collector of the Geological Survey, who found a small exposure low down in the quarry, from which he obtained several specimens of *Rhynchonella Cuvieri* and *Inoceramus mytiloides*.

[2] This year (1898) the quarries have been opened again for the purpose of burning the chalk to lime, so that there is now an opportunity of checking the accuracy of the above account or at least of part of it, for I understand that only the upper portion is as yet exposed.

stratigraphical position as the Beer Stone, the section in the large quarry at Beer may be given for comparison with the above:—

		Feet.
Zone of Terebratula gracilis.	Soil and broken chalk	9
	White chalk with many layers of flints	24
	White chalk with few flints; *Terebratula gracilis*	17
	Soft white chalk, passing down into rough nodular chalk; *Echinoconus subrotundus*	2½
Zone of Rhynchonella Cuvieri.	Hard compact yellowish limestone, passing down into hard shelly chalk	2
	Rough yellowish nodular chalk, with *Inoceramus mytiloides, Rhynchonella Cuvieri*, etc.	14½
	Good crystalline freestone in several beds	13
		82

The beds below are not now exposed, but it is known that 5 or 6 feet of rough splintery chalk occurs beneath the above, resting on hard chalk with grains of quartz and glauconite.

Returning to Widworthy, the freestone has also been quarried in the Park east of Widworthy Court, but no exposure is now open.

A sand-pit, north of Wilmington and ⅝ mile north of Widworthy Church, discloses the existence of another small outlier of the Turonian Chalk, and is interesting as showing its junction with the beds below. The section here is as follows:—

		Ft.	In.
Turonian [=Middle Chalk.]	5. Soft white chalk	2	6
	4. Hard rubbly chalk, very hard at the top and containing green-coated nodules, more massive below, with grains of quartz and glauconite	2	6
	3. Soft marly glauconitic chalk	0	9
Cenomanian [=Lower Chalk.]	2. Hard quartziferous limestone with glauconite-grains; upper surface well marked and encrusted with brown phosphate; base not well marked	2	0
	1. Rough calcareous sandstone full of fossils, weathering into sand with hard lumps: about	6	0

These beds are cut off by a fault at the northern end of the pit, but the throw is not more than 8 feet, and on the north side the rough fossiliferous sandstone passes down into coarse calcareous sand with few fossils, of which about 18 feet is seen.

No. 4 of the above section contains *Inoceramus mytiloides*, but no other fossil was seen in it nor in No. 3. I regard these as the basement-beds of the Turonian or Middle Chalk.

In No. 2 I found *Scaphites æqualis*, *Turrilites costatus*, *Holaster subglobosus*, *Ostrea vesicularis*, and *Discoidea subuculus*. This bed is clearly the equivalent of the uppermost Cenomanian bed on the coast, that which is numbered 12 in Mr. Meÿer's Beer Head section.

The fossils of No. 1 include *Ammonites Mantelli*, *A. navicularis*, *Pecten asper*, *Lima semiornata*, *Holaster subglobosus*, *H. altus*, *H. carinatus*, *Pseudodiadema variolare*, and *Rhynchonella dimidiata*. This bed and the underlying sand correspond with the similar calcareous sandstone at Beer Head (No. 10 of Mr. Meÿer).

Another quarry at the western end of Wilmington continues the section a little lower, and of this I took the following notes:—In the soil at the top of the pit are loose lumps and blocks of the quartziferous limestone (No. 2 of the last section) and larger masses of hard calcareous sandstone, which is known as grizzle by the workmen. These blocks seem to be such portions of the sandstone as have resisted the action of acidulated water better than the rest of the rock, which has been largely decalcified and disintegrated. Measured from a cleared space at the bottom of one of these blocks, the depth of the quarry is 31 feet, and the face is vertical, for the sandstone is soft enough to be chopped out with the broad end of a pick. The whole of this is dug for sand, and used for making concrete, for rough-casting walls, and for other purposes.

This calcareous sand or soft sandstone is equally coarse from top to bottom; the highest 3 or 4 feet includes lumps of less disintegrated rock, and these are picked out and thrown aside. They contain many fossils, which are mostly in a good state of preservation and are easily detached from the weathered lumps.

The rest of the sand cuts with an even face, but is traversed by three layers of siliceous concretions; the highest of these layers consists of large flattish and lenticular concretions, white or pink outside, brown within, and containing nuclei of chalcedonic chert; the lower layers are smaller irregular concretions with projecting knobs, and some are cylindrical like siliceous sponges. They contain sponge-spicules, and seem to be sponges more or less filled with sand and cemented by chalcedonic silica.

In this mass of sand fossils are rare, with the exception of *Exogyra conica* and *Janira quinquecostata*, but the fossiliferous sandstone passes down into it without the slightest sign of a break.

Wishing to ascertain how much deeper the sand extended, I instructed a workman to dig a hole in the floor of the quarry, but at about 12 inches below the floor he came upon a hard rocky sandstone, differing from the rest in being somewhat ferruginous and compacted by a hard tufaceous kind of calcium carbonate, probably redeposited carbonate. The sand-grains were large, and some small pebbles occurred; the only fossils seen were *Holaster carinatus*, *Exogyra conica*, and a saurian tooth.

I was informed that a hole had been dug in the orchard, just outside the pit and about on a level with its floor, through 6 or 7 feet of similar rocky material, without reaching the bottom of it. Nor did I find any section which exposed the base, though it is probably sometimes to be seen in the sand-pit by the side of the railway a little more than ½ mile north of Wilmington. Here the beds are dipping to the east at about 3°; at the western end green and brown sand with cherts are seen, and farther east more than 20 feet of coarse yellowish-white sand like that at Wilmington, passing beneath grizzle and quartziferous limestone at the eastern end. The junction was not visible at the time of my visit, but the workman said that at the base of the sand there was a hard whitish sandstone-rock.

It would appear, therefore, that the full thickness of the calcareous sandstone is from 38 to 40 feet, which, with 2 feet of overlying quartziferous limestone, gives a total of 40 to 42 feet for the Cenomanian near Wilmington. This is a much greater thickness than it attains anywhere along the coast, the greatest development there being in Hooken Cliff, where it is 24 feet thick.

The following is a list of the fossils which I was able to obtain, and it will be seen that the fauna is similar to that of the beds on the coast, as recorded in the paper by Mr. W. Hill and myself (Quart. Journn. Geol. Soc. vol. lii, 1896, pp. 159–164) :—

List of Fossils from the Cenomanian of Wilmington.

	Calcareous Sandstone.	Quartziferous Limestone.
Ammonites Mantelli, Sow.	*	
—— *navicularis*, Mant.	*	
—— *varians*, Sow.	*	*
Scaphites æqualis, Sow.	......	*
Turrilites costatus (?), Lam.	*	
—— *Schendizerianus* (?), Bosc	*	
Pleurotomaria Mailleana, d'Orb.	*	
—— sp.	*	
Avellana cassis, d'Orb.	*	
Cyprina sp.	*	
Exogyra conica, Sow.	*	
—— *haliotoidea*, Sow.	*	
Inoceramus striatus, Sow.	*	
—— sp. (flatter)	*	*
Janira quinquecostata, Sow.	*	
Lima globosa (?), Sow.	*	
—— *semiornata*, d'Orb.	*	
—— *Reichenbachi* (?), Gein.	*	
Ostrea vesicularis, Lam.	*	*
—— *Normaniana*, d'Orb.	*	
—— *vesiculosa*, Sow.	*	
—— *frons*, Park. (=*carinata*, Sow.)	*	
Pecten asper, Lam.	*	
—— *hispidus*, Goldf.	*	
—— *Puzosianus*, d'Orb.	*	
Plicatula inflata, Sow.	*	
Spondylus striatus, Sow.	*	
Rhynchonella dimidiata, Sow.	*	
—— ——, var. *convexa*, Sow.	*	
—— *Grasiana*, d'Orb.	*	
—— *Mantelliana*, Sow.	......	*
—— *Wiestii*, Dav.	......	*
Terebratula biplicata (?), Sow.	*	
—— *squamosa*, Mant.	*	
Catopygus columbarius, Lam.	*	
Cottaldia Benettiæ, Kœnig	*	
Discoidea subuculus, Klein	*	*
Echinoconus castanea, Brongn.	*	*
Hemiaster bufo?	*	
—— *Morrisii* (?), Forbes	*	

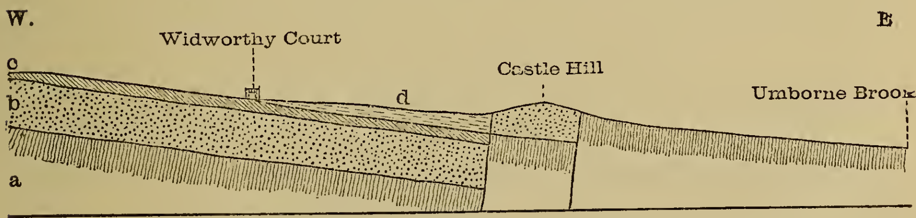
LIST OF FOSSILS (*continued*).

	Calcareous Sandstone.	Quartziferous Limestone.
Holaster carinatus, Ag.	*	*
—— *subglobosus*, Leske	* (?)	*
—— ——, var. *altus*, Ag.	*	*
Pseudodiadema Benettiæ, Forbes	*	
—— *Michelini*, Ag.	*	
—— *ornatum*, Goldf.	*	
—— *variolare*, Brongn.	*	
—— sp. (nov.?)	*	*
Plagiophthalmus oviformis, Bell	*	
Ditrupa difformis, Lam.	*	
Porosphæra sp.	*	*
Eschara sp.?	*	
Hexactinellid sponge	*	

All the above—except *Plagiophthalmus oviformis*, the *Hemiaster* identified as *bufo*, and the *Cyprina*—occur in the corresponding beds on the coast. The *Holaster altus*, Ag., is described in a separate note (see p. 246).

Some lumps containing remains of silicified sponges were sent to Dr. G. J. Hinde, but they were not in such a state as to allow even of generic identification.

Fig. 2.—*Section across the Widworthy outlier.*



d=Chalk (Turonian). *b*=Upper Greensand.
c=Cenomanian Sands. *a*=Triassic Marl.

[Scales: Horizontal, 3 inches=1 mile; vertical, 1000 feet=1 inch.]

The geotectonic position of the outlier has also some points of interest. From the high ground near Honiton (Honiton Hill, etc.) the general dip of the beds is easterly, till they are cut off by a long and powerful fault which, near Hayne Farm, brings the red Triassic marl up against the Cenomanian sand, and has here a throw of at least 300 feet. Near Wilmington this fault branches into two, and a long narrow strip of Greensand is wedged between the Chalk on the west and the Red Marl on the east; this strip, however, seems to thin out near Sutton Barton, for the well at that place is 108 feet deep, and is said to have traversed some thickness of chalk before reaching sand.

The surface of the ground is very irregular, and the valley-system has not been influenced in any way by the lines of faulting;

but on the watershed between the valleys of the Umborne and Offwell brooks, where the surface has been modelled chiefly by the action of rain, the Greensand has resisted detrition better than either the Chalk or the Red Marl, so that the ground falls away on each side of the faulted strip, except where the Red Marl is capped by Greensand, as on Widworthy Hill. This relation is shown in the accompanying section (p. 245), which is drawn nearly east and west through Widworthy Park.

[It has been explained in the paper already referred to, 'On the Delimitation of the Cenomanian,' Hill & Jukes-Browne, Quart. Journ. Geol. Soc. vol. lii (1896), and also in the note on p. 239, that the calcareous sandstones of Wilmington and the Devon coast are the local equivalents of the Chalk Marl, and that they form a zone of *Ammonites Mantelli.* Between this zone and the succeeding one of *Rhynchonella Cuvieri* there is a break, with an absence of anything to represent the upper part of the Lower Chalk.

Hence the succession of zones seen at Wilmington above the Upper Greensand may be expressed as follows:—

		Feet.
TURONIAN.	Zone of *Terebratulina gracilis*	? 40
	„ *Rhynchonella Cuvieri*	30
CENOMANIAN.	(Upper beds wanting.)	
	Zone of *Ammonites Mantelli*	40

—A. J. J.-B., April 22nd, 1898.]

NOTE *on* HOLASTER ALTUS, Ag.

[PLATE XXIV.]

Among the commonest and most conspicuous fossils in the Wilmington Sands are certain species of the genus *Holaster.* One of them is *Holaster lævis*, var. *carinatus*, Lam.; but as the examples of this form do not differ materially from those found elsewhere, they need not detain us.

In respect of those which are entered in the list on p. 245 as *Holaster subglobosus*, Leske, and *Holaster altus*, Ag., the case is different; for the species or variety *altus* has not previously been discussed by any English echinologist, nor recorded from any English locality, though it is well known in France.

Holaster altus was first described and figured from a Swiss specimen by Agassiz in 1839.[1] He distinguished it from others (1) by the great height of the test, (2) by the great width of the ambulacral plates; and he adds, 'There exist two well-marked sulci (sillons)—one on the anterior face in which lies the odd ambulacral area, the other on the posterior face.' Further, he remarks:—'I do not hesitate to identify with this species several

[1] 'Descr. Échin. foss. de la Suisse,' p. 20 & pl. iii, figs. 9 & 10.

specimens which from their aspect come from the craie marneuse of France.'

The figure given by Agassiz shows some other characters which are quite as important as those he mentions:—

(1) It is of small size, its dimensions being: Length $1\frac{2}{10}$ inch (30·8 mm.), breadth $1\frac{1}{10}$ inch (28 mm.), height 1 inch (25 mm.). It is therefore of great proportional height, but it is stated that other examples are not so high as that figured.
(2) The posterior border, as viewed from the side, is truncated vertically.
(3) The apex is excentric anteriorly, the distance from it to the posterior border being about two-thirds of the length of the test.

It will be seen that the English specimen delineated in Pl. XXIV, fig. 4, agrees very closely with Agassiz's specimen in its dimensions and general characters.

But a closely-allied form was described by Renevier in 1867 under the name of *Holaster Bischoffi*,[1] and it was afterwards figured by P. de Loriol-Lefort.[2] The descriptions of this species given by both these writers will apply equally well to Agassiz's *H. altus*, except in three respects: it is still smaller than *altus*; it is described as subcylindrical, and 'rather flattened' or 'not very convex' on the upper surface. From the figure this seems to mean that the posterior ridge is nearly parallel with the median line of the under surface, the height of the test being nearly the same above the vent as at the apex.

Specimens which agree closely with P. de Loriol-Lefort's figure and description of *H. Bischoffi* are not uncommon in the Cenomanian of Beer Head, and were mentioned in a former paper[3] as either a well-marked and unusual variety of *Holaster subglobosus* or a distinct species. A brief description of the form was there given.

Being in some doubt whether to identify the Wilmington examples as *H. altus* or *H. Bischoffi*, and in more doubt as to whether these forms were really distinct species, I sent five specimens to M. P. de Loriol-Lefort, and asked him to pronounce an opinion. His reply, which he kindly allows me to publish, is as follows:—

'Je les ai comparés avec des exemplaires de l'*Holaster altus*, Ag., du Cénomanien de Rouen, et avec des individus de l'*Hol. Bischoffi* de Cheville. Je crois que vos exemplaires de Wilmington doivent plutôt être rattachés à l'*Hol. altus*. L'*Holaster Bischoffi* est une petite espèce, un peu cylindrique, étroite, moins large que l'autre; elle est rare dans nos gisements. . . . Ceux que je viens d'examiner à nouveau ressemblent absolument aux deux plus petits exemplaires que vous m'avez envoyés (ceux de la roche dure); mais ces derniers

[1] Bull. Soc. Vaud. Sci. Nat. vol. ix ('Faune de Cheville,' p. 446).
[2] 'Échinologie Helvétique,' vol. ii (1873) p. 333, pl. xxviii, figs. 1 & 2.
[3] 'A Delimitation of the Cenomanian,' Quart. Journ. Geol. Soc. vol. lii (1896) p. 144.

passent aux autres. Je commence à croire que, lorsqu'on connaîtra bien l'*Hol. Bischoffi*, par une série un peu nombreuse d'exemplaires, et qu'on aura pu étudier le test qui manque toujours, on arrivera probablement à réunir l'*Hol. Bischoffi* à l'*Hol. altus*. Dans l'état actuel des choses, je crois qu'il sera préférable de nommer votre espèce *Holaster altus*. Ces *Holaster* sont difficiles à bien démêler, offrant certains passages; ainsi vos trois premiers [de Wilmington] ressemblent à une variété de l'*Hol. subglobosus* que j'ai fait figurer.'

Two specimens from Beer Head had previously been sent to M. Gauthier, of Sens, who considered them to be *Holaster altus*, and wrote that most authors regarded this form as only a variety of *H. subglobosus*, but that M. Bucaille, after having changed his mind several times, had ended by re-establishing *H. altus* as a distinct species in his 'Études sur des Échin. foss. du Département de la Seine Inférieure,' p. 6, pl. v.

Having had the opportunity of examining upwards of sixty specimens from Wilmington, and about twenty from the coast-sections, I am not surprised at the doubts of M. Bucaille, and am convinced that the anticipation of M. de Loriol-Lefort as to the union of *H. Bischoffi* with *H. altus* will prove correct. So far as I am able to judge, there is among the Devon specimens every gradation from a form which cannot be distinguished from *H. Bischoffi*, through forms which are undoubtedly identical with French specimens of *H. altus*, to one which, if found alone, would be regarded as a rather small and well-marked variety of *H. subglobosus*.

It is a curious fact, however, that I have not seen a typical *H. subglobosus* among all those from the calcareous sand of Wilmington which have passed through my hands, although I have two from the overlying bed which, though small, certainly belong to that species.

The impression that one receives from an examination of a large number of these Holasters is that one is looking on at the actual process of the evolution of a new species; for, in this area at any rate, the *Bischoffi*-type seems to be the oldest; on the coast it is most abundant in the bed numbered 10 by Mr. Meÿer and in the lower part of his No. 11, where it is accompanied by the *altus*-type and its varieties, while in the upper part of 11 true *subglobosus* occurs occasionally; lastly, in No. 12 typical *subglobosus* occurs without the others. At Wilmington the *altus*-type prevails, and seems to be throwing out varieties which are broader, lower, and larger, and which are gradually developing into the form which we know as *H. subglobosus*.

If this view be correct, it is unfortunate that the form last evolved should have been the first described, and that our laws of nomenclature require that the earlier form should be placed as a variety of the later one. Perhaps, in spite of the preservation of the intermediate forms, it will be more convenient to regard the one extreme (whether it be called *altus* or *Bischoffi*) as having an equal right to be called a species as the other extreme (*subglobosus*); for if these intermediate forms had been all destroyed, I think that most echinologists would not have hesitated to regard the two extremes as distinct species.

The following are the dimensions, in millimetres, of a series of seven specimens from Wilmington, the last being exceptionally large:—

	Length.	Breadth.	Height.
No. 1	22	20	18
No. 2	26	24	19
No. 3	27	25	19
No. 4	30	25	23
No. 5	30	28	24
No. 6	35	31	23
No. 7	38	35	27

Dr. Wright, in his 'British Cretaceous Echinodermata' (Pal. Soc. Monogr. p. 319), entered the name of *Holaster altus*, Ag., as a synonym of *H. subglobosus*, but he does not mention it in his description of that species, nor elsewhere in his monograph, so that one can only conclude that he had no knowledge of its occurrence in England. Prof. E. Forbes [1] drew up a table of comparative dimensions of *Holaster subglobosus*, and this is reproduced by Wright; the smallest specimen recorded therein has nearly the same proportions as the largest of the series given above.

Dr. Wright [2] describes a species under the name of *Holaster suborbicularis*, which, however, is certainly not the *suborbicularis* of Defrance, Brongniart, or Goldfuss. He says that it is plentiful in the Chalk Marl and Chloritic Marl; but there must be some mistake about this, as I have only seen one or two specimens that might belong to it. It differs from all varieties of *H. altus* in the flatness of both the upper and lower surfaces, in its lesser height, and in having a much larger vent.

I will therefore conclude by pointing out the principal points in which *Holaster altus* differs from *H. subglobosus*:—

(1) In its outline, which is oval, while *subglobosus* is often as broad as it is long.

(2) In the posterior truncation of the test, while *subglobosus* tends to become cordiform and bluntly pointed posteriorly.

(3) In the marked posterior sulcus, which is slight or absent in the other.

(4) By its excentric apex, that of a typical *subglobosus* being subcentral. The position of the apex, however, varies much.

(5) By the horizontality of the apical and posterior ridge.

(6) By the deeper anterior sulcus, which is bounded on each side by a slight carina, more marked in some than in others.

[1] Mem. Geol. Surv. dec. iv, text to pl. vii.

[2] 'Brit. Cret. Echinodermata,' Pal. Soc. Monogr. p. 314.

EXPLANATION OF PLATE XXIV.

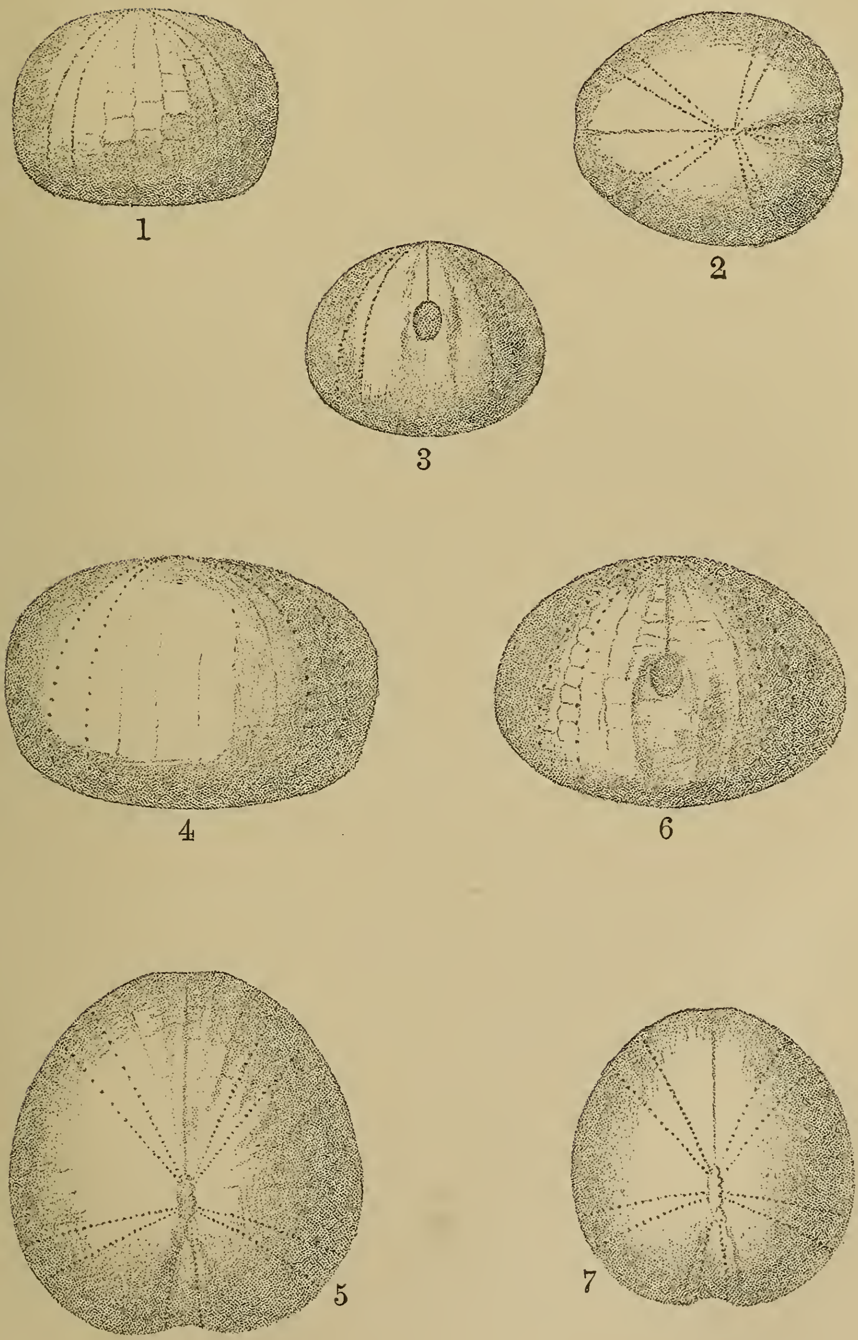
(All the figures are of the natural size.)

Fig. 1. A form comparable with *Holaster Bischoffi*, Renev. Side view of a large specimen.
2. The same viewed from above.
3. The same viewed from behind.
4. *Holaster altus*, Ag., the largest specimen found.
5. The same viewed from above, but the original is not quite so wide.
6. The same, posterior view.
7. *Holaster altus*, a specimen of medium size.

Discussion.

Mr. Strahan regretted that the useful work in this paper had been obscured by an unnecessary introduction of the Continental nomenclature of the strata. Not only was such a nomenclature out of place in dealing with so strictly local a subject, but the names themselves had no definite meaning in this country, for the Author's recent delimitation of the Cenomanian was not accepted by Continental geologists. The introduction of such names had never failed to cause confusion in British local stratigraphy, and should be reserved for papers dealing with international questions.

Mr. E. T. Newton and the President also spoke.



HOLASTER ALTUS, Ag.

21. *On some* SUBMERGED ROCK-VALLEYS *in* SOUTH WALES, DEVON, *and* CORNWALL. By T. CODRINGTON, Esq., M.Inst.C.E., F.G.S. (Read February 23rd, 1898.)

[Abridged.]

THE following particulars of some rock-valleys below the sea-level were for the most part gathered by me in former years, during the execution or the projection of engineering works with which I was more or less connected, or well acquainted. Information has also been afforded me from time to time by the courtesy of the engineers of other works in which similar sections have been exposed. The main object in the present paper is to put the facts observed on record in a connected form.

The details of the sections now given are, from a geological point of view, more incomplete than could be wished, as must almost always be the case when observations are made during the progress of engineering works by those to whom they are not matters of primary importance. Things observed are not always recorded, or perhaps their significance is not understood until they are lost to view. Notes and sections, when made, are lost sight of, or are laid aside for further information or a more convenient season, which, as in the case of some of these sections, may be a long time in coming.

The localities naturally fall into two groups:—(1) on the southern coast of Wales, from Milford Haven to the Severn; and (2) on the southern coast of Devon and Cornwall, from Dartmouth to Falmouth.

I. SOUTH WALES.

Milford Haven.

This estuary extends 20 miles inland, with two main branches, which are fed by streams rising on the Prescelly Hills (1760 feet), 12 miles to the north-east. There are besides many tidal creeks, locally called 'pills,' branching out of the estuary.

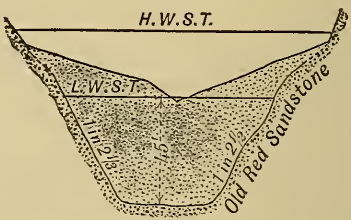
The bottom of one of these, Neyland Pill, situated nearly opposite Pembroke Dock, was thoroughly explored some 35 years ago by borings. The rock-bottom was traced from side to side at about 19 places in the length of a mile from the mouth of the pill. Fig. 1 (p. 252) is a characteristic example of the cross-sections.[1]

At the uppermost section of the pill, a mile from its mouth, the rock-bottom is 12 feet below the level of low-water spring-tides, and is covered with 23 feet of mud and silt. Each successive section shows the bottom of the rock-valley deepening gradually to near the

[1] [With this paper were exhibited 45 cross-sections of valleys drawn to an uniform scale, and other sections. Examples of these have been selected for publication.]

mouth of the pill (fig. 1), where the deepest part of the valley is 45 feet below the level of low-water spring-tides, and is filled with mud and silt to a depth of 44–50 feet. At the mouth of the pill the rock was not traced to the deepest part of the section, but just beyond, and outside the pill a complete section was made in which the rock-valley beneath the mud is well marked, the deepest boring being 45 feet below the level of low-water spring-tides through 22 feet of silt.

Fig. 1.—*Neyland Pill.*



[Scales: Horizontal, 400 feet=1 inch.
Vertical, 100 feet=1 inch.]

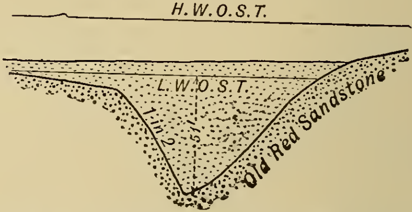
Not far from the mouth of the pill there is a depth of 66 feet in the main channel of Milford Haven.

The rock-bottom and sides of the pill are of Old Red Sandstone, and there is the same general outline of cross-section above and below the present water-line. The sides have slopes of 1 vertical to $2\frac{1}{2}$, $2\frac{1}{4}$, and $1\frac{1}{2}$ horizontal. The late Mr. Okeden, who made the borings, found Diatomaceæ in the clay brought up by the boring-tool, and he preserved and mounted many specimens, now unfortunately lost.

About 4 miles lower down the Haven is Milford, where docks have been constructed at the mouth of a pill, similar in general features to Neyland Pill. Fig. 2 is a section across the mouth of the pill, as revealed in the progress of the dock-works. The bottom of the rock-valley is 51 feet below the level of low-water spring-tides, and had 58 feet of mud over it. Farther out, at low-water mark, the depth to the rock was found to be 65 feet, with that depth of mud over it. The rock, as at Neyland, is Old Red Sandstone.

Fig. 2.

Milford Docks
Section through Entrance Lock.



[Scales : Horizontal, 400 feet=1 inch.
Vertical, 100 feet=1 inch.]

The length of the main stream flowing into Neyland Pill is about 6 miles, draining about 10 square miles of country. That flowing into Milford Pill is some 3 miles long, draining an area of about 6 square miles. Both streams originate in ground about 300 feet above the sea-level.

The deepest sounding in Milford Haven, opposite Milford, is 72 feet below the level of low water, and there is no deeper sounding down to the entrance of the Haven. The 10-fathom line of the chart runs across the mouth, with a loop extending up the Haven, and there are many rocks inside this line. Outside it the 20-fathom line is less than $\frac{1}{4}$ mile distant. The whole of the Haven would be laid dry if the land were raised enough to bring the bottom of the rock-valley at Milford Docks above low-water spring-tides.

There are indications of similar submerged valleys farther north on the Welsh Coast. A survey made of the river Tivy, 25 miles north of Milford Haven, shows that at from 4 to 5 miles from the sea, above the lower Cilgerran slate-quarries, where the river has not been partly filled in with quarry-refuse, the bottom is 20 feet below the level of low water as it was in 1851. Above Cilgerran slate-quarries there are depths of as much as 25 feet below the same level. Low water is now several feet higher, in consequence of the accumulations of quarry-refuse in the river.

Still farther north, at Barmouth,[1] it is on record that the rock-bottom of the Mawddach was traced by the cylinder-foundations of the railway-viaduct to 40 feet below the level of low water, where it was shelving rapidly downward beneath a bed of peat of unascertained thickness, but too deep to be penetrated for foundations.

Along the south coast the next indication of a submerged valley is at Loughor, where the piles of the bridge across the river were driven 37 feet below the level of low water without reaching rock.

Rivers Tawe and Neath.

There are evidences of submerged rock-valleys in the rivers Tawe and Neath, though complete sections have not been made out.

At Landore, 2 miles above Swansea, the river Tawe is crossed by the South Wales Railway. When the first viaduct was built, a boring was put down to a depth of 30 feet, showing, in descending order blue clay, sand, gravel, and boulders. The viaduct has been reconstructed, and the foundations of the main piers (according to information given me by Mr. Inglis, the engineer of the Great Western Railway Co.) are in hard Boulder Clay, which was penetrated by piles for 30 to 40 feet before a hard bearing was reached. Over the Boulder Clay, in ascending order, are soft blue clay with small boulders, then silt, then hard clay and shingle. In a section at Swansea Docks described by Mr. M. Moggridge in 1856,[2] the lowest bed, below the level of low water, and not passed through, is described as brown clay and gravel with boulders, some of the latter large enough to require blasting. This is no doubt the Boulder Clay of the Landore section. The material most abundant in it was Coal Measure sandstone, next Millstone Grit, Old Red Sandstone nearly as abundant, and Carboniferous Limestone less so, though a large boulder was of this material. Assuming that these rocks came from the northern outcrop, they must have travelled 18 or 20 miles down the valley. Above this bed was marine clay with *Scrobicularia piperata*, in which were peaty beds containing remains of oak, beech, birch, alder, and hazel.

[1] H. Conybeare, Proc. Inst. C. E. vol. xxxii (1871) p. 139.
[2] Quart. Journ. Geol. Soc. vol. xii, p. 169.

At Neath a boring, made many years ago to find a foundation for the railway-bridge, reached 52 feet below the bed of the river, passing through blue clay and peat, and ending in gravel. More recently further evidence has been afforded by trial-shafts and borings along the line of a proposed tunnel under the river, and by the cylinder-foundations of a bridge for the Rhondda & Swansea Bay Railway. The bridge is $1\frac{1}{2}$ mile below Neath, and is 444 feet long. The cylinders of the westernmost pier reached the Coal Measures at 28 to 31 feet below the level of low water, and one of the cylinders in the next pier, 58 feet distant, probably touched Coal Measure shale; but the cylinders of the other four piers all ended at from 36 to 42 feet below the level of low water in stiff dry clay-with-stones, which was found by boring in one of the cylinders to reach a depth of more than 55 feet below the level of low water. The bridge is on the west side of the existing valley, here more than a mile wide and but little above high water. At what depth the rock-bottom may be east of the bridge there is no evidence.

The deposits passed through by the cylinders, in ascending order, are (1) the hard dry clay and stones, penetrated to about 28 feet, and of unknown depth; (2) gravel and large stones; and (3) sandy clay and mud, from about 20 feet below the level of low water upwards. The large stones in (2) were of irregular shape and size up to about 7 feet across, waterworn but not round. The blocks in the hard dry clay below (1) were similar, and the materials noticed were Pennant and Grit. It is believed that the first cylinder sunk (6 feet in diameter) rests entirely on a large boulder, supposed to be rock *in situ* until other cylinders of the pier were sunk.

I was not fortunate enough to see the sinking of the cylinders, but the railway-cutting near Cwrt Sart, about a mile to the eastward, was pointed out as exhibiting the same formation. At that point a long rounded hill, called Giant's Grave, rises out of the valley to upwards of 100 feet. On the west of it is the river Neath, flowing through marsh-land, and on the east of it is a valley some 20 feet higher in level separating Giant's Grave from Mynydd y Gaer, rising to 1000 feet, through which the road and the railways pass. The latter cut into the isolated hill, and furnish a section at from 20 to 40 feet above the sea of what is (to all appearance) Boulder Clay. The lower part is more clayey than the upper part, but the constituents are the same:—rounded stones, gravel, and clay, containing boulders and blocks of Millstone Grit, Old Red Sandstone, and Coal Measure sandstone. One boulder of Millstone Grit measured $2\frac{1}{2} \times 2 \times 1\frac{1}{2}$ feet and another $3 \times 2 \times 1\frac{1}{2}$ feet, and there are many, some well rounded and smoothed, others subangular, up to a cubic foot in size. The blocks of Coal Measure sandstone are larger and more angular, though embedded in pebbles and rounded stones. One polygonal block, which measured $6 \times 5 \times 2$ feet, was covered with angular and rounded stones embedded in gravel and clay. In the side of the cutting there remains a block of sandstone $8 \times 3 \times$? 5 feet plainly glaciated on the smoothed upper surface, and I also observed a smaller rounded and smoothed block unmistakably striated.

The borings and trial-shafts for a tunnel were sunk at the mouth of the river below Briton Ferry, some 2 miles below the bridge. In the deepest shaft, 350 yards west of the present low-water channel, rock was reached at 53 feet below the level of low water. The borings east and west of this shaft reached rock at 33 and 35 feet below the level of low water, but though 53 feet may be about the greatest depth of this particular rock-channel, there is ample room for a deeper one on either side of it.[1]

The deposits above the rock were found to be gravel and clay, and sand and clay in layers under a varying thickness of sand.

Low-water mark is now nearly 2½ miles to the seaward of this section, and a depth of 53 feet at low water is not reached for more than 2 miles farther out.

The valleys of the Tawe and the Neath lie parallel to each other, about 5 miles apart, separated by ground 1000 feet high. They extend in a N.N.E. direction for 22 miles to the Old Red Sandstone mountains of Brecknockshire, which rise 2,300 to 2,600 feet above the sea. The drainage-area of each valley is about 100 square miles.

To the eastward of the Neath river the Ogmore, the Taff and Ely, the Rumney, and the Usk flow into the Bristol Channel, the first-named in a well-defined valley, but the others through a wide alluvial flat beneath which the position of submerged rock-valleys has not been traced, though at Cardiff and Newport considerable thicknesses of deposits over the rock have been proved, often having a coarse gravel at the base. An interesting section of a submerged land-surface was exposed in the construction of Barry Docks. It was described by Mr. Strahan,[2] who showed that a subsidence of at least 55 feet must have taken place since the formation of the lowest peat-bed.

The Wye.

Before and during the construction of the Chepstow railway-bridge, the bed of the river Wye was explored by sinking a 3-foot trial-cylinder, by borings, and by the sinking of twelve cylinders of 6 and 8 feet diameter to the rock, through 44 to 58 feet of overlying deposits. The general section thus obtained is illustrated in fig. 3 (p. 256). The eastern or left bank of the river is a precipitous cliff of Mountain Limestone, 125 to 130 feet high from low water. The rock was traced for 100 feet from the face of the cliff; it is less precipitous near low-water level, and generally horizontal beyond, where it is 22 feet below the level of low water or 63 feet below high-water spring-tides, and is overlain by a thin stratum of red clay. Against the foot of the cliff there is an accumulation of rock-fragments as

[1] The writer is indebted to Mr. Yockney, M.Inst.C.E., the engineer of the railway, and to Mr. Goldwyer, M.Inst.C.E., the resident engineer, for particulars of these two sections.

[2] Quart. Journ. Geol. Soc. vol. lii (1896) p. 474.

much as 10 feet thick, over which is gravel, with loose rocks, and then silt and mud, also containing loose stones. These deposits are about 15 feet thick, and rise considerably above half-tide level. It is unfortunately not known whether the rock-fragments are of limestone, a talus from the cliff above, or whether they consist of rocks from a distance. For 170 feet the rock-bottom was unexplored, but at 300 feet from the face of the cliff is the group of six 8-foot cylinders forming the main pier of the bridge, and occupying an area of about 50 × 20 feet. They were sunk through 44 feet of overlying deposits to the rock, which was reached at 31 to 42 feet below the level of low water. The three cylinders north-west of a diagonal across the pier are upon limestone, dipping 40° east, and the three cylinders on the south-east are upon what is recorded as 'hard sandstone,' 'sandstone alternating with red marl,' 'hard red marl and sandstone in thin beds.' It would seem that the fault shown on the Geological Survey map not far off, with a downthrow to the west, is here, and that the beds south-east of the limestone are Old Red Sandstone.

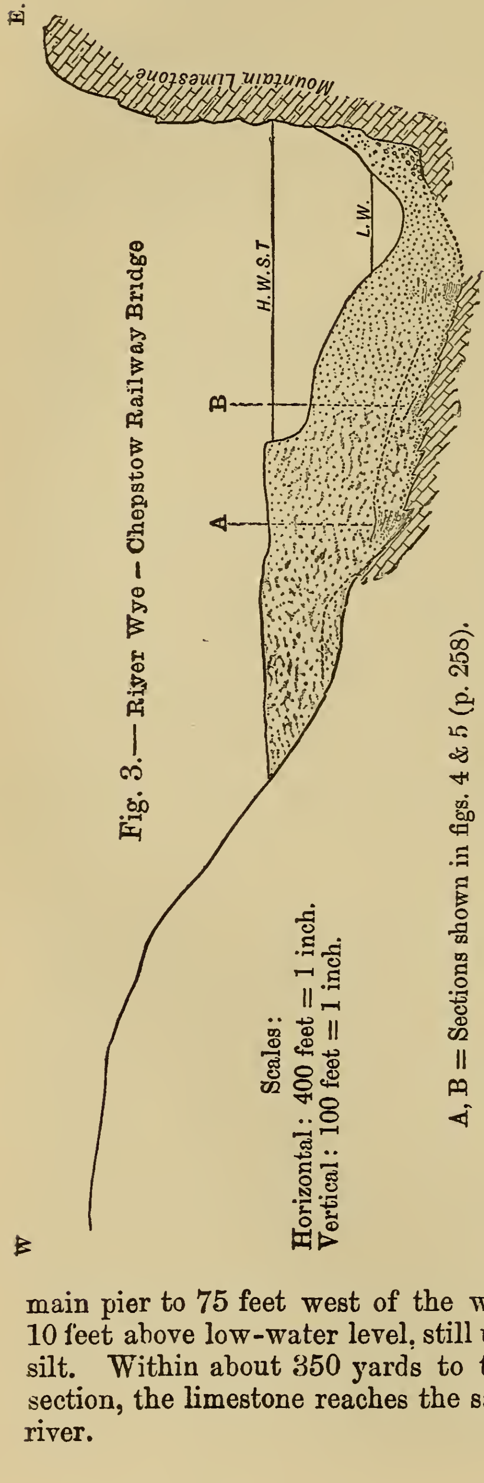


Fig. 3.—River Wye – Chepstow Railway Bridge.

Scales:
Horizontal: 400 feet = 1 inch.
Vertical: 100 feet = 1 inch.

A, B = Sections shown in figs. 4 & 5 (p. 258).

At 100 feet west of the main pier is another pier, of three 6-foot cylinders, and at 100 feet still farther west a similar pier. All these cylinders are founded on dark Carboniferous Limestone, at 13 to 16 feet below the level of low water.

The rock-bottom was traced by boring all the way from the main pier to 75 feet west of the westernmost pier, where it was 10 feet above low-water level, still under 25 feet of clay, gravel, and silt. Within about 350 yards to the westward on the line of the section, the limestone reaches the same height as it does east of the river.

The deposits over the rock-bottom are recorded in sections made when the cylinders were being sunk. At the main piers both sandstone and limestone are covered with 4 or 5 feet of what is called red marl, but it may be more accurately described as stiff, red, sandy clay. Over that is a layer of 3 feet of boulders and coarse gravel in red clay, some of the boulders being of conglomerate, others of sandstone and red limestone, one more than 6 feet across. Then comes 4 feet of fine gravel (limestone), over which is a bed of leaves, timber, hazel-nuts, roots, and branches. This bed is 22 feet below the level of low water, or more than 62 feet below high water; it is covered with coarse sand, which passes upward into soft grey sand and clay, over which are silt and mud to 6 or 8 feet above low-water level.

At the next pier (fig. 4, p. 258), red sand, sandy clay, and gravel overlie the limestone, the surface of which is broken up. In one cylinder a sandstone-boulder (6 feet across and 2 feet thick) rested on the limestone embedded in this deposit, and in another a piece of sound oak 8 or 9 inches in diameter lay across the cylinder close to the rock, covered with 2 feet of red sand-and-gravel. In each of the three cylinders of this pier, over the red sand-and-gravel, and 2 or 3 feet above the limestone-rock, there is a layer of 6 to 10 inches of hard blue clay, and over that grey sand and silt with a few small shells, stalks of plants (probably sedges), hazel-nuts, and wood. Above low-water level the silt becomes more muddy; it reaches 28 feet above that level, making the total thickness of the deposits over the rock at this pier 45 feet.

At the westernmost pier (fig. 5, p. 258) the solid limestone is overlain by a few feet of broken rock in dry sandy clay, over which is coarse gravel with clay and a few boulders, and then sand and clay with more boulders of sandstone and conglomerate. At 3 feet below the level of low water this is succeeded by a bed of stiff, sandy, blue clay, 3 to 5 feet thick, with stalks of plants (probably sedges), and over that blue silt, clay, and mud reach to above high-water level, making a total thickness of 55 feet over the rock.

The boulders of conglomerate and sandstone probably are derived from the Old Red Sandstone beds which are exposed higher up the Wye Valley.

The Severn.

At the mouth of the Wye, the Severn is but shallow, with a sandy bottom, but just above, near Chapel Island, there is 54 feet of water at low-water spring-tides, and below, halfway between the Wye and the Severn Tunnel, the chart shows a sounding of 82 feet at low water.

At the Severn Tunnel, $2\frac{1}{2}$ miles below the mouth of the Wye, a complete section of the river-bottom was made.[1] For $1\frac{1}{2}$ mile on the eastern side the bed of the river consists of bare New Red Sandstone rock well above low water, called 'The English Stones.'

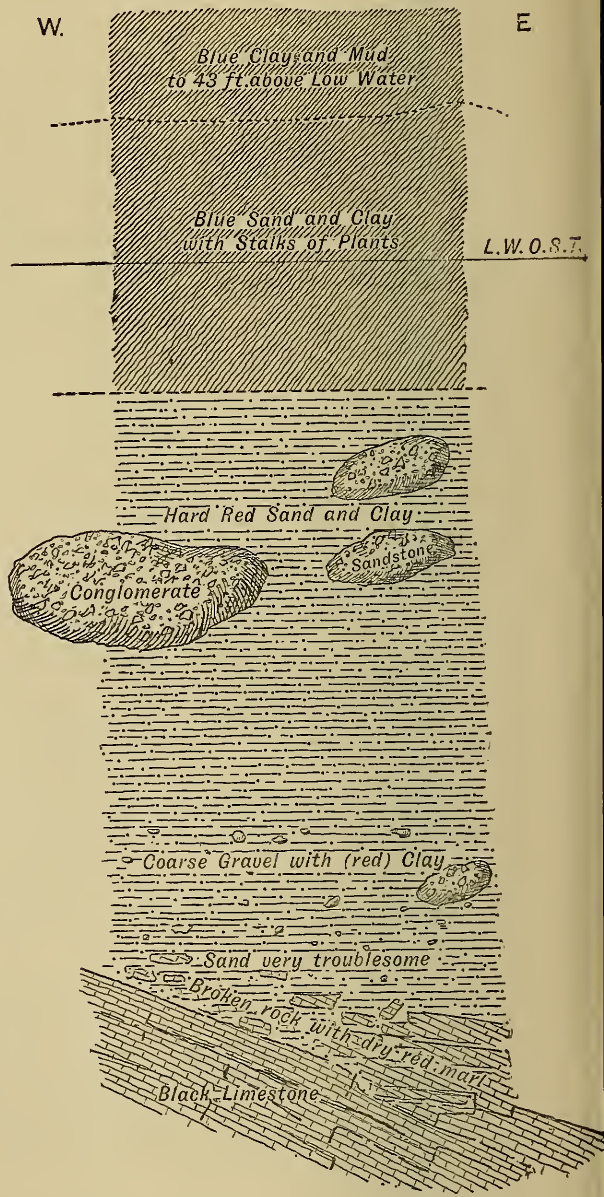
[1] See T. A Walker, 'The Severn Tunnel.'

Chepstow Bridge Cylinders.

(See horizontal section, fig. 3, p. 256.)

Fig. 4.—*Section in cylinder at B.*

Fig. 5.—*Section in cylinder at A.*



[Scale: 4 feet = 1 inch.]

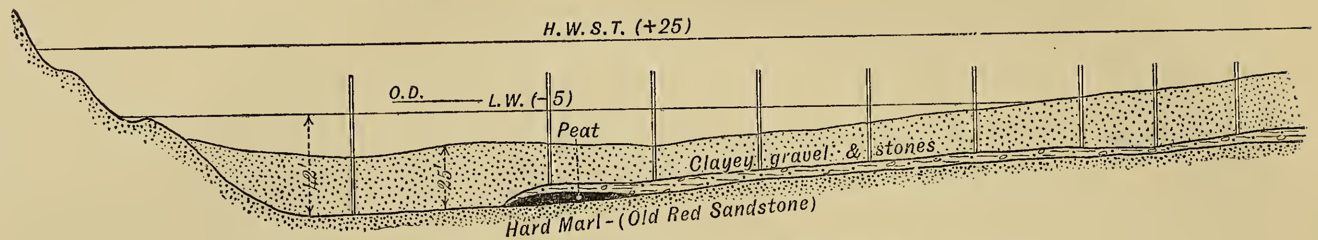
Then comes the deep channel called 'The Shoots,' 550 yards wide at the level of low water, and 280 yards wide at the bottom, which is as much as 60 feet below the level of low-water of spring-tides. The sides are steep, on the western side almost precipitous in places. This deep channel is excavated in the Pennant Beds of the Coal Measures. West of 'The Shoots' the rock is above low water for about 300 yards, and near the western shore is a second low-water channel 12 feet deep.

The rock-bottom is bare all across the present river, but in the cutting at the eastern end of the tunnel an old channel was laid open, the beds in which are described as follows by Mr. C. Richardson, the engineer of the tunnel:—The New Red Sandstone rock, which in the bed of the river is considerably above the level of low water, at the end of the tunnel is 13 feet below that level, from which it rises gradually eastward. Upon it lies a coarse gravel with large masses of Old Red Conglomerate, Millstone Grit, and Mountain Limestone, over which is a finer gravel, with clean river-sand over it. It is stated by Prof. Sollas[1] that the lowest gravel contained glaciated stones. These beds, which were quite free from mud, are covered with silt or muddy sand, over which is a bed of peat below half-tide level, or about 20 feet below ordinary high-water spring-tides; then comes a pale-coloured clay, then another peat-bed 2 feet thick, over which is blue clay up to the surface of the ground at about high-water level. These beds preserve their general level, undulating slightly, all along the cutting, for more than $\frac{3}{4}$ mile. They are cut through down to the silt beneath the lowest peat-bed by four old rivercourses which are filled up with mud. The trunk of a large oak-tree lay below the upper peat. Many years before, when the Bristol & South Wales Union Railway was being constructed, a peat-bed 2 to 7 feet thick was found in five places east of this cutting, resting directly upon the red marl, under 11 to 14 feet of clay.

The cylinder-foundations of the Severn Bridge, 14 miles above the tunnel, furnished another section of the bed of the Severn (fig. 6, p. 260). Twenty-one piers, composed of forty-eight cylinders, were sunk in the bed of the river to the marl-beds of the Old Red Sandstone. The deepest part of the rock-bottom is near the western side, where it is 42 feet below the level of low water, and is covered up by 24 feet of sand and silt. The rock rises thence gradually to the eastward, and reaches the level of low water at the eastern shore, rather more than $\frac{1}{2}$ mile distant. A little to the east of the deepest part of the rock-section, there is a bed of peat about 2 feet thick immediately over the rock, 39 feet below the level of low water, and 68 feet below high-water spring-tides. The peat, which is covered by about 3 feet of clayey gravel and stones, was found only in one pair of cylinders, but a bed of clayey gravel and stones was found overlying the marl nearly to the eastern bank, with one

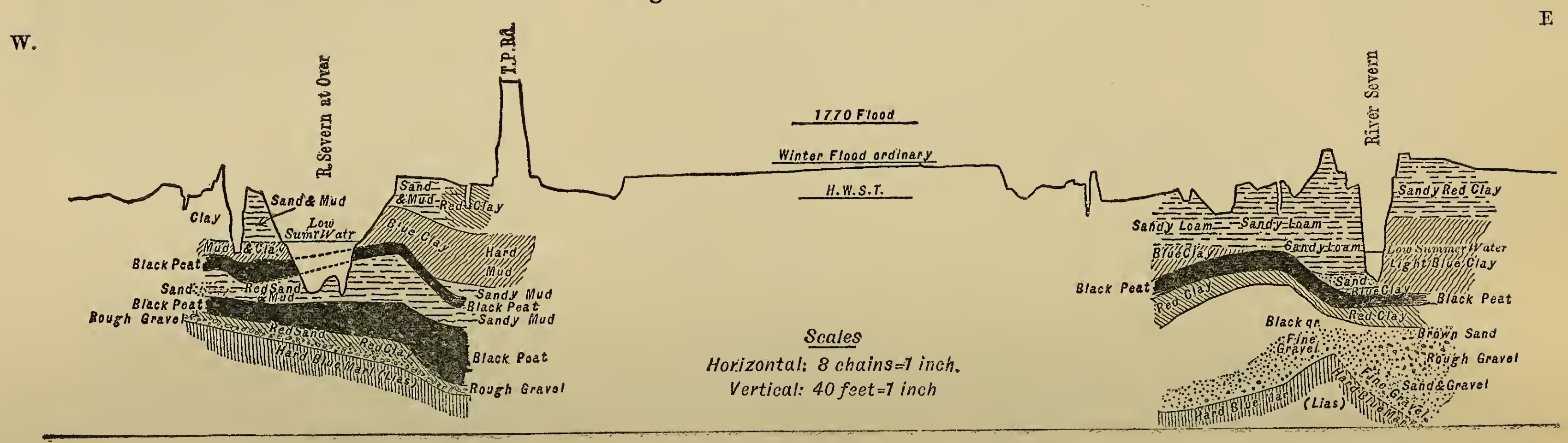
[1] Quart. Journ. Geol. Soc. vol. xxxix (1883) p. 622

Fig. 6.—River Severn - Severn Bridge.



[Scales: Horizontal, 400 feet = 1 inch; vertical, 100 feet = 1 inch.]

Fig. 7.—River Severn, Gloucester.



break. Sand and silt, from 14 to 26 feet thick, cover the gravel for the whole width of the river. Borings made for a proposed earlier bridge, $\frac{1}{4}$ mile lower down the river, seem to indicate that the peat-bed extends in that direction, widening out considerably.[1]

Near Gloucester, the two branches of the Severn are crossed by the South Wales Railway, and trial-pits were sunk before the bridges were constructed. Six were sunk at Over, giving a section extending 100 yards on each side of the river, and five on the other branch, giving a section of about the same length (fig. 7, facing this page). The Liassic clay was reached at from 15 to 28 feet below the level of low summer-water at Over, and at from 18 to 31 feet at the eastern branch of the river. At Over, about 2 feet of rough gravel overlies the Lias, with 2 feet of red clay and sand over it. Then comes a bed of black peat from 3 to 10 feet thick (the bottom of which is 33 feet below the level of high water), and then 4 to 8 feet of sandy mud, over which is a second peat-bed 2 to 4 feet thick, covered up by blue clay, sand, and mud to the ground-level. At the eastern branch of the river, the gravel immediately over the Lias is 6 to 18 feet thick, and the red clay over it 2 to 5 feet thick. A bed of black peat, the only one in this section, overlies the red clay; it is 2 to 4 feet thick, and in thickness and level appears to correspond with the upper peat-bed at Over. Sand and mud cover up the peat to the ground-level.

The Avon.

About 7 miles below the mouth of the Wye, the Avon enters the Severn estuary through the remarkable Clifton gorge, upwards of 200 feet deep, and more than 700 feet wide where the Suspension Bridge crosses it. The improvement of the channel in recent years has not revealed any complete cross-section of the rock-bottom of the river, but the sides have been found to slope down beneath the mud as steeply as 1 in 1, and to 27 and 32 feet below the level of low water. At the Zigzag[2] just above the Suspension Bridge, nearly 7 miles from the Severn, the rock-bottom was traced to a depth of $23\frac{1}{2}$ feet below the level of low water on each side, leaving 72 feet in the middle unexplored. The mud is 24 feet deep: gravel and large stones are usually found overlying the rock, which is Mountain Limestone.

West of the Avon an alluvial flat constitutes the southern shore of the Severn estuary as far as Highbridge. As to the rivers beyond that point I have no special information.

[1] Mr. G. W. Keeling, M.Inst.C.E., has kindly supplied the particulars of the Severn Bridge section.

[2] The writer is indebted to Mr. McCurrich, M.Inst.C.E., for this information.

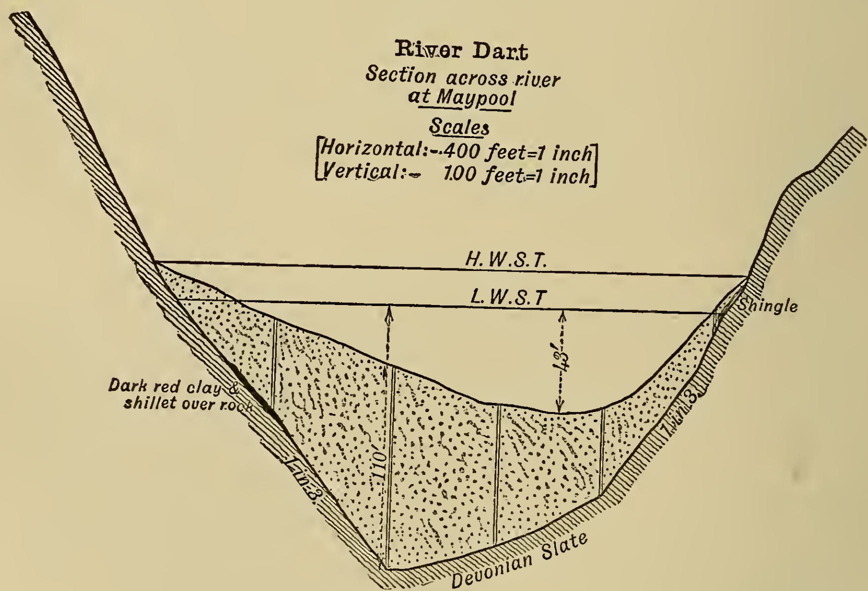
II. Devon and Cornwall.

The Dart.

The lower course of the river Dart lies between steep banks of Devonian slate. Its entrance from the sea is but 250 yards wide, inside which is Dartmouth Harbour, into which several creeks open Two miles up the river is another narrow part, which is crossed by two greenstone-dykes. Above that is a remarkable lake-like expanse of water more than a mile wide, and reaching to within $1\frac{1}{4}$ mile of Torbay.

Across the narrow part of the river, below this, near Maypool, borings were made for a proposed bridge. There is 43 feet of water at low-water spring-tides at the deepest place where the section (fig. 8) was taken, and 43 feet of mud and silt was found

N. Fig. 8. S.



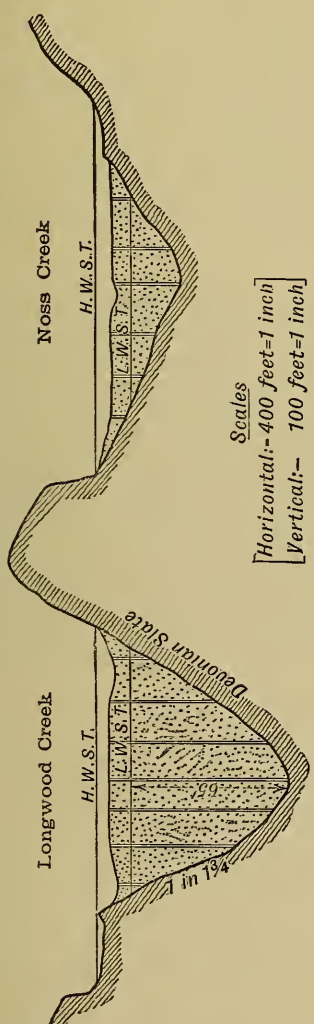
below that. The greatest depth to the rock-bottom reached was 110 feet below the level of low water spring-tides, under 85 feet of mud and silt. The average slope of the rock-sides, as shown in the section, is 1 in $3\frac{1}{3}$ on the south side, and 1 in 3 on the north side, corresponding with the slopes above the water-level, which rise to 130 and 150 feet above the river. The real slopes are steeper, as the section crosses the river obliquely ; for the same reason, a section at right angles to the valley would be narrower. Dark red clay and fine shillet (Devonian shale) are recorded as overlying the rock on the southern slope.

About $\frac{3}{4}$ mile below this section, on the left bank of the river, Longwood Creek is crossed by the railway. The piles of the timber viaduct were driven down to the rock, and the cross-section of the creek so obtained is given in fig. 9. The greatest depth to the rock reached was 65 feet below the level of low-water spring-tides, the silt being 75 feet deep over it. The rock-sides slope 1 in $1\frac{3}{4}$ and 1 in 3.

Noss Creek is crossed by a viaduct close by.

Just above Kingswear, opposite Dartmouth, is Waterhead Creek, crossed by a timber viaduct, during the construction of which borings were made, and piles were driven down to the rock at frequent intervals. The greatest depth reached was 91 feet below the level of low-water spring-tides, the mud and silt at that point being 95 feet deep. The sides of the rock-valley were found to slope 1 in $2\frac{1}{3}$ and 1 in $2\frac{1}{2}$.

Fig. 9.



At Kingswear Jetty several lines of borings were made, and many piles were driven, extending into the river for 120 feet from low-water mark, nearly at right angles with the Waterhead Creek section. The rock was proved to a depth of 71 and 73 feet below the level of low-water spring-tides. The silt was 52 feet deep, and over the rock was found about 4 feet of stiff red clay and stones. A little seaward of the jetty the entrance to the harbour has since been widened by dredging, and beneath the silt there a deposit was found too stiff to dredge. On examination in a diving-dress it was found to contain boulders of Dartmoor granite and white quartz.

The continuation of the slopes of the rock-sides at the Kingswear Jetty section down to the Maypool depth, and completing a section across the river from the rock exposed in the channel on the south side, gives a cross-section very similar to that of the rock-valley at Maypool (fig. 8).

Between Kingswear and Maypool now there is nowhere a greater depth of water than 54 feet, and the bottom is everywhere mud, sand, or gravel. Lower down in the narrow entrance is a depth of 78 feet, but seaward of that, and within a line drawn across from Coombe Point to inside the Mewstone, there is no depth greater than 40 feet, the bottom being nearly flat, of mud, sand, gravel, and shells, with rocks appearing here and there above it. Outside this line the depth increases, and the 10-fathom line is but 200 to 600 yards distant, passing close to the Mewstone, thence to Berry Head and outside Torbay. The depth of the rock-bottom at Maypool is not reached until nearly as far out as the 20-fathom line, about 2 miles outside the mouth of the Dart.

It may be noticed here that part of the town of Dartmouth (Butter Row, etc.) appears to be situated on a silted-up creek. The depth of the silt is considerable, and when a new quay-wall was built a few years ago the rock-sides of the creek were found to slope downwards to such a depth that the bottom was not reached by borings carried down from low-water spring-tides.

The drainage-area of the river Dart is 200 square miles, extending to Dartmoor (1971 feet above Ordnance datum). Waterhead Creek and Longwood Creek, where they join the Dart, are only $1\frac{1}{4}$ mile from the water-parting between that river and the coast between the Mewstone and Berry Head. The ground at the dividing ridge is 480 to 580 feet above the sea.

About 12 miles south-west of the Dart is the Salcombe estuary, which enters the sea between Prawle Point and Bolt Head, passing through the Archæan (?) rocks in a narrow channel. Inside that, in the Devonian shale, the estuary widens considerably and branches into seven creeks. There are no sections, but appearances lead me to think that there are submerged rock-valleys of considerable depth. The streams running into the creeks are short, rising in ground from 300 to 450 feet above the sea-level. The whole area now draining into the estuary does not exceed 50 square miles, but in former times the upper part of the drainage-area of the Avon may have been included. Farther west the estuaries of the Avon, Erme, and Yealm, which rise on Dartmoor at 1500 to 1600 feet above the sea, present similar features.

Plymouth and Neighbourhood.

A remarkable series of rock-valleys below the sea-level has been explored in the neighbourhood of Plymouth.

The general configuration of Plymouth Sound and the waters communicating with it will be seen on reference to a map. At the inner end of the Sound, east of Plymouth, is the entrance to Cattewater and the Laira, a section of the latter being afforded by the cylinder-foundations of a railway-bridge. Opposite the entrance to Cattewater is Sutton Pool.

West of the town of Plymouth is Millbay, occupied by the Great Western Docks, the bottom of which was thoroughly explored by borings. Farther west is the narrow entrance to Hamoaze through Devonian Limestone, inside which the water widens out and branches into many creeks or lakes, all in Devonian shale. Eight of these lakes are crossed by timber viaducts of the Cornwall Railway, in spans of 66 feet, the pile-foundations of which gave accurate sections of the rock-bottom. The Tamar is crossed by Saltash Bridge, and Tamerton Lake and the Tavy by viaducts of the South-Western Railway.

The Laira.

A section was revealed by the cylinder-foundations of the railway-bridge, which has been described by Mr. R. H. Worth.[1] The sides of the rock-valley have slopes as steep as 1 in 2, and dip down to 87 feet below the level of low-water spring-tides, leaving a width of 212 feet in the middle of the river unexplored, and possibly deeper. This valley is in the limestone-rock and is filled up to low-water level with sand, much of it of a coarse grain. Two layers of oyster-shells of considerable thickness were met with, one at about 30 feet, and the other at between 60 and 70 feet below the level of low water.

Towards the Sound, the rock-bottom of Cattewater is more than 64 feet below the level of low water, and in Sutton Pool the rock-side on the west slopes down at the rate of 1 in 2 to 60 feet below the level of low water. Complete sections are not, however, available.

Millbay.

Before and during the construction of the Great Western Docks nine sections of the rock-bottom were made from east to west about 100 feet apart, across what is now the outer basin, one along the inner basin in nearly the same direction, and five across it from north to south. The result was to reveal a rock-bottom in the form of a valley 73 feet below the level of low-water spring-tides opposite the outer pier, gradually shallowing to 46 feet at the wall of the inner basin, and then bending round to the east, towards the entrance of the old Union Dock, where the rock-bottom is 22 feet below the level of low-water spring-tides. Inside what was formerly Millbay the valley in the rock was filled up with silt to about the level of low-water spring-tides, the depth of it being from 55 feet at the outer end to 27 feet near the entrance to the Union Docks. In one section red clay-and-stones, about 3 feet thick, is recorded under the silt.

The lateral slopes of the valley are in places as steep as 1 in $1\frac{1}{2}$, and in one section 1 in 1. The inclination of the rock-bottom in the longitudinal section is regular within Millbay, outside which it falls more rapidly and soon joins the deep-water channel which forms the entrance to Hamoaze. The greatest depth between Millbay and Drake Island is 108 feet below the level of low-water spring-tides, with a rock-bottom; but not far off, opposite Eastern King Point, there is a sounding of 138 feet, and there is a deeper place outside the entrance to Hamoaze. Across the entrance, between Devil's Point and Wilderness Point, the width from shore to shore is only 370 yards, but the depth is 120 feet below the level of low water, and the rock-bottom on the western side slopes at 1 in 2. The rock on each side, and presumably at the bottom of the channel, is Devonian Limestone. Within the entrance, where Hamoaze widens out, the shores are of Devonian shale.

[1] Trans. Plymouth Inst. and Devon & Cornw. Nat. Hist. Soc. vol. xi (1890–91) p. 66.

Hamoaze.

Inside Devil's Point, on the Devon side of Hamoaze, is Stonehouse Pool, continued in a narrow creek for a mile inland, in which there is a considerable depth of mud, but about which information is wanting except at the inner end, where the creek is crossed by the Cornwall Railway. There, at $1\frac{1}{4}$ mile from the mouth, occurs 5 feet of silt over a rock-bottom 9 feet above low-water level.

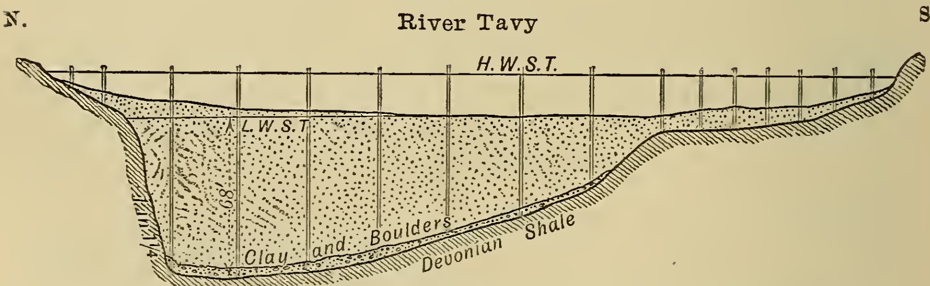
Passing up the eastern side of Hamoaze, we next come to Keyham Lake, the rock-bottom of which was proved by borings through silt. The greatest depth to the rock reached was 25 feet below the level of low water, at nearly $\frac{1}{2}$ mile from the mouth of the creek.

The piles of the railway-viaduct across Weston Mill Creek showed the rock-bottom to be a valley with sides sloping at the same inclination as above the sea-level, namely, 1 in 6 to 1 in $4\frac{1}{2}$, and with the bottom 66 feet below the level of low water in the creek, or 60 feet below that of low-water spring-tides in Hamoaze, where the deepest sounding opposite the creek is 72 feet below the level of low water. The mud is 72 feet deep at the deepest place on the section.

At the crossing of Tamerton Lake by the South-Western Railway the rock-bottom was traced only to a depth of 15 feet below the level of low water, where it was shelving downwards, the deepest part of the rock-valley being north of the bridge.

The cylinder-foundations of the viaduct across the Tavy gave a complete section of the rock-valley of that river (fig. 10). From the

Fig. 10.



[Scales: Horizontal, 400 feet=1 inch; vertical, 100 feet=1 inch.]

south the bottom slopes downward gradually to a depth of 68 feet below the level of low water, and then rises abruptly at a slope of 1 in $1\frac{1}{4}$. In every cylinder the rock (Devonian shale) was found to be covered with a deposit described as 'stiff yellow clay, including small granite-boulders,' or 'granite-boulders in hard yellow clay,' from 2 to 4 feet in thickness. Above this bed, which thinned out against the sides of the valley, is sand, about 68 feet thick at the deepest part, and reaching 8 or 10 feet above low-water level on the north side.[1]

[1] The particulars of this section were kindly supplied to me by Mr. R. H. Worth, who published it, and sections of some of the creeks round Plymouth, in Trans. Plymouth Inst. 1890–91.

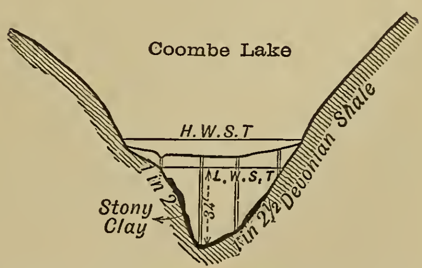
About $1\frac{3}{4}$ mile south of the confluence of the Tavy with the Tamar, the latter river is crossed by Saltash Bridge. Borings made about 1855, prior to the commencement of the bridge, proved the rock-bottom on the Devon side near high-water mark to be 13 feet below the level of low water, beneath 28 feet of silt with slate and stones. The rock was followed for 360 feet into the river to a depth of 30 feet below the level of low-water spring-tides, when it slopes downward at 1 in 5. At low-water mark, where the eastern pier of the bridge stands, there is 18 feet of blue silt and small slate, with large stones occasionally, and farther out in the river the rock-bottom is covered by 3 feet of blue silt with fragments of shells.

About the site of the central pier the bed of the river was examined by 175 borings made inside a 6-foot cylinder sunk into the mud at 35 different places. Where the central pier stands a cylinder 37 feet in diameter was sunk to the rock, which was ultimately laid dry. The rock-bottom was found to be irregular, but with a general slope of 1 in 6 to the Cornish side, in which direction it was traced to a depth of 76 feet below the level of low-water spring-tides, sloping westward at $2\frac{1}{4}$ to 1, with 24 feet of mud and silt over it. Immediately over the rock yellow clay and gravel, gravel and stones, and large stones are recorded. Oyster-shells in considerable numbers were found in the blue mud and silt excavated from the 37-foot cylinder.

On the Cornish shore the rock-bottom was found by divers to fall steeply towards the middle of the river, and, judging by the slope on that side, the greatest depth to the rock may be more than the 76 feet to which it was traced. The rock at the central pier was a trap or greenstone, so hard that tools could with difficulty be got to work it. A dyke of igneous rock in the clay-slate crosses the river on the line of the bridge, and four others are shown on the Geological Survey map across the mile of narrow channel at Saltash, above and below which, in the clay-slate, the Tamar widens out considerably.

Half a mile from Saltash Bridge, on the Cornish side, a timber viaduct crossed a short creek called Coombe Lake (fig. 11). The rock-bottom was proved to reach 35 feet below the level of low-water spring-tides, the sides sloping 1 in 2 and 1 in $2\frac{1}{2}$, corresponding with the slopes above water. The viaduct has in recent years been reconstructed in masonry, and the pier-foundations gave the same section of the rock-bottom, but resting on the rock was found a bed of stony clay, about a foot thick. The upper 2 or 3 feet of the rock (Devonian

Fig. 11.



[Scales: Horizontal, 400 feet=1 inch; vertical, 100 feet=1 inch.]

shale) was soft and broken up. The infilling of silt is about 40 feet deep.

Forder Lake, a creek over $\frac{1}{2}$ mile long, is crossed by the railway near its mouth. The deepest part of the rock-valley was found to be 66 feet below the level of low-water spring-tides, the sides sloping at 1 in 2 and 1 in 5, corresponding with the slopes above the sea-level. The infilling of silt is 70 feet deep. The deepest sounding opposite the mouth of this creek is 22 feet at low water, with a mud bottom.

Wiveliscombe Lake furnished a similar section, reaching 46 feet below the level of low water, with a depth of 56 feet of silt and mud.

Nottar Creek is tidal for $2\frac{1}{2}$ miles; it is crossed by a viaduct at about $\frac{1}{3}$ mile from its mouth. The rock-bottom was found to reach 46 feet below the level of low-water spring-tides, and the silt is 55 feet deep.

At the crossing of the St. Germans river the rock-bottom was proved to be 41 feet below the level of low-water spring-tides, with about 50 feet of silt over it.

Farther on in this direction the railway crosses rock-valleys above the sea-level, which have sections altogether similar to those of the valleys now partly below that level.

The drainage-area of the Tamar and Tavy above Saltash is about 450 square miles, extending nearly to the north coast, to Dartmoor (1971 feet), and to the Brown Willy range (1360 feet). The drainage-area of the Plym and Torry, flowing into the Laira, is about 70 square miles, rising to 1600 feet; that of the Lynher, entering Nottar Creek, about 50 square miles, rising to about 1300 feet. The Tidi, entering St. Germans river, drains only 25 square miles, rising to about 900 feet above the sea, and the other creeks are fed by streams of quite insignificant length, which drain only a few miles of country, though they rise in comparatively high ground. The streams running into Coombe Lake and Forder Lake flow from land 250 to 300 feet above the sea, that into Weston Mill Creek from land 300 to 350 feet, and those into Stonehouse Creek and Millbay from land 200 feet above the sea. It is evident that neither in area of cross-section nor in depth do the rock-valleys bear any proportion to the present drainage-areas.

The deep-water channel from Hamoaze follows the western shore to opposite Drake Island, and then bends round to the north of it, passing by Eastern King, Millbay, and the Hoe to the mouth of Cattewater, where it turns south. There are soundings of 20 to 23 fathoms along this line to opposite Millbay, and of 14 to 15 fathoms opposite the Hoe; outside that, to the Breakwater, the Sound is nowhere deeper than 9 fathoms, with a bottom of blue clay, which probably covers a deeper channel in the rock. Outside the Breakwater the depth increases gradually to the 10-fathom line, which lies $\frac{3}{4}$ mile outside the Sound. Seaward of this the depth increases more rapidly to 14 and 22 fathoms, but it is quite $1\frac{1}{2}$ mile outside the Sound before a depth as great as that at the entrance to Hamoaze is reached.

Cornwall.

About 20 miles west of the Plymouth group of valleys is the Fowey estuary, suggesting similar submerged valleys, of which, however, there is no direct evidence.

About 7 miles farther west the construction of the Gover Viaduct, near St. Austell, furnished a section of the valley in which the Pentuan stream-tin works were situated. The river rises near Hensborough Beacon (1027 feet), and has a course of about 8 miles. At Gover the rock-bottom of the valley is 179 feet above the sea, and the present bottom is 39 feet higher. The Pentuan stream-tin works extended from about 3 miles lower down the valley to within ½ mile of the sea, a distance of more than a mile. At the upper end of the workings the rock-bottom is above the sea-level, but near the sea, according to the section given by W. J. Henwood,[1] it is 36 feet below the level of low water. The tin-ground there rested immediately upon a clay-slate bottom, and consisted mostly of rounded fragments of granitic rocks from the hills above St. Austell, with angular fragments of greenstone and clay-slate. J. W. Colenso[2] states that the tin-ground was distinguished by the streamers as 'loose ground,' consisting of sand, pebbles, and stones, and 'tough ground,' in which the whole was cemented together by yellow clay, so as to render it difficult to separate and wash. The same writer notices that the rock beneath appeared to be worn by friction, but not that under the 'tough ground.' The surface of the rock was irregular, while the top of the tin-ground was even, so that the latter ranged in thickness from 3 to 6 or even 10 feet. Rooted in the tin-ground were stumps of trees, to which oysters were attached, at 30 feet below the level of low water, or 48 feet below high-water spring-tides. A bed of silt, with leaves, roots, etc., succeeded, and silt and sea-sand alternated for a thickness of about 52 feet. A mile higher up the valley there was no sea-sand.

Westward again is Falmouth estuary, with its numerous creeks, one of which, Restronguet Creek, is the continuation of the Carnon Valley, both of which have been extensively explored in the search for stream-tin. In the middle of the creek, about a mile from its mouth, near Point, a shaft was sunk through iron cylinders to the rock-bottom of clay-slate at 64 feet below the level of low water.[3] The tin-ground, according to the irregularities in the surface of the rock, was from 6 inches to 6 feet thick, and over it lay 63 feet of silt and mud, with oysters and cockles. About ¾ mile higher up the creek, at Narabo Inlet, is the section described by W. J. Henwood,[4] where the rock-bottom was 56 feet below the level of low water, and the tin-ground was immediately overlain by a bed of wood, moss, leaves, nuts, etc., 44 feet below the level of low water, containing a few oyster-shells and animal remains, including human

[1] Journ. R. Inst. Cornwall, vol. iv (1873) pp. 243, 254.
[2] Trans. R. Geol. Soc. Cornw. vol. iv (1832) p. 30.
[3] Journ. R. Inst. Cornw. vol. iv (1873) p. 204.
[4] Trans. R. Geol. Soc. Cornw. vol. iv (1832) p. 58.

skulls. The tin-ground consisted of rounded masses of tin-ore, sometimes unmixed with any other material, and rounded fragments of slate, granite, and quartz. In other sections in this valley the tin-ground is described as containing angular and subangular blocks of granite-rocks, slate, elvan, etc., with tin-ore in large rounded masses, or in the state of gravel and sand. The upper surface of the tin-ground was perfectly even, falling seaward with the valley.

At a short distance below Higher Carnon, about 3 miles from the mouth of the creek, a timber viaduct of the Falmouth Railway afforded a section of the valley. The rock-bottom is a few feet below the level of low water, and is now covered with 24 feet of gravel and silt. Originally the tin-ground in this part of the valley was immediately overlain by fluviatile deposits of recent age.

The streams flowing into the Carnon rise in the Gwennap and Stithian Hills, from 4 to 7 miles off, and about 600 or 700 feet above the sea, the former hills being of clay-slate and the latter of granite. The Falmouth estuary, opposite Restronguet Creek, is 72 feet deep, with a sand- or gravel-bottom. It deepens seaward to 114 feet at the narrow entrance, outside which the bay is shallower, and the depth is not so great as that of the rock-bottom in Restronguet Creek for a mile out.

Close to Penryn the crossing of a creek furnished a section of a regularly-shaped rock-valley, 24 feet below the level of low water, filled up to that level with silt.

III. General Observations.

About as far north of Milford Haven as Plymouth and Falmouth are to the south of it is the old rock-valley of the Mersey, filled in with Boulder Clay and Glacial deposits, to which Mr. Mellard Reade[1] first called attention, and which has since been traversed by the Mersey Tunnel and the Vyrnwy Aqueduct.

On the western coast of Wales the valleys opening into Caerdigan Bay are striated by land-ice, and near Barmouth, where, as already mentioned, the rock-bottom of the Mawddach Valley has been traced to 40 feet below the level of low-water, striated rocks are exposed at low tide. Sir A. Ramsay long ago pointed out that there are well-marked glacial striations on the rocks of the coast of Pembrokeshire, and that Boulder Clay with ice-scratched stones is common there, and occurs here and there all over South Wales. Prof. David has described in detail the evidences of glaciation in South Brecknockshire and East Glamorgan.[2] He has shown that Boulder Clay containing rocks from the Brecknockshire mountains occurs in the Taff Valley down as far as Treforest, and also in the Ely Valley as far south as St. Fagan's and St. George's, near Cardiff, where it is about 20 feet above sea-level. He observed an extensive striated surface of Coal Measure sandstone under the Boulder Clay

[1] Proc. Geol. Soc. Liverp. 1873, p. 42.
[2] Quart. Journ. Geol. Soc. vol. xxxix (1883) p. 39.

near Treforest, and a striated surface under Boulder Clay 12 to 15 feet thick at the western end of the tunnel at Pen-cae-draen, between Hirwain and Glyn Neath, in the Neath Valley, the striations being in the general direction of the valley, though 400 feet above the river. This was as far as Prof. David followed the evidences of glaciation in that direction, but there is a similar deposit lying on a planed surface of Coal Measure sandstone at a corresponding level 2 miles lower down the valley, where the railway cuts into the eastern side near Hendre Wyddel, and Boulder Clay and erratic blocks are to be found all down the valley.

The section of Boulder Clay near Cwrt Sart has been noticed. It is about as far from the Brecknockshire mountains as the Boulder Clay near Treforest, and 10 miles farther north than the Boulder Clay at a corresponding level at St. Fagan's. It would seem that the Boulder Clay which, in the upper part of the Neath Valley, Prof. David considered to be the product of land-ice descending from the Brecknockshire mountains, extends down to the mouth of the river, where it now lies far below sea-level, and it would appear that the Neath and Tawe valleys, like the Mersey Valley, are partly filled with glacial deposits. To what extent the scooping out of the valleys may be attributed to glacial action is difficult to say.

I am not aware of any Boulder Clay in the valleys connected with Milford Haven; but, with the evidences of glacial action in the neighbourhood, it appears reasonable to attribute to land-ice from the Prescelly Hills a share in the excavation and the moulding of the rock-valleys now submerged in Neyland and Milford Pills.

The evidences of glacial action in South Devon and Cornwall are scanty, but not altogether absent.[1] In the Bovey Heathfield, lying unconformably upon the Miocene beds, is a deposit of sandy clay, with a large admixture of angular and subangular stones varying in size from that of a hazel-nut to blocks of a foot in diameter, which has most of the characteristics of Boulder Clay, and in a clay resting upon it the dwarf Arctic birch and willow were found. Erratic blocks and scratched stones have been observed in various places in South Devon: Pengelly described blocks of white opaque quartzite,[2] some as large as $10 \times 3\frac{3}{4} \times 3$ feet and $10\frac{1}{2} \times 5\frac{1}{2} \times 3$ feet, which are found resting on Devonian shale, or sometimes 'in a heterogeneous accumulation of clay and stones'[3] in the neighbourhood of Tamerton Foliot, and which he calls 'whitakers.' That, however, is a local name for a white spar, and is not the name of any particular blocks; erratics of the same material, and also of Dartmoor granite, strew all the neighbourhood down to the level of the river Tavy. Many are built into fences, while many remain in the soil. The blocks described by Pengelly are probably those near Blaxton Farm. One group is on the water-parting between two valleys tributary to the Tavy, and about 400 feet above the sea. Another group is on the

[1] W. Pengelly, Trans. Devon. Assoc. vol. xv (1883) p. 369.
[2] *Ibid.* vols. vii, ix, xii (1875–77–80).
[3] *Ibid.* vol. xii (1880) p. 311.

flank of the more southern valley, about 100 feet lower. Yet another group of large blocks is passed through by the railway near Gawton, between Beer Alston Station and the tunnel, about 4 miles higher up the valley. They lie near the water-parting between the Tavy and the Tamar, which are there not much more than a mile apart, at about 400 feet above the sea. Other blocks strew the slope of the Tamar Valley.

In the bottom of the Tamar Valley at Rumleigh, about a mile above Calstock, is a Boulder Clay deposit worked for brickmaking. The upper 4 to 6 feet, reaching to 10 or 12 feet above high water in the river, is lighter in colour and less clayey than the lower, which is visible to a depth of 20 feet. The matrix is a mixture of clay and small stones, and contains angular slate, rounded boulders of granite, white opaque quartzite, and a hard, dark, jasper-like rock with brown veins. A block of granite with large felspars, subangular, but smoothed, measured $2 \times 2 \times 2$ feet, and many other boulders nearly or quite as big remain in the bottom of the pit.

It would be interesting to trace the origin of these boulders to the high ground drained by the present river, but it is more to the present purpose to lay stress upon the marked glacial character of the deposits. Mr. R. H. Worth, who brought this and the similar deposit near Weir Head to my notice, assured me that what was called 'stiff yellow clay with granite-boulders' and 'granite-boulders in hard yellow clay' found in the cylinders of the Tavy bridge-foundations corresponded in all respects with these deposits. There appear thus to be here, as in South Wales, glacial deposits in rock-valleys now below the sea-level, the valleys of course being older than the deposits laid down in them. In this connexion the observation of Colenso, that the rock-bottom under the stream-tin deposit at Pentuan appeared to be worn by friction, made some years before Agassiz drew attention to glacial action in this country, is interesting.

It is difficult to suppose that the rock-valleys now many feet below the level of low water were scooped out, by whatever cause, or moulded by land-ice at that level. If those in South Wales were to be raised above the sea-level, the sea-bed, as far out as the 10-fathom line, would be laid dry. This would include all Milford Haven except a few narrow pools, all Caermarthen Bay inside Caldy and Worm's Head, all Swansea Bay, and all the Bristol Channel to the east of Barry, except a narrow channel extending up to the Flat Holme, and a few pools higher up. The sections which have been described would thus be far from the sea, and it may be reasonably supposed that the valleys would have been considerably above it. An elevation of 20 fathoms would lay dry all the Bristol Channel east of Swansea and Ilfracombe, and leave the mouth of Milford Haven more than a mile from the sea.

To raise the rock-valley of the Dart at Maypool above the sea, everything out to the 20-fathom line must be laid dry. This line passes $1\frac{1}{2}$ mile outside the mouth of the Dart, 1 to 2 miles outside

Torbay, and 14 miles from the shore in West Bay between the Exe and Portland. About the same elevation of the land would be necessary to raise the bottom of the rock-valley at the entrance to Hamoaze to low-water level; though, as its bed now lies, much less would lay all Plymouth Sound dry. The 10-fathom line on the chart is well outside the Sound, and the 20-fathom line only $\frac{3}{4}$ to $1\frac{1}{4}$ mile farther out.

An elevation of the land to the extent of 120 feet during the Glacial Period is a very moderate supposition. It was probably much more. Whatever it was in the areas under notice, there must have occurred subsequently the depression required to bring the raised beaches down to the sea-level, after that the elevation necessary for the growth of peat and forests now far below the level of the sea, and then the depression of the land to its present level.

To the last period of the long duration of time covered by these and other movements the greater part of the deposits now filling up the submerged valleys appears to belong. In the South Wales sections the upper part of the silt is quite recent, being the *Scrobicularia*-clay common in the Bristol Channel. Beneath this, in the Chepstow cylinders the clay, silt, and sand containing stalks of plants, nuts, leaves, and timber extend downward to the red gravel with boulders, and in one cylinder oak-timber was found in the gravel close to the rock-bottom. In the cutting east of the Severn Tunnel, the silt with peat-beds extends down to the sand over the gravel-with-boulders. In many sections on the borders of the Bristol Channel gravel is found beneath the silt with peat, the division between them being marked.

The submerged rock-valleys around Plymouth are filled in with recent marine deposits. There are beds of oysters in the sand of the Laira section, and many oyster-shells and fragments of other shells were found in the Saltash cylinders. A marine deposit appears to extend down to the clay-with-stones in the Tavy and the Coombe Lake sections, and down to the rock at Saltash, except where patches of yellow clay, gravel, and stones were found on the rock.

In the stream-tin sections in Cornwall, the deposits down to the 'tin-ground' are also of recent date. At Pentuan oak-trees were found rooted in the tin-ground. Peat immediately overlies the tin-ground at Sandycock and Poth in the neighbouring valley, under 36 feet of recent marine and fluviatile deposits. In Restronguet Creek horns and bones of deer were found in the silt over the tin-ground, and at Narabo Inlet human skulls were found in the bed immediately over the tin-ground. In these sections there is an alternation of marine and freshwater deposits. Higher up the valleys where the marine deposits do not extend, the contents show that the beds down to the tin-ground are of quite recent date. In the tin-ground itself no organic remains have been discovered.

It thus appears that the upper portions of the deposits filling in the submerged rock-valleys down to the gravel-with-boulders in the Bristol Channel, to the clay-with-boulders near Plymouth, and to the tin-ground in Cornwall are no older than the submerged forests.

For the deposits below there remains all the time back to the period of the excavation of the valleys, and there is little to show to what part of that time the several deposits belong. The gravel and large stones over the Boulder Clay in the Neath section, some of the gravel with erratic boulders in the Wye cylinders, and the coarse gravel with glaciated blocks in the cutting east of the Severn Tunnel may, I think, be referred to the latter part of the Glacial Period. The same may be said perhaps of the clayey gravel and stones overlying the rock-bottom of the Severn at the bridge, though if so the gravel overlying the peat in one pair of cylinders must be newer than the rest.

The clay and stones, clay and gravel, large stones and boulders found overlying the rock-bottom in the Dart, at Millbay and at Saltash, are probably of Glacial age, but they have been too little seen for anything to be said with confidence. Further information may show, as at Coombe Lake and in the Tavy section, that they are part of a continuous layer of 'boulder-clay' over the rock.

The stream-tin gravels of Pentuan and Carnon are considered by Mr. Ussher[1] to be newer than the raised beaches, and that view appears to have been adopted by Sir J. Prestwich, who included these gravels among 'Head' or 'Rubble-drift' deposits.[2] The reasons given by Mr. Ussher do not seem to me to be conclusive. Stream-tin detritus, or a gravel of local rocks and tin-ore of all sizes, occurs at St. Agnes Beacon, near the north coast, 8 miles from Carnon, under alternating sands and clays of uncertain age, but undoubtedly far older than the raised beaches. They are 300 to 400 feet above the sea, they appear to be unconnected with the present configuration of the surface, and they are overlain by 'head' or-rubble drift. De la Beche considered that they belonged to a class of deposits that may once have covered a considerable portion of the district, and which have been since removed, with a large mass of pre-existing rocks, to form the surface as we now see it. They are classed by him as Tertiary, and by Mr. Ussher as ranging from Tertiary to early Pleistocene times.[3] Considering the small proportion that the tinstone bears to the containing rock, the degradation of the latter necessary to produce stream-tin detritus must have been very great, and it is not surprising that it began so far back; but the existence of these old stream-tin gravels appears to nullify the conclusion that, because stream-tin detritus is not found in the raised beaches, it is therefore more modern than they. The older gravels must have furnished part of the materials for the stream-tin gravels of the existing valleys, and that would account for the mixture of rounded

[1] 'The Post-Tertiary Geology of Cornwall,' 1879, p. 45.

[2] Quart. Journ. Geol. Soc. vol. xlviii (1892) p. 342.

[3] See also J. Hawkins, Trans. Roy. Geol. Soc. Cornwall, vol. iv (1832) p. 137; De la Beche, 'Report on the Geology of Cornwall, Devon, & West Somerset,' 1839, p. 259; and Ussher, 'The Post-Tertiary Geology of Cornwall,' 1879, pp. 12–39.

and angular forms in the tin-ground; for the difference which has been observed between the tinstone in the tin-ground and that in the local mineral veins; and for the absence of other ores in the former which are abundant in the latter—difficulties which have always been recognized in speculations on the origin of stream-tin.

Having regard to the resemblance which the 'tough ground' at Pentuan as described by Colenso bears to the clay-with-boulders in precisely similar positions at the bottom of some of the valleys round Plymouth, and to the considerations set forth above, I am disposed to think that the stream-tin gravels are rather of Glacial age than that they are more recent than the raised beaches.

It will be noticed that the most easterly valley in the English Channel which has been described is that of the Dart, and unfortunately there is no information about the rock-bottoms of the rivers farther up the Channel. The foundations of the long bridge over the Teign near Teignmouth might afford an interesting section, but there are no records of them, and of the Exe nothing is known.

Farther eastward, beyond the shallow West Bay, are the valleys which were once tributaries of the old Solent, and the Thames Valley. Whatever may be the age of the gravels bordering the former valleys at high levels, they are certainly in part post-Glacial, and since they were spread out the rivers have scooped out wide and deep valleys. In the Thames Valley the Boulder Clay is at the lowest 90 to 120 feet above the sea-level, and the river must have lowered its bed by more than that since the Boulder Clay was deposited. It seems to follow, therefore, that if the valleys which have been under consideration are older than the Boulder Clay, they must have existed long before the valleys of the Solent and the Thames were scooped out to anything like their present depth, and when land perhaps drained by tributaries flowing eastward to the Solent filled up part of the English Channel.

The difference in age, and in the conditions under which they originated, have left their mark on the natural features of the two sets of valleys; but later, perhaps after the opening of the Straits of Dover, the conditions seem to have become more alike. Raised beaches and submerged forests appear all along the coast, except in the shallow West Bay between Portland and the Exe, and the later alluvial deposits with peat-beds are found in all the valleys from Milford Haven to the Thames. The relative position of these later deposits is, however, different. In the western valleys they overlie the Glacial beds, but in the valleys of the Solent and the Thames they lie at a lower level than the Glacial and post-Glacial beds which border the sides of the valleys. In the Thames Valley at Tilbury Docks peat-beds were found at 50 to 60 feet below high-water level, lying on gravel over the Chalk, and the chalk-bottom was as much as 74 feet below that level, or 56 feet below the level of low water, in one place. This is, after all, very little deeper than the present river-bottom close by, and may not be the deepest part of the old channel, but it is 160 feet lower than the Boulder Clay at Horn-church, about 6 miles distant, the lowest Boulder Clay hitherto found in the Thames Valley.[1]

The Boulder Clay appears to occupy a similar position in relation to the valleys of the Blackwater and the Colne, and also to the river-valleys of East Anglia. Farther north, in the valley of the Humber, the relation of the Glacial beds to those of more recent age is the same as in the western valleys which have been described. The chalk-bottom at Hull[2] is as much as 87 feet below the level of low water, and on it lie 50 or 60 feet of Glacial beds—Purple Clay, Hessle Sand, and Hessle Clay—upon which is a peat-bed with trees rooted in the Hessle Clay, as much as 17 feet below the level of low water. Above the peat is silt with *Scrobicularia*, in some places 30 feet thick. Still farther north, the Esk at Whitby, the Tees, and the Tyne flow in pre-Glacial valleys, of which the rock-bottoms are many feet below the level of low water, and which contain Glacial beds, peat, and silt in the same succession.

The resemblance between these northern valleys and those to which this paper relates, and the difference between both these groups and the valleys nearer to the former land-connexion with the Continent, are not, perhaps, without significance. It is, however, a matter beyond the scope of this paper, in which my object has been to show that over a large extent of coast in South Wales, South Devon, and Cornwall there are valleys excavated in rocks of different kinds, the bottoms of which are now as much as 80 and 110 feet below the level of low water, which are partly filled with deposits not older than the submerged forests, beneath which deposits of Boulder Clay and other Glacial beds are found overlying the rock-bottom; and that consequently these valleys must have been excavated to their present depth before the Glacial Period, and before the rivers in the eastern part of the English Channel, tributaries to the old Solent and the river Thames, had cut through the Glacial deposits which border on their valleys at high levels.

Discussion.

Mr. Strahan wished to add his expression of welcome to the Author after a long absence. The description given of valleys filled with mud to so great a depth below sea-level emphasized the fact that the land must have stood at a considerably higher level in comparatively recent times, not only in South Wales, but all round our coasts. In most cases the tide had repeatedly scoured out and redeposited the muds and silts; but in the almost land-locked area of Barry Dock, which he (the speaker) had recently described, the sequence of deposits had been preserved, and more than one land-surface remained intact, the lowest, with land-shells and tree-stools in place, proving a subsidence of about 60 feet. There, moreover, proof had been obtained that the change of level had taken place

[1] See T. V. Holmes, Quart. Journ. Geol. Soc. vol. xlviii (1892) p. 365.

[2] J. C. Hawkshaw, Proc. Inst. C.E. vol. xli (1875) p. 93; Wood & Rome, Quart. Journ. Geol. Soc. vol. xxiv (1868) p. 182.

during and after Neolithic times. While not disputing the identification, he wished to know on what evidence some of the deposits had been classed as Glacial, and what was the distinction between them and the 'stony clay' referred to in other valleys. In the estuary of the Dee there occurred a layer of great boulders at the base of the alluvial deposits; these had no doubt been washed out of a Boulder Clay, but did not themselves constitute a Glacial deposit.

Mr. C. E. de Rance spoke of the great value of such a record of observed facts as that given by the Author in his paper. It mattered little whether true Glacial deposits had been discovered or not in these submerged valleys in South Wales and the South-west of England, as there could be no doubt that these valleys were excavated by rain and rivers before the Glacial episode. Similar valleys in North Wales, Cheshire, and Lancashire occur at depths of nearly 200 feet below the mean tide-level, and are filled up to the existing height with undoubted Glacial deposits, through which post-Glacial valleys have been excavated $1\frac{1}{2}$ mile wide and 180 feet deep, at the bottom of which occurs the modern alluvium, consisting of silt, peat, and heavy gravel. The peat is connected with the thick peat of West Lancashire and Cheshire, which descends to a level of at least 70 feet below mean tide. On its surface is *Scrobicularia*-clay, in which Roman coins occur just below high-water mark at Fleetwood: so that the post-Glacial subsidence is older than the Roman epoch. He connected the massive gravel with the stream-tin deposits of the South-west, which he considers to be of post-Glacial age. The facts given by the Author, correlated with the observations made farther west, point to a common cause.

Dr. Hicks agreed with the Author that the valleys in South Wales referred to were of pre-Glacial age and had originally been filled with Glacial deposits. These, and others which the speaker had examined on the Welsh coast, still contained Glacial deposits in the parts beyond the reach of tidal erosion. The varying depths at which the rock-bottom had been reached were partly due to more rapid marine encroachment in some areas than others.

Prof. Seeley regarded these valleys as evidences of upheaval of the country, and of its excavation by subaerial denuding agents during the Miocene or Pliocene period. Deep and narrow valleys in Cambridgeshire, especially the west, were filled with Boulder Clay, and they had been shown by well-sinkings to descend much below the present sea-level; so that the elevation, which affected a wide area of country, was pre-Glacial and may have been a condition leading up to glaciation. The inland valleys often retained the filling of Boulder Clay, but those which descended to the sea had been more or less scoured out, though filled with a subsequent downwash of mud.

Mr. A. E. Salter understood from the paper that the Author correlated the deposits found in these submerged valleys with the Glacial deposits of the Thames and Frome areas on the one hand, and with the stream-tin deposits of Cornwall on the other. In the former cases, however, the Glacial deposits are devoid of mammalian remains which occur in the lower Pleistocene gravels in various localities of the same area. On the other hand, the stream-tin deposits contain such remains, and also give the same evidence of depression as do the deposits described in the paper. For these reasons, these deposits appeared to him to be post-Glacial.

Mr. J. E. Clark called attention to two important points which the paper seemed to establish. The submergence in the South-west exceeded that in the South-east, exactly as had been shown between North-western and North-eastern England, and again in Western and Eastern Scotland. The deeply submerged peats and tree-stools indicated, again as in the North, that the post-Glacial recovery brought the land-level almost to normal pre-Glacial conditions. But its brief duration was strikingly shown by the York Central Plain. If the Glacial beds were stripped away, there would now be a vast inland sea, hundreds of square miles in extent, reaching beyond York, whereas the post-Glacial Ouse had only time to cut a narrow, 70 feet deep, gorge through the present site of the city.

Mr. Lamplugh commented on the steep trough-like character of these old valleys in every part of the country, and on the fact that they often occur within broad and shallow depressions of higher antiquity. They were evidently due to an elevation of comparative rapidity and of short duration, so that the streams had never reached their new base-level of erosion. Hence they did not register the full amount of the elevation.

Mr. Clement Reid and Prof. W. W. Watts also spoke.

The Author, in reply, said that the Boulder Clay in the Neath bridge-foundations was no longer visible, but the deposits close by were still to be seen. The contained rocks appeared to be from the high ground not far off. Most of the points raised in the discussion were dealt with in the paper, for the favourable reception of which he thanked the Fellows.

22. *The* Structure *of the* Davos Valley. By A. Vaughan Jennings, Esq., F.L.S., F.G.S. (Read January 5th, 1898.)

[Abridged.]

In several of the high Alpine passes and valleys there are certain structural features which show that important changes in the process of denudation have taken place, and that in many cases there has been an alteration or complete reversal of the drainage-system.

Among a considerable number of instances, that of the Upper Engadine or source of the Inn is perhaps the most familiar. Prof. Heim,[1] Prof. Bonney,[2] and others have called attention to this area as showing the way in which the gorges of the southern side of the Alps are cut back with far greater steepness than the river-valleys of the northern slopes. While Prof. Bonney regards the difference as due to the greater rainfall and more rapid current on the southern side, and the consequently greater erosive power of the torrents, Dr. Preller[3] believes that it is not possible to account for the present condition of the district without presupposing a subsidence on the south. Whichever view may be held, however, there is no doubt as to the facts. It can hardly be disputed that the Inn once took its rise beyond Maloja, and that the glaciers on the south once contributed to its formation streams now diverted towards the Italian plain. The valley has in fact been decapitated, and its feeding-streams have been diverted into a new and opposite course.

The object of the present paper is to call attention to the conditions which exist in the adjacent area of Davos: conditions which are to some extent parallel, but, on the other hand, are distinctly more complicated and less easy of explanation.

Though the term 'Davos Valley' is commonly used, it is not strictly accurate, or at least conveys a wrong impression in suggesting a similarity to the structure of the Engadine. The district is an almost level area some 4 miles in length; and the rivers which flow from either end, a tributary of the Landquart on the north and the Landwasser on the south, ultimately fall into the Rhine near Chur. The Landwasser is fed by three principal streams from the east—the Fluela, the Dischma, and the Sertig; and just below the influx of the latter it descends steeply towards Glaris and the great Züge gorge. It receives also streams from the western side, and a very insignificant outflow from the deep lake which occupies the northern fourth of the area. The northern outlet is only by the Lareter Bach, descending from the slopes of the Todtalp and dropping through a steep cleft to Klosters. There is thus a

[1] Heim, Schweiz. Alpenclub, 1879.
[2] Alpine Journal, vol. xiv, p. 221; Geol. Mag. 1888, p. 540.
[3] Geol. Mag. 1893, p. 448.

very marked difference between the whole formation of the 'valley' and that of the Upper Engadine.

The level area is occupied by a river running southward, and the lake is a deep one, of very different character from the Silser and Silvaplana Lakes.

It is possible that, as Prof. Theobald held,[1] the Landwasser once had its source on the Rhätikon ridge, but was subsequently severed from it by the back-cutting of the Landquart. There are, I believe, difficulties in the way of accepting this theory, but I do not propose to discuss it at present, since such changes belong to a geological period far more remote than that in which the Davos area acquired its present characteristics. There can be little doubt that the present great valley-systems were defined before the glacial epoch,[2] but it seems that the present features of this district are due to causes operating during and since that time. A short description of the region will, it is hoped, make this clear.

A survey of the district divides itself naturally into three sections:—The central level, with the lake, the upper Landwasser and its tributaries; the northern ridge, forming the watershed towards Klosters; and the southern outlet, where the rushing waters of the Landwasser and the Sertig Bach have carved out the striking Clavadel-Frauenkirch terraces.

The central level is about 4 miles long, reaching from the head of the lake to the southern end of Davos Platz. Round the margin of the lake runs the contour-line of 1560 metres, and if the same line is traced southward it will be found at the mouth of the Sertig Thal to lie along the level of the Wildboden. In other words, the flat-topped terraces so conspicuous opposite Frauenkirch are on the same level as the surface of the Davoser See.

Between these two points the river runs entirely on superficial deposits. There is no spot between the lake and Frauenkirch, or indeed far south towards Glaris, where the two banks of the river are composed of solid rock *in situ*. The whole extent of the level is a mass of detritus, filling in a steep-sided valley, in which the real rock-floor is nowhere visible. It is true that Davos does not stand on an alluvial flat in the usual sense of the term, owing to the presence of great talus-fans on both sides; but the appearance of the central area is such that one finds the unscientific visitor quite ready to believe in the former extension of the lake. The stretch of level which produces this effect is not, however, at the head of the lake, but on the side of the present outflow.

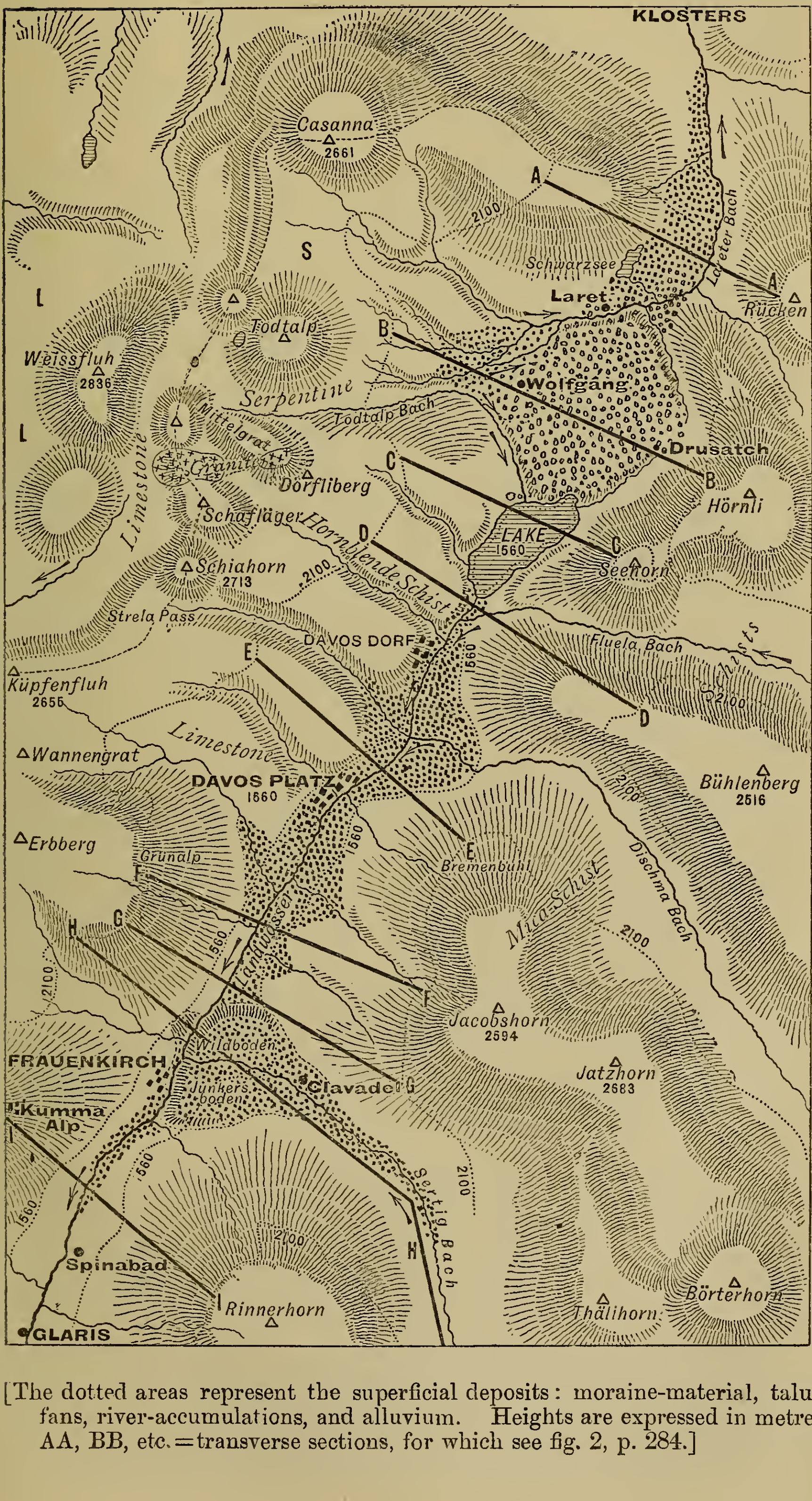
On the western side several streams flowing from deep-cut gorges have poured their burden of detritus in spreading fans over the foot of the mountains. The Schiatobel, between Davos Platz and Davos Dorf, forms the convex surface on which much of the new town is

[1] 'Naturbilder d. Rhät. Alpen'; see also Lubbock, 'Scenery of Switzerland,' London, 1896, p. 456.

[2] The term is used in this paper merely to signify the latest time of glaciation of the district.

Fig. 1.—*Map of the Davos Valley.*

[Scale 1 : 25,000, or about ½ inch = 1 mile.]



[The dotted areas represent the superficial deposits: moraine-material, talus-fans, river-accumulations, and alluvium. Heights are expressed in metres. AA, BB, etc. = transverse sections, for which see fig. 2, p. 284.]

built. The Albertitobel, south of Davos Platz, contains only a small stream, but one which is powerful and even disastrous in floodtime. Its talus-fan is of immense thickness and spreads right and left, underlying the rounded hillocks of the Gemsjäger hay-meadows and the southern extension of the town.[1] Opposite to it, the rapid weathering of the Jacobshorn has resulted in the accumulation of a great fan on the eastern slope.

These great deposits at the mouths of the incurrent valleys, and the weathering of the slopes between them, have not only disturbed the general level of the area, but add greatly to the difficulty of the geologist in trying to ascertain the real contour of the solid rock. It is important to note that the edges of these talus-fans are abruptly truncated by a former river-cutting, so that there is a series of steep banks, sometimes 30 feet in height, terminating the detrital slopes of the Schiatobel, the Kajölertobel, and others. Had the Landwasser occupied its present course[2] while these talus-fans were accumulating, they would not have assumed their actual form. The sharp angle between their surface-slope and the steep-cut terminal bank indicates some comparatively sudden change in the drainage-conditions of the district.

The main tributaries of the Landwasser, as before mentioned, come from the three great valleys on the east:—the Fluela, the Dischma, and the Sertig. These have their origin far back on the chain of peaks west of the Engadine, and receive the waters from the snow- and ice-fields of the Schwarzhorn, the Piz Vadret, the Kühalp, and the Ducan.

The Fluela Bach drops through a steep gorge at the foot of the Seehorn and then turns southward, receiving, by an insignificant stream winding through meadows, the discharge of the Davoser See. Where it emerges from the mouth of the Fluela Thal the simplest engineering would divert the stream into the lake; and, indeed, within the last 30 years it has been known in floodtime to force its way thither across the hayfields.

The Dischma Bach drains a wider valley, and finds its way down the middle of its alluvial triangle into the Landwasser. It may be noted that while the foot of the talus-slopes of the Bremenbühl creeps out, tree-clad, to the level, with no sign of stream-cutting at its base, the opposite slope is steep and bare, as if the current had formerly scoured its surface.

Such being the general character of the Davos level, it becomes necessary to examine the structure of the district round and north of the lake. Here we find on the east the great rock-walls of the Seehorn, the Hörnli, and the Rücken, dipping so steeply that in

[1] Herr Pfarrer Hauri informs me that the upper part of this mass was formed by a great 'slip' from the gorge above, during floods, at the end of the last century. The contour of the older, slowly-accumulated fan can, however, be easily seen a short distance south of the railway-station.

[2] In speaking of the 'present course' I refer to the recent natural course before the 'correction' or canalization was undertaken some years back.

places the 30-metre contour-lines on the map are only $\frac{1}{2}$ millimetre distant. The slopes of the Seehorn dip straight into the lake; those of the Rücken disappear in the Lareter gorge; but the steepness of the Hörnli mass is suddenly broken at the Drusatch Alp, and a long, low, pine-clad ridge stretches from that point transversely across the valley to Wolfgang.

On the west rise the livid green and purple wastes of the Todtalp, a great mass of intrusive serpentine which justifies its name by the weird colouring of its weathered slopes and the terrible sterility of its upper plateaux. Its eastern face is scored by hundreds of deep-cut trenches, and the vast talus at its foot spreads fan-like downward, overlapping the end of the Drusatch-Wolfgang ridge.

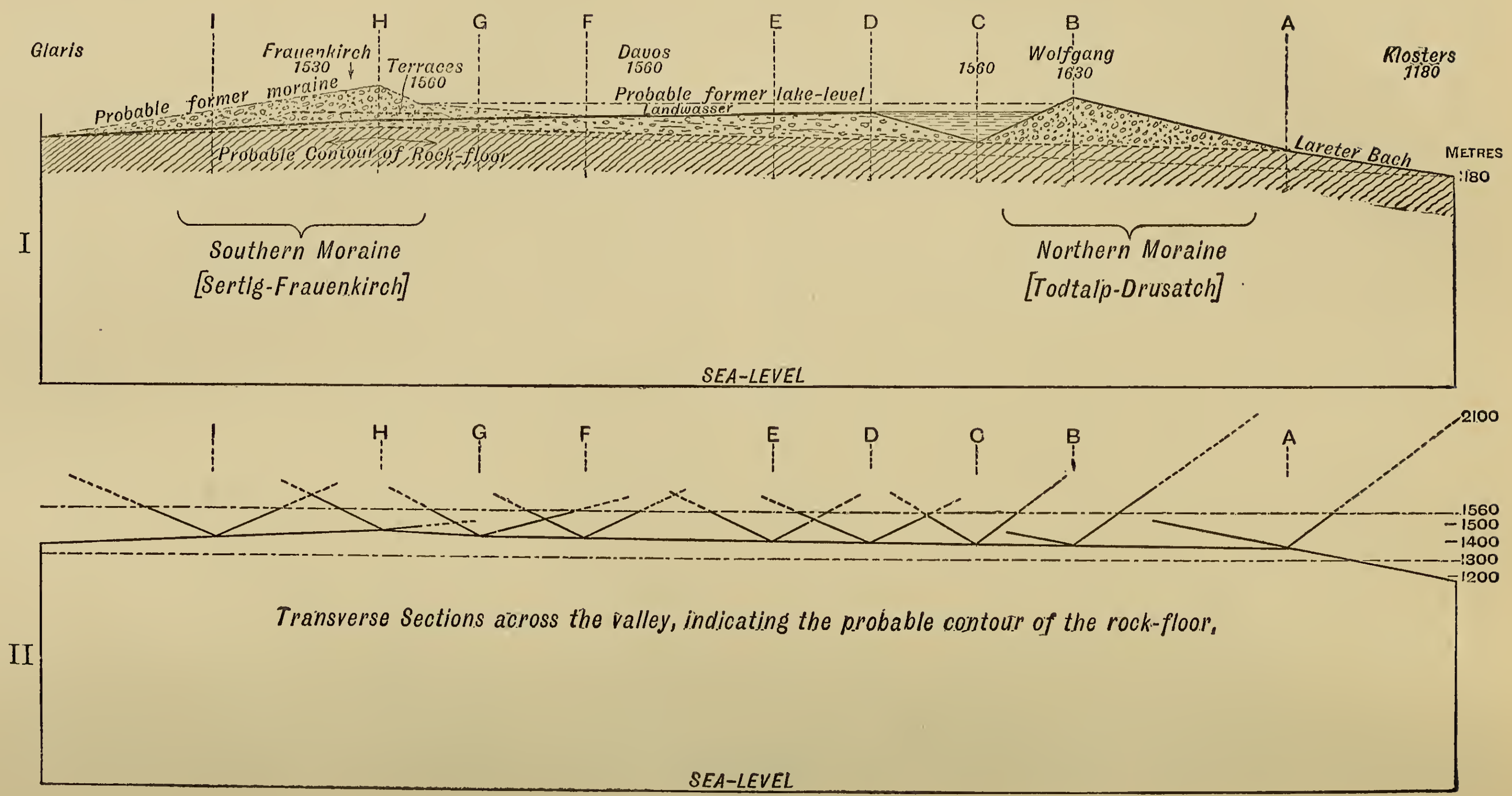
Most of the streams which are so rapidly denuding it combine with the Stutzbach to form the Lareter Bach and thus discharge to the north. This is not the case with the southernmost, the Todtalp Bach itself: rising far back under the Mittelgrat, and running at first north and east, the stream then bends round the southern edge of the talus-fan and falls into the lake. It seems impossible to regard this as the original course. Everything appears to suggest that it formerly drained northward, but has been gradually pushed over by the accumulating talus. This leads one to consider what determines the watershed of the whole area and what is the real nature of the bridge between the Todtalp and the Hörnli. Its position and contour, its sharp distinction from the lateral mountain-slopes, and its situation at the end of a lake all suggest the idea of a moraine.

It is, I believe, impossible to find solid rock *in situ* anywhere between Drusatch and the Todtalp. The steep Hörnli slopes are separated by nearly 2 miles from the solid serpentine, and though the latter is prolonged down just to the west of Laret, there is even here a wide interval filled with superficial deposit between it and the schists on the east. The Drusatch-Wolfgang ridge is composed mainly of blocks of serpentine from the Todtalp, and this has naturally led to its being mapped as such. Mixed with these, however, are large erratics of granites, gneisses, and schists, as well as fragments of limestone and verrucano. It will be suggested that there may still be a transverse solid rock-ridge below; but it would be difficult, if not impossible, to account for the formation of such a ridge, and still more difficult to explain the lake.

The maximum height of the mass above the present lake-level is 200 metres, and there seems no reason to doubt a similar thickness below. The northward extension is also considerably larger than one would at first suspect. It forms the plain round Laret and the Schwarzsee, as also the rising ground of Weiden between the railway and the Klosters road; and then is prolonged in a sloping tongue down between the Lareter Bach and the Riedloch Bach. Only at Selfranga, above Klosters, is the solid rock (limestone and serpentine) met with in the river-bed. From below Laret to this point the river runs between the cliffs of gneissose rocks on the east, and the mass of detritus between them and the Schwarzsee. The

Fig. 2.

DAVOS VALLEY. Section along the Landwasser and Lareter Valleys. Scale 1–100,000 [Vertical x 2]



serpentine *in situ* on the Schwarzsee Alp is $\frac{1}{2}$ mile distant, and thus there is every reason to suppose that the real rock-floor lies far below the present stream-bed.

Turning now to the southern end of the area, we find the mouth of the Sertig Thal marked by scenic features readily noticed by the least observant eye. On the eastern side are two great flat-topped terraces, the Wildboden and the Junkersboden, which present to the west a very steep bank more than 100 feet in height. They are separated by the Sertig Bach, which has cut through the mass to the same depth. Eastward the top of the terrace rises gradually past the contour of 1560 metres, and then steeply up to Clavadel. This village is also situated on the comparatively level top of a mass of superficial deposits: the rock *in situ* being exposed many metres above. Looking up the Sertig Thal, the remains of a former extension of the same deposits may be seen far higher up the valley. There is a large mass left on the southern side, behind the electrical works at Bei der Säge; and a chalet at Stadel stands on a similar terrace, at a height of nearly 1800 metres.

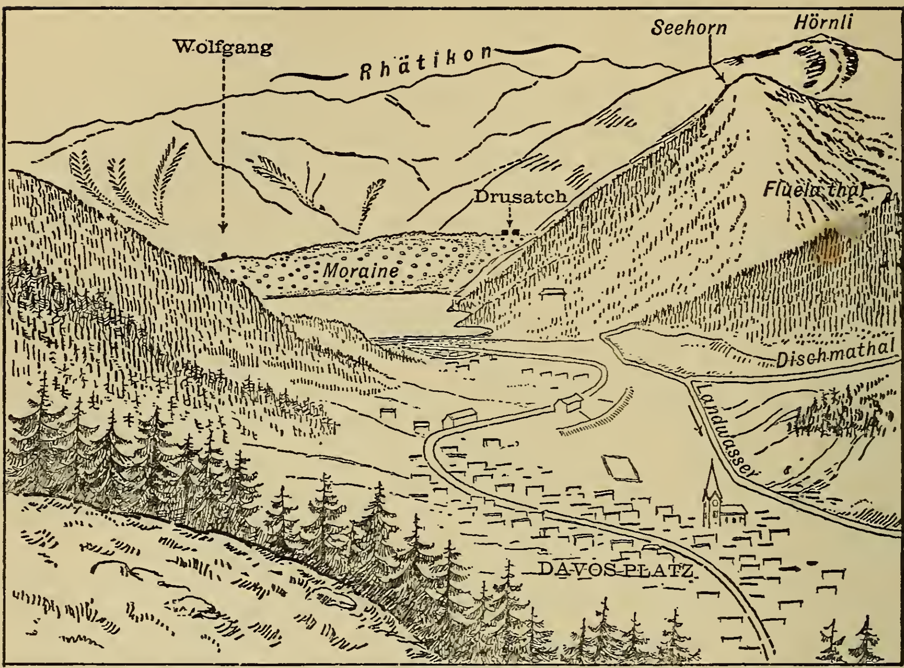
The flat top of the Wildboden and Junkersboden terraces has naturally suggested to some the idea of deposition in a lake; but there is no doubt that the whole series form part of a great detritus-fan which at one time filled the Sertig Valley, and was banked up against the mountain-slopes west of the Landwasser. Enormous as the amount of transported material is, once it was much greater, as the height of the remains on the side of the Sertig Valley conclusively shows. Clavadel itself stands 100 feet higher than Wolfgang, and the maximum height of the detrital mass must have been considerably above that.

Such a barrier as this would have been quite sufficient to hold up the waters of a lake reaching north to the Wolfgang-Drusatch ridge. That the cutting-through of its margin by the Landwasser is of relatively late date is shown by the sharp angle made by its terminal bank with the surface-contour.

Further evidence is now obtainable, owing to the fact that a cutting is being made on the west side of the Landwasser opposite Wildboden. Here is a large rounded mound projecting towards the river. While intact, this would have been naturally regarded as part of the talus from the western mountains. Its excavation, however, proves it to be a part of the great Sertig fan cut off from the main mass by the recent erosion of the Landwasser. The beds of sand and pebbles of which it consists dip at an angle of some 30° to the north and west; and this high angle confirms the impression of the great vertical height of the ancient barrier.

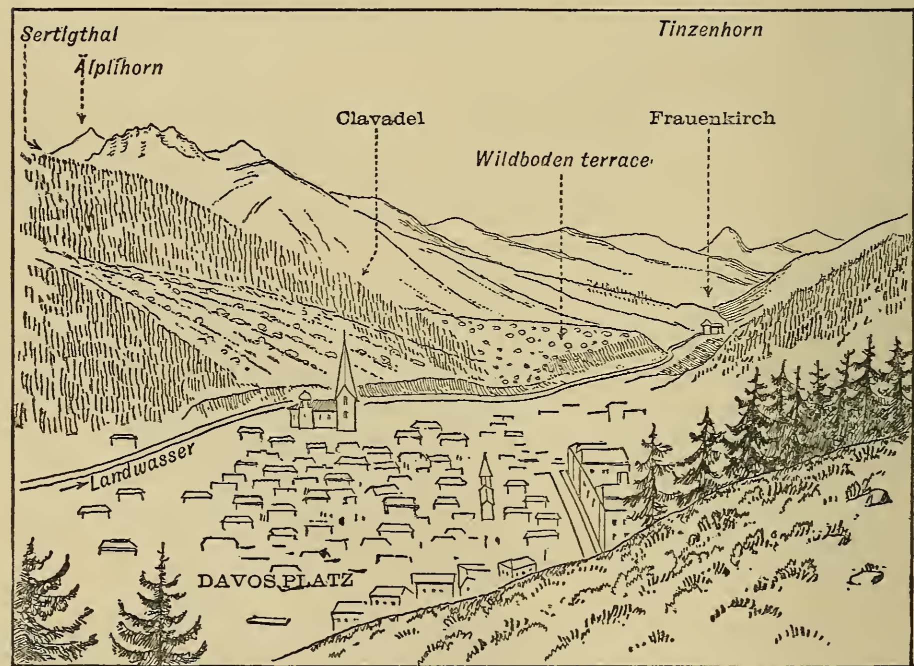
So far, then, as a general observation of the valley is concerned, one is led to the following conclusions:—That throughout the whole area the river is running over superficial deposits, and its course gives no indication of the real contour of the rock-bed; that the lateral talus-fans have been cut through at a relatively recent date since their accumulation; that the northern end is blocked by moraine-

Fig 3.—*Views of the Davos Valley (adapted from photographs).*



Looking Northward

Road



Looking Southward

material of great thickness, but for which the lake would drain to the north and would carry with it the waters of the Fluela and the Dischma; that the contours suggest the former existence of a larger lake stretching south towards Frauenkirch, and that in that part there is evidence of the previous existence of a great detrital fan sufficient to account for the formation of the lake in question.

It remains to consider whether there is any method of arriving at a knowledge of the fundamental structure of the area, and whether there is any collateral evidence derivable from other sources.

With the former object in view, it occurred to me that something might be learnt by making a series of transverse sections across the valley. By taking a number of fixed points at a constant level on both sides, and drawing lines down from these to the points where the rock *in situ* disappears beneath the superficial accumulations, one can form an idea of the slope of the sides of the valley. By prolonging the lines under the central alluvium one might arrive at the approximate level of the rock-floor. That such a method would be exact for any particular section is not suggested, but a number of sections would give a relative series of points indicating the real position of the solid rock.

The contour-line of 2100 metres (about 7000 feet) is one which can be traced easily on the map: it corresponds roughly to the upper limit of the pine-woods; and at this level there is, all along, a marked alteration in the slope of the mountains, which evidently represents some period of change in the denudation of the district far earlier than the time which we are considering.

For these reasons I selected it as a fixed point, and drew to scale the nine sections marked on the sketch-map (fig. 1, p. 281). It is often difficult to fix the position of the 'junction' of the solid rock with the surface-accumulations, and I do not claim any great accuracy for the separate sections. The general result, however, is distinctly confirmatory of the opinions already arrived at.

Thus the section (C) across the lake from the Seehorn indicates a depth of 150 metres, and this agrees with the results of soundings. Between the Dörfliberg and the Bühlenberg the rock-floor seems to lie at the same depth, while between Davos Platz and Clavadel it is reduced to 120 metres. A section along the bed of the Sertig and across to the Erbberg gives the thickness of the loose material beneath the river as less than 100 metres. These measurements may be far from the truth in themselves, but as a comparative series they indicate that the solid rock-axis is south of Davos.

Lastly, in trying to determine the former direction of drainage in the district, we have to consider the evidence of ice-movement. Here we find facts entirely in support of the theory of a former northerly discharge.

The great intrusive serpentine of the Todtalp has well-defined boundaries and the rock is unmistakable.[1] It has been rapidly

[1] See Ball, 'The Serpentine & Assoc. Rocks of Davos,' Zürich, 1897.

weathering through an enormous period of time, but no erratic blocks of it occur along the lake-side, nor indeed anywhere south of the lake-head. This fact alone seems to me to be conclusive as to the former direction of drainage ; but there is also positive evidence in the presence, north of the lake, of many rocks that can have come only from the south.

In the Fluela Pass one of the most conspicuous rocks is a coarse-grained white augen-gneiss derived, I believe, from the region of the Weisshorn. Erratic blocks of this occur frequently near the foot of the pass, along the lower slopes of the Seehorn, and on the Drusatch Alp.

Blocks of a muscovite-granite are abundant behind Höhwald, at the head of the lake, and appear to be erratics from the mass which crosses from the Schafläger to the Mittelgrat.

Another important constituent of the moraine is the dark compact hornblende-schist with veins of epidote, which occurs *in situ* on the Dörfliberg and elsewhere south and east. A group of huge erratics of this rock, one of which must contain some 2000 cubic feet, may be seen at the north-western corner of the lake.

More important is the common occurrence between Höhwald and Wolfgang of limestone-fragments. The present river-system could not bring them to this point either from the Weissfluh or Casanna; they must have travelled from the limestone-mass above Davos.

The same is the case with the verrucano. Fragments of this are common in the moraine from Wolfgang to Laret, but the rock does not occur in the region above. They must have come also from the south, and most probably from some point above Frauenkirch.

All observations of transported blocks thus tend to show the northward movement of the ice, while there is a striking absence of any proof of the reverse condition.

Such being the characters of the area, it only remains to attempt a reconstruction of its more recent geological history.

The general direction of the Fluela, Dischma, and Sertig valleys points to the conclusion that they formerly discharged their waters northward into the Landquart basin ; and the evidence of former ice-movement is entirely in favour of this view. The watershed was then apparently between Davos and Frauenkirch, perhaps nearer the last-named locality.

During the glacial time the ice-borne blocks from these valleys and from the Todtalp were accumulating. When climatic conditions became less severe and the ice receded, the resulting moraine held up the waters of the lateral valleys and caused the lake, which probably extended to Frauenkirch and was there banked up by the great detrital fan of the Sertigthal. When running water became once more the chief agent of change, the relatively small streams at the northern end could have but little effect in removing the solid

Wolfgang moraine; while the powerful Sertig river was cutting rapidly through the great mass of detritus at Frauenkirch.

The result of this would be a breaking-down of the southern barrier, and the flow of the lake-waters in that direction, carrying with them the currents of the Dischma and the Fluela. The lowering of the lake-level would stop any outflow over the Wolfgang saddle, and the present conformation of the area would be established.

Discussion.

Prof. Bonney said that he thought that the Author was quite right in his main contention, namely, that the flow of the water from the trough at Davos had been to the north, and that the blockage north of the Davoser See was quite unimportant, though he believed that he had seen rock *in situ*. He thought, however, that the original watershed had been well to the south of Frauenkirch, and quoted a number of similar cases of beheaded valleys. That seems clear from the north-western course of the tributaries which join the Davos trough from the east. In other words, he thought the Glacial and post-Glacial changes superficial, and that the main sculpturing of the region was done in earlier times.

Mr. Harmer wished to add, as a case in point, that the old valley, from the centre of which the Waveney and the Little Ouse took their rise, flowing the one eastward and the other westward, was occupied, near the present watershed, by a considerable thickness of the Chalky Boulder Clay.

The President and Mr. Whitaker also spoke.

The Author said he was very glad to have Prof. Bonney's support on the main principles of his paper. As regarded details, he was prepared to admit that the old watershed might have been somewhat south of the Sertig river, and that that river might once have belonged to the same system as the Fluela and the Dischma. The depth of the Züge gorge indicated that the watershed could not have been much farther south. In the northern part he admitted that the solid rock occurred near the river at Laret, but still far from the eastern rock-slope; and he believed that it could not be found in the stream-bed south of Selfranga.

23. *On the* Origin *of the* Auriferous Conglomerates *of the* Gold Coast Colony (West Africa). By T. B. F. Sam, Esq., C.E. (Communicated by J. L. Lobley, Esq., F.G.S. Read April 20th, 1898.)

[Abstract.]

This paper gives an account of a recent journey from Adjah Bippo to the Ankobra Junction in the Gold Coast Colony. A range of clay-slate hills is succeeded for 6 miles by flat ground in which diorite was found, and that by a lofty hill in which clay-slate dipping east occurs. The Teberibie range with reefs of conglomerate, and a second range with similar reefs, were crossed.

Gold-bearing alluvia are briefly described, and the gold is supposed to have come from the hills. The Adjah Bippo, Tarkwa, and Teberibie formations are considered to be part of a syncline. Certain auriferous conglomerates, and others presumed to be identical with them, are thought to be ancient alluvial deposits.

Discussion.

Mr. F. Struben said that he had carefully examined the auriferous conglomerates stated by the Author to exist on the Gold Coast, and as he (the speaker) had had considerable practical experience of conglomerates, having discovered those of Johannesburg in South Africa, he had no hesitation in stating that those of West Africa were identical in their character and age with those of Johannesburg. He did not agree with the Author in thinking that the West African conglomerates were derived from the disintegration of the existing range of mountains which rises a little farther inland, but he thought that they undoubtedly belonged to a far earlier period, and were similar in age to those of South Africa. They were evidently part of the series of sedimentary deposits which so largely predominate over the surface of the African continent. He thought that in these conglomerate-beds of West Africa there would be found deposits as extensive and as rich in gold as those of South Africa.

Mr. J. C. Wylie said that, from personal knowledge and actual work on the conglomerate-reefs of Johannesburg and the Tarkwa district of the Gold Coast, he fully endorsed the previous speaker's remarks as to their identical character. Further, that in many cases a main reef of poor quality ran parallel to a narrow leader of rich quality, in the manner so well known around Johannesburg; and that in both countries the gold was principally in the cement, and not in the pebbles of the conglomerates. It gave him pleasure to hear such a paper from a native gentleman of the Gold Coast, as it showed considerable powers of observation.

Mr. Teall asked what evidence there was in the paper of the auriferous character of the conglomerates.

Mr. Lobley regarded the auriferous conglomerates of Adjah Bippo as so like those of the Transvaal as to be identical, and held therefore that this paper had an important geological value. The age of these conglomerates, from the South African geological structure, he regarded as Palæozoic.

24. *On some* PALÆOLITHIC IMPLEMENTS *from the* PLATEAU-GRAVELS, *and their* EVIDENCE *concerning* 'EOLITHIC' MAN. By WILLIAM CUNNINGTON, Esq., F.G.S. (Read April 6th, 1898.)

[Abridged.]

SINCE the publication of the late Sir Joseph Prestwich's series of papers (1889–1896) on the chipped flints found by Mr. Benjamin Harrison on the Chalk-plateau of Western Kent, these specimens have attracted wide attention. For it was conclusively shown in those papers that the chipped flints came from a gravel which was much earlier than the gravels containing Palæolithic implements in the valleys of the existing rivers of the district. A British Chalk-plateau, in a period of intense cold or of on-coming cold, would hardly afford a comfortable cradle to the human race; and though Kent was not claimed as man's birthplace, it was held that the chipped flints of that county were the earliest and most primitive known specimens of his handiwork.

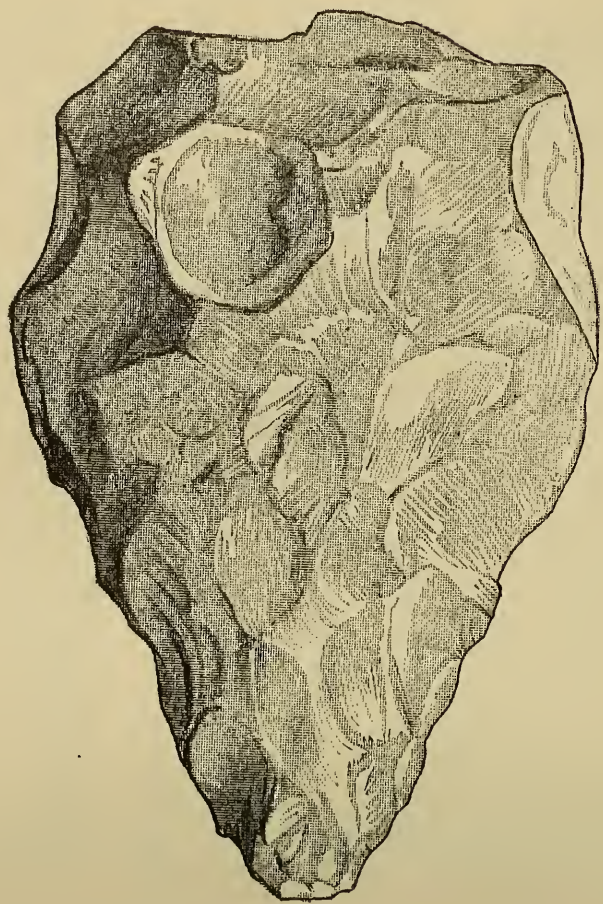
The enormous antiquity of these chipped flints was deduced, in the first place, from the stratigraphical relations of the gravel where they occur, which was referred to the Pliocene.[1] The gravels are part of Prestwich's 'Southern Drift,' and were formed before the erosion of the Darent gorge or of the transverse Ightham valley. The plateau-gravels are therefore older than the existing river-system; but at present there is no evidence whatever to show that they are of pre-Pleistocene age.

The main claim of the plateau-flints to notice rests on the assumption that the chipping is of so primitive a character that it cannot be the work of the skilled flint-flakers of the Palæolithic age. These chipped flints have accordingly been held to represent the first crude attempts by man to fashion stone into serviceable form.[2] They have therefore been named 'Eoliths.'

Fortunately the study of the flints has not been hampered by paucity of material. Their number is enormous. Mr. Harrison, for example, collected over 2000 specimens between 1892 and September 1894.[3] Sir Joseph Prestwich figured a large series, which may be divided into two sets—flaked Palæolithic implements and chipped 'Eoliths.' The former were not found *in situ*, and in some cases[4] were of a colour different from that of the plateau-flints; but it is only flints of the plateau-coloured type that we need consider: the rest may be dismissed as specimens of a later date, which had fallen upon the surface of the plateau-gravel, or have been found in

[1] Prestwich, Quart. Journ. Geol. Soc. vol. xlvii (1891) p. 129.
[2] Proc. Geol. Assoc. vol. xiii (1893) p. 162.
[3] Prestwich, 'Coll. Papers on Controv. Questions in Geology,' London 1895, p. 50.
[4] *Ibid.* p. 64.

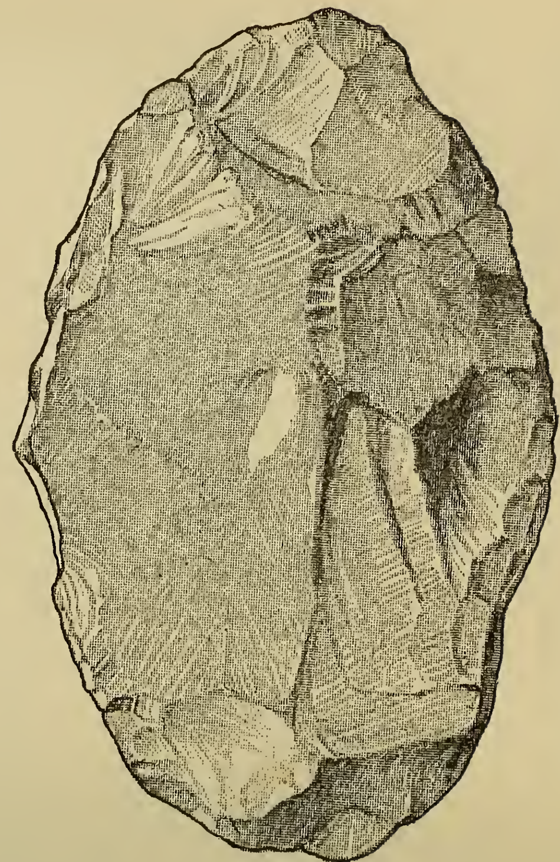
Fig. 1.—*No.* 551, *from Ash* (*Kent*).



A fine spear-shaped Palæolith, slightly damaged by later chipping and by frost-flakes. (10 × 6·3 cm.)

[Figs. 1-4 are of the natural size. Measurements are stated in centimetres.]

Fig. 2.—*No.* 760, *from West Kent.*



A typical Palæolithic oval implement, slightly worn, has glacial striæ filled with silica. It is plateau-chipped at the edges, from opposite sides. (9 × 6 cm.)

unstratified drift above. Hence the main question turned upon the evidence of the 'Eoliths,' in which sceptics could not see any trace of human work.

I was at first led to accept the 'Eoliths' as artificial, as I knew of no natural flints of the same shape and character. But a more detailed study of specimens, most kindly lent or given to me by Mr. Harrison, caused me to recant my belief in the human origin of the 'Eolithic' chipping. My reasons were stated in a short paper in 'Natural Science'[1]; they are mainly based upon the facts that the chipping is of different dates, even in the same specimen, and that it was produced after the specimens were embedded in the plateau-gravel.

Since that paper was published Mr. Harrison has kindly sent me some further specimens which advance the question an important stage. I am very grateful to him for his permission to describe some of these specimens. They prove two propositions:—

1st. That man lived on the Kent plateau before or during the deposition of the plateau-gravels.

2nd. That the 'Eolithic' chipping is not the work of man.

The first proposition is established by the specimens bearing the numbers, in Mr. Harrison's catalogue, 545, 551, 760, 784, 792 (Jan. 2nd, 1898), for they are, in my opinion, unquestionably Palæolithic implements.

No. 551 (fig. 1) is a good example of a pointed, spear-shaped implement; the flakes struck from it were long and thin, and cut the edge obliquely. The specimen is in excellent preservation, and only slightly rolled, exhibiting, however, traces of crushed chipping, and some frost-flakes of later date. No. 760 (fig. 2) is also a good implement, and is of the oval type. No. 545, from South Ash, is another oval implement, but it has been very much worn and rolled, although retaining evidence of Palæolithic work. No. 792, found at West Yoke, on the first day of the present year, shows distinct Palæolithic work, with sundry chippings of the edge, frost-flakes of different dates, and is slightly damaged by a modern blow. A flake, dated by Mr. Harrison Jan. 2nd, 1898, looks like a fragment of an oval implement: he says of it, 'I send a bulbous flake; compare side working with the work on plateau-specimens.' The comparison has been made; the style of the chipping seems to be identical in each.

Mr. Harrison also speaks of a deep-stained, much worn Palæolith (No. 712) found at South Ash, with traces of the 'old style' of chipping on the edge. This, and another larger example (No. 689) from West Yoke, with 'old old' markings on one edge, are now in the museum at Nice.

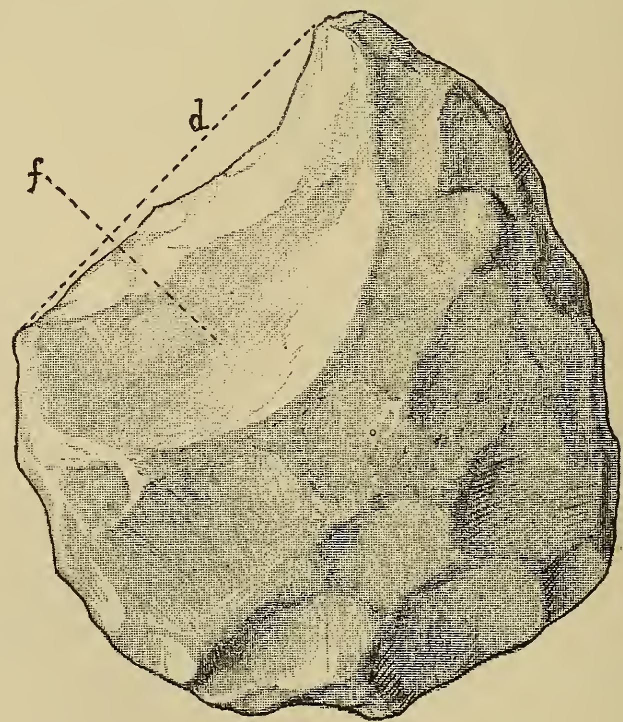
The specimens were not found, *in situ*, in the gravels; but they present evidence which appears to me conclusive that they were derived from the plateau-gravels. The flints of this deposit have very distinctive characters: they are of a deep brown colour; they

[1] 'The Authenticity of Plateau-Man,' Nat. Sci. vol. xi (1897) pp. 327–333.

are generally acknowledged to have been glacially scratched, and then thinly coated with a deposit of white silica. These Palæolithic implements show the same characters: they have the typical brown colour, the usual striæ, and the white silica; in fact they wear the livery of the plateau-gravels, in which they must once have been included.

Man therefore lived in Kent during or prior to the deposition of these gravels; and, as the implements are Palæolithic, the gravels are of Palæolithic age. It may be urged that, having admitted so much, it would be as well to admit that the chipped plateau-flints were also shaped by man. It may be said that to deny that claim is no longer of any avail, the existence of plateau-man having been

Fig. 3.—*No.* 784, *from Fakeham* (*Kent*).



The edge-chipping in this case was produced after the implement had been finished by Palæolithic man. (8 × 7 cm.)

conceded. But the discovery of the Palæolithic age of the plateau-gravels, though an important contribution to the geology of Kent, is a smaller matter than the claim that the West Kent plateau was the home of a pre-Palæolithic people whose implements carry us nearer than any yet known 'to the dim red dawn of man.'

The Palæolithic specimens found by Mr. Harrison prove the authenticity of plateau-man, which is a local question, but it is by evidence that I hold to be absolutely fatal to the authenticity of

'Eolithic' man, which is the general question that has given these flints such wide interest.

The most instructive of these plateau-specimens is No. 784 (fig. 3), a broken implement of the oval type. To understand its significance let us examine in detail the evidence which it affords. It has passed through seven stages:—

(1) It was wrought by man into an oval Palæolithic implement.
(2) It was greatly abraded, worn possibly by the action of blown sand.
(3) It was broken, the upper left-hand quarter being removed, leaving a smooth concave fracture, part of which is seen at *f*. The cause of the fracture is immaterial, but it was probably due to the action of frost: this forces from flints flakes which leave deep hollows, or broad concave surfaces rippled by conchoidal fracture. To such frost-flaking I attribute the fractured surface *f*.
(4) This fracture cut obliquely through the implement, leaving a thin edge along *d*, which has since been chipped back to its present position. The chips were all marginal, and nearly vertical to the plane of the specimen. The chipping appears to me of exactly the same character as that on specimens given me by Mr. Harrison as typical 'Eoliths.'
(5) The specimen was stained with the deep brown hue characteristic of the plateau-flints. This staining was probably due to the action of ferruginous solutions, depositing ferric oxide in the interstices left by removal from the flint of the more soluble silica.[1]
(6) The implement was marked by a series of glacial striæ.
(7) A thin layer of white silica was deposited over the surface, filling up the glacial striæ.

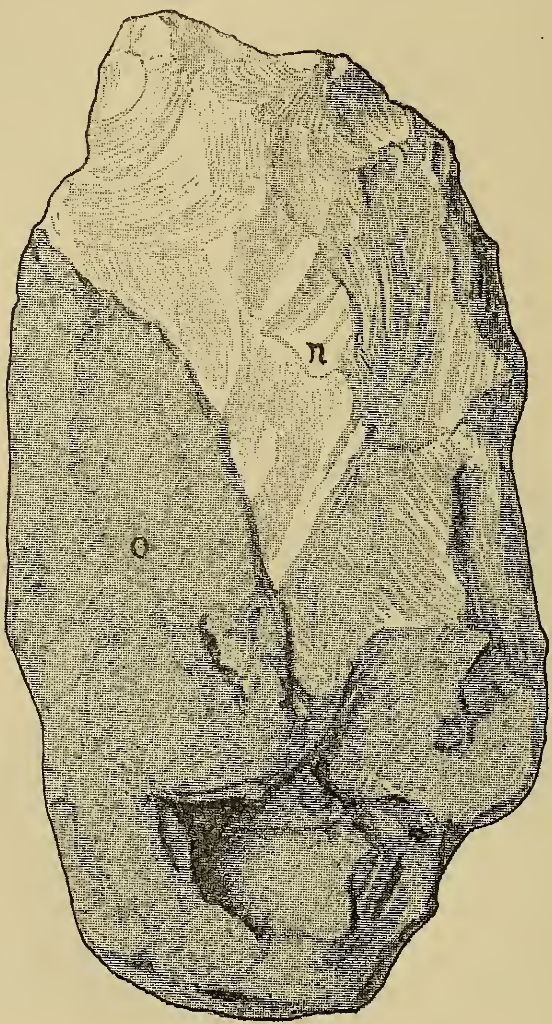
The present condition of this very instructive Palæolith may be explained in one of two ways. Either it has been broken and then chipped by natural agencies, in which case the plateau-'Eoliths' were also chipped by natural agencies (agencies which I consider to have been the movements in beds of frozen or thawing gravel); or if this explanation be rejected, and the marginal chipping be held to be the work of man, then that work must have been done by post-Palæolithic man. In either case we may conclude that the use of the term 'Eolith' should be suspended till proofs of the existence of a pre-Palæolithic race are established.

Some specimens lately found by Mr. Harrison at Maplescombe (Kent) are by his request now exhibited to the Society. Though not immediately bearing upon the subject under consideration, they are of much interest as examples of the continuity of Palæolithic

[1] See T. G. Bonney, 'The Formation of Flints,' Phonogr. Quart. Rev. vol. i (1894) pp. 37–41.

work after the great climatic change. They are rude implements, fashioned by man, from flints taken from the plateau-gravels, subsequently to the close of that period. Fig. 4 represents one of these (No. 827): the part marked *o* is the old brown coating, the 'livery' of the plateau-flint, and *n* is the flaked work, of a light colour, forming the implement.

Fig. 4.—*No.* 827, *from Maplescombe* (*Kent*).



A rude pointed implement, flaked by man, after the flint of which it is made had passed through the changes of the plateau period. A post-Glacial Palæolith. (11 × 6 cm.)

I gladly express my obligations to Prof. Bonney, Mr. Teall, and Dr. Gregory for valuable help in the examination of the specimens, and to the last-named gentleman for kind assistance in the preparation of this paper.

Discussion.

Prof. Seeley remarked that, as a member of the Committee of the British Association assisting Mr. Harrison in collecting plateau flint-implements, he had been impressed by the skill with which the evidence was marshalled (by Mr. Harrison and others) to illustrate the use of the flints in the domestic life of the people. But with regard to a large part of the evidence, he thought that there was experience of the production, both by natural strain in beds of chert and flint and by chance blows of the hammer, of some such forms as had been termed Eolithic, not only in general shape, but also in the finely-chipped condition of the edge, which was regarded as especially worked. In many beds of river-gravel flints occurred which showed no indication of design in their forms, but had a margin chipped, as though the flints forming the gravel had been frozen together, and the strain had shivered the acutest edge. He was inclined to follow therefore the example of Sir John Evans, in suspending his judgment with regard to many of these reputed Eolithic flints.

Mr. H. B. Woodward said that he had recently seen, in Dr. Blackmore's museum at Salisbury, a series of the 'Eolithic implements,' and he was much impressed by the apparent evidences of design which they afforded. He had also, under the guidance of Dr. Blackmore, examined the plateau-gravel at Alderbury whence many of the flints had been obtained, and these were considered to have been hacked rather than chipped into their present forms. It was noteworthy that Dr. Blackmore had not obtained a single Palæolithic implement from this plateau-gravel, whereas in lower-level gravels near Salisbury such implements did occur, and among them were specimens which had been fashioned after the same type as some 'Eoliths,' but more highly finished.

Prof. T. Rupert Jones, referring to the remarks made by one of the foregoing speakers, observed that doubtless frost in splitting flints can form more or less parallel-sided flakes, often concave and thin on one edge, and convex and thick on the other, and that the thin edge may be readily modified by natural causes; but the hooked and hollow-curved plateau-implements have the concave edge thick, and intentionally chipped and hammered. The local association of so-called Palæoliths with the others (known as 'Eoliths' and 'old brownies') in the plateau-gravel shows that ancient man varied his work; and the fact that 'Palæoliths' occur elsewhere without the 'Eoliths' does not prove that the two patterns had never been made at the same time. The several well-known series of plateau-implements now in museums, showing numbers of definite patterns, are sufficient evidence of intention and design on the part of early man. There are many of both odd-shaped and regularly-shaped forms, of which the intended uses are ambiguous for us who know so little of savage life; their hammered edges, however, are not of accidental but of intentional origin.

Mr. A. E. Salter said that he would like to know upon what grounds the Author denied a pre-Pleistocene age to the gravels associated with these implements. With the exception of the Dewlish *Elephas meridionalis*, the high-level drift-deposits of the South of England had yielded no remains of extinct mammalia. The highest drifts, like those at Well Hill (Kent), Burgh, Headley, and Netley Heaths, on the North Downs, and similarly-placed deposits in Hants, Dorset, etc., had yielded no implements at present; but they were found in the lower plateau-gravels about 150 to 200 feet below them, as at Curly Hill on the Chobham Ridges, and Alderbury Hill near Salisbury. It would thus appear that these chipped flints were strewn on the surface at a period between the deposition of these two series of gravel-deposits. The gravels yielding Palæoliths in abundance, such as those at Wrecklesham, Caversham, Belbins, etc., were situated at still lower levels. He thought that only implements found *in situ* in definite beds of gravel should be brought forward in support of any argument dealing with their age, as those strewn on a very old land-surface, such as the Kentish plateau, might gradually descend in a loose soil, owing to the action of earthworms or other similar agencies.

Mr. Rudler admitted that the scepticism which he first entertained had given way, when he had seen a number of the plateau-flints arranged in serial sequence so as to suggest evidence of designed forms. At the same time, he remained uncertain with regard to a large number of the so-called 'Eoliths.' While admitting some and rejecting others, there was a remainder respecting which he deemed it prudent to maintain an attitude of cautious reserve. It would probably be argued, however, that to admit even one concedes the whole case in favour of plateau-man.

Mr. Strahan said that reference had been made to striated flints of human workmanship from the plateau-gravels. The existence of such flints would be most important, for it would tend to prove not only the Glacial age of the gravels, but the pre-Glacial age of the human workmanship. The specimens exhibited, however, were far from supporting the suggestion. One flint alone showed characteristic glacial markings, but that specimen had been found lying loose on the surface of the ground, and showed no trace of man's handiwork. Of the others, some undoubtedly seemed to have been fashioned, but none of these showed striations. He considered that undoubted implements, striated beyond dispute, and collected from a recognizable source, should be produced before conclusions so important could be accepted.

Mr. E. T. Newton expressed his belief that many of the plateau-flints had been chipped by man.

The Rev. R. Ashington Bullen said that he spoke with great diffidence before such a body of geological experts, but would point out that, with regard to stone-implements, Sir Joseph Prestwich was as good a judge as any man. We must remember that his attention was attracted to these rudely-worked flints in the Somme Valley in 1859, that he did not rush to conclusions, but only published them after 30 years' consideration, and ranged his great geological attainments on the side of Mr. Harrison. Judging from the hard iron encrustations on the implements from Shepherd's Barn (500 feet above O.D.) and other places on the Chalk-plateau, and the iron-pan near Bat's Corner (700 feet above O.D.), from which undoubted implements were taken (at between 6 and 9 feet from the surface), the speaker considered the implements to be of Pliocene age. Two types of implements exhibited were certainly of human workmanship—(*a*) those with a straight edge, which are analogous to currier's 'sleekers,' used in dressing the softer leathers; as plateau-man dressed in skins, if at all, their use to him is obvious, and thick wooden sleekers of the same type were in use at Shalford tannery in this century; (*b*) tools on the 'engineers' bit' or 'centre-bit' principle, for piercing: these go back from the fine small Neolith to the more clumsy plateau-implement. Two of the 'sleekers' are from pits sunk by Mr. Harrison; one is from the Glacial gravels of Wells (Norfolk).

Mr. A. S. Kennard regretted the absence of the Author, and observed that to doubt the primitive character of these plateau-implements, because in one solitary instance somewhat similar work was found on a presumed Palæolith, seemed to be building on very slender foundations. With regard to the statement that Mr. Harrison had found over two thousand in a short space of time, he pointed out that the bulk of these had been found by the field-labourers on the Chalk-plateau, who had been taught by Mr. Harrison what to collect. He strongly objected to referring the work to so-called natural causes, when no attempt had been made to show what these causes were, and how and when they operated. No response had ever yet been vouchsafed to the oft-repeated challenge to produce from Glacial beds flints similar in shape to those from the plateau. Of the human origin of the work on these rudely-trimmed flints he had no doubt.

Mr. F. W. Harmer, referring to the remarks of a previous speaker, desired to protest against any attempt to correlate the Crag-beds of East Anglia with any of the gravels of the South of England by that most unreliable of all tests, similarity of lithological character. Beds of iron-pan may have originated at any period, and in the Pliocene deposits of Norfolk they are by no means confined to any special horizon.

The President, Mr. W. V. Ball, and Dr. G. J. Hinde also spoke.

Dr. Gregory, replying on behalf of the Author, expressed regret at the latter's unavoidable absence, which placed his case at a great disadvantage. The Author's experience of flint-implements was very extensive, as he had been working steadily at the question since 1851. He noticed in the discussion absolute unanimity on one point: no one denied that some of the specimens exhibited were worked by man, and that they were genuine plateau-gravel flints, which must have been flaked before the deposition of the gravels. Every speaker had therefore admitted that man lived in Kent before or during the deposition of part of the plateau-gravels. Thanks, therefore, to Mr. B. Harrison's magnificent perseverance and industry, man's age in Kent had been carried back one stage farther. In the congratulations to Mr. Harrison on that achievement, no one would join more heartily than the Author. But that admission did not affect the question of the specimens described as 'Eoliths' or 'rudes.' Those who believed in these specimens still could not agree as to which are genuine and which not. Prof. Rupert Jones had that evening doubted one which Mr. Harrison selected as a fine example. The thickness of the edges to which Prof. Jones had called attention increased the speaker's scepticism as to their authenticity. In reply to Mr. Salter, he had no doubt that the Author would admit the gravels as Pliocene if *Elephas meridionalis* were ever found in them; but there was no evidence at present to refer the gravels to the Pliocene age. The undoubted implements exhibited did not show well-preserved glacial striæ; but after examination of the series, the speaker thought that some of the scratches were truly glacial. In reply to Mr. Kennard, he said that the case did not rest on one specimen alone, though special attention had been called to one; and the number of specimens obtained by Mr. Harrison between 1892 and 1894 was quoted from Sir Joseph Prestwich. The question of the natural agencies was not at issue that evening, and so the specimens to which Mr. Kennard had referred were not exhibited. The critical points of the present paper had been ignored in the discussion: no attempt had been made to show that the implements were not Palæolithic, or that the 'Eolithic' work was not later than the Palæolithic work. He quoted the opinions of Mr. Montgomery Bell and Mr. Harrison to show the identity of the working of the broken edge of the Palæolith with that of the Eoliths. It was only the 'Eolithic' implements that the Author had denied. The wide general importance of this question was the claim that the Kent plateau had been the home of a primitive pre-Palæolithic people, which, he held, the Author's arguments conclusively disproved.

25. Note *on an* Ebbing *and* Flowing Well *at* Newton Nottage (Glamorganshire). By H. G. Madan, Esq., M.A., F.C.S., Fellow of Queen's College, Oxford. (Communicated by A. Strahan, Esq., M.A., F.G.S. Read April 20th, 1898.)

In the village of Newton Nottage, near the watering-place of Porthcawl, about halfway between Cardiff and Swansea, there is an ancient dipping-well, the water in which has 'from time immemorial' been noticed to vary in depth with the ebb and flow of the tide. It is mentioned by Camden in his 'Britannia,' vol. i. p. 737 (2nd ed. [Eng.] 1723: orig. work pub. in 1586), though he does not appear to have visited the place himself, but to have received a letter from 'the learned Sir J. Stradling' giving a fairly detailed description of the well.

In October last I spent 4 or 5 days on the spot, and made nearly forty visits to the well, determining the level of the water every hour (and every half-hour when it seemed desirable) at different states of the tide, and noting the geological characters of the neighbourhood, the height of the well above mean tide-level, etc. I also brought away specimens of the water collected at different times, and have analysed them, with the results stated at the end of this paper.

First, with regard to the position, topographical and geological, of the well. It lies on a direct line drawn north and south between the church of Newton Nottage and the sea, about 80 yards south of the church and 500 yards north of the shore. There is a falling gradient of about 1 in 20 between the church and the well. Between the well and the sea there is a range of sandhills about 20 or 30 feet high, ending in a pebble-ridge about 10 or 12 feet above ordinary high-water mark. Behind the church, on the north side, there is a line of Carboniferous Limestone-cliffs running east and west, nearly parallel with the shore-line. Along the shore the Carboniferous Limestone crops out at about half-tide level, and rises into a promontory forming the eastern extremity of Porthcawl Bay. Overlying the limestone, between the shore and the cliffs just mentioned, there is a stratum of Keuper conglomerate cropping out along the shore and reaching up to the base of the cliffs behind the church. This conglomerate is mainly composed of pebbles of Carboniferous Limestone, and was evidently formed from the débris of an ancient shore, existing at a time when the land was at a lower level than now, and when the sea washed right up to the base of the cliffs behind the church and village of Newton. Fortunately, at the time when I was there a sewer was being laid along the road from Newton westward to Porthcawl, and the cutting gave a good section to a depth of from 8 to 10 feet. Below the surface-layer of sand (about 1 foot thick) there is a stratum of reddish-brown loamy clay with pebbles, about 7 feet thick. This rests on the conglomerate, into which the cutting did not penetrate far, so that I was unable to ascertain the thickness of this bed. The strata are nearly horizontal, perhaps with a very slight westerly dip, and the conglomerate seems to thin out to nothing at Porthcawl itself, where I noticed in a cutting along one of the streets, first 1 foot of sand, below it 2 to 5 feet of brown clay, and then hard limestone, the surface of which was very irregular in level, evidently a denuded shore. The conglomerate appears again westward of Porthcawl, but I saw no object in tracing it farther for my present purpose.

At the base of this stratum of conglomerate, where it rests upon the Carboniferous Limestone, there is evidently a considerable body of water flowing southward and seaward, as is proved by the existence of several fresh-water springs which burst out along the shore due south of Newton Nottage at about half-tide level. It is this underground water that is tapped by the public well which I went to examine, and also by several other wells in the village, now covered over and provided with pumps.

The ancient dipping-well itself is an oval pit, $6\frac{1}{2}$ feet in its longest and $4\frac{1}{2}$ feet in its shortest diameter. The depth of the bottom of the well from the surface of the ground is $13\frac{1}{2}$ feet, and the walling is continued for about 2 feet above the ground-level, and covered in by slabs of stone. Access to the well is afforded by a covered flight of twenty steps, 27 feet long. There is an Ordnance temporary bench-mark on the stone slab covering the entrance to the passage, from which it appears that the bottom of the well is 8 feet above Ordnance datum-level. The distance of the well from the shore (high-water mark) is 500 yards, as deduced from the mean of several pacings of the interval.

The point which I wished especially to ascertain was the exact relation (if any) of the variation in level of the water in the well to the rise and fall of the tide. For this purpose it was necessary,—

(1) To ascertain the exact times of high and low water. This information I obtained from the harbour-office at Porthcawl, the distance between Porthcawl harbour and the shore at Newton being so small (about 1 mile) that the tide-table is practically the same for both.

(2) To measure the exact depth of water in the well at short intervals between the time of high water and that of low water. This was done by lowering a white deal rod vertically into the water until the lower end rested upon a marked spot on the lowest step, which was within an inch or two of the bottom of the well. On withdrawing the rod it was easy to note the exact boundary between the dry and the wetted portion, and a line was at once drawn there with a pencil, the date, hour, and minute being appended. The distance between the mark and the lower end of the rod was then measured with a foot-rule, the result giving the depth of water above the lowest step at the time of observation. The mean actual variation in level was about 30 inches.

In this way I made nearly forty observations at intervals of one hour (and in many cases at the intermediate half-hour) during three successive days, covering the periods of several tidal waves. The conditions during this time were very favourable. The tides were slack and uniform; the weather was calm and fine; the barometer did not vary $\frac{1}{20}$ inch during the whole week; and there was no rain to introduce a source of error by filling up the land-springs.

From the results of these observations I constructed the curve shown in the accompanying diagram (p. 304), in which the abscissæ represent the time-intervals elapsed since the period of low water, and the ordinates show the depths of water in the well at the corresponding times. In the upper part of the diagram I have drawn a curve representing the height of the tide at the same times (reduced to the same scale), assuming that the movement of the tidal wave is regular and is expressed by a symmetrical curve, as it would be on that coast in the absence of such disturbing causes as wind.

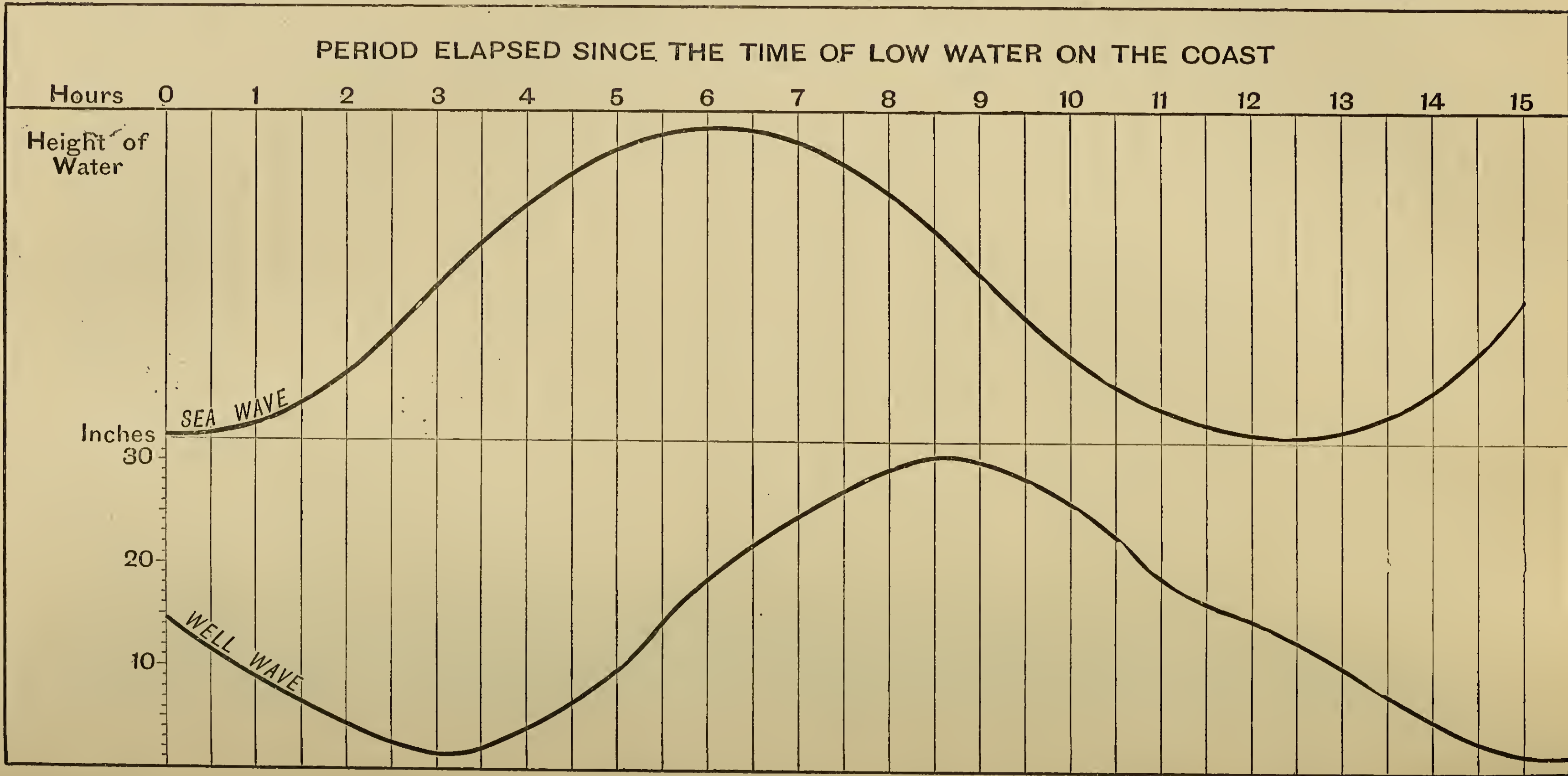
It will be evident, I think, from the diagram that the rise and fall of the water-level in the well are as regular and symmetrical as the rise and fall of the tide, but that the maximum depth, or the crest of the wave, is 3 hours (+ or − a few minutes only) behind the crest of the tidal wave; and similarly that the minimum depth, or the trough of the wave, in the well is 3 hours (approximately) behind the trough of the tidal wave.

One slight irregularity will be noticed in the well-curve, as drawn. This is based on one observation only, and is sufficiently accounted for by the fact that two large water-barrels were at the time filled by a pump connected with the well, for conveyance to an adjacent farm. The fact that the quick withdrawal of nearly 100 gallons of water only lowered the water-level temporarily by about an inch is a satisfactory proof that the well is not fed by a mere small local spring, but is in free communication with a large body of underground water. This is further proved by what I was told respecting at least two other wells in the village (now not easily accessible, else I should have tested the accuracy of the information), which are reported to ebb and flow synchronously with the well under examination.

Thus it would appear that the prevalent idea that the water-level in the well is highest exactly when the tide is lowest, and lowest when the tide is highest, is not quite correct: the real fact being that the water in the well goes on rising for no less than 3 hours after high water, and ebbing for 3 hours after low water.

I brought away with me two samples of the well-water—one collected when it was at its lowest level, the other taken when it was at its highest level. On subjecting them to analysis, I find that there is practically no difference in their composition. This would seem to prove that no sea-water finds its way directly into the well to cause the ebb and flow, although the large proportion

THE EBBING AND FLOWING WELL AT NEWTON (GLAMORGANSHIRE)
COMPARISON OF THE TIDAL WAVES IN THE SEA AND THE WELL.



of chlorine (and therefore of salt) seems to point to the fact that some salt water must come into the well by the ordinary process of diffusion, sufficient to render the well-water slightly brackish, though this is quite imperceptible to the taste.

The results of the analysis are set forth below, and I may mention that they are in close agreement with an analysis made of the same water a few years ago by Dr. A. Vœlcker, the details of which were furnished to me by the kindness of Mr. Edward Knox, of the Estates Office, Margam Park, by whose direction the analysis was made (see Postscript, p. 306).

Analysis of the water of a well at Newton Nottage, collected on October 8th, 1897.

[The results are expressed in parts per 100,000.]

Total solid residue		80
Chlorine		16·4
[Corresponding to 27·2 parts of sodium chloride.]		
Sulphates (the sulphate radicle, SO_4)		5·15
Calcium		11·0
Magnesium		0·76
Hardness,—		
Temporary	22·8°	
(on Clark's scale, 16°)		
Permanent	17·2°	
(on Clark's scale 12°)	——	
Total hardness		40°
(on Clark's scale, 28°)		

The interpretation of the observations detailed above does not seem to present any serious difficulty. It is clear that there is, as already mentioned, a large body of water contained in the basin of Keuper conglomerate which overlies the Carboniferous Limestone between the ancient sea-cliff immediately north of the village of Newton and the present shore-line. This underground water is in free communication with the sea, along the line where the conglomerate crops out below high-water level on the shore.

The tidal wave, on reaching this outcrop, is taken up by the water in the permeable strata and propagated landwards, but with a greatly diminished velocity, owing to the resistance to its motion offered by the solid, though porous, stratum of conglomerate. This retardation is sufficient to cause an interval of 3 hours to elapse before the successive phases of the wave (that is, crest and trough) reach a point 500 yards from the line where the free wave stops and the subterranean wave begins. Hence we have high water in the well 3 hours later than high water in the sea, and low water in the well 3 hours after the time of low water in the sea: the 'establishment' (as hydrographers would call it) of the well being 3 hours later than that of Porthcawl.

An illustration of a very analogous phenomenon may be adduced from the science of optics. When a series of light-waves, travelling in a medium of low refractivity, arrives at the surface of a medium of greater density (optically speaking), the velocity (though not the frequency) of the wave is lessened, and it takes a longer time to reach a given point in the denser medium than it would have done if its course had been continued in the rarer medium.

Postscript.

[ANALYSIS OF THE WATER OF THE TIDAL WELL AT NEWTON NOTTAGE, made about the year 1889 by Dr. Vœlcker, for the special purpose of ascertaining its quality as a water for drinking purposes.

(The results are expressed in grains per gallon, or parts in 70,000.)

Total solid residue	60·48
Oxidizable organic matter	0·15
Chlorine	15·98
(Equal to chloride of sodium	26·35)
Nitric acid, as nitrates	2·62
Hardness, according to Clark's scale	26·4°

The water also contained,

Free ammonia	0·0005
Albuminoid ammonia	0·0025

The foregoing analysis is inserted by kind permission of Mr. Knox.—May 31st, 1898.]

DISCUSSION.

Mr. J. G. WOOD considered that the observations, valuable so far as they went, required to be continued, over a more extended period and under more varying conditions of tide, before any definite conclusion could be arrived at. The diagram assumed an uniform interval of 12 hours between low water and low water. This would be nearly correct at spring tides, but much too short at neap tides. Again, the rise and fall at spring tides would be about 20 feet more than at neap tides. It was essential to correlate all such variations of tide with the fluctuations of the well.

As another instance of fresh water fluctuating inversely with the tide, the speaker referred to the wells at Perim described by Mr. Moore in the Woolhope Club Transactions for 1892; and he also mentioned a well at Chepstow, described by himself in the same volume, which was commonly said to ebb and flow in like manner. In fact it does not ebb, but can be pumped dry, and will remain dry while the tide is in. The increase of pressure on a fault which fed the well was the probable cause of its temporary failure. Similar causes might possibly be at work at Newton Nottage, owing to the complications of the strata in the district.

Dr. CHURCHWARD asked whether there was any iodine or bromine found on analysis of the water. He also wished to know the depth from which the samples of the water were taken in the well. One would consider this of some importance, as tending to show whether the sea-water had percolated or diffused through the fresh well-water source. Probably the water at the bottom of the well would only show whether the above-named ingredients were there.

Mr. Lobley adduced the fact that, at a long distance from the sea, the Woodhall Spa spring of Lincolnshire contains a large amount of iodine and bromine.

Mr. Strahan said that he had been aware for some time of the existence of these phenomena in the Newton Nottage well, and was glad to have been furnished with such precise observations and so clear an explanation. It would seem that a similar rise and fall of water must take place in any rock-cavity communicating with the sea, and that the movement must lag behind the tide in proportion to the constriction of the communicating passage. He thought that the trace of salinity in the water was due to the sea, although the author's analysis showed no bromine or iodine: for, in walking along the shore in that neighbourhood, he had seen sea-water issuing copiously from fissures and holes in the conglomerate long after the retreat of the tide. He hoped that, if opportunity offered, the Author would make further observations on the influence of both spring and neap tides upon the movements in the well.

The President also spoke.

26. *The* Pliocene Deposits *of the* East *of* England: *The* Lenham Beds *and the* Coralline Crag. By F. W. Harmer, Esq., F.G.S. (Read March 9th, 1898.)

I. Introduction.

The Pliocene deposits of the East of England have been studied for many years, and by many competent observers, but, unfortunately, no general consensus of opinion has been arrived at, either as to their systematic arrangement, or the conditions under which they originated: the views, for example, of Sir Joseph Prestwich, which have obtained considerable acceptance, differing in many important respects from those of the equally eminent authorities Mr. Searles V. Wood and his son.

Prestwich, in his well-known paper,[1] divided the Coralline Crag into eight constant and determinable zones, and, on the other hand, regarded the Red Crag as forming two divisions only: the lower, including the deposits of Walton-on-the-Naze, Sutton, Bawdsey, Butley, Sudbourne, and Aldeburgh,[2] and the upper, consisting of what he originally called 'the unfossiliferous sands of the Crag' (now believed to be a part of the deposit which has been deprived of its shells by the infiltration of water containing carbonic acid)[3] and of the Chillesford Beds. The Norwich Crag, with which he grouped some deposits containing *Tellina balthica*, he held to be equivalent, partly to his lower (namely, to the Crag of Walton, Sutton, Butley, etc.), and partly to his upper or Chillesford division.[4]

I still hold, for reasons to be given hereafter, that there is no sufficient evidence for dividing the Coralline Crag into the eight zones proposed by Prestwich; indeed, I now believe that the tripartite arrangement, formerly adopted by Mr. Wood, jun., and myself,[5] can be no longer maintained, and that the Coralline Crag is practically one formation, of the same character, and deposited throughout under similar conditions. With a series of beds 60 feet in thickness, there is, however, necessarily some difference in age between those which occur at any one place in vertical section.

As to the Red Crag, the facts which I propose to offer in a succeeding paper will show, I think, that the division of this formation into four zones, proposed by S. V. Wood, sen., in 1866,[6] represented by the deposits occurring at Walton, Sutton, Butley, and

[1] Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 121, fig. 4.
[2] *Ibid.* p. 354.
[3] Wood & Harmer, and Whitaker, *ibid.* vol. xxxiii (1877) pp. 75 & 122.
[4] *Ibid.* vol. xxvii (1871) pp. 471–73.
[5] Suppl. 'Crag Mollusca,' Introd. p. iii, Monogr. Palæont. Soc. 1872.
[6] Quart. Journ. Geol. Soc. vol. xxii, p. 538.

Chillesford respectively, still holds good, and further that there are Red Crag-beds which do not exactly correspond with those found at any of these localities, which may therefore be conveniently separated from them. The various Red Crag-beds are, in my opinion, the marginal accumulations of a sea gradually retreating northward and eastward, in consequence of the earth-movements described in my paper on 'The Pliocene Deposits of Holland.'[1] The molluscan fauna of the different exposures of the Red Crag assumes a more recent and a more boreal character as we trace them successively in a north-easterly direction, and they arrange themselves therefore in horizontal rather than in vertical sequence.

I still consider that the Crag of Norfolk and of the northern part of Suffolk is newer than any part of the Red Crag, except perhaps that which occurs in the upper part of the section in the Stack-yard pit at Chillesford; and that the Weybourne and Belaugh beds, containing *Tellina balthica,* mark a yet more recent horizon of the Pliocene period.

Early in Red Crag times, I believe, the communication which had previously existed between the North Sea and the English Channel was interrupted,[2] and in consequence southern species of mollusca became by degrees less abundant in the former, and finally disappeared from it, while, coincidently, an invasion of the Crag area by boreal and arctic forms took place. Hence, if we can trace out the history of the gradual disappearance of the southern, and of the gradual arrival and increasing abundance of the northern shells, and if we can ascertain the relative proportion of these different groups at different localities, we shall have the material at hand for correctly classifying the various beds of the Upper Crag.

The old lists of the Crag mollusca as a rule did not distinguish between the rare and the abundant species, and therefore the conclusions drawn from them are not wholly reliable. To attach the same importance, for the purpose of analysis, to a species of which a single specimen, or at the most a very few, may have been discovered as the result of the labours of nearly a century, as to one of which a hundred specimens may be easily obtained in the course of a few minutes, is obviously misleading. The collections in our museums are not so instructive as they would be if the efforts of collectors were not so largely directed to the acquisition of rare species and of perfect specimens. From a geological point of view, it is the abundant rather than the rare species which are important, and shells which are seldom found in collections, as it is difficult to obtain them whole, are sometimes among the most characteristic of the deposit in which they occur. In order to ascertain the age of a bed or the character of its fauna, it is necessary to count specimens, so to speak, rather than species.

Much more attention than formerly has been paid of late years to this point, but the Crag mollusca as a whole have not been so dealt with. In the lists which I hope to publish with my next paper, I

[1] Quart. Journ. Geol. Soc. vol. lii (1896) p. 748.
[2] See also Prestwich, Quart. Journ. Geol. Soc. vol. xiv (1858) p. 331.

shall attempt to distinguish between those forms which I think may, and those which may not be considered as representative of each bed. It is difficult in some cases to know where to draw the line, and possibly the experience of other collectors may not always coincide with my own; I hope, however, that reliance may be placed on the general conclusions to be drawn from my lists.

II. The Lenham Beds.

Our knowledge of the Lenham fossils is principally due to Mr. Clement Reid, who from the most unpromising material has succeeded in obtaining from that locality a collection of 61 species of mollusca, not including 6 as to the identification of which he is in doubt.[1] This list, though doubtless containing but a small proportion of the molluscan fauna of the period, may possibly be considered as fairly representing it.[2] The 67 species named belong to 50 genera, and they are more or less of a character similar to those found in the Coralline Crag. With the exception of 15 (or 23 per cent.), they all occur in that deposit.

In the work just mentioned[3] Mr. Reid groups the Lenham Beds with the sands of Louvain and Diest, and with the fossiliferous strata of Antwerp and Utrecht, and, taking them as a whole, he considers that they are of the same age as, or even slightly newer than, the Coralline Crag. I have given elsewhere my reasons for believing that some of the strata met with in the Utrecht boring, regarded by Dr. Lorié[4] as Diestien, belong to the Scaldisien, that is, to a more recent formation,[5] and I do not think that any of them are as old as those of Lenham. The sands of Diest and Louvain, including the zone à *Terebratula grandis*, are now believed by Belgian geologists, and I think with reason, to be older than the Antwerp beds (zone à *Isocardia cor*). It is the latter zone only, and not the whole of the deposits generally known as Diestien, which represents, I consider, the Coralline Crag of Suffolk, 87 per cent. of the mollusca from the *Isocardia*-beds occurring also in the latter. On both palæontological and stratigraphical grounds, I believe that the Lenham Beds, although undoubtedly of Pliocene age, as held by Prestwich and Wood, may be considerably older than the Coralline Crag.

[1] Mem. Geol. Surv. 'Pliocene Deposits of Britain,' 1890.

[2] [In the discussion which followed the reading of this paper, Mr. Reid suggested that if the smaller forms of the Lenham fauna were known, its general character might appear to be different. He considers that 'the smaller mollusca generally give a larger percentage of persistent forms.' I doubt this very much. An examination of the molluscan fauna of the Coralline Crag, the other deposit in question, does not seem to me to lend any support to such a view.—May, 1898.]

[3] *Op. cit.* p. 57.

[4] 'Contrib. à la Géol. des Pays-Bas,' No. 1, Extr. des Archives du Musée Teyler, Haarlem, ser. ii, vol. ii (1885).

[5] Quart. Journ. Geol. Soc. vol. lii (1896) p. 762. It does not seem to me that any of the Pliocene deposits described by Dr. Lorié are older than the Coralline Crag.

The names of the 15 species found at Lenham, but not in the Coralline Crag, are as follows:—

Extinct Forms.	Miocene.	Italian Pliocene.	Red Crag.
Terebra acuminata, Bors.	*	*	
Triton heptagonum, Broc.	*	*	
Pleurotoma consobrina, Bell.	*		
" *Jouanetti*, Desm.	*		
" *turrifera*, Nyst [1]	*	*	possibly derivative.
Xenophora, sp.			
Pecten, sp. nov.			
" sp. nov.			
Cardium, sp. nov.			
Tellina Benedenii, Nyst [1]	?		*
Southern Forms.			
Arca diluvii, Lam.	*	*	
Cardium papillosum, Poli	*	*	
Gastrana fragilis, Linn.	*	*	
Northern and Southern.			
Nucula sulcata, Bronn	*	*	
Trochus cinerarius, Linn. (North African)		*	*

Besides employing the time-honoured method of testing the comparative age of any Tertiary horizon, namely, by observing the proportion between its recent and extinct shells, we may go a step farther back, and enquire what percentage were survivors from earlier, that is from Miocene seas, or may have existed at the same period elsewhere, under different conditions, in deposits which, though contemporaneous, are not homotaxial.

The resemblance of the molluscan fauna of the Coralline Crag to that of the Mediterranean at the present day has often been emphasized, but a similar correspondence exists, and for the same reason, between the molluscan fauna of the Miocene deposits of Northern Europe and that of the Pliocene of Italy and Sicily. Many species which flourished in the North Sea during the Coralline Crag period have now become extinct there, but they continue to exist in the Mediterranean; so, dealing with an earlier period, we find that a large number of mollusca occurring in the Belgian[2] and North German Miocene,[3] which had disappeared from these latitudes before the

[1] Found also in the Diestien Beds of Belgium.
[2] Van den Broeck, 'Esquisse Géol. & Paléont. des Dépôts Plioc. d'Anvers,' 1876, p. 40, etc.
[3] Von Kœnen, 'Mioc. Nord-Deutschl. u. seine Molluskenfauna,' Cassel, 1872; Stuttgart, 1882.

deposition of the Coralline Crag, still survived in the older Pliocene seas (Piacentian) of Southern Europe.[1] The Pliocene deposits of the Mediterranean thus represent, in a sense, an older fauna than do those of similar age in the Anglo-Belgian basin. Now, not only do the Lenham Beds contain a somewhat larger percentage of extinct species, but they are more closely connected with the Miocene on the one hand, and the Pliocene of the Mediterranean on the other, than is the Coralline Crag, as shown by the following numbers:—

	Species still existing.	Occurring in Miocene deposits.	In the Pliocene of the Mediterranean.
Lenham............	57 per cent.	75 per cent.	72 per cent.
Coralline Crag ...	61 ,,	59 ,,	61 ,,

These three independent methods of testing its fauna agree in indicating that the Lenham Beds are older than the Coralline Crag. In the foregoing comparison I have taken only the more abundant species of the latter. If the rarer forms had also been included, the difference between the two deposits would have been still greater. The list of Lenham mollusca is not likely to contain any but species which are more or less characteristic.

The view that the Lenham deposit is older than the Coralline Crag seems to be confirmed by a more particular examination of its molluscan fauna. In addition to the species enumerated in the preceding table (p. 311) we find at Lenham the following similarly characteristic Miocene or Italian Pliocene forms, namely:—

Fusus lamellosus, Bors.	*Cancellaria contorta*, Bast.
Pyrula reticulata, Lam.	*Hinnites Cortesyi*, Defr.

These occur but rarely in the Coralline Crag, and were probably beginning to die out in the Anglo-Belgian area during its deposition. There is one species, however, *Arca diluvii* (which Mr. Reid informs me is one of the most abundant Lenham fossils), the presence of which at that locality is specially significant. This mollusc, widely diffused during the Miocene epoch, and very common in the Bolderien of Belgium, seems to have disappeared from the North Sea before the Coralline Crag period,[2] no trace of its existence having been met with either in that formation or in any of the Diestien deposits of Belgium or Holland, but it still continued to inhabit the Mediterranean during the Pliocene era, as it does to this day.

Another species, *Cardium papillosum*, may be also mentioned. This Miocene and southern form, existing in the Mediterranean both in Pliocene times and at present, is unknown from any of the Pliocene deposits of Belgium or East Anglia, but it is one of the most abundant Lenham fossils. It may be noticed, on the other hand, that the different species of *Astarte*, which occur in the Coralline Crag in

[1] As the climate of the Pliocene period changed, certain species died out, but they continued to exist longer in southern than in northern latitudes.

[2] *Arca diluvii* is said by MM. Viellard & Dollfus to occur, but only in the oldest portion of the Pliocene of Normandy, 'Etude Géol. sur les Terrains Crét. et Tert. du Cotentin,' Caen, 1875, p. 154.

such countless profusion, are equally rare at Lenham and in the Miocene deposits of Belgium.

The fauna of the *Isocardia cor*-beds of Belgium, which resembles so closely that of the Coralline Crag, presents, on the contrary, no such marked affinities with the Miocene and the Italian Pliocene deposits.

While thus the Lenham fauna contains at least 13 (out of 61) characteristic Miocene or Italian Pliocene species, unknown or rare in any North Sea deposit later than the Miocene, not a single mollusc (the undescribed forms perhaps excepted) has been met with at Lenham which has not also been found in beds as old as the Coralline Crag. The mollusca occurring at Lenham, but not in the latter, are therefore almost entirely of an older rather than of a newer type, 10 out of the 15 before mentioned being extinct and 3 southern.

The evidence of the Lenham polyzoa is not of great value, 2 species only being known to Mr. Reid, but, so far as it goes, it points in the same direction. One of these, *Fascicularia aurantium*, is extinct, and the other, *Cupularia canariensis*, a form still existing, ranges no farther north than Madeira or the Canaries. The polyzoan fauna of the Coralline Crag, on the contrary, includes many species which are found in British seas.

Mr. Reid indeed insists that the fossils from Lenham present a more decidedly southern (but therefore, I suggest, older) facies than do those of any other of the recognized Pliocene deposits of the Anglo-Belgian area. The present distribution of mollusca in the British seas seems to be largely due to tidal currents which carry forward the free-swimming larvæ as far as their influence extends. As will be seen hereafter, the tidal currents which reached the Coralline Crag area probably came, not from the north, but from the south—that is, from the direction of Lenham. It seems, therefore, to me more reasonable to suppose that the southern and Miocene forms found at Lenham, but not in the Coralline Crag, had died out in these latitudes previously to the deposition of the latter, than that two faunas differing so considerably one from the other should have co-existed in the same basin, and under similar conditions as to current-action, within 60 miles of each other. No such difference in geographical distribution as this is known to occur in British seas at the present day.

The question of the origin of the 'boxstones' found in the nodule-beds at the base of the Coralline and Red Crags may be conveniently discussed at this point. They are composed of fine ferruginous material, not unlike that of some of the Diestien or the Lenham sandstones, and are rounded and waterworn, resembling in shape the beach-pebbles of flint now found in places on the Norfolk coast. Mr. Reid believes that they have been derived from a single horizon, which is not of Miocene age,[1] and with this con-

[1] Mem. Geol. Surv. 1890, 'Pliocene Deposits of Britain,' p. 12, etc. See also Ray Lankester, Quart. Journ. Geol. Soc. vol. xxvi (1870) p. 500.

clusion I agree entirely. The mollusca obtained from the boxstones, although not identical with those from Lenham,[1] are generally of a similar character, including *Conus Dujardinii*,[2] *Nassa conglobata*, *Voluta auris-leporis*, and *Isocardia lunulata* (characteristic fossils of the Miocene deposits of the North Sea, or of those which I regard as to some extent representing them, namely, the Pliocene deposits of the Mediterranean), associated with other forms of a more modern, but still Coralline Crag type.

The marine vertebrata of the nodule-beds include also a similar admixture of Miocene and Pliocene forms, as, for example, *Herpetocetus scaldiensis*, *Hoplocetus crassidens*, and *Squalodon antwerpiensis*, said to occur in the Bolderien deposits of Antwerp together with species of Diestien age.[3]

Thus the boxstone fauna seems to be much of the same intermediate character, between those of the Miocene of Belgium and of the Coralline Crag, as is that of Lenham; and I am inclined to agree with Prof. Ray Lankester that it is from a former extension of a deposit of similar, though possibly not identical age, that the boxstones and some other extraneous fossils found in the nodule-beds have been derived.[4]

The stratigraphical evidence lends, I think, some support to this hypothesis. It has been often pointed out that the Lenham Beds are connected by a chain of outliers with the sands of Louvain and Diest, and they are probably contemporaneous with some part of them. The upheaval which has affected these deposits has been greatest in Kent, where they occur 620 feet above the sea-level; but their height becomes gradually less, until at Louvain it is barely 200 feet. They have been everywhere extensively denuded, except east of Louvain (see map, fig. 1, p. 316), where they cover the country with a continuous sheet; but they dip towards the north-west, and beyond Malines disappear under newer beds.

Since the publication of my paper on the Pliocene deposits of Holland, an important communication from the pen of M. Rutot, the distinguished Belgian geologist, has appeared,[5] with maps showing the probable extension of the North Sea over Belgium at the commencement and towards the end of the Diestien period; the boundaries there given I have reproduced in the accompanying map (fig. 1) by the kind permission of M. Rutot. That to the south indicates the southern margin of the sea in which an earlier part of the formation, namely, the sands of Louvain and Diest, zone à *Terebratula grandis* (and, as I think, of Lenham), originated, and that to the north the limits of the basin of the later portion, the zone à *Isocardia cor*.

As the earth-movements which affected Holland and Belgium were

[1] The Lenham fauna must have contained many species which are not at present known from that locality.

[2] *Conus Dujardinii* occurs also in the older portion of the Diestien beds of Belgium (zone à *Terebratula grandis*).

[3] Van den Broeck, 'Esquisse Géol. & Paléont. des Dépôts Plioc. d'Anvers,' pp. 68 & 120.

[4] Quart. Journ. Geol. Soc. vol. xxvi (1870) p. 501.

[5] 'Les Origines du Quaternaire de la Belgique,' Mém. Soc. Belge de Géol. vol. xi (1897) p. 1.

felt also in this country, it may be that in the width of the belt of the Diestien sands between Louvain and Malines we have an approximate measure of the recession of the sea which took place in England between the Lenham and the Coralline Crag periods, and I have ventured so to show it on the map. If this view be correct, it is not difficult to understand that the cliffs which fringed the southern shore of the Coralline Crag sea may have included beds of Lenham or approximate age, from the destruction of which the beach-pebble-like boxstones were derived. They could hardly have come from a Miocene source. There is no indication that the sea of the Bolderien period approached the shores of East Anglia, or that it was connected with the Atlantic towards the south-west.[1] It was not until after the close of the Miocene epoch, and in consequence probably of the great disturbances which then ensued, that the German Ocean encroached upon the land over the east of Belgium and the Pas-de-Calais, towards Kent, opening up communication with seas to the south-west.[2] Moreover, the elevation of the southern part of the Tertiary basin was accompanied by a corresponding depression towards the north, so that the Miocene strata of Belgium were at that period, in all probability, submerged and covered by Diestien beds, and so protected from denudation.

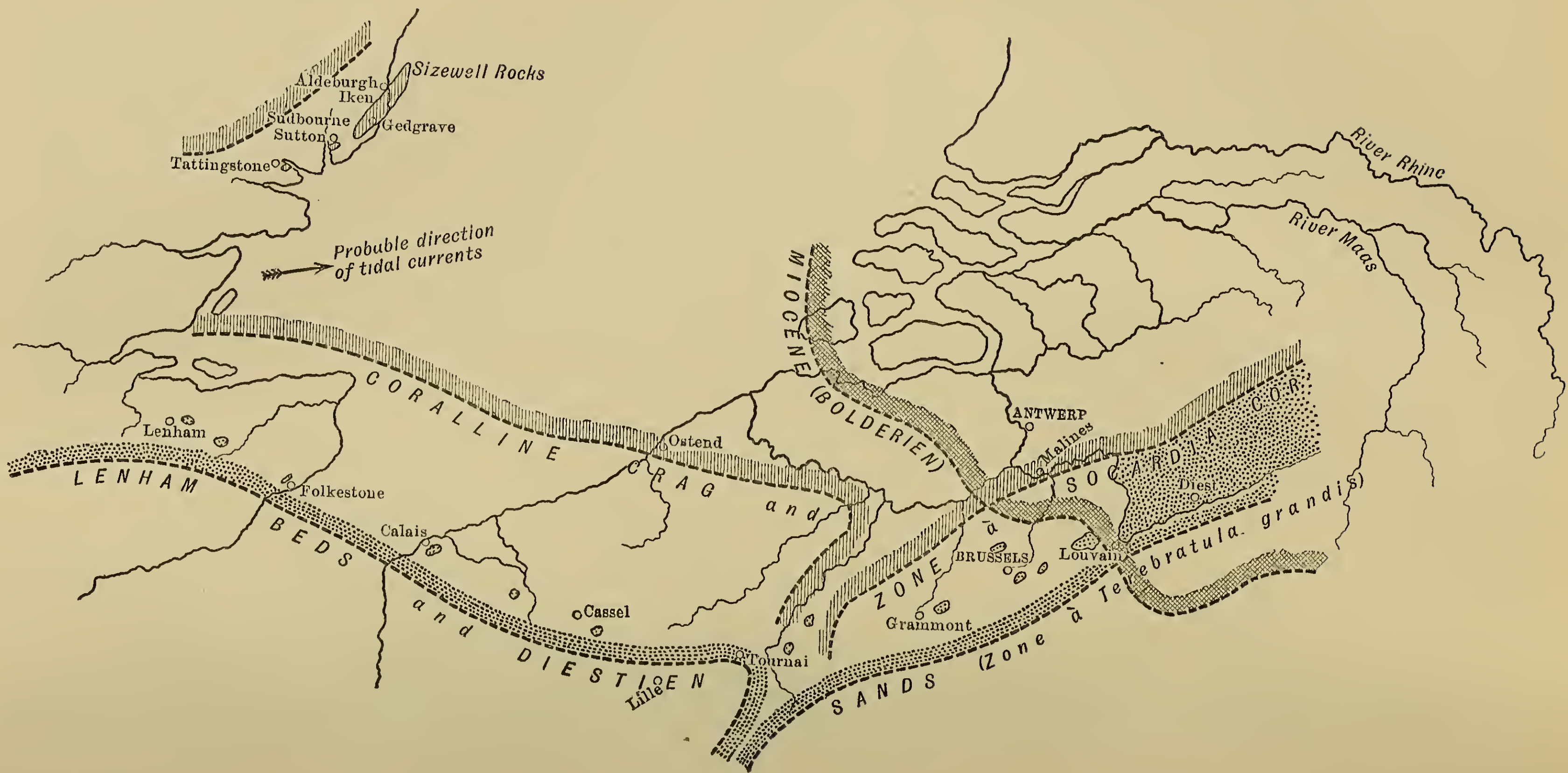
It is difficult, therefore, from a stratigraphical point of view, to find any other source for the boxstones than the older Pliocene sandstones of the South of England, which, like some part of the sands of Louvain, had, I consider, been elevated into land before the deposition of the Coralline Crag. Originating, probably in the first instance, as beach-pebbles, the boxstones may have travelled as littoral drift along the western margin of the Crag sea,[3] or they may have been brought to their present resting-place by the southern currents then prevailing. It should be noticed that they occur almost entirely in one part of the Crag district. That they are found in the same area under both the Coralline and the Red Crags seems a difficulty, because those two formations must have originated under different conditions. Possibly the nodule-bed

[1] I have indicated in the map (fig. 1, p. 316) the southern and western limits of the Bolderien sea, according to M. Rutot.

[2] It may be noticed that in the Coralline Crag Miocene shells occur which are found in the Faluns of Touraine, but are not known from the Belgian and North German Miocene.

[3] The travel of the beach along the south coast of England is now, as it always must have been, from west to east—that is, in the direction of the flowing tide. 'The head of the tide,' namely, the point at which the tidal currents running down the eastern coast of England and up the English Channel meet (see Kinahan, Quart. Journ. Geol. Soc. vol. xxxiii. 1877, p. 31), is situated at present in the immediate neighbourhood of the Straits of Dover. If the North Sea during the Coralline Crag period was less open to the north than it is at present, as seems probable (see p. 351), the position of the head of the tide would have been situated farther north than it is now, and the influence of the tidal currents from the south would then have been felt off the coast of Suffolk. The fact that southern currents do not now penetrate to any extent into the German Ocean is probably the reason why so few of the southern species of mollusca found in the English Channel and on the western coast of England occur on the shores of Norfolk. (See Trans. Norfolk & Norwich Nat. Soc. 1871–72, p. 42.)

Fig. 1.—*Map showing the probable western and southern limits of the German Ocean during the Miocene, and at the commencement and towards the end of the Diestien period.* (Scale: $\frac{1}{2,500,000}$ = about 39 miles to the inch.)



was accumulated previously to the deposition of the Coralline Crag, or cliffs of older Pliocene sandstones may have continued to exist along the south-western margin of the Crag sea during a part of the Red Crag period.

If the conclusions to which the facts here enumerated seem to point be correct, the Lenham Beds may be considerably older than the Coralline Crag, these two deposits being separated from each other by an interval sufficiently long to allow for the consolidation and subsequent denudation of the former,[1] as well as for the disappearance from the Anglo-Belgian basin of a number of species of mollusca which abounded in it during the Miocene, and continued to do so until the earlier part of the Pliocene period.

Although the Lenham Beds are connected stratigraphically with the sands of Louvain and Diest, the molluscan faunas of the two deposits, while presenting some resemblance, are, as to individual species, by no means identical. The difference may be due to the fact that the collection of fossils from either is small, and therefore imperfect; or the Diestien Sands may represent a considerable period, and the fossiliferous beds which they contain may be of a somewhat later age than the Lenham deposit. Fossil shells are not common in these sands, and when they do occur it is in the form of casts, which is also the case at Lenham.

The species known from the Diestien Sands (zone à *Terebratula grandis*) are the following:—

List of Mollusca from the Diestien Sands of Belgium.

	Lenham or Box-stones.	Miocene or Ital. Pliocene.	Cor. Crag.	Extinct.
Voluta Lamberti, Sow.	*	*	*	*
Nassa labiosa, Sow.	...	*	*	*
„ *reticosa*, Sow.	...	...	...	*
„ var. *elongata*, S. V. W.	...	...	...	*
Pyrula reticulata, Linn.	*	*	*	*
Cassis Saburon, Brug.	...	*		
Buccinopsis Dalei, Sow.	*	*	*	
Murex scalariformis, Nyst	...	*	...	*
Trophon consocialis, S. V. W.	...	*	*	*
Fusus gracilis, Da Costa	...	...	*	
Pleurotoma crassa, A. Bell	...	...	*	*
Conus Dujardinii, Desh.	*	*	...	*
Pleurotoma inermis, Part.	...	*	*	?
„ *intorta*, Broc. } „ var. *plicatilis*, Nyst }	...	*	...	?
Aporrhais pes-pelicani, Linn.	*	*	*	
Turritella incrassata, Sow.	...	*	*	
Natica millepunctata, Lam.	*	*	*	
„ *varians*, Duj.	*	*	*	*

[1] Prestwich believed that the Lenham Beds had been upheaved prior to the deposition of the Coralline Crag, Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 134. See also A. Bell, Geol. Mag. 1872, p. 209.

List of Diestien Mollusca (*continued*).

	Lenham or Box-stones.	Miocene or Ital. Pliocene.	Cor. Crag.	Extinct.
Trochus obconicus, S. V. W.	...	...	*	*
„ *zizyphinus*, Linn.	*	*	*	
„ *multigranus*, S. V. W.	...	...	*	*
Margarita maculata, S. V. W.	...	*	*	*
Calyptræa chinensis, Linn.	...	*	*	
Ringicula buccinea, Broc.	...	*	*	
Bulla cylindracea, Penn.	...	*	*	
Scaphander lignarius, Linn.	*	*	*	
Dentalium dentalis, Linn.	*	*	*	
Ostrea princeps, Sow.	*	...	*	*
Pecten grandis, Sow.	...	...	*	*
„ *tigrinus*, Müll.	...	*	*	
„ *pusio*, Linn.	...	*	*	
„ *opercularis*, Linn.	*	*	*	
Lima Loscombii, G. B. Sow.	?	*	*	
Modiola phaseolina, Phil.	...	*	*	
„ *sericea*, Brongn.	...	*	*	*
Pectunculus glycimeris, Linn.	*	*	*	
Limopsis aurita, Broc.	...	*	*	
Nucula lævigata, Sow.	...	*	*	*
Leda semistriata, S. V. W.	?	...	*	*
Lucina borealis, Linn.	...	*	*	
Diplodonta astartea, Nyst	?	*	*	
Cardita scalaris, Leathes	...	*	*	
„ *chamæformis*, S. V. W.	...	...	*	*
„ *orbicularis*, Leathes	...	*	*	*
Cardium decorticatum, S. V. W.	*	...	*	*
Astarte Basterotii, Laj.	*	...	*	*
„ *corbuloides*, Laj.	...	...	...	*
„ *incerta*, S. V. W.	...	...	*	*
„ *Omalii*, Laj.	*	*	*	*
„ *sulcata*, Da Costa	...	*		
Cyprina islandica, Linn.	*	*	*	
„ *rustica*, Sow.	*	*	*	*
Isocardia cor, Linn.	*	*	*	
Venus casina, Linn.	...	*	*	
„ *ovata*, Penn.	...	*	*	
„ *imbricata*, Sow.	...	...	*	*
Cytherea Chione, Linn.	*	*	*	
Donax politus, Poli	*	...	*	
Tellina Benedenii, Nyst	*	?	...	*
Abra prismatica, Mont.	...	*	*	
Mactra solida, Linn.	...	...	*	
„ *arcuata*, Sow.	*	...	*	*
Cultellus tenuis, Phil.	...	...	*	*
Solen ensis, Linn.	*	*	*	
Thracia inflata, Sow.	...	...	*	*
Corbula striata, W. & B.	...	*	*	
Panopæa Faujasii, M. de la G.	*	*	*	
Glycimeris angusta, Nyst	*	*	*	*
Teredo norvegica, Speng.	?	*	*	
Saxicava rugosa, Linn.	...	*	*	
Terebratula grandis, Blum.	*	*	*	*
Lingula Dumortieri, Nyst	...	...	*	*

The fauna of this zone resembles generally that of the Coralline Crag, but it contains a few Miocene species not known from, or rare in, that formation, such as *Pyrula reticulata*,[1] *Cassis Saburon*, *Murex scalariformis*, *Conus Dujardinii*, and *Pleurotoma intorta*. On the whole, it presents a somewhat more recent facies than that of Lenham, although it seems older than the Coralline Crag.

M. Van den Broeck has, however, discovered a fossiliferous bed at Waenrode, near Diest, from which the following species have been obtained :—

	Extinct	Cor. Crag or Diestien	Lenham or Box-stones	Miocene
Cassis Saburon, Brug.	...	*	...	*
† „ *Rondettii* (?) Bast.	*	...	...	*
Pyrula reticulata, Sism.	*	*	*	*
Aporrhais pes-pelicani, Linn.	...	*	*	*
Turritella incrassata, Sow.	...	*	*	*
Scaphander lignarius (?) Linn.	...	*	*	*
†*Pecten Caillaudi* (?) Nyst..............	*	...	...	*
Nucula lævigata, Sow.	*	*	...	*
Leda semistriata, S. V. W.	*	*	?	
Cardium subturgidum, d'Orb.	*	...	...	*
Lucina borealis, Linn.	...	*	...	*
† „ *Drouetti* (?) Nyst	*	...	...	*
Cryptodon flexuosum, Mont.	...	*	...	*
Isocardia lunulata, Nyst	*	...	*	*
Cytherea rudis (?) Poli	...	*	...	*
Tellina compressa, Broc.	...	*	...	*
Abra prismatica, Mont.	...	*	...	*
Cultellus tenuis, Phil.	*	*		
Corbula striata, W. & B.	...	*	...	*
Teredo, sp.				

If it were not for the presence of the three species marked †, the identification of which seems to be uncertain, this group of fossils would be as nearly related to the Pliocene as to the Miocene. Out of the 19 species named, 14 occur also in the Coralline Crag and the Diestien, and 16 in the Miocene of Belgium ; but there are 3, *Leda semistriata*, *Tellina compressa*, and *Cultellus tenuis*, that are not known from the last-named formation. If we omit the doubtful species, the proportion is 13 out of 14 in the former case, and 11 out of 14 in the latter. The percentage of Coralline Crag forms generally in the Belgian Miocene is very different. M. Van den Broeck enumerates 175 species of mollusca from the Miocene zone à *Panopæa Menardi*, only 79 (or 45 °/₀) of which are found in the Coralline Crag, and 143 from the zone à *Pectunculus pilosus*,[2] only 77 (or 53 °/₀) of which are common to that deposit. The list

[1] *Pyrula reticulata* and *Pleurotoma intorta* are, however, found also in the zone à *Isocardia cor*.

[2] 'Esquisse Géol. & Paléont. des Dépôts Plioc. d'Anvers,' 1876, pp. 42 & 56.

of shells from Waenrode is very short, and it may not be truly representative. So far as the evidence goes, however, the fauna does not seem to me typically Miocene, though Belgian geologists believe, on stratigraphical grounds, that it is at the latest of Miocene age.[1] Without expressing, therefore, any decided opinion on the subject, I merely call attention to this interesting discovery of a bed which, like that of Lenham, contains a fauna closely resembling at the same time those of the Coralline Crag and of the Belgian Miocene.

Tabulating these results, we have:—

	Extinct forms	Coralline Crag
Waenrode	42 %	68 %
Diestien beds.		
Zone à *Terebratula grandis*	46 %	85 %
Lenham	43 %	77 %
Belgian Miocene.		
Zone à *Pectunculus pilosus*	53 %	54 %
,, *Panopæa Menardi*	59 %	45 %

III. The Coralline Crag.

As is well known, the Coralline Crag occurs: (*a*) at Tattingstone, 4 miles south of Ipswich, limited there probably to a very small area, and exposed in one section only[2]; (*b*) at Ramsholt and Sutton, on the eastern bank of the Deben estuary, where it may be traced, though not continuously, for rather more than ½ mile; and (*c*) in the main mass of the formation, extending from Boyton and Gedgrave to Iken and Aldeburgh (Butley Creek and the river Alde intervening), and thence to some submarine rocks off the coast at Sizewell, 5 or 6 miles N.N.E. of the last-named locality. Traces of it are said to have been found at Trimley (*teste* Acton)[3] and at Waldringfield (Whitaker),[4] and possibly it may exist elsewhere under the high land between the Orwell and the Deben, or between the latter river and Butley Creek. Along the low land fringing those rivers, however, no Coralline Crag is known, the Red Crag being shown in many places to rest directly on the London Clay, as it does also along the coast from Walton-on-the-Naze to Bawdsey.

The method adopted by Prestwich was to take the beds present in the small outlier at Sutton (which he described at some length) as typical of the formation generally, but he did not attempt to show, either by stratigraphical or palæontological evidence, that the divisions observed at Sutton are constant over the whole area,

[1] M. Van den Broeck was at first inclined to think that the Waenrode deposit was Pliocene, Ann. Soc. Roy. Malacol. Belg. vol. xix (1884) p. lvi.

[2] [I understand that a second exposure of Coralline Crag has recently been discovered at Tattingstone.—June, 1898.]

[3] Suppl. 'Crag Mollusca,' Introd. p. iii, Monogr. Palæont. Soc. 1872.

[4] Mem. Geol. Surv. 1885, Ipswich, p. 65.

nor do I think that it is possible to do so; he stated, however, but as a matter of opinion only, the horizons to which he considered the beds occurring at other localities should be referred. He claimed that these supposed zones are characterized by distinctive groups of fossils, and that their deposition was attended by great physiographical changes, including a submergence of the Crag basin, by which at one stage the North Sea attained a depth of from 500 to 1000 feet, while at another the climate of Northern Europe was refrigerated sufficiently to permit of floating ice reaching East Anglia, with boulders from either Scandinavia or the Ardennes.

The Coralline Crag, both in the Sutton outlier and in the main mass of the formation, seems to fall naturally into two divisions (a view held by all observers up to the present time), the lower consisting of shelly incoherent sands, generally of a whitish colour, and the upper of a porous ferruginous limestone, soft and friable when first quarried, but acquiring a hard crust by exposure to the air.[1] The colour of the latter, normally a light ochreous yellow, assumes on further oxidation a dark rusty hue. Specimens of *Pecten* and other mollusca whose shells are composed of carbonate of lime in the form of calcite (the translucent variety), and the remains of polyzoa, are common in this rock-bed, as they are also in the shelly sands, but the opaque or arragonite mollusca are represented in it by casts only.[2] These casts occur, however, in many places and at different levels, generally in layers, and often in great abundance.

At first sight nothing could well seem more distinct than the soft shelly beds of the lower, and the hard ferruginous rock of the upper part of the Crag, but I now believe that the difference is more apparent than real, and that the rock-bed is merely an altered condition of the shelly sands,[3] its ferruginous character being due to the infiltration of water charged with oxide of iron, arising from the decomposition of part of the glauconite of the unaltered Crag. Indeed, I have lately discovered, in an important section at Iken, which will be described later on (see pp. 338, 339), the two kinds of Crag side by side, and passing into each other.

Prestwich separated from the rest the upper or ferruginous portion of the Crag, which, as will be seen by the sections (figs. 5 & 7, pp. 328 & 332), forms nearly one half of the entire mass of the formation, calling it zones G & H. The nodule-bed at the base of the Crag, found in one spot only at Sutton, he described as

[1] It sometimes becomes sufficiently hard to be used for building, as for example in the tower of Chillesford Church.

[2] See P. F. Kendall, Geol. Mag. 1883, p. 497.

[3] More than 20 years ago attention was simultaneously called by Mr. Whitaker, and by Mr. Wood & myself (Quart. Journ. Geol. Soc. vol. xxxiii, 1877, pp. 75 & 122), to the alteration of the Red Crag by infiltration; and M. Van den Broeck, about the same time, made similar observations in Belgium. It is not a little strange that it occurred to none of us that the Coralline Crag might have been affected in the same way.

zone A,[1] dividing the shelly sands between A and G, which have in all a maximum thickness of no more than 30 feet, into five zones: B, C, D, E, and F. Whether we examine it chemically or microscopically, however, we can find no essential difference in the material of which these several beds, B to F, are composed. It is throughout mainly of organic origin, consisting of the comminuted shells of marine organisms or of calcareous matter derived from their decomposition, with only a small admixture of inorganic ingredients. The proportion of the latter varies slightly in specimens taken at different spots, as will be seen below.

Mr. Francis Sutton, of Norwich, a well-known authority, has kindly analysed for me some examples of the two varieties of Crag, with the following result:—

	Carbonate of Lime	Silica	Oxide of Iron and Alumina
Shelly sands (No. 1)	78·62 %	7·75 %	3·50 %
Ferruginous Crag (No. 2)	78·95 %	11·50 %	7·20 %

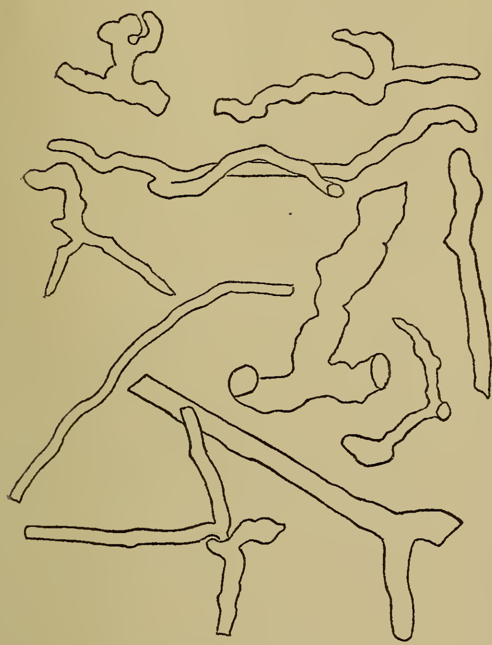
More recently his son, Mr. W. Lincolne Sutton, the public analyst to the Corporation of Norwich, has tested some fresh samples, and reports as follows:—

	Carbonate of Lime	Silica	Oxide of Iron and Alumina
Shelly sands (No. 3)	70·9 %	13·5 %	7·1 %
„ „ (No. 4)	74·7 %	12·8 %	5·5 %
Ferruginous Crag (No. 5)	79·2 %	11·4 %	4·2 %

Dr. G. J. Hinde, F.R.S., has been good enough to examine samples 3 & 5 for me microscopically, and says: 'Under a low power or with a hand-lens the Crag is seen to contain, as is well known, specimens of foraminifera and entomostraca, fragments of mollusca and polyzoa, and the spines of echinoderms, with grains of quartz, some angular, others rounded, and dark green granules of glauconite, rounded and polished. Among the finer material I find an immense number of minute almond- or diamond-shaped calcspar-crystals, amorphous particles, and coccoliths, and numerous rod-like bodies, simple or branching, usually vermiform' (see fig. 2); these he considers may be 'the solid infillings, by a silicate of iron, of borings in molluscan shells by the action of organisms supposed to be of the nature of algæ or fungi. They are not seen until the shells have been dissolved by acid, are translucent, and polarize feebly. Numerous coccoliths are present, somewhat larger than those in the Upper Chalk, and I do not think that they have been derived from that formation. It is important to notice that only two microscopic chips of flint were observed, with perhaps an occasional flake of mica and a grain of felspar.'

[1] The basement-bed, zone A of Prestwich, is, of course, of a different character, originating under conditions dissimilar to those of the rest of the Crag.

Fig. 2.—*Rod-like bodies in Coralline Crag residues (after solution in hydrochloric acid).*



×100 diameters.

In some borings at Gedgrave and Sudbourne, to be described hereafter, I found at the base of the formation a bed, 12 inches or so thick, resting on the London Clay, which it resembles in colour, consisting of blue Crag which differs from the shelly sands in containing a larger proportion of quartz-grains. Analysed, it was proved to contain:—

	Carbonate of Lime	Silica	Alumina and Oxide of Iron
No. 6	57·30 %	35·10 %	3·80 %

the iron being mainly in the unoxidized or ferrous state.

Dr. Hinde observed in this blue Crag 'numerous grains of a translucent mineral, probably a silicate of iron, allied to glauconite; they are mostly subangular, and polarize feebly between crossed nicols.' No polyzoa were noticed, but this absence may be accidental, as Prestwich found them at the base of the Crag at Sutton.

The consolidation of the ferruginous Crag and the dissolution of the arragonite-shells seem to have taken place at a comparatively remote period, that is, previously to the deposition of the Red Crag, as both Sir Joseph Prestwich[1] and Mr. P. F. Kendall[2] found blocks of the former in the latter deposit; but the Coralline Crag has also been subjected to the action of acidulated water in more recent times. Mr. Sutton has analysed some dark red earth from the cylindrical pipes, familiar to all students, which penetrate the Crag from the surface downward, often to a considerable depth, and finds that it contains the merest trace of calcium carbonate, as will be seen from the following analysis:—

	Carbonate of Lime	Silica	Oxide of Iron	Alumina
No. 7	0·56 %	74·20 %	11·40 %	2·10 %

[1] Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 341.
[2] Geol. Mag. 1883, p. 499.

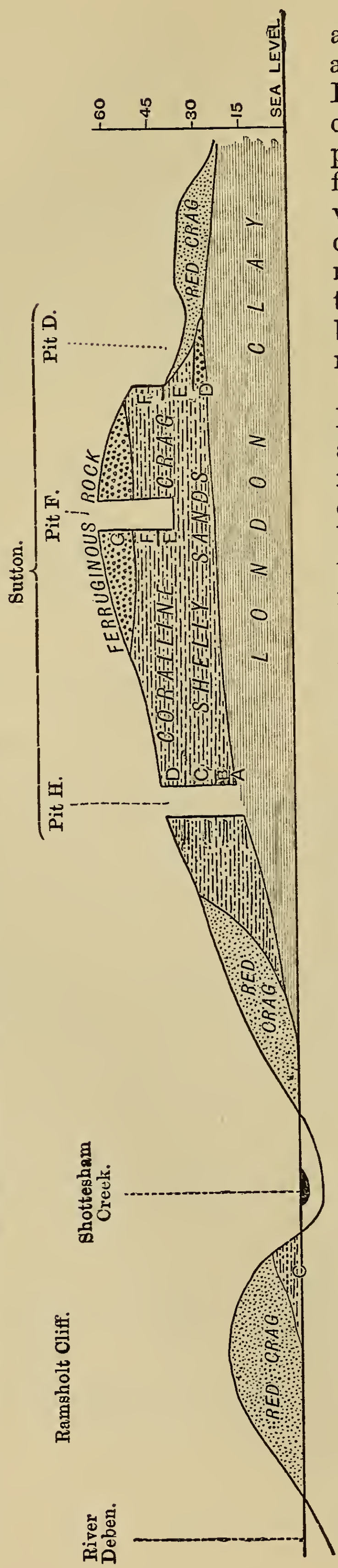


Fig. 3.—Section showing the irregular surface of the London Clay under the Coralline Crag at Ramsholt and Sutton, and the want of stratigraphical accordance between the supposed zones of the latter at those localities.

The Coralline Crag of Ramsholt and Sutton occupies one side of an old channel or depression in the London Clay, which at that point coincides to some extent with the present estuary of the Deben (see fig. 3). At Ramsholt the Crag was formerly exposed in a low cliff close to the river, but it is not now visible; its junction with the London Clay there was probably little, if at all, above Ordnance datum.

Prestwich regarded the Ramsholt bed as belonging to his zone C, and he gave a list of 17 species of mollusca from it, besides echinodermata, etc., some of which he believed to be more abundant there than elsewhere. Most of the mollusca, however, are common everywhere in the formation, and I do not think that generally the species mentioned can be looked upon as more characteristic of one portion of it than of another.

At Sutton, a short distance ($\frac{1}{3}$ mile) from Ramsholt Cliff, there was formerly a pit (H of Prestwich's section) at which the nodule-bed (zone A) was observed by himself and Prof. Ray Lankester. At that spot the Crag is, I believe, at a higher level than that of Ramsholt, resting on the London Clay 8 feet above high-water mark (see fig. 3).[1] Prestwich, however, called the beds there exposed zones A, B, & C.

At his pit D, 500 yards northeast of the last, where the London Clay rises 12 feet higher, he classed the beds as zones D, E, & F, while at pit F, 250 yards distant, he considered them to belong to zones E, F, & G. It will be seen by reference to fig. 3 that, taking the dip into account, in

[1] The measurements in Prestwich's paper and sections are somewhat difficult to follow. Some are taken above high-, some above low-water mark of the River Deben, and some, possibly, above Ordnance datum.

no two of these four sections are the supposed zones in the same relative position, nor is any reason suggested, except that the London Clay floor was uneven,[1] why no beds representing periods B & C should have been deposited in the locality of pit D. The gradient of the surface of the London Clay between pits H and D is, however, only about 1 in 100, so that this explanation seems inadequate.

Prestwich cited the following genera as specially characteristic of certain zones in the Sutton Crag, namely:—*Cyprina*, *Pecten*, *Mya*, *Cardita*, *Astarte*, *Anomia*, and *Venus*; but these are met with not only in all parts of the Coralline, but also and abundantly in every portion of the succeeding Red Crag formation. Mr. Burrows, one of the authors of the great work on the Foraminifera of the Crag, just completed,[2] speaks of a band containing *Cyprina islandica* as apparently constant to zone D, and he names a dozen other species of mollusca, smaller forms, which he considers peculiar to Prestwich's zone F, or more abundant in it at Sutton and Gedgrave than at any other horizon. *Cyprina islandica* has, however, existed in the North Sea, probably without intermission, from the Miocene period to the present day, so that its presence or absence at any one spot in the Crag must be accidental; and it does not seem to me that the other species named by him can be regarded as characteristic even of the whole of the Coralline Crag, still less of any special zone in it. With one or two exceptions, they are Miocene forms, which continued to exist, and even to abound in the Crag area during the subsequent period represented by the Walton bed and the Scaldisien of Belgium, some of them being still found in British seas. It would, however, be equally possible to make up a list of shells which are common at Sutton, and rare or unknown at Gedgrave, or *vice versâ*, but it is a constant feature of the shelly sands that some localities yield a more varied or a somewhat different fauna as compared with others.

Any resemblance, moreover, which the molluscan fauna of the beds regarded by Prestwich as zone F at Sutton may bear to those of Gedgrave Hall seems to me to be antagonistic to, rather than in favour of, his views, since the shelly seam at the latter place is within 15 feet of the base of the formation, which at Sudbourne, in the immediate neighbourhood, is 60 feet in thickness. Stratigraphically, therefore, the Gedgrave shell-beds belong to a lower part of the Crag rather than to the supposed upper zone F, to which they have been assigned.

The evidence upon which I rely for the separation of the Lenham Beds from the Coralline Crag, or which I propose to offer in favour of zones of the Red Crag, is, I submit, of an essentially different character. We find at Lenham Miocene forms which, so far as the evidence goes, had ceased to exist in the Anglo-Belgian basin before the deposition of the Coralline Crag, and have never since reappeared; while the older Red Crag deposits contain southern and extinct species, which gradually became less abundant in the

[1] Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 116.
[2] Monogr. Palæont. Soc. 1866–97; see also Geol. Mag. 1895, p. 511.

Fig. 4.

Map of the main mass of the CORALLINE CRAG; showing the position of the various sections and borings alluded to in this paper.

The dotted area represents that covered by the Coralline Crag.

Note.—The position of pit 30 should have been indicated just below the letter K (in 'Kiln'), due west of Aldeburgh.

North Sea area, and finally died out altogether, their place being taken in the newer beds by arctic and boreal forms, unknown from the older formation.

The principal difference between the various portions of the lower or unaltered condition of the Coralline Crag seems to be that in some the mollusca are chiefly of large, in others of smaller species, a third variety of Crag being composed of comminuted material only. Certain localities, however, as for example the Gomer pit, are characterized by an abundance of univalves, which generally are much less common than bivalves in these beds, but such differences are by no means persistent. Layers of large shells, containing especially *Cyprina islandica*, occur in all parts and at all levels in the Crag, as will be seen hereafter, and I am unable to find any bed which is continuous except for a short distance, nor is this to be wondered at. It is not probable that at any one period the sea-bottom was for some miles continuously covered with a thin layer of the dead and drifted valves of *Cyprina* and other large molluscs, and that then these species disappeared for a time from the Crag area. Shells are sorted out by currents of varying strength, just as pebbles are in beds of gravel, small specimens naturally accumulating in one place, larger ones in another, and comminuted shells or fine calcareous sand in a third.[1]

There are localities in the Crag, however, at which it seems at first sight that beds, the fossils of which are more or less of a similar character, may be traced continuously from one section to another, as, for example, between the Broom pit at Gedgrave (No. 11 of map, fig. 4) and the Hall pit (No. 12) in Sudbourne Park. At each of these we find one seam with *Cyprina* and other large molluscs, and another seam immediately over it containing principally smaller shells, both being on about the same level at the two places. To an observer who believes, as Prestwich did, that the Crag rests on the more or less horizontal surface of the London Clay,[2] these would seem to be the same, but between the two pits the base of the Crag dips 8 or 9 feet (see fig. 5, p. 328), and thus beds which appear to be in correspondence are not really so.

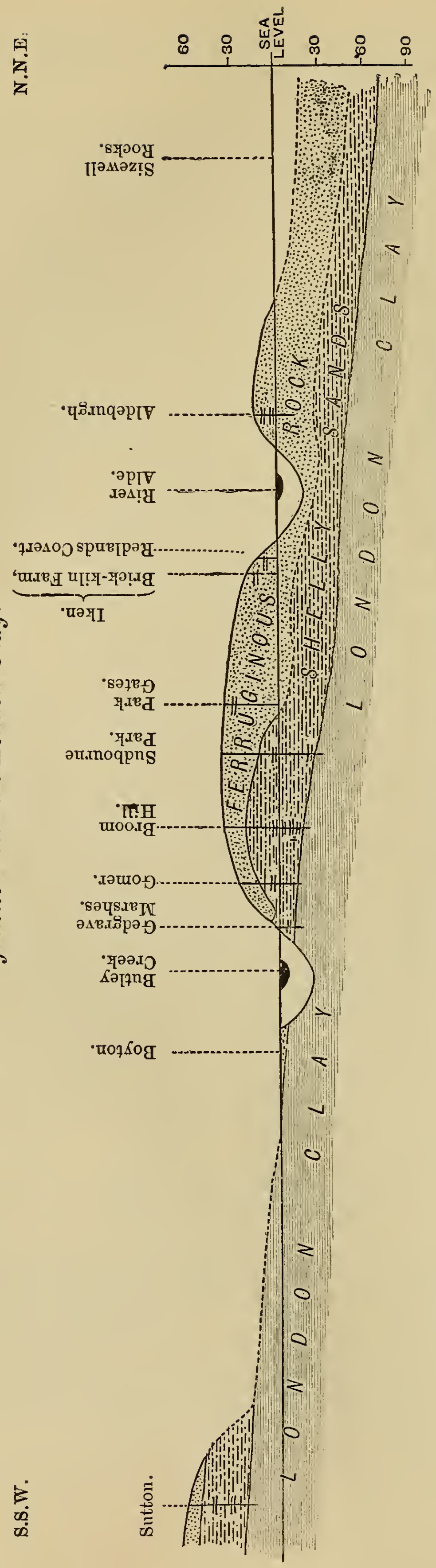
I have attempted, from the notes given in Prestwich's memoir, to construct a diagram (fig. 6, p. 329) showing the structure of the Coralline Crag from Ramsholt to Aldeburgh according to his views, but the result does not seem to me to lend much support to the zone-theory.

In the table on pp. 330–1 are enumerated the features upon which Prestwich relied to justify the separation of the Coralline Crag into

[1] In the Natural History Museum at South Kensington there is a large block of limestone from the Calcaire grossier, similar in character to the shelly sands of the Coralline Crag, containing in profusion the drifted and stratified shells of mollusca, which are more or less of the same size throughout, and but few univalves. Both univalves and larger bivalves were present in the seas of that period, as may be seen by reference to one of the wall-cases close by. None, however, were deposited at the spot from which this block was taken, the selective power of the currents which there prevailed having sorted out only forms of a certain size and weight.

[2] See his section from Sutton to Iken, Quart. Journ. Geol. Soc. vol. xxvii (1871) pl. xx.

Fig. 5.—*Section showing the structure of the Coralline Crag (according to the present writer) and its progressive dip N.N.E. of its junction with the London Clay.*



[The thick straight bars = indicate the position of the seams of large shells. The more recent beds are omitted.]

the eight zones proposed by him, together with my remarks thereon. It will be seen that many of the characteristics which he considered distinctive of certain parts of the formation only are of the most general character and are equally applicable to others; but even if this were not so, slight lithological differences are hardly a satisfactory test of age, unless they can be traced stratigraphically. The sediment now accumulating at the bottom of the North Sea is not everywhere the same.

Mr. Burrows, in the Geol. Mag. paper before alluded to, claims the evidence of the foraminifera as being in favour of the zone-theory. I differ from that gentleman with much regret, but I cannot think that the facts he recites are conclusive. In his paper, and in the monograph by himself and his coadjutors, certain species of foraminifera are stated to be specially characteristic of zones D, E, F, & G at Tattingstone, Sudbourne, Gedgrave, and Aldeburgh,[1] but on referring to the list published by him [2] it will

[1] No evidence is offered as to zones A, B, C, or H.

[2] 'Crag Foram.,' Monogr. Palæont. Soc. 1897, p. 374.

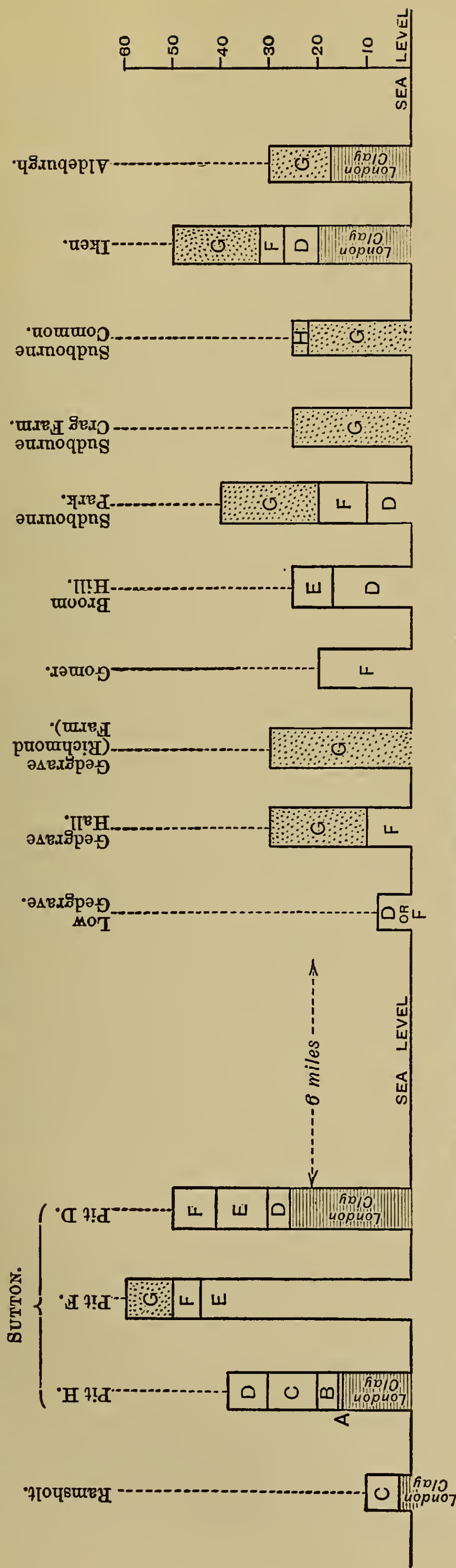


Fig. 6.—*Diagram showing the comparative positions of the supposed zones in the Coralline Crag, according to Prestwich.*

[Zones A to F represent the shelly sands, and zones G & H the ferruginous rock.]

be seen that none of these are confined to any one zone, most of them being common at one locality in what he regards as zone D, at another in E, and in F or G at a third or fourth. On the contrary, it is sometimes the case that forms are common at one spot and rare at another in beds considered by Mr. Burrows to belong to the same zone. Even if this were not so, I cannot think that the evidence of the foraminifera is of great value. Most of the forms in question are still living, and they have a world-wide distribution, being found in all seas and at all depths. Of one, *Miliolina seminulum*, the authors of the Palæont. Soc. monograph say, 'Scarcely a sample of sea-sand, either dredged or littoral, from any quarter of the globe, can be examined without finding specimens of it.'[1] Moreover, the foraminifera are not generally so distinctive of special formations as are the mollusca, having a wide range in time as well as in space; the Crag species, with one or two exceptions, are recent forms, going back also to early Tertiary, and some of them even to the Mesozoic or Palæozoic epochs.

[1] *Op. cit.* p. 10 (1866).

Table showing, according to Prestwich, the features characteristic of the various zones into which he proposed to divide the Coralline Crag.

		Remarks.
A.	Bed, 1 to 1¼ foot thick, containing phosphatic nodules, mammalian remains, and derivative fossils and boulders.	Apparently confined to one district in which a similar bed occurs at the base of the Red Crag. A few phosphatic nodules only, but no boulders, were found at the base of the Coralline Crag in borings at Gedgrave and Sudbourne.
B.	Comminuted shells, with *Turritella*, and single valves of *Cyprina, Pecten, Mactra*, etc.	This bed, 4 feet only in thickness, was observed by Prestwich at one spot only at Sutton. The features mentioned are equally applicable to other parts of the formation.
C.	Light-coloured marly Crag, abounding in large shells, *Mya* and *Cyprina* (sometimes double), *Anomia, Diplodonta, Astarte*, and *Venus*.	At one spot only at Sutton. The species of mollusca named are among the commonest forms of both the Coralline and Red Crags. With the exception of *Cyprina*, which is common everywhere, the species enumerated by Prestwich (*op. cit.* p. 115) as characteristic of zone C at Ramsholt differ entirely from those here named from Sutton.
	Foraminifera abundant. Univalves scarce.	The authors of 'The Foraminifera of the Crag' state (*op. cit.* pp. 374, etc.) that these organisms are more or less abundant in every part of the formation. Univalves are also scarce at localities regarded by Prestwich as belonging to other zones.
D.	Comminuted shells, large entire or double shells. Bands of limestone in upper part.	Features common to other parts of the Crag. Found in borings at Gedgrave at one spot only.
E.	Sand with numerous polyzoa, often in the position of growth, and *Echini*.	Common features of the polyzoan rock-bed, regarded by Prestwich as zone G, at Sudbourne, Iken, and Aldeburgh. The spines of echinodermata occur at all levels.

TABLE (*continued*).

		REMARKS.
F.	Sand with numerous small entire shells and seams of comminuted shells.	Features common to all parts of the unaltered Crag.
G.	Comminuted shells with remains of polyzoa, forming a soft building-stone. False stratification and oblique bedding are constant characters.	Indurated character of polyzoan rock due to infiltration, and not peculiar to the upper part of the Crag. False bedding not confined to the upper part of the formation.[1]
H.	Sand and comminuted shells.	Possibly an atmospherically-altered condition of the surface of the indurated Crag.

The term 'zone' is, I submit, rightly used for a deposit clearly marked out from others, either by the general character of its fauna, or because it represents some important physiographical change in the conditions of any period; but it conveys a wrong impression when employed for such minor divisions as those of the Coralline Crag, even if they could be shown to be persistent throughout the formation. It may be safely asserted, I think, that no evidence has been adduced to show that any one of the alleged zones is characterized by the presence of species which did not also exist at earlier or later periods in the seas of the North of Europe, and which were evidently then appearing for the first time, or disappearing from the Anglo-Belgian basin.

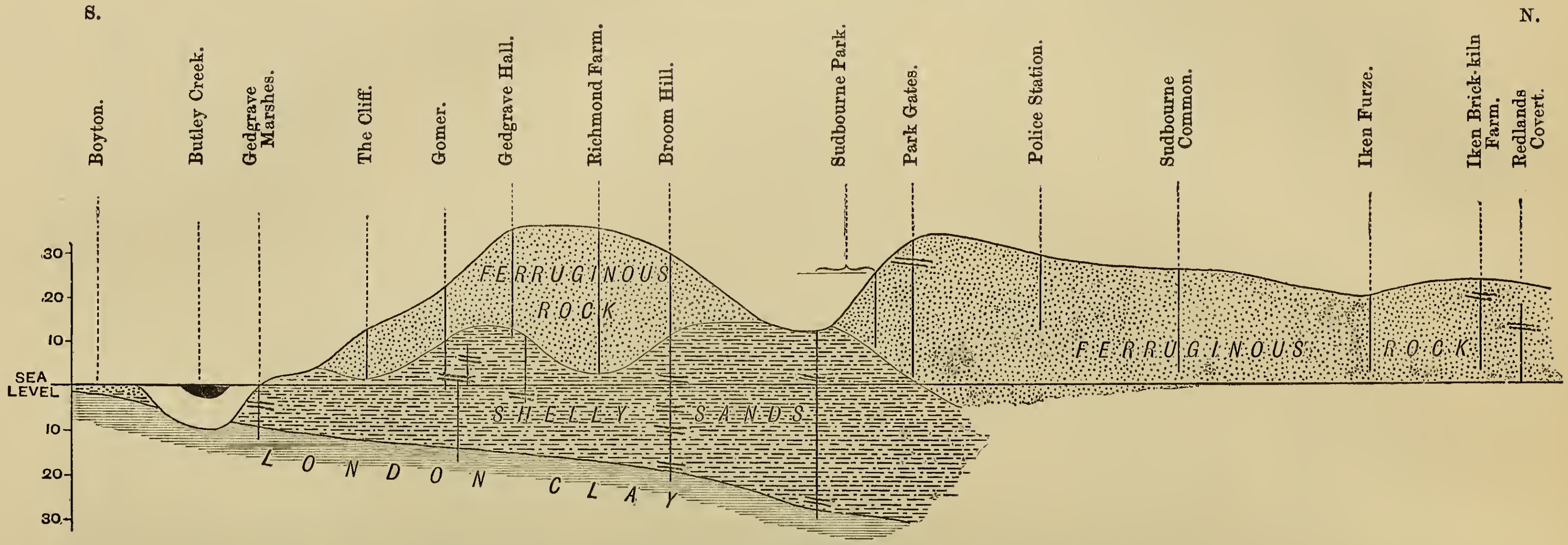
As the base of the Coralline Crag had been reached at one locality alone, namely, in the Sutton district, it seemed to be of some importance to ascertain by boring not only the total thickness of the formation where it is best represented (that is, in the neighbourhood of Orford), but to acquire some knowledge, if possible, of any lower beds which might be present there.

The apparatus that I used for boring was, with some modifications suggested by my early failures, that designed by MM. Van den Broeck & Rutot, and described by them in a paper published by the Société Belge de Géologie.[2] It is admirably adapted for rapidly penetrating beds of dry and moderately coherent material. The only part of the Coralline Crag, however, which it is necessary to explore in this way lies below the water-line, the upper part of the Crag

[1] Mr. Clement Reid considers that the whole of the Coralline Crag is 'more or less current-bedded,' Mem. Geol. Surv. 1890, 'Plioc. Deposits of Britain,' p. 36.

[2] Bull. Soc. Belge de Géol. vol. ii (1888) p. 135.

Fig. 7.—*Sections and borings in the Coralline Crag between Boyton and Iken, showing the irregularity of the divisions between the ferruginous rock-bed and the unaltered shelly sands.*



[Seams of large shells shown by thick bars =. Newer beds omitted.]

being sufficiently shown by numerous sections; but the difficulty of boring through loose and wet sand is very great, and requires much patience, especially when a depth of 15 or 20 feet is reached.[1]

The different borings made in the neighbourhood of Orford show that the junction between the London Clay and the Coralline Crag has an average dip, in a northerly or north-easterly direction between Butley Creek at Gedgrave and Sudbourne Hall, of 8 feet to the mile; beyond the latter place it lies too deep to be reached by my apparatus.[2] The gradient between Sutton and Gedgrave is about 6 feet per mile (see fig. 5, p. 328), and between Sutton and Tattingstone rather less. At the last-named locality the Crag-beds approach the 100-foot contour-line, but occur somewhat below it. At Sutton, as we have seen, they rest upon the London Clay at 20 feet above high-water mark, and they are there about 40 feet thick in vertical section.

Tracing the Coralline Crag from Sutton towards the north-east, it is found at Boyton occurring slightly below the level of the marsh, but at present it is not accessible there—unfortunately so, as some species were obtained in abundance at Boyton which are not common at Gedgrave and Sutton. Both the Coralline and Red Crags and the nodule-bed also are present there, and it may be possible hereafter, by boring, to clear up the question of the true position of the last-named deposit. So far as one can judge from the available evidence, the nodule-bed formerly exposed at this locality is below the Coralline Crag.[3] The shells obtained by the coprolite-diggers were so mixed that it was impossible to say certainly from which formation they had been derived. Some geologists have suggested, but I think without sufficient evidence, that at Boyton there is a Red Crag fauna of a special and distinct character. I visited the locality in 1897: no section was then visible, but on the site of one of the old workings there was a heap of soil, and from it I picked out a few specimens or fragments of the following (all of them being later Red Crag forms, and of the usual Red Crag colour):—

Purpura lapillus.	*Astarte Omalii.*
Buccinum undatum.	*Cyprina islandica.*
Trophon antiquus.	*Tellina obliqua.*
,, *contrarius.*	,, *crassa.*
Turritella incrassata.	,, *prætenuis.*
Pecten opercularis.	*Mactra solida.*
Cardium edule.	,, *ovalis.*
,, *grœnlandicum.*	,, *elliptica.*
,, *Parkinsoni.*	*Mya arenaria.*
Cardita senilis.	,, *truncata.*

[1] If some light and portable apparatus could be devised, suitable for boring through wet and sandy soil, it would be of great value to amateur geologists.

[2] The greatest depth attained by me was 31 feet.

[3] See also Whitaker, Mem. Geol. Surv. 1886, Aldborough, p. 9. On one of Mr. Wood's survey-maps is the following note:—'This rectangular mark [shown also in fig. 4, p. 326, of the present paper] is that which Mr. Robert Bell has drawn in a copy-map sent to me, to represent the coprolite-trench from which so many shells are obtained. He says there is about 18 inches of Coralline, overlain by 30 inches of Red Crag and sand.'

I believe that most of the Boyton specimens to be found in our Museums have come from the Coralline Crag, and that the Red Crag of that neighbourhood belongs to the Butley zone. Sometimes, however, the Coralline Crag shells have been discoloured by infiltration from the immediately overlying Red Crag.

On the east side of Butley Creek, at several points in the parish of Gedgrave, and near the edge of the marsh, the London Clay was reached by boring through the Coralline Crag at depths of 9, 12, and 13 feet respectively. A few small phosphatic nodules occurred everywhere near the base of the Crag, but neither in any of the borings at that place nor elsewhere did we meet with derivative fossils or large stones, such as those found in the basement-bed at Sutton. At one of these borings (No. 2 in fig. 4) we found, at a depth of 6 feet, fragments of *Cyprina*, *Astarte*, etc., and lower down some small shells. At another (No. 4) the Crag was very shelly, containing *Astarte Burtinii* and *Turritella incrassata,* no large forms being observed. At another spot (No. 5), on higher ground, but within a few yards of the last, large species, as for example *Cyprina* and *Venus*, were abundant, the borer grinding through them for 4 or 5 feet. The well-known pit in the Gomer field (No. 10) is now ploughed up; from it were formerly obtained, at about the same level as that of boring No. 5, a large variety of species, including many univalves (see the list published by Prestwich [1]), which are almost unknown from the other pits in the neighbourhood.[2] But I may mention, as illustrating the want of correspondence between these shelly bands, that Mr. Buckingham, the veteran collector at Orford, has made a number of attempts during the last few years to find a new exposure of the old Gomer bed, though without success.

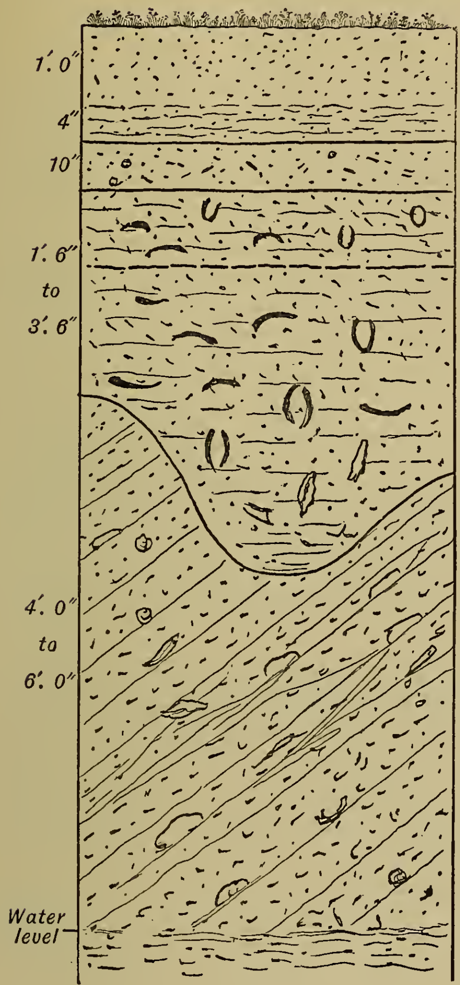
Personally I have not seen the Gomer section for nearly 30 years, as it has always been closed during my many visits to Orford, but Mr. P. F. Kendall has sent me the accompanying sketch (fig. 8), made in 1884, which he is kind enough to allow me to reproduce. One interesting feature of it is the small band of unstratified argillaceous Crag, $1\frac{1}{2}$ to $3\frac{1}{2}$ feet only in thickness, in which he observed a number of lamellibranchs (27 species) with the two valves united, and in the position of growth. *Trophon alveolatus* and *Tr. consocialis*,[3] with other gasteropoda, were commonly found in this bed. Lower down, *Cardium decorticatum* was met with in great abundance. This species occurs also in profusion in the highest part of the Crag at Aldeburgh (see p. 338), and at the Park-gates pit at Sudbourne, but only in the form of casts. Near the water-line at the Gomer section there was a bed of comminuted Crag with many fine gasteropoda, especially a *Brocchia*, almost unknown elsewhere; and many such facts might be adduced to show a want of correspondence in the molluscan fauna of different exposures of the supposed zones.

[1] Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 124. In none of my borings did I find any trace of this Gomer shell-bed with abundant univalves.

[2] Mr. Wood, sen., obtained from one pit at Sutton, with a vertical range of a few feet, specimens of nearly all the species known from the Coralline Crag.

[3] These two furnish an example of species which are found at Gedgrave, but not, so far as I know, at Sutton. They occur also at Ramsholt and Boyton.

Fig. 8.—*Section of the Gomer pit* (*from a sketch made by Mr. P. F. Kendall in* 1884).



1 Made earth, passing into

2 Red loamy sand.

3 White pulverulent Crag with small gasteropoda. Argillaceous Crag with greatly decomposed shells, passing into

4 Yellow argillaceous Crag, with no trace of bedding, containing many specimens of *Cyprina islandica*, *C. rustica*, and *Panopæa Faujasii*.

5 Crag containing *Cardita senilis*, *Venus casina*, *Astarte Omalii*, *A. Basterotii*, *Trophon consocialis*, *Tr. alveolatus*, *Natica millepunctata*, *Trochus zizyphinus*, *Tr. conulus*, etc. Many of the bivalves have both valves united and the siphonal ends upward.

6 False-bedded Crag made up of comminuted shells. Characterized by abundance of *Turritella triplicata* (*incrassata*) and *Cardium decorticatum*. Contains bands or patches of Pectens, the 3 species *P. maximus*, *P. opercularis*, and *P. tigrinus* being commonly associated.

7 Comminuted Crag, with many rare gasteropoda, notably *Capulus* (*Brocchia*) *partim-sinuosus*.

The following lamellibranchiata were found with both valves united, principally in Bed 5:—

Anomia.	*Diplodonta rotundata.*	*Cyprina islandica.*
Pecten maximus.	*Cardita corbis.*	*Venus casina.*
„ *opercularis.*	„ *scalaris.*	„ *ovata.*
Modiola.	„ *senilis.*	*Gastrana laminosa.*
Pectunculus glycimeris.	*Cardium decorticatum.*	*Mactra.*
Limopsis aurita.	*Astarte Basterotii.*	*Thracia.*
Nucula nucleus.	„ *Galeottii.*	*Solen ensis.*
Leda.	„ *mutabilis.*	*Panopæa Faujasii.*
Lucina borealis.	„ *Omalii.*	*Mya truncata.*

The Gomer beds, regarded by Prestwich as belonging to his zone F, are at a lower level, taking the dip into account, than those at the Broom Hill pit, which he calls D & E. Stratigraphically, therefore, the former, which are within 15 feet of the base of the Crag, in which univalves are abundant, should be placed in zone C; but, according to Prestwich, one of the characteristic features of zone C is said to be the scarcity of such forms.

The Crag of the Gomer field seems to be, up to some height above the water-level, of the unaltered type, but there is a roadside section (No. 3 in fig. 4), near Butley Ferry, in the immediate neighbourhood, where ferruginous Crag, made up of comminuted material without fossils, comes down almost to the level of the marsh (see fig. 5, p. 328). This belongs to zone G, the upper part of the formation, according to Prestwich, but as such it seems there out of place, being probably within 10 feet of the London Clay. The difficulty disappears if we regard it as merely the altered form of the shelly Crag present in the adjoining field.

At Gedgrave Hall there is a large pit (No. 6) showing about 20 feet of indurated Crag, but immediately below it towards the marsh is another (No. 7) composed of whitish shelly sand, the upper part irregularly coloured by recent infiltration, in which few but the smallest species of mollusca are present, *Nucula nucleus* and *Donax politus* being specially abundant.[1] A boring at this spot was interrupted by tabular layers of limestone, very hard, and difficult to penetrate. These were considered by Prestwich to be distinctive of his zone D. We met with them, however, in no other boring, though they may be occasionally observed elsewhere above the water-line. I look on these bands as purely local, due to infiltration and redeposition of the calcareous matter, and as of no stratigraphical significance.

At the Broom Hill pit (No. 11), near the Keeper's Lodge, so much resorted to by collectors, at which few specimens of gasteropoda are found, the junction of the Crag with the London Clay was only reached at a depth of 22 feet (probably 19 or 20 feet below the marsh). Fragments of large lamellibranchs, and small shells, perfect, were brought up constantly by the borer. Layers of the former seemed to occur at 5 feet, 9 feet, and at the base of the Crag. The upper part of the section exposed at this place has been more or less affected by infiltration. The lowest beds are of a whitish colour, but they gradually become more ferruginous upwards; in places they seem to shade off into each other, so that it is difficult to draw the line between them. Prestwich called the beds at Broom Hill D & E, but if colour be a test, some of them should rather have been placed in his zone G. The section is, however, instructive, showing the process by which the upper part of the Coralline Crag has been transformed.[2]

[1] This is the bed regarded by Mr. Burrows as belonging to zone F; see p. 325.

[2] Among the material brought up by the borer at the Broom Hill pit I noticed the following species:—

Anomia striata.
Ostrea ungulata.
Pecten Gerardii.
,, *tigrinus.*
Pectunculus glycimeris.
Lucina borealis.
Cardita corbis.
,, *scalaris.*
,, *senilis.*
Astarte Basterotii.
,, *Burtinii.*
,, ,, var. *pisiformis.*
,, *Galeottii.*
Astarte parvula.
Venus ovata.
,, *casina.*
Cyprina islandica.
Tellina donacina.
Mactra triangula.
Corbula nucleus.

Turritella incrassata.
,, *acutangula.*
Ringicula buccinea.
Adeorbis.

Between the Broom Hill pit and that in Sudbourne Park near the Hall (No. 12), rather more than a mile to the north, the base of the Crag dips still farther, its junction with the London Clay occurring at the latter place at a depth of 31 feet (probably about 27 feet below Ordnance datum). This boring took 4 or 5 days to complete, the difficulty being to extract the loose and wet material. Unless the hole is kept clear as the work goes on, the borer is set fast, and can be regained only with great labour. There was a marked absence of fossils at this spot, little else being brought up but comminuted Crag. No seam of large shells was met with, the only recognizable fragment being a small portion of the hinge of a *Cyprina*, from a depth of 30 feet. The last foot or two of the Crag both here and in other borings was of a bright blue colour.[1]

Exposures of the shelly sands in the Orford district are now confined to the small area between this section and Butley Creek, none being known to me to the north, except the small seam before alluded to in the Bullock-yard pit at Iken, Brick-kiln Farm (No. 27). Prestwich stated, however, that beds belonging to his zones D & F might be found at Iken; but now the Crag there exposed (with the above exception) is in the decalcified and ferruginous condition of the upper part of the formation, that is, of his zone G.

The various sections of the altered Crag show the same difference in character as do those of the lower and unaltered Crag. At one pit it consists of fine material without fossils, except perhaps an occasional valve of *Pecten opercularis*; at another it is crowded with the casts of large shells; while at a third are found layers of reef-building polyzoa in their natural position.

I bored at the pit of ferruginous Crag at Sudbourne Park gates (No. 14), finding comminuted material only, for nearly 20 feet, and to a lower level than that at which the shelly sands occur at the section near the Hall, but without reaching them. The surface of the Crag at this pit (No. 14) is about 33 feet above Ordnance datum; adding to this 27 feet, the approximate depth below Ordnance datum of the base of the formation at pit No. 12, just below, we can ascertain with some approach to accuracy that its total thickness at Sudbourne is 60 feet.[2] It was from Sudbourne that three of the samples of material, Nos. 5, 4, and 6, which were analysed by Messrs. Sutton, were taken, the first being from the upper part of the indurated Crag at section No. 14, the second from the shelly sand in the Hall pit

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These species, coming from the lowest part of the Crag, are all found at higher levels in the immediate vicinity, and at Sutton. At this spot univalves are equally scarce in the 20 feet of Crag above, and in the 20 feet below the water-level, while at the Gomer pit, less than a mile distant, as we have seen, they are very abundant in the same stratigraphical position. If the Gomer beds, containing univalves abundantly, were continuous, we ought to have met with them at other localities in some of our borings, which was not the case.

[1] See p. 323.

[2] This was the estimate originally made by Mr. Wood and myself in 1872, Suppl. 'Crag Mollusca,' Introd. p. iii, Monogr. Palæont. Soc. Prestwich's figures are 83 feet.

(No. 12), and the third from the seam of bright blue stuff brought from the bottom of the boring at the same place.

There is no evidence to show that the Coralline Crag extends either west or east of the main mass of the formation exposed between the rivers Deben and Alde. The Red Crag rests against it, however, on the west side in the parishes of Chillesford and Iken, on the east side near Orford Castle, and at pits 19 & 20 at Sudbourne. Mr. Whitaker states,[1] moreover, that White Crag, considered by him as of Red Crag age, was met with in borings at the Lantern marshes at Orford, resting on the London Clay at a depth of about 30 feet, no Coralline Crag being there present.

Having established the fact of the progressive dip of the junction between the Coralline Crag and the London Clay between Sutton and Sudbourne, and having failed to discover in the beds penetrated any evidence of the continuity of the supposed zones in the outliers at the former locality, it did not seem necessary to carry the borings farther north, especially in view of the increasing difficulty and expense of doing so. As, however, the gradient is more or less uniform where it can be tested, it does not seem improbable that the line separating the two deposits, which can be drawn with accuracy from Sutton to Sudbourne, may be produced towards Aldeburgh and Sizewell also (see fig. 5, p. 328). If this be so, the base of the Crag would be reached at a depth of about 48 feet under the former, and of about 68 feet under the latter place, making the total thickness of the formation 60 feet at Aldeburgh, as it is at Sudbourne.

In the sections (figs. 3, 5, & 7, pp. 324, 328 & 332) I have shown the various positions in which seams of large shells, either perfect or in the form of casts, occur in the unaltered and in the decalcified Crag. I have already stated where they are to be found in the former. In the latter they may be seen at the following, among other localities:—At pit No. 14, near Sudbourne Park gates; at Iken, Nos. 27 & 28; at Aldeburgh, No. 29, close to the river-bank; No. 31, near the railway-station; and at Nos. 32 & 33, farther north. Some of these seams are chiefly composed of the casts of *Cardium decorticatum*, while in others *Cyprina islandica* is the prevailing form. The first-named occur in several places in the upper part of the Crag, as at Sudbourne and Aldeburgh, and it might be supposed that they represent a later, as those containing *Cyprina* represent an earlier zone. At Iken, however (No. 27), midway between those two localities, both forms are present in the rock-bed, though *Cyprina* is by far the most common.[2] These species occur in all parts of the Red Crag, however, and neither of them has any stratigraphical value. In his list of the mollusca of the Coralline Crag, Prestwich remarks of both that they occur *passim*.

My son, W. D. Harmer, has taken two photographs of the sections at Iken (No. 27). The first (fig. 9, p. 340) shows a small patch of shelly

[1] Mem. Geol. Surv. 1886, Aldborough, p. 53.

[2] Mr. Kendall found a bed containing *Cardium decorticatum* abundantly in the lower part of the Crag at Gomer (see p. 334).

sand, about 6 inches thick, and 3 or 4 yards long, which is exposed in the side of a gangway leading down into a deep Crag pit, used as a bullock-yard. In it occur, in the order of their abundance, *Cyprina islandica*, *Cardita senilis*, *Cardium decorticatum*, *Mytilus edulis*, *Venus casina*, and some other of the larger characteristic Crag species, with a few smaller ones, such as *Limopsis aurita*, *Cytherea rudis*, *Venus ovata*, and *Mactra triangula*. They are quite perfect, and in similar condition to those that may be found in the shelly sands at Gedgrave or Sudbourne. The matrix in which they are embedded resembles that of the shelly sands of those localities, being composed of calcareous matter full of minute shell-fragments, and containing much glauconite. It has been to some extent coloured by infiltration from the overlying ferruginous beds, but the fragments of the arragonite-shells and the grains of glauconite have not been affected thereby to any great extent. The same seam is seen in the pit itself (see fig. 10, p. 341) to occur in the midst of the ferruginous rock-bed, but it appears to be gradually losing its unaltered condition,[1] the small shells and the shell-fragments having disappeared, and only the thick and strong specimens, such as *Cyprina*, remaining. Tracing the seam laterally along the sides of the pit, the *Cyprinæ* are replaced by casts, with an occasional valve, almost decomposed, and in a very friable condition.[2]

In another pit at Iken (No. 28), below the last and near the marsh, there is a similar seam of large shells, in the ferruginous rock, but in the form of casts only. These *Cyprina*-beds, which have been supposed to be distinctive of Prestwich's zone D, and which I have traced to the base of the Crag, are thus found to exist also in what is evidently the highest part of the formation.

Beds containing the casts of large shells are found in all the Aldeburgh sections, as at Nos. 29, 31, 32, & 33.[3] At pit No. 31, near the railway-station, the seam is from 4 to 6 feet thick, and contains, in addition to the species found at Iken, specimens of *Voluta Lamberti* (very large) and *Panopæa Faujasii*.[4] Beds of large shells in the form of casts are quite as abundant in the upper part of the Crag at Iken and Aldeburgh (Prestwich's zone G) as the shells themselves are in the lower portion (zone D) at Sutton, Gedgrave, and Sudbourne.[5]

[1] The sharp fracture, when they are broken, of the shells in the gangway (fig. 9) is in striking contrast with the soft and marly condition of some of the specimens in the pit-section (fig. 10).

[2] Mr. Kendall informs me that some years ago, by digging through the floor of the pit of indurated Crag at Aldeburgh (No. 32), he found a number of specimens of *Cardium decorticatum* in a similarly rotten and partly decalcified condition.

[3] At pit No. 34 there is a seam containing specimens of *Mytilus* in great profusion, a form which is by no means so abundant at other localities.

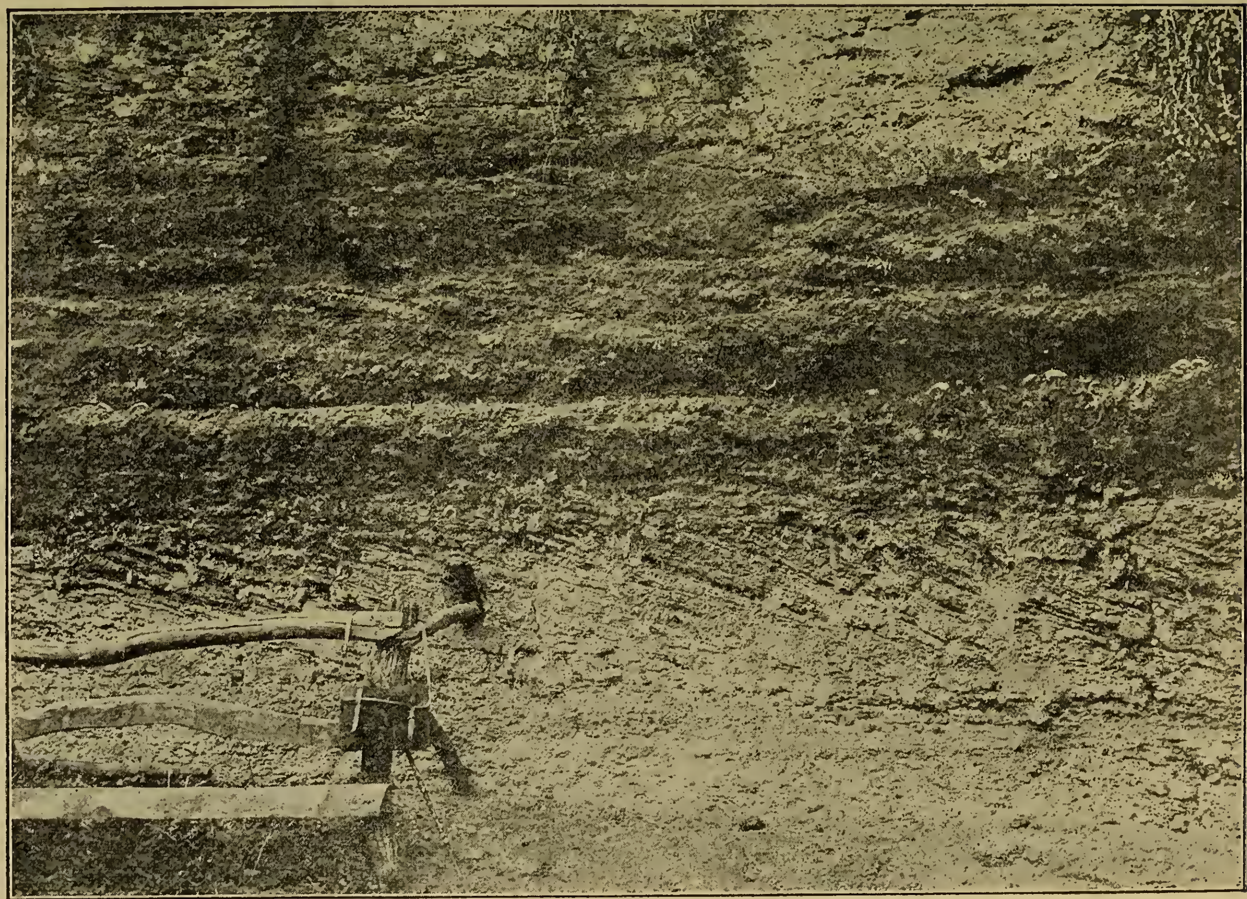
[4] I bored here for 20 feet, through comminuted ferruginous Crag, without reaching the shelly sands.

[5] It has been shown that large species of mollusca occur abundantly in places in the upper or ferruginous part of the Crag. It can hardly be supposed that small forms were absent from the sea of that period, but in material so loose and friable it is less probable that traces of them would be preserved.

Fig. 9.—*Section in gangway leading down to Bullock-yard Pit, Iken.*

[Here a lenticular seam of shelly sand, with perfect shells and comminuted shell-fragments, is included in the ferruginous rock of the highest part of the Coralline Crag.]

Fig. 10.—*Section of the Rock-bed in Bullock-yard Pit, Iken.*



[Here the seam (*xx*) of shelly sand, distinctly seen in fig. 9, passes into ferruginous Crag, but contains occasional valves of *Cyprina*, etc.]

Seams of reef-building polyzoa are present at various localities in the upper part of the Crag (zone G of Prestwich), as, for example, at Aldeburgh (pits 30 & 33), at Iken (pit 24, etc.), and at Sudbourne (pit 18); but this is also the case, as Sir Joseph reminds us, at Sutton, in what he regards as zone E.[1]

At pit 22, where the ferruginous Crag (zone G) is composed simply of comminuted material, specimens of *Fascicularia* are very common, but they occur also at other localities in the unaltered Crag, as at Broom Hill (No. 11), and at Sutton (Prestwich's zones E & F). Generally the Crag along its eastern margin, as at pits 15, 20, 22, & 23, is composed of comminuted material only, the seams of large shells occurring principally in the western portion; this may be accidental, or it may be due to the action of currents varying in strength.

Thus no satisfactory division can be drawn between the shelly sands and the ferruginous rock. We have seen that at one locality (No. 3) the indurated Crag comes down to within 10 feet of the base of the formation, while at another, within a distance of 2 miles (No. 12), the shelly sands have a thickness of 40 feet. It is clear that the rock-bed has been affected by the percolation of acidulated water, as it is in this way that the arragonite-shells have been removed. The irregular line separating the two varieties of Crag may be due therefore to the greater or less depth to which the infiltration has penetrated. That this explanation is the correct one is, I think, proved by the Iken section, where for a short distance only a small portion of the shelly sands has been accidentally protected from its operation.

If, then, the separation between the two principal and apparently self-evident divisions of the formation breaks down, it will add to the difficulty of maintaining the distinction between the remaining zones B, C, D, E, & F, into which Prestwich proposed to divide one of them—divisions which cannot be worked out stratigraphically, and which do not, I submit, represent any distinctive palæontological horizons.

I have discussed the zone-theory of Sir Joseph Prestwich at considerable length, and with much detail, not only because it seems due to so eminent a man to do so, but also because of the great importance of the subject. It is hopeless to attempt to arrive at any clear conception of the history of the older Pliocene period in England, unless we can first ascertain whether this hypothesis, with all its far-reaching consequences, should be accepted or not.

Let us, however, enquire whether there is any evidence in favour of his view that, commencing with a gradual invasion of the English part of the area by the sea (indicated by the basement-bed A), the formation of the Coralline Crag was attended, first by an important subsidence, and then by a re-emergence of the Anglo-Belgian basin. The former is said to have taken place during period B,[2] beds C &

[1] Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 119.

[2] *Ibid.* p. 135. Only one exposure of zone B is recorded by Prestwich, namely, a bed at Sutton 4 feet thick.

D being afterwards deposited in a comparatively deep and tranquil sea, which, during period E, is supposed to have attained a depth of from 500 to 1000 feet. Beds F & G were believed by Prestwich to indicate a gradual upheaval, the latter having originated in water sufficiently shallow to allow of the denudation of the older portion of the Crag by current-action, and the heaping-up of the resulting material in the form of submarine banks.

In the first place, I would point out that in no part of the Coralline Crag have we any indication of deep-water conditions. Sir John Murray states that along the continental shores which face the great oceans the sea-bottom is generally covered with mud below the 100-fathom line,[1] and Prof. Herdman finds this mud-zone in the Irish Sea at 50 fathoms.[2] Such deposits are known to all geologists, as for example, in the Argiles bleues of Antibes and the Ligurian coast, where fossiliferous beds have quietly accumulated in deep water near the old shore-line. They are not distinctly stratified as is the Coralline Crag, and the shells are not arranged in layers, but occur here and there at different levels.

Coming nearer home, we have in Belgium the *Isocardia cor*-beds, contemporaneous with the Coralline Crag, which, though not representing deep-sea conditions, are of a character similar to those just mentioned. In them, as M. Van den Broeck informs me, the lamellibranchs are always found with the two valves united, and never arranged in layers. The enormous preponderance of the specimens found in the Coralline Crag consists, on the contrary, of the drifted and stratified remains of dead animals. A few bivalves occur in it double, and some, as at Gomer, in the position of growth; but there is no reason, on the one hand, why lamellibranchs may not occasionally be found living in sheltered spots on banks of dead shells, nor why, on the other, living shells should not sometimes be carried along the bottom by currents with other débris, and be buried with them. Constant reference is made in the British Association Reports on Dredging to the occurrence of dead mollusca with both valves united,[3] and my son, Dr. S. F. Harmer, informs me that such an occurrence is by no means unusual.

The difference between the *Isocardia*-beds of Belgium and the Coralline Crag is most marked and very instructive. In the one case, we have an ancient sea-bottom, with the mollusca *in situ*, as they lived; in the other, masses of dead shells accumulated by the action of currents. The beds of Prestwich's zone E, which he considers to be indicative of deep-sea conditions, are of the same drifted and stratified character as the rest of the formation.[4]

The mollusca found in the Coralline Crag cannot be regarded as

[1] *Challenger* Reports, Summary, vol. ii. p. 1433.

[2] Rep. Brit. Assoc. (Ipswich) 1895, p. 703.

[3] See, for example, Rep. Brit. Assoc. (Dublin) 1857, List of Shells from Turbot Bank, p. 230.

[4] As to this, see also Clement Reid, Mem. Geol. Surv. 1890, 'Plioc. Deposits of Britain,' p. 36, who says:—'I have been unable to recognize in Prof. Prestwich's division *e* a single stratum unaffected by current-bedding.'

deep-water forms. Many of them have a wide bathymetrical range, but, speaking generally, the fauna belongs, as has often been pointed out, to the Coralline zone of Edward Forbes (15 to 50 fathoms), although a few species characteristic of both deep and shallow water are present. If, however, as I believe, the shells have been drifted, the Coralline Crag fauna indicates the depth of the sea in which the mollusca lived, rather than that of the deposit in which they are embedded.[1]

Prestwich believed that the polyzoan fauna of the Coralline Crag points generally to deep-water conditions, and he specially instanced the genus *Lepralia* (of which many species, according to Busk, occur in it) and some others, as characteristic of deep seas. The classification of the Polyzoa has been much altered of late years, but all the recent species described by Busk as *Lepralia* are found at moderate depths, and he said of them that they have perhaps a greater power of adaptation to different circumstances than is possessed by any other group of these animals.[2] In a letter to Mr. Wood, Busk expressed his opinion that the Crag polyzoa may have lived at any depth from the surface downwards,[3] and with this opinion my son, who has paid much attention to this subject, agrees. Mr. A. W. Waters states, it is true, that in the Bay of Naples the Cyclostomata (polyzoa unprovided with an operculum) are not, as a rule, found in shallow water, though the Cheilostomata often are[4]; but almost all the Crag forms belonging to the first are of extinct species, of whose habits we are ignorant, while the few living Crag species of the latter are said to live in shallow as well as in deep water. Polyzoa are, moreover, quite as abundant in the current-bedded portion of the upper part of the formation, which Prestwich considered was deposited in shallow water, as in those beds which he believed to have originated at a greater depth. Many of the recent polyzoa have, like the mollusca, a wide bathymetrical range, and, at least, it may be said of the Crag forms that they lend little support to the deep-water theory.

No such depth as 500 to 1000 feet is known at present in the southern part of the North Sea, nor in the English Channel. If such a subsidence had occurred during the Crag period, it could not have been local merely, but would have extended either in an easterly or a westerly direction. In the one case it would have caused the submergence of the Miocene beds of North Germany, in the other it would have carried the sea over a great part of the midland counties of England; but of such extensions of the German Ocean during the Pliocene period there is no evidence, and they

[1] On the Turbot Bank, off the Antrim coast, to which reference will be made hereafter, a few deep-water species were found, dead, in 25 to 30 fathoms, which were afterwards discovered living in a deeper and adjoining part of the Irish Sea.

[2] 'Crag Polyzoa,' Monogr. Palæont. Soc. 1859, p. 38.

[3] Suppl. 'Crag. Mollusca,' Introd. p. v, Monogr. Palæont. Soc. 1872.

[4] Quart. Journ. Geol. Soc. vol. xl (1884) p. 681.

seem equally improbable. The Belgian geologists know of no such invasion of their country by the sea. They are rather of opinion that it receded in a northerly direction towards the end of the Diestien period (see map, fig. 1, p. 316). Moreover, such a subsidence, greatly increasing the depth of the North Sea and carrying it over a largely extended area, must have brought about an entirely new set of conditions, with new shore-lines, an altered system of drainage, and sediments as well as currents of a different character.

Alterations in the relative level of land and sea are supposed to take place very slowly, and a depression and re-elevation of such magnitude would probably have been attended not only by the deposition of beds varying in composition and commensurable in importance with the protracted period which they represented, but also by some marked changes in the molluscan fauna. The Pliocene strata of Holland, which are many hundreds of feet in thickness, and have accumulated *pari passu* with the subsidence which has affected that country, are, for example, easily separated into zones, even by the chance specimens found in boring. It seems inconceivable, therefore, that if such vast changes had taken place in the conditions of the Crag basin as those postulated by Prestwich, the Crag fauna would have remained substantially unaltered during the whole time, and that the various stages would have been severally represented by a few feet only of current-caused sediment of the same character throughout, even when tested by chemical analysis. I am not aware that a single fact has been adduced, either by the geologists of England or the Continent, in confirmation of the theory of a great subsidence during the Coralline Crag epoch.

I am equally unable to accept Prestwich's view that at one part of the Coralline Crag period the temperature of Northern Europe fell so considerably as to permit of the presence of floating ice in the Crag basin, bringing boulders into it either from Scandinavia or the Ardennes. This hypothesis, which seems to rest on the otherwise unexplained presence of a single waterworn block of porphyry ('neither angular nor striated')[1] in the basement-bed at Sutton, seems to me at variance both with the fossil evidence and with the probabilities of the case.

Among the extinct species of the Coralline Crag we find, as is well known, a number of genera characteristic of warmer seas than our own, while the recent forms are preponderatingly southern. With one exception, *Buccinopsis Dalei*,[2] a survivor from Miocene times, but not at present known living south of the western coast of Ireland, all the more abundant recent mollusca of the Coralline Crag are now to be found, either in the Mediterranean, or along the Atlantic coasts of France and Portugal, while a third of the number have an exclusively southern range.[3] Purely northern

[1] Quart. Journ. Geol. Soc. vol. xxvii (1871) p. 117.
[2] See also Geol. Mag. 1896, p. 27.
[3] There is a similar absence of boreal and arctic shells from the Diestien beds of Belgium.

forms are so rare in the Coralline Crag that, if it were possible to count specimens rather than species, the southern would outnumber the northern by many hundreds, possibly by many thousands, to one.[1]

No ice reaches our shores at the present day either from Scandinavia or Belgium, and the winter temperature of Northern Europe would have to fall considerably before such a condition could arise. As to Scandinavia, the almost entire absence of boreal or arctic shells from the Coralline Crag makes it probable either that the Crag basin was then closed, or at least less open to the north than it is at present (see also p. 350), or that the temperature of Scandinavian seas was affected, as it now is, but to a greater extent, by the warm currents of the Gulf Stream ; while, as to Belgium, no similar ice-borne débris occur in the Diestien beds of that country. It should be noticed, moreover, that the block of porphyry in question was not found in the Coralline Crag, but at its base, in a bed full of extraneous fossils and débris, having no distinctive character of their own, forming a medley and heterogeneous group, derived from various Mesozoic as well as Tertiary formations. It seems to me more than probable that the block of porphyry also was derived from some older formation, and that therefore it has no bearing on the question of climate. A similar argument may be applied to the occurrence of those mammalian remains which have been supposed to indicate the character of the land-fauna of the Coralline Crag period. Such fossils, however, occur at the base of the Red Crag also, and this point may be perhaps more conveniently discussed when dealing with that formation.

I entirely agree with those who think that the climate of the Coralline Crag period was warmer and not colder than that of Great Britain at the present day, resembling rather that of the Mediterranean, or even the Azores, and I see no reason for admitting the probability of great climatic changes during any part of it.

[1] Prestwich, however (Quart. Journ. Geol. Soc. vol. xxvii, 1871, p. 135), following Gwyn Jeffreys, who considered them to be identical with the well-known Crag species, tabulated the undermentioned as northern forms of the Coralline Crag :—

Astarte undata (American), Gould = *A. Omalii*. } Extinct species according to
Glycimeris siliqua, Chem. = *Gl. angusta*. } S. V. Wood.

(*A. Omalii* and *Gl. angusta* are both found in the Miocene of Belgium, and therefore can be hardly considered as boreal species.)

Tellina calcarea, Chem. = *T. obliqua*.

(*Tellina calcarea* [*lata*] is, I consider, an entirely distinct form, specially characterizing, moreover, one of the later horizons of the Upper Crag. It is unknown in the Coralline Crag.)

Several other species are mentioned by Prestwich, but either they are rare in the Coralline Crag, or are also found in the Mediterranean or the Lusitanian areas.

Two species of foraminifera are mentioned as northern :—*Lagena globosa* and *L. ornata*. The former is said, by the authors of 'The Foraminifera of the Crag,' to be found in all seas, and to have existed since the Silurian period (p. 177). The latter is unknown from the Coralline Crag. It is found, but rarely, at St. Erth (p. 380) and in the Pliocene of Sicily.

My theory of the Coralline Crag is simpler than Prestwich's. I not only believe with him that in the upper part, but that in the whole of the formation we have the remains of a series of submarine banks. This view, first suggested by Mr. Wood, Sen., in 1863[1], has since been adopted by Mr. C. Reid.[2] I doubt, however, whether these banks originated 'far from shore,' as the latter writer is inclined to think. The bed, a foot thick, observed by Prestwich at Sutton (his zone A) was evidently accumulated under conditions different from those of the rest of the deposit, representing the commencement of the re-invasion of East Anglia by the sea. No trace of any stone-bed was met with in any of the six borings at Gedgrave and Sudbourne in which the London Clay was reached, but this is not conclusive that no such bed exists there, as the borer might possibly in every case have failed to strike a stone, and the nodule-bed certainly occurs at Boyton, only a mile distant from one of them, on the south side of Butley Creek. It seems to me that, with the exception of this thin basement-bed, the Coralline Crag from top to bottom was deposited under more or less uniform conditions, in water sufficiently shallow to be within the reach of currents, at no great distance from the margin of the Crag sea, and in banks which were probably parallel with it. Notwithstanding the slight differences noted by Mr. Sutton between the different samples submitted to him, differences not greater than those to be observed in contiguous parts of the sea-bottom at the present day, the material of which this formation is composed has essentially the same character throughout; and if this be so, it seems that little deposition of sediment took place in the Crag area (or that it was afterwards removed by current-action), until those conditions were established which caused the accumulation of the banks postulated by my theory.

I see no reason for supposing that these conditions differed greatly from those now existing in the German Ocean, or in the shallow seas surrounding the British Isles, except that they were associated with the prevalence of a warmer climate. The present may thus throw light on the past, and if we cannot absolutely restore the geographical features of the Coralline Crag period, we may at least picture to ourselves generally the circumstances under which it must have originated.

In the first place, there is no evidence that beds of dead and drifted shells are now being laid down simultaneously in British Seas over large and continuous areas. Deposits of shelly sand may accumulate, however, in at least two ways: as submarine banks, limited in extent and caused by current-action, or as littoral drift. The former seems to me to represent the conditions attending the deposition of the Coralline Crag, the latter those under which the different Red Crag beds originated. Two examples of the first may be given.

[1] Quoted in 'Foraminifera of the Crag,' Monogr. Palæont. Soc., Introd. p. ii (1866).

[2] Mem. Geol. Surv. 1890, 'Plioc. Deposits of Britain,' p. 41.

Some years ago dredging was carried on rather extensively under the direction of Committees of the British Association for the Advancement of Science. In every case but one recorded by them, a much larger proportion of living than of dead specimens of mollusca were found. On the Turbot Bank before-mentioned, however, 9 species only of the former were found, as compared with 175 of the latter, many of the specimens of the dead lamellibranchs being double.[1] The Turbot Bank stretches from the entrance of Belfast Lough towards the Copeland Islands, and lies at a depth of about 25 to 30 fathoms. It rests against, and gradually shallows towards the shore, extending seaward for a short distance only, and shelving rapidly into deeper water.

The coast of Antrim is separated from the Mull of Cantire by a narrow channel through which the tidal currents run with great velocity. Consequently no deposition takes place there, glacial strata being still exposed at the bottom of the sea, uncovered by more recent beds. The influence of these currents is felt to a considerable depth, so that the dredging operations were sometimes seriously hampered by them. It is to these currents that the accumulation of dead shells farther south, on the Turbot Bank and elsewhere, is due. The shells are swept up by them from the sea-bottom on which the molluscs live, and redeposited, not where the currents are running strongly, but in comparatively sheltered places where their influence is less felt.[2]

The molluscan fauna of the Turbot Bank is of a character zoologically similar to that of the Coralline Crag, nearly all the existing British species known from the latter being common to the two deposits. The percentage of single to double and of dead to living shells is, however, much larger in the Crag.

Some beds, composed almost entirely of organic material, principally the shells, often fragmentary, of dead mollusca, extending over a limited area only, have more recently been discovered near the southern end of the Isle of Man by the Liverpool Biology Committee, and are described in their annual Reports. To these deposits, which are similar in character to the shelly sands of the Coralline Crag, the term 'neritic' has been applied by Prof. Herdman.[3] From him, and from Mr. J. Lomas, F.G.S., of University College, Liverpool, I learn that they are due to the strong currents which sweep through the Calf Sound; that they are not spread evenly over the sea-floor, but occur in the form of banks; and that beds of large shells are often found in one place, and smaller shells in another. Moreover, dead and living shells seldom occur together, and it happens frequently that in spots where molluscan life is most abundant no fossil record of it is accumulating. Most of the mollusca found in the Irish Sea live at a depth of less

[1] Report Brit. Assoc. (Dublin) 1857, p. 230.

[2] Other banks, containing many dead shells and due to the same cause, occur in the immediate neighbourhood, as, for example, 'the Riggs,' situated a mile south of Donaghadee and a mile from land, in about 20 fathoms.

[3] In a letter to me Prof. Herdman speaks of this material as 'recent crag.'

than 50 fathoms. Below that but few occur, except *Isocardia cor.* This mud-loving form is very rare in the Coralline Crag.[1]

Mr. W. H. Wheeler, M.I.C.E., of Boston, in an interesting paper read before the Institution of Civil Engineers in 1896,[2] shows, *inter alia*, 'that the contour of the sea-bed, on a sandy coast, when covered with a moderate depth of water, remains in a stable condition, and that so long as the conditions remain the same, the form of the banks and the depth of the channels are not altered.' He points out that the channels lying between the sandbanks which exist on both sides of the German Ocean at the present day, as in the roadsteads of Calais, Dunkerque, and Ostend on the one hand, and those of the East Anglian coast on the other, have remained without noteworthy alteration for many years. Both the banks and the channels are due to the action of currents, and when they have been once established, and an equilibrium of forces has been set up, no further change can take place until there is some variation in the physiography of the area, such as an elevation or depression of neighbouring land; then a new state of things will arise, and new deposits will accumulate. This, no doubt, is one reason why such well-marked distinctions often exist between succeeding geological zones. The formation of deltas and of deep-sea deposits goes on without intermission, but the sediment of shallow basins affected by currents (like the North Sea at the present time, or, as I believe, its western portion during the Coralline Crag epoch) represents isolated rather than continuous stages in geological history.[3]

The form and alignment of the area now covered by the Coralline Crag are, I think, suggestive. From Tattingstone in the south to the sunken rocks of Sizewell in the north it trends constantly from S.S.W. to N.N.E., with an uniform and slightly-curved outline, parallel to the line forming the north-western boundary of the Red Crag formation, which marks possibly the ancient shore-line of the Crag basin.

The form of the main mass of the Coralline Crag from Gedgrave to Aldeburgh resembles strikingly that of some of the existing sandbanks of the East Anglian coast. Although there has doubtless been much denudation of the Crag between Tattingstone and Sutton, that of the Orford district may still retain to some extent its original form, and may indicate the trend of the coast during the period in question.

The absence of any deposits in East Anglia of the character of the *Isocardia*-beds of Antwerp, that is, of an undisturbed sea-bottom,

[1] Similar banks of dead or broken shells occur in the vicinity of Dungeness. These also are due to current-action, occurring consequently with their longer axes parallel to the coast-line. Other cases of the same kind might be mentioned.

[2] 'Littoral Drift in relation to River-outfalls & Harbour-entrances,' Proc. Inst. C. E. vol. cxxv, pt. 3.

[3] The Pliocene beds of Holland, forming part of the old delta of the Rhine, represent on the contrary, I consider, a continuous sequence.

seems also to indicate that the Coralline Crag is not so much a fragment of a once widely-spread formation as has been often supposed, but one of a series of banks, which existed in a part of the sea where, owing to the bottom being continuously swept by strong currents, no general deposition of sediment was taking place.

The presence of currents causing the accumulation of banks of shelly sand in sheltered spots does not seem so favourable to the growth of mollusca, which flourish most in less exposed situations. Along the convex portion of the Norfolk coast at the present day between Weybourne and Yarmouth, molluscs are but rarely met with; but on the more sheltered part, from Wells to Hunstanton, where the influence of the tidal currents coming from the Lincolnshire coast is less felt, shells lie in places on the beach as thickly as they do in the Crag-beds.

Polyzoa, on the contrary, seem to flourish best in clear water agitated by currents, and their great abundance in the Coralline Crag, not only in the form of comminuted material, but in places in their original position of growth, is especially worthy of notice. D'Orbigny's remarks on the habits of polyzoa, made in 1850, seem to me so applicable to our present enquiry that I venture to quote them in full. He says, 'Qu'ils vivaient dans des eaux agitées, ce qui est prouvé par le manque de sédiments vaseux et surtout par les lits inclinés des couches, comme on le reconnaît si bien sur tous les points, lits inclinés spéciaux aux bancs sous-marins formés par l'action des courants dans les mers anciennes comme dans les mers actuelles.' [1]

The connexion of the Coralline Crag sea with the Atlantic by means of a channel or strait over some part of the South of England seems to be indicated not only by the close correspondence of the mollusca of that formation with those of the Mediterranean,[2] but also because in a closed basin no such currents as those to which I think the deposition of the Coralline Crag was due could have existed.

As we have seen, the currents which attend the flowing tide along the English shores of the North Sea come from the north, and not through the Straits of Dover. The fact of the great subsidence, regularly increasing in a northerly direction, which has affected Holland, and possibly Scandinavia,[3] since the Diestien period is an additional reason for thinking that the Coralline Crag sea may have been less open to the north than it is at present; and if this was so, the velocity of the tidal currents flowing through the southern

[1] 'Paléont. Franç.—Terr. Crétac. (Bryozoaires)' vol. v, p. 11; see also Prestwich, Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 129.

[2] The correspondence between the existing molluscan fauna of the Mediterranean and that of the Coralline Crag has been often emphasized, but there is also much resemblance between the latter and that of the older Pliocene beds of Italy and Sicily. Many species, of course, occur in the last-named which did not live at that period in our northern latitudes.

[3] There seems to be good reason for supposing that Scandinavia formerly stood considerably higher than it does at present.

channel must have been much greater than it is at present through the Straits of Dover.

The hypothesis that the Coralline Crag represents, not the bottom of a sea in which the mollusca found in it lived (as do the *Isocardia*-beds of Belgium), still less that it originated at any considerable depth,[1] but that it was accumulated by currents coming from the south-west, which heaped up, in comparatively shallow water, the remains of marine organisms, in banks more or less parallel with the then existing coast of the German Ocean, and at some distance from the mouth of any river discharging into it,[2] seems to be in accordance with all the facts of the case. It explains why we find, at the same level, seams, in one place of large, in another of smaller shells, and in a third of fine comminuted material. We can understand that when, by the temporary and local diversion of the currents, no sediment was for a time deposited on any portion of the banks, they would there become occupied by sheets of reef-building polyzoa, which would afterwards be smothered and unable to exist, when another alteration brought over them quantities of the fine mud.[3] Crustaceans and echinoderms would live under such conditions, as they now do on the Turbot Bank, but their numbers would be few in proportion to the drifted shells of mollusca.

For the reasons given above, it seems probable that the conditions under which the Coralline Crag originated were similar to those now obtaining in the northern part of the Irish Sea, where strong tidal currents, sweeping through the narrow channel that separates Ireland from Scotland, are causing the accumulation of banks containing dead shells, at no great distance from the shore and parallel to it.

In a future paper I hope to deal with the questions of the classification and mode of origin of the various deposits of the Upper Crag formation of Suffolk and Norfolk.

IV. Recapitulation.

In the foregoing pages I have set forth the reasons which lead me to think:—

1. That the Lenham Beds, containing a considerable proportion of characteristic Miocene or Italian Lower Pliocene mollusca (13 out of 67) unknown or very rare in the Coralline Crag, are older than that formation.

[1] Our estimate of the depths of the western (and littoral) portion of the Crag basin during the deposition of the Coralline Crag should depend, not on the character of its mollusca, which are not, as a rule, *in situ*, but on the view that we may take as to the strength and volume of the currents then prevailing.

[2] The Thames, in its present form, had not at that time, I consider, come into existence.

[3] Mr. Kendall reminds me that valves of *Pecten*, etc., encrusted with adnate polyzoa, occur chiefly in those parts of the Crag where the reef-building forms are found. These also could exist only when the currents passing over that portion of the area were free from sediment.

2. That the Lenham Beds had probably been upheaved, consolidated, and exposed to denudation before the deposition of the Coralline Crag, and may have been, as formerly suggested by Prof. Ray Lankester, the source from which the boxstones found at the base of the Suffolk Crag have been derived. These boxstones contain a fauna, not identical with, but possessing the same general character as that of Lenham, that is, an admixture of distinctive Miocene and Coralline Crag species.
3. That in the interval between the deposition of the Lenham Beds and the Coralline Crag the Crag sea retired, in consequence of the upheaval of the southern part of the area, to the north, as it did also in Belgium towards the close of the Diestien period.
4. That the Lenham Beds are most nearly, though not exactly, represented by the zone à *Terebratula grandis* of Belgium, and possibly by some fossiliferous deposits recently discovered at Waenrode, near Diest, while the Coralline Crag corresponds very closely with the Belgian zone à *Isocardia cor.*
5. That the Coralline Crag between Sutton and Aldeburgh does not rest upon the horizontal surface of the London Clay, as supposed by Prestwich, it being shown by borings that the junction between the two formations dips regularly towards the north-north-east.

.That no satisfactory evidence, whether stratigraphical or palæontological, is forthcoming to show that any divisions to be observed in the Coralline Crag at Sutton are persistent at other localities in the formation.

7. That none of the supposed zones in the Coralline Crag at Sutton have been shown to be characterized by the first appearance in the Crag basin, or by the disappearance from it, of any species of mollusca or foraminifera. On the contrary, that the forms which have been enumerated as specially distinctive of certain horizons are found also in other parts of the Coralline, and often in the Red Crag too.
8. That no great subsidence of the Crag area during the older Pliocene period, as believed by Prestwich, took place. Such a subsidence must have caused the submergence of districts adjoining it either in this country or on the Continent, and for this no evidence exists.
9. That neither the fauna of the Coralline Crag nor the character of the sediment composing it supplies any indication of deep-sea conditions, the sediment consisting almost entirely of the drifted remains of dead mollusca and polyzoa, or of calcareous matter derived from their decomposition, with reefs of living polyzoa in places, and differing from the contemporaneous *Isocardia cor*-beds of Belgium, which represent an undisturbed sea-bottom, with the shells *in situ* as they lived.
10. That there is no evidence of any great changes of climate during the Coralline Crag period: the waterworn block of

porphyry found at the base of the Coralline Crag at Sutton, which was held by Prestwich to indicate the presence of floating ice in the Crag basin, occurring in a bed full of derivatives, and being possibly itself derived from some older formation.

11. That Prestwich's theory of a temperature sufficiently cold to produce floating ice during the Coralline Crag period is in entire opposition to the palæontological evidence, which indicates that the climate was at that time not colder but warmer than the climate of Great Britain at the present day, more nearly approaching that of the Mediterranean or the Azores.
12. That, so far from it being possible to separate the Coralline Crag into eight constant zones, the division of this formation hitherto adopted into shelly incoherent sands and indurated ferruginous rock can no longer be maintained, the latter being merely an altered condition of the former, as proved not only by general considerations, but by the discovery of a section at Iken, showing the two varieties of Crag side by side, and passing into each other.
13. That with the exception of the basement-bed, 1 foot only in thickness, the material of the Coralline Crag is of similar character throughout, being almost entirely organic, with only a small admixture of inorganic matter; nor is any essential difference between the different parts of it distinguishable, either by microscopical examination or chemical analysis.
14. That, excluding the basement-bed before mentioned, the Coralline Crag was throughout accumulated under similar conditions: namely, in the form of submarine banks, caused by currents, which prevented deposition when they ran strongly, but swept up from the sea-bottom the remains of mollusca, etc., redepositing them in more sheltered situations.
15. That such conditions occur at the present day in the Irish Sea, as for example off the Antrim coast, where an accumulation of dead shells, known as the Turbot Bank, has been caused by the tidal currents which sweep with much velocity through the narrow channel separating Ireland from Scotland; and also at the southern end of the Isle of Man, where deposits mainly composed of organic material, called by Prof. Herdman 'neritic,' exist, being similarly caused by a strong current running through the Calf Sound. Sandbanks caused by tidal currents occur along the coast of East Anglia at no great distance from the shore, and more or less parallel to it.
16. That during the deposition of the Coralline Crag, the German Ocean was less open to the north than it is at present, if, indeed, it was not entirely closed, but that it was connected with the Atlantic by a strait or channel over some part of the southern counties of England, through which currents ran strongly, and that the influence of these currents extended

farther into the North Sea than does that of similar English Channel currents from the westward at the present day.

17. That the Red Crag, with which I hope to deal more fully in another paper, was the marginal accumulation of a sea gradually retreating northward and eastward.
18. That, in opposition to the views of Prestwich, who regarded it, with the exception of the Chillesford Beds and 'the unfossiliferous sands of the Crags,' as throughout of the same age, the Red Crag formation includes a continuous sequence of deposits, arranged, however, horizontally, and not vertically, the different beds being found to contain a gradually diminishing proportion of southern, and a gradually increasing number of northern species of mollusca, as we trace them in a northerly and easterly direction.

Discussion.

Mr. Clement Reid congratulated the Fellows on having before them the valuable series of borings made, purely for scientific purposes, by Mr. Harmer. He was unable to agree with the Author that there was at present any sufficient evidence for separating the Lenham Beds from the Coralline Crag, as forming an older zone. The slight differences in percentage of the recent and southern mollusca were due in the first place, he thought, to the unavoidable study of the larger species alone in the ironstone-moulds of Lenham; the smaller mollusca generally give a higher percentage of persistent forms. In the second place, at Lenham, owing to the geographical position, the sea was warmer; and the deposits also resembling those of Italy rather than those of East Anglia, there was necessarily a greater resemblance to the Mediterranean Pliocene fauna. If such very slight differences were sufficient to mark a time-interval between the Lenham Beds and the Coralline Crag, he could not understand why the Author should correlate the Lenham Beds with the 'boxstones,' the small fauna of these containing a far stronger southern and extinct element than was found at Lenham.

Mr. H. W. Burrows considered that, until a critical examination had been made of the somewhat scanty and unsatisfactory molluscan fauna of the Lenham Beds, no satisfactory results could be obtained by comparing slight percentage-differences of the species with those of other deposits for purposes of correlation. The speaker was not convinced by the arguments of the Author in regard to the oneness of the Coralline Crag. Admitting that the evidence for a zonal distribution is not yet complete— neither mollusca nor polyzoa having been studied from that aspect—yet the foraminifera in some important respects confirm the zonal arrangement. This subject had already been dealt with by Mr. Holland and the speaker in the Monograph of the Crag Foraminifera, and, when the general facies of each zone is considered, a marked resemblance is found to exist in beds referred by Prestwich to the same zone in widely separated areas of the Crag district. On broader lines it was noted that the foraminifera bring into prominence the Italian Pliocene character of the St. Erth Beds, as emphasized in the 'occurrences' appended to the descriptions of the Crag foraminifera.

Mr. P. F. Kendall observed that there were three classes of evidence which had been adduced in support of the zonal division of the Coralline Crag,—stratigraphical, lithological, and palæontological. Mr. Harmer had shown by his borings that the first of these gave results contradictory of Prestwich's views, for beds which had been included in the same zone were found to lie on different horizons. The lithological test seemed equally to fail; the Gomer beds agreed lithologically with a different zone from that to which they had been referred. The speaker had been unable to recognize any clear palæontological distinctions between the several zones. The bands of large shells at Aldeburgh, Gomer, and Ramsholt yielded a fauna having the same general characteristics, though one was nearly at the top of the Coralline Crag, another near the middle, and the third at the base.

Prof. Seeley stated that when, in earlier times, the Crag phosphate-pits were opened over a wide area, he had no difficulty in recognizing two divisions of the Coralline Crag at Ramsholt and Sutton as well defined by mineral character; but there was certainly change, both in stratigraphy and in fossils, as the beds were followed to the north. It might be that the multitude of pits around Ramsholt had made that part of the Coralline Crag best known, and led to the inference that that Crag was older, from its larger fauna. He had seen no facts of superposition to support that view. The fossils varied from place to place, much as the existing life varied when followed along the same coast. He was inclined, when new sources were suggested for the 'boxstones,' to ask whether it was certain that they were in all cases derivative. The rolled condition might be consistent with hardening of the sand around fossils by infiltration of mineral matter. A large percentage of the stones contained fossils which might add a few species to the true fauna of the Crag.

Mr. A. E. Salter, the Rev. J. F. Blake, and Prof. W. W. Watts also spoke.

The Author thanked the Fellows for their patient attention, and in reply to Mr. Reid he pointed out that, although the evidence was incomplete, so far as it went it was decidedly in favour of his contention that the Lenham Beds were older, perhaps considerably so, than the Coralline Crag. The species occurring at Lenham, but not in the Coralline Crag, were generally of an older, and none of them of a newer type. The theory that the Lenham Beds were older was stratigraphically in accordance with the facts to be observed both in England and Belgium, as more fully set forth in his paper. [See also the footnote in brackets, p. 310.]

To Mr. Burrows he replied that he had been trying for many years to find some proof from the mollusca of the existence of the zones in the Coralline Crag proposed by the late Sir J. Prestwich, but without success. No evidence was offered by Prestwich, except of the most general character, and the features which he regarded as characteristic of certain zones were equally applicable to others. The evidence of the foraminifera did not seem to the Author of much weight. With few exceptions the Crag forms were world-wide in their present distribution, and went back to older Tertiary, Mesozoic, or even Palæozoic times. Quoting from the list published by Mr. Burrows and his colleagues, he showed that the forms regarded by that writer as characteristic of certain zones were equally common in Zone D at one place, in E at another, and in F or G at a third. No attempt had been made to work out the supposed zones stratigraphically, nor was it possible to do so.

27. *The* Garnet-Actinolite Schists *on the* Southern Side *of the* St. Gothard Pass.

By T. G. Bonney, D.Sc., LL.D., F.R.S., V.P.G.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read May 18th, 1898.)

Contents.

I. Introduction.

At intervals during the last 20 years I have studied the well-known garnet-actinolite schists which are exposed on the southern slope of the St. Gothard Pass from perhaps 500 to about 1600 feet above the mouth of the tunnel.[1] They extend westward along the flank of the Val Bedretto to beyond All'acqua, with one slight interruption near this spot, and can be followed eastward to the vicinity of the Pizzo Columbe, that is, for a total distance of from 16 to 17 miles, the breadth of the outcrop, which is locally interrupted by elongated masses of more normal hornblendic schist, being at its maximum about $1\frac{1}{4}$ mile. They are intersected by the Val Tremola [2] and the Val Canaria with its tributary glens, and are exposed on the right bank of the Val Piora. Here the lower part of the mass must be about 6700 feet above sea-level, that is to say, the outcrop rises at least 2500 feet in about 5 miles.

My later visits threw some light on the origin of these rocks; but I felt that more work in the field was necessary before I could come to any conclusion. Therefore I determined to return to the district and examine more particularly the outcrops near the Val Piora, of which hitherto I had seen little, having spent my time on another group of schists, which apparently overlie them. This intention was carried out in July 1897, and I had the good fortune to be accompanied by my friend and former pupil Mr. John Parkinson, F.G.S., to whom I am indebted for much assistance both then and afterwards.

So far as I have discovered, with the kind help of Dr. J. W. Gregory, no one has paid much attention to this group of rocks. They are described briefly and clearly by K. von Fritsch ('Beiträge zur

[1] These figures are only approximate. I have measured (by aneroid) the lowest outcrop by the high road, but there are others yet lower in the slopes some distance to the east. Moreover, it is not easy to fix precisely the exact position of the upper limit—nor does it seem to me very important.

[2] For which reason I have referred to them since 1886 (Pres. Addr. Quart. Journ. Geol. Soc. vol. xlii, *Proc.* p. 72) as the Tremola Schists.

geol. Karte der Schweiz,' 1873, Lief. xv, pp. 65, 66). In the 'Livret-Guide Géologique,' VIème Congr. Géol. Int. 1894, they are mentioned at p. 156, and in the section are coloured as Bündner Schiefer (Ob. Trias bis Dogger), an identification which, it is needless to say, is more easily assumed than proved. Prof. C. Schmidt refers to them in a discussion of the geology of the Simplon region (Arch. des Sci. Phys. et Nat. 1895, p. 84), and regards them with the adjacent crystalline rocks as 'schistes cristallins anciens' and 'roches archéennes' (p. 85). See also Eclog. Geol. Helvet. vol. iv (1896) p. 367, etc. In Mitth. der naturforsch. Gesellsch. in Bern (1895, Nos. 1373–1398, p. 73) they are also briefly noticed, and in a section drawn across the Ofenhorn schists corresponding with the 'Upper Schists' of the Val Piora district, are coloured as 'Jüngere metamorphe krystall. Schiefer, Mesozoisch bis Cambrisch.' A wide limit of choice!

II. Description of Sections.

Time will be saved by describing as concisely as possible the more important facts noted in the field, indicating the conclusions to which they point, and by discussing afterwards the evidence obtained from microscopic examination. I will take the localities studied from west to east, commencing with the St. Gothard; for in walking beyond it up the Val Bedretto I did not diverge from the lower part to investigate these schists, though from what I saw I infer that they soon become much less conspicuous than on the St. Gothard Pass.

(*a*) The St. Gothard.[1]

By following the general line of the high road we reach, perhaps about 550 feet above Airolo, a well-foliated greyish biotite-gneiss in which red garnets are scattered sporadically, at first small, then of larger size, often with a slight streak-like association. A little higher up these occasionally range from $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter. Here the rock shows a banded structure: zones, perhaps 8 or 9 inches thick, alternating with others from 10 to 12 inches, in which garnets are less abundant. Then hornblende (generally actinolitic) becomes more abundant. For instance, at about 650 feet up, a small quarry exhibits a grey garnetiferous schist, poor in hornblende, passing down into a darker variety, with fewer garnets, but with the usual large and rather blade-shaped actinolites. This mineral now becomes more frequent, and the garnet-actinolite schists[2] continue till the road passes from the left to the right bank of the torrent descending the Val Tremola. In fact the whole ascent seems to be over one or other of these rocks, with an occasional 'relapse' into biotite-gneiss[3] and one or two greener bands.

[1] I had been already four or five times over this section, and we visited it in 1897, both going to and coming from Val Piora.

[2] I use the term in a general sense, for variations are not unfrequent, and the two minerals seem to occur often in inverse proportion.

[3] As at about 1400 feet above Airolo.

Many of the actinolites seen in these schists exhibit a tendency to 'fray out' at the ends; often they have a tufted arrangement (see figs. 2 & 3, p. 362). While many of them lie in the planes of cleavage-foliation [1] (which is sometimes conspicuous), others make all angles with it. Bands in which actinolite is more than usually abundant sometimes seem to show traces of a granular or even of an ophitic structure, the whole suggesting that the mass originally may have alternated from a hornblendic biotite-granite, more or less garnetiferous, to a coarse diorite (also containing the last-named mineral), the two not having been at the outset very sharply distinguished, and being now, owing to the effects of pressure, still more difficult to separate. In the upper part, though actinolite may still be observed, the rock comes nearer to an ordinary hornblende-schist.

After a time, when the zigzags are ended, and the road runs at the base of the crags bounding the right side of the more level part of the Val Tremola, biotite-gneiss sets in, and here and there are stratiform masses of a rather dark variety of hornblende-schist.

In the above-mentioned series the actinolites, judging from their appearance, are later in date than the cleavage-foliation. The garnets, however, though often well preserved, are perhaps more generally either a little distorted or crushed, so that they probably are anterior to the main disturbance. It is difficult to form an opinion of the age of the biotite, but the abundant small flakes of silvery mica (paragonite?) are most likely posterior to that disturbance.

(*b*) Val Canaria.

This valley descends from the watershed of the Lepontine Alps, and joins the Val Bedretto about ¾ mile below Airolo. The floor is strewn hereabouts with large boulders of garnet-actinolite schist, together with the ordinary biotite-gneisses of the district and some other schists. The first afford instructive subjects for study, and correspond with the rocks exposed on the St. Gothard road. Though I have often spent a spare hour or two among them, I have not ascended the Val Canaria to the outcrops from which they have come. Still, when I was examining the noted section (once supposed to prove that the 'Upper Schists' were more recent than the rauchwacke) in the lateral glen on the western side of the Val Canaria,[2] I climbed up till I reached the garnet-actinolite rocks *in situ* at a height of about 1200 feet above Airolo. I see no reason to doubt that the rocks exposed in the Val Canaria are practically identical with those studied on the St. Gothard.

[1] The strike, where I have measured it, of this structure (which often corresponds with the mineral banding) varies from N.N.E. to N.E., on the whole nearer the former, and it dips at a high angle (60°–70°) to the western side. The significance of this fact is noticed below. Crushed-out quartz-veins may be seen.

[2] Quart. Journ. Geol. Soc. vol. xlvi (1890) p. 187, & vol. l (1894) p. 285.

(c) Val Piora.

The lower slopes on the right bank of this valley are excavated in the group described in my papers on 'Mesozoic Rocks & Crystalline Schists in the Lepontine Alps,[1]' namely, in micaceous schists, often dark, sometimes containing blackish garnets abundantly, and occasionally staurolite, which pass on the one hand into marbles, on the other into rather impure quartz-schists. Rauchwacke, sometimes with gypsum, occurs locally, and is more abundant in the upper part of the valley. The actinolitic and garnetiferous rocks apparently overlie these, and are followed by gneisses of the type usual in this district.[2] The former appear to be thinner than at the St. Gothard, but constitute a line of craggy slopes and cliffs sometimes inaccessible. We examined numerous fallen blocks, and worked along the crags as best we could, from the Lago Cadagno to the Lago Tom.

It may suffice to give a description of two sections, and then a general summary of the remainder of our work. Of these two sections, one is above the north-eastern, the other above the north-western end of the Lago Tom.

The former (one of the lowest set of outcrops visible) showed, in descending order: (1) A considerable mass of hornblendic or actinolitic rock, the crystals of the latter varying in length, but usually not exceeding $\frac{1}{2}$ inch. This seems to pass (in the lower part) into a darker variety of hornblendic rock. Occasionally it is distinctly fissile from the effects of pressure,[3] but in places it exhibits a streaky structure, which this agency alone seems inadequate to explain. The rock sometimes resembles the hornblende-schist of the Lizard district, but it becomes, in its lowest part, markedly actinolitic, the crystals ranging up to nearly 1 inch in length, and being confusedly scattered. In this rock we find lenticles of a variety described in the next section; these sometimes are about $\frac{1}{2}$ yard long and 2 or 3 inches thick. (2) A more felspathic variety of the actinolite-rock,[4] the 'blades' from $\frac{1}{2}$ to $\frac{3}{4}$ inch in length lying in all directions, though in places the mineral is, so to say, condensed in streaks (fig. 1, p. 361). (3) After an interval of about 8 feet vertical (hidden by turf) and a little to the west comes an outcrop of the typical garnet-actinolite gneiss, in which are two or three bands of rather coarse hornblendic rock suggesting an intrusion.[5] (4) An outcrop, some distance lower down, of garnetiferous gneiss or micaceous schist, apparently passing, as on the St. Gothard, into very typical garnet-actinolite schist. Similar varieties were seen in the fallen

[1] Quart. Journ. Geol. Soc. vol. xlvi (1890) p. 187, and vol. l (1894) p. 285.

[2] In reality this is an inversion, the true order (descending) being (a) rauchwacke, (b) upper schists, (c) garnet-actinolite schists, and (d) biotite-gneisses.

[3] The force appears to have acted roughly perpendicular to the mineral banding.

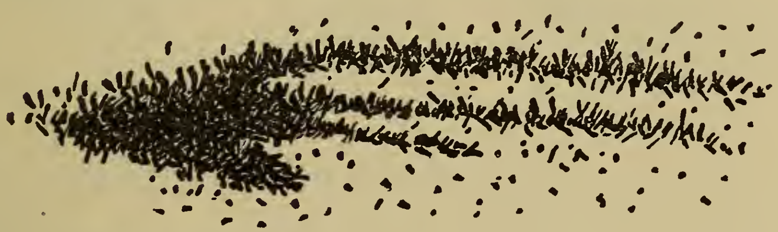
[4] The more fine-grained varieties being seemingly the more fissile.

[5] The total vertical distance in which (1), (2), and (3) cropped out was some 8 or 9 yards.

blocks. Some of these exhibited distinct alternations of felspathic and hornblendic rock. In one case a sort of tongue of actinolitic diorite, without definite ordering, passed rapidly into a very close-banded or foliated rock more of the Lizard type, but with signs of crushing and a rather actinolitic habit. The evidence, however, as we interpreted it, was favourable to the idea that, while pressure had produced its usual effects, some structures indicated fluxional movements in an ill-mixed or differentiated rock.

The second section (described in the same order) afforded (1) loose blocks, fallen from the cliffs above. These consisted of (*a*) gneiss, moderately coarse, rather felspathic, and fairly micaceous, representing a type common in the mountains on this side of the Val Bedretto; (*b*) dioritic rock; and (*c*) the garnet-actinolite schist, the

Fig. 1.—*Hornblendic streaks in a rather felspathic diorite, fringed with bristling actinolite-crystals, or passing into a tangle of the latter.* (*Above Lago Tom.*)



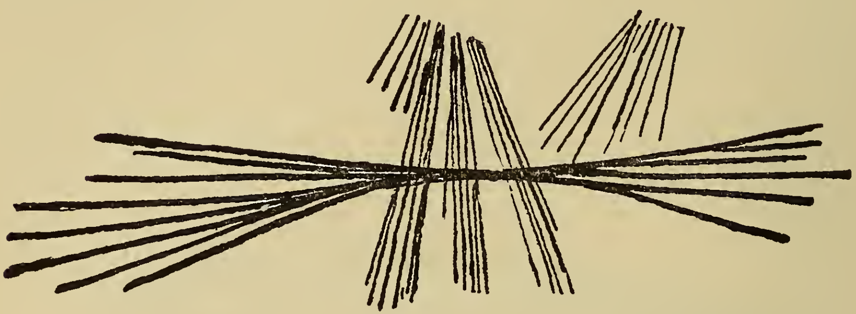
latter mineral often occurring in bunches, its crystals being frequently some 3 inches long and about as thick as a small bodkin. These were best developed along the planes of cleavage-foliation, and exactly resembled some of the specimens from the southern side of the St. Gothard and the entrance of the Val Canaria. (2) A dioritic rock of the ordinary character, with darker more hornblendic bands. (3) The same, but with the hornblende more distinctly actinolitic. This rock, which exhibits minor variations, extends for a considerable distance. (4) Rather felspathic hornblende-schist, often distinctly banded. In one case the more felspathic and more hornblendic bands (each of which exhibits a faint streaking or foliation in itself) run about 3 inches thick. This rock passed in one place into a biotite-gneiss, with but little quartz; in another a dark hornblendic rock appears in a way suggestive of an intrusion.

What we saw in other places was in general accord with these two sections, and with those on the southern side of the St. Gothard, so that the field-evidence seemed to point to the following conclusions:—

(1) More or less gneissoid schists, varying from micaceous to hornblendic, often actinolitic, and sometimes rather rich in garnets, are interbanded: the passage from the one to the other being occasionally rather rapid (in a few instances even suggestive of intrusion), but generally a more or less gradual one.

(2) Garnets are frequently present, but are usually less abundant in the more hornblendic varieties. The larger specimens generally occur where biotite is the more abundant ferro-magnesian mineral, though occasionally fine crystals may be found associated with bunches of long slender actinolites.

Fig. 2.—*Bunches of actinolite on a block, the principal group sketched being about* $5\frac{1}{2}$ *inches from end to end, and about as thick as a stout pin or slender bodkin.* (*Loose block, from cliffs north of Lago Tom.*)



(3) The actinolite[1] appears to be longest and best developed on the planes of cleavage-foliation, but it can be also found piercing the rock at all angles. Sometimes it assumes, instead of the 'bodkin' shape, a rather broad-bladed form, nearly $\frac{1}{2}$ inch in diameter, with 'frayed' ends. The actinolite is not restricted to one variety of rock or associated always with garnet. For instance, I have found it in the usual silvery schist (with abundant paragonite and some biotite), in a pale greenish schist (coloured probably by chlorite or by minute hornblende), in a gneissose rock, somewhat resembling a fine-grained granite, and in a darkish massive rock obviously rich in hornblende.

Fig. 3.—*Rough sketch of tuft of hornblende-crystals: about 2 inches long, top hid by débris.* (*Loose block, at opening of Val Canaria.*)

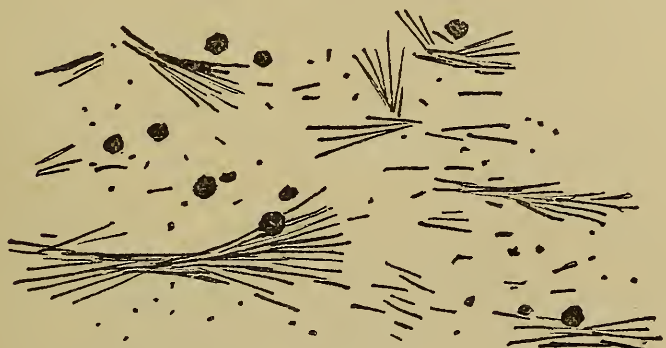
Garnets also may occur in any of these. They range commonly from the size of a large pea downwards, but occasionally run up to nearly an inch in

[1] See figs. 2, 3, & 4 in illustration of these remarks.

diameter. The largest are sometimes associated with veins; the smaller are generally scattered throughout the rock.

(4) Pressure evidently has acted on the rocks, but to a variable extent. Sometimes its effects are inconspicuous (unless we regard the actinolitic habit of the hornblende as an indication); sometimes the rock is almost fissile. Traces, however, of a cleavage-foliation can be generally detected, and are often obvious.

Fig. 4.—*Diagrammatic sketch of a face of garnet-actinolite rock. (Slopes above Airolo.)*



[Some of the actinolite-crystals are quite 4 inches long.]

(5) Pressure, though it may account for this foliation, seems inadequate as an explanation of the more marked instances of mineral banding, in which felspar, mica, or hornblende may predominate for a thickness of $\frac{1}{4}$ inch upwards.

(6) The relation of these varieties in the field appeared explicable on either of two hypotheses: (*a*) that a group of sedimentary rocks, which varied somewhat in chemical composition, had undergone extreme metamorphism; or (*b*) that the apparent bedding had been produced by fluxional movements in a magma, which, either from differentiation or from the intrusion of one variety into another, was not uniform in composition.[1]

There is much to be said in favour of both these hypotheses. In my earlier work, at a time when the effects of pressure on rocks of this kind were ill understood, and those of fluxional movements were almost unknown, I adopted the former one; but I am now convinced (especially since my work last summer) that the second hypothesis affords a better explanation of the phenomena as a whole.

[2] I do not remember to have found the above-described group of rocks so well developed in any other part of the Alps, although gneisses of the St. Gothard type—that named Montalban by the late Dr. Sterry Hunt—occur sometimes, and seemingly at about the same horizon. These 'Tremola Schists,' however, appear to be uncommon, though I have seen rather similar rocks in the Upper Iselthal and the Zillerthal, and specimens from other Tyrolese localities in the Museum at Innsbruck. Prof. Lapworth has shown me some fine specimens of these rocks which he obtained at Kongsvold (Norway).

III. Results of Microscopic Examination.

As these rocks are well known to petrologists, and their minerals are seldom, if ever, exceptional, I will not lengthen this paper by giving minute descriptions of individual specimens, but will briefly notice the chief constituents, and then discuss certain structural peculiarities which appear to throw light on the past history of the group.

The specimens, when examined by the microscope, exhibit, as we might expect from macroscopic inspection, certain features in common, together with considerable variety in constituents and structure. All show a cleavage-foliation, but some less distinctly than others; all contain nearly the same minerals, but differ in the amount of garnet, of mica (both biotite and paragonite), and of hornblende, as to both size and arrangement. In all a kind of groundmass is present, consisting of a water-clear mineral, with more or less of a silver-white micaceous constituent. The latter is generally subordinate to the former, though once or twice it predominates. In this groundmass are scattered iron-oxide, garnet, staurolite, hornblende (rarely absent), and biotite (in larger flakes). The water-clear mineral in the groundmass forms a kind of mosaic, the grains varying from subrotund to angular, and seldom exceeding ·01 inch in diameter. They are well cemented together, showing no sign of recent fracture or crushing, but sometimes contain minute enclosures irregularly disposed, like a little dust. They generally resemble quartz and give, with crossed nicols, similar colours. Some may be this mineral, but the majority are undoubtedly felspar, a few exhibiting twinning on the albite-type. Two or three, which occur in small veins, or are in contact with calcite (an occasional constituent), are partially idiomorphic. The micaceous constituent has been identified as paragonite by previous observers. It occurs in small colourless flakes, often with rectilinear outlines, generally from about ·003 to ·007 inch in length. In one or two specimens, as we should expect from their macroscopic aspect, it is so abundant that in places the water-clear mineral can be distinguished only in minute interstitial granules. This mica generally exhibits more or less of a foliated structure, and sometimes, where abundant, appears to be crumpled. Though iron-oxide and biotite might be occasionally claimed as constituents of the groundmass, I think that they are more properly reckoned with the minerals which have a porphyritic habit. These are as follows:—

(1) Iron-oxide, which is not very abundant, occurs in granules or grains, and in fairly well-formed flattish crystals, the mode of association of the first suggesting that they are the detritus of a larger grain. The mineral here and there is faintly translucent, having a deep reddish-brown to brownish-red colour. Some of it may be magnetite, but most is hæmatite, perhaps also ilmenite.

(2) Garnet (not in every slice) of a pale pinkish-red tint, with enclosures of iron-oxide and other small minerals, and with cavities,

the last sometimes so abundant as to give a rather 'dirty' aspect to the mineral. It shows occasionally a rude cleavage and slight local depolarization, indicating strain. Sometimes idiomorphic crystals occur, but in other cases one part retains the external angles, while the remainder has an irregular outline. A few of the crystals appear to have been more or less broken up, the larger fragments still lying almost in contact. But more usually either the whole grain, or at any rate a part of it, exhibits that peculiar granulated character and partial intermixture with the groundmass which in a garnet prove crushing.[1] One or two isolated fragments occur in the slices, but, as a general rule, there are no marked indications of shearing, nor is the mineral distinctly flattened, as sometimes

Fig. 5.—*Biotite including a small flake of the green variety* [*opposite to* a], *with grains of iron oxide and groundmass.* (*From a small quarry rather higher than that mentioned on* p. 358.)

×60.

occurs.[2] The appearances suggest that the original crystal has been more or less cracked, sometimes a little deformed, while occasionally a portion has been shattered and mixed up with other pulverized minerals in its immediate vicinity.

(3) Staurolite. This mineral seems to occur only where the garnets are abundant, and is never plentiful or large. It is not a

[1] It is well represented in the coloured plate accompanying Mr. G. Attwood's paper (Quart. Journ. Geol. Soc. vol. xliv, 1888, p. 636), and described in my note, *ibid.* p. 651.

[2] See, for instance, Proc. Roy. Soc. vol. xlii (1887) p. 322.

dark variety, and is generally rather irregular in outline, as if a crystal or grain had been broken up and re-cemented.[1]

(4) Biotite is always present, though the quantity is very variable, and three types may be distinguished: (*a*) one, perhaps the least frequent, in small flakes, somewhat irregular in outline, in rather streaky groups; (*b*) small, fairly regular flakes, associated, as described below, with large crystals of actinolitic hornblende; (*c*) large flakes, with well-defined but not crystalline outlines, clear and fresh-looking. The first type has probably been formed by the breaking up of a larger flake under pressure; the second I pass over for the moment, as it can be most conveniently discussed in connexion with the hornblende. The third type occurs in comparatively large flakes, say up to $\frac{1}{6}$ inch broad, is strongly pleochroic, and contains granules of iron-oxide and the water-clear mineral of the groundmass, sometimes with small flakes of a rather pale green mica. The last pierces the biotite at various angles with its basal plane, sometimes also is included in it, and occasionally is quite separate (see fig. 5, p. 365). This mineral usually is free from inclusions, and rather feebly pleochroic, changing from a pale greenish straw-colour to a light dullish green. I have no doubt that it is a hydrous biotite, for flakes of that mineral sometimes are in this condition at their edges. But, from the way in which it occurs as an inclusion in the larger anhydrous mineral, it must either differ in chemical composition (so as to be more readily affected by water) or (as I think more probable) it must be an older mineral, which was hydrous at the time of inclusion. The flakes of ordinary biotite lie with their basal cleavages in various directions, perhaps more often than not at a high angle with those of cleavage-foliation, and the facts mentioned above lead me to infer that they were formed at a comparatively late date in the history of the rock.

(5) Hornblende. A small grain of rather fragmental aspect may be occasionally seen in the groundmass, but this mineral generally occurs in fairly definite crystals. Now and then (especially in one specimen) these are almost idiomorphic; they are always more or less lancet-shaped and sometimes acicular,[2] the outlines in the latter case being always rather irregular. They are in colour a rather rich green, and strongly pleochroic. They include grains of iron-oxide, of the water-clear groundmass, and well-defined small flakes of biotite. In some cases we find a number of parallel prisms of hornblende, like an imperfect grating or gridiron, separated by larger intervals of a water-clear felspar or even by a mosaic of the same, as if an effort had been made at crystal-building, which had only produced a skeleton. The more elongated forms often exhibit a fringing growth of small flakes of biotite, or rather pass into this externally, so that the flakes conform very nearly to the outline

[1] The occurrence of staurolite in a rock which probably has been in a molten condition is unusual, so far as we know, but a parallel may be found in andalusite.

[2] The 'needle,' it must be remembered, is a stout one, often quite a thick bodkin.

of the crystal (see fig. 6, below). Occasionally we find that an end or a small portion of a hornblende-crystal is apparently replaced by these flakes.[1] Sometimes also a separate grain of hornblende may be found, rather prismatic in outline, which seems to form a nucleus to three or four flakes of biotite and presents, if I may so express it, a residual aspect.

Fig. 6.—*One end of a lancet-shaped crystal of actinolite, tipped and fringed with flakes of biotite.* (*From the ascent to the St. Gothard Pass.*)

×25.

[a = actinolite ; b = biotite.]

(6) Chlorite. This mineral has a more or less fan-like growth, is fairly pleochroic, changing from a light tawny buff to a rather pale dull green, exhibiting low polarization-tints and straight extinction. It is abundant only in one slice. Here it occurs in somewhat irregular patches, which, however, in one or two cases are seen to be associated with hornblende, and led me to infer that the mineral has replaced biotite.

(7) Epidote, not unfrequent in grains and rather irregular prisms, having the usual aspect and tints, without and with the polariscope, though this instrument shows that low-coloured grains sometimes occur with the others, and the possibility that certain of these may be zoisite is suggested.[2]

[1] As if (to use a simile) the design of a hornblende-building had been carried out with biotitic materials.

[2] They do not generally admit of accurate measurements.

(8) Calcite (or a closely-allied carbonate) is present in some slices; occasionally it forms fair-sized grains, sometimes it is interstitial in a hornblende 'gridiron' or is moulded on an idiomorphic felspar-crystal.

(9) Rutile, zircon, and one or two other accessory minerals occur, but are far from common, and call for no special notice.[1]

IV. Inferences as to Mineral and other Changes.

The microscopic studies summarized above fully confirm the inferences suggested by work in the field, that we are dealing with a group of rocks which originally varied from ordinary diorite to hornblende-biotite granites, not rich in quartz, in which garnets are present to a variable extent, and are more common in the latter rocks. In these they also attain a larger size, and are occasionally associated with a little staurolite. The different members seem to pass, though not seldom rapidly, one into another, and alternate, sometimes on a large, sometimes on a small scale; in short, they often mimic true stratification. But whatever may have been the origin of the group, after its members became holocrystalline, pressure came into play, and crushed them more or less, the extent depending on their composition and on local circumstances. The garnets generally did not suffer severely: the quartz, when present, was more or less broken up, the felspar was generally much crushed; afterwards it was in some cases converted into paragonite (silica being set free), though a fragment now and then survived, but in others (and more commonly) it went back to a water-clear felspar, not always quite identical in chemical composition, for I regard the dust as representing an unused aluminous silicate. Possibly the difference mentioned may have depended upon whether the water in the rock percolated or was almost stagnant.

The original hornblende and biotite were also crushed, and when the groundmass was reconstructed, or perhaps at a slightly later date, they were rebuilt, the hornblende with a more or less actinolitic habit. The larger flakes of biotite, which include grains occurring in the groundmass, may have been growing simultaneously with the other mineral, but the smaller flakes associated with it, as described above, must, I think, be later in date. Though not exactly pseudomorphs, they appear to be determined in position by the hornblende,

[1] Some bed-like masses of a fairly typical hornblende-schist are found in the Tremola group, occurring, so far as my memory goes, in the flatter part of the valley above the first long series of zigzags. Their relations to the rest of the group are not easily determined, but I suspect them to be intrusive sheets, modified by subsequent pressure. The three specimens which I have examined under the microscope show a more or less foliated structure and the following minerals: hornblende, generally in somewhat elongated prisms, but hardly actinolites, well cleaved, and a rich green in colour; biotite in flakes, comparable in size with the other, variable in amount; secondary felspar; perhaps a little quartz; some epidote, iron-oxide (certainly ilmenite in one case), calcite (rather abundant in one specimen), rutile (rather frequent in another), and one or two accessories. These specimens do not suggest, like the others described above, a 'rebuilding' of hornblende or biotite on a large scale.

and, in some instances, to occur whe re the included felspar-granul are more abundant than is usual. Hence I infer that we may account for them in the following way:—Whenever hornblende and felspar, especially if intimately mingled, were in contact and in a rather unstable condition,[1] the ferromagnesian constituents of the former, and the alkaline-aluminous of the latter, might be combined to produce biotite, for the last-named is often the offspring of the other two minerals.[2] The larger biotites, however, may result from the reunion of the minerals of an original but crushed-up crystal. The frequent occurrence of flakes, the basal planes of which make high angles with the cleavage-foliation, suggests that often they did not begin to form till the pressure had been relaxed.

The more or less actinolitic hornblende may be thus explained. This shape, as I have already shown, is commonly assumed when the mineral crystallizes under a pressure definite in direction.[3] But in this case something more has to be explained. Acicular or lancet-shaped crystals, often 2 inches long, occasionally more, form bunches, which sometimes diverge from a centre in opposite directions (see figs. 2–4, pp. 362–363). The finest examples of this structure lie in the planes of cleavage-foliation, though some occur, especially if the crystals are more lancet-shaped, with different orientations, probably when that foliation is not very distinct. A single instance may suffice to present the problem to be solved. A flattish crystal of hornblende, about $\frac{1}{8}$ inch wide, splits up into a group like the sticks of a partly-opened fan: the ends of the outermost, at the distance of an inch or a little more from the beginning, being a good $\frac{1}{4}$ inch apart (and sometimes even more), while a considerable space on either side is quite free from hornblende. Was the powder of that mineral spread rather abundantly over an area shaped like an acute-angled triangle, or, if it were more uniformly disseminated through the mass, could it be forced to concentrate along certain lines? Which mode of distribution is the more probable? Suppose an ordinary, moderately coarse diorite to be simply crushed; then a number of patches of powdered hornblende and felspar will be formed, rudely ellipsoidal in shape and elongated considerably in the direction of least resistance.[4] If shearing also occurs, the result will be somewhat similar, but the patches will be much longer. They will be drawn out in streaks, perhaps with more mixing of constituents. This would explain the coincidence of long actinolites with the cleavage-foliation, but not their occurrence in fan-shaped groups or the rather frequent presence of fair-sized crystals at high angles with that structure. Moreover, so far as

[1] This might depend on differences of temperature in the mass or in the amount of water present.

[2] That this does occur has been already shown (though in that case the circumstances were different): Hill & Bonney, Quart. Journ. Geol. Soc. vol. xlviii (1892) pp. 127–132.

[3] Quart. Journ. Geol. Soc. vol. xlix (1893) p. 94 & vol. l (1894) p. 279.

[4] As in the case of ordinary cleavage.

we can infer from the other constituents, the amount of shearing has not been great. Hence it seems more probable that, when a crystal has begun to form, it can bring together its constituents from some distance, even when the rock is in a powdered condition. Such an occurrence is familiar enough in a molten rock, but in the cases before us the constituents must travel rather as particles in suspension than as molecules in solution.[1] The force of crystallization, if the term be permissible, must act, like gravitation, across space; it may be more aptly compared with magnetism, for it is selective in action, and perhaps capable of being excited by certain conditions. I mean that it is active when crystal-building is going on, but is at other times, as it were, dormant. This seems to me the 'how'; as to the 'why' it is better, I think, to confess ignorance than to try to mask this under long words. How, then, shall we account for the divergent habits of the actinolites? I have elsewhere shown[2] that hornblende under severe pressure tends to assume an acicular form, and we can understand the needles developing in the planes of cleavage-foliation as those of least resistance, but this is not all. The stouter crystals, as I have already said, have a tendency to run into slightly diverging needles at their ends, while the longer resemble the sticks of a half-opened fan. I infer from what I have seen in the field and under the microscope that when the forces which operate in crystal-building are unequal, when 'growth' is more easy in the direction of any axis, the tendency to unequal development is exaggerated by obstruction. Now a crystal of ordinary hornblende is commonly rather elongated in the direction of the vertical axis; hence, when it has to encounter opposition in growing, as, for instance, to force its way through powdered rock, the crystal will lengthen much more rapidly than it will thicken, and this tendency will be exaggerated if the vertical axis happen to lie in the plane of easiest development—namely, that of cleavage-foliation. Should the crystal encounter obstacles as it enlarges, these may be pushed aside if small enough, or incorporated with it, as we so often see, or they may cause it to branch into either divergent needles or root-like processes. The results will be either tufted forms, or some kind of skeletal crystal, or a micrographic structure. To an influence of this kind I attribute the frost-flowers on glass and some of the mineral structures called dendritic.

The effects of crystallization in the presence of obstacles of slightly larger size are often exhibited when a film of mud covering a sandstone-flagged pavement is frozen. If the film be thin, it produces coarse and rather large frost-flowers; if thick, groups of tufted and branching crystals, with a general resemblance in size and shape to the actinolites in the above-described rocks, but, as might be expected under the circumstances, more closely connected together. In order to test this idea, Miss Raisin, who has been

[1] The segregation of powdered flint from china-clay (Sedgwick, Trans. Geol. Soc. ser. 2, vol. iii, pt. iii, 1835, p. 461) and the 'kernel-roasting' of copper-ore to some extent illustrate the same propensity.

[2] Quart. Journ. Geol. Soc. vol. xlix (1893) p. 94.

investigating the nature of certain forms assumed by pigments in drying, undertook some experiments with substances which readily crystallize. As these will be shortly published,[1] I restrict myself to stating the general results. In crystallization from a simple solution, the larger and better-developed crystals occur near the edge of the drop, and by this, apparently, their direction of growth is to some extent determined. In the interior they are apt to be smaller in size and more confusedly scattered. In crystallization among a uniformly-obstructing medium (such as gelatine), or sometimes from a thin mixture of a pigment like Prussian blue, the same rule generally held near the edge, but the crystals in the interior were larger, better developed, and more definitely grouped,[2] showing a marked tendency to branching and to growing on a 'fern-leaf' pattern. With a thicker mixture of a pigment (especially if it were slightly coarser) the crystals were yet larger and often more roughly formed, growing in straight lines with frequent bifurcations which diverged at low angles, or forming tufted growths; in fact they approached more nearly to the habit of the actinolite described above.[3] But when a still larger amount of pigment was mixed in the solution, then the crystals, so far as could be judged from an examination with reflected light (for the material practically was no longer translucent), became smaller again and formed a confusedly-matted mass, though in this the 'actinolitic' habit was still perceptible. Thus I believe that the peculiar shapes of these secondary actinolites are in reality a record of past episodes in the history of the rock—that they were formed after it had been largely pulverized, but before reconsolidation had taken place, and perhaps under considerable pressure.

V. Connexion of Changes with Earth-movements.

One question remains: When did this reconstruction of the 'Tremola Schists' take place? Was it the result of one of the two great earth-movements which produced the existing Alpine chain, or should it be assigned to an earlier date? That such movements also occurred in pre-Triassic and even in pre-Carboniferous times is certain.[4] Fragments of schists from the 'Upper Group,' as I have more than once described, occur in the Triassic rauchwacke and can hardly be distinguished from specimens which may be collected *in situ* in the immediate neighbourhood. But these Tremola Schists also yield some indirect evidence. Though

[1] [They have now (June 24th) appeared in Proc. Roy. Soc. vol. lxiii, p. 217.]

[2] We might say that the struggle for existence led to a survival of the fittest.

[3] On this subject a considerable amount of literature exists, from which the following is a selection: Lehmann, Zeitschr. für Kryst. etc. vol. i (1877) p. 453; H. J. Slack, Trans. Roy. Micr. Soc. vol. v (1871) p. 115; H. Vater (on Calcite), Zeitschr. für Kryst. etc. vols. xxi, xxii, xxiv, xxvii (1892–96), five parts.

[4] Alpine Journ. vol. xiv, p. 38, etc.; Quart. Journ. Geol. Soc. vol. xlvi (1890) p. 204.

certain of them are rather fissile, they are, as a general rule, fairly well consolidated: the minerals of the groundmass presenting a mosaic structure, usually without any obvious indication of crushing. The same remark holds good, so far as I have examined them, of the other gneisses and schists (including the granitoid mass called the Fibbia Gneiss) on the upper part of the St. Gothard Pass; but the gneisses on the northern side of the great trough occupied by the head-waters of the Reuss and Rhone exhibit much more distinct signs of having been crushed. Parts of the felspars have indeed been replaced by minute white mica and free quartz, but the reconstruction here is less complete than in the case of the Tremola Schists. Again, while the general trend of the great rock-masses at the St. Gothard is not far from west to east, the strike of the apparent bedding and the cleavage-foliation in the Tremola Schists generally varies from N.E. to N.N.E., a strike indeed which, as it has been more than once observed, is sometimes very marked, and can be detected at intervals, in almost every part of the Alpine chain. This structure, for reasons already published, I regard as pre-Triassic. Hence I think it probable that the Tremola Schists attained very nearly to their present condition at a date prior to the mountain-making of the existing Alpine system.

Discussion.

Gen. McMahon remarked on the important character of this communication. The Author had added to the list of rocks originally regarded as sedimentary but now proved to be of igneous origin. The influence of fluxion-movements on an igneous rock prior to consolidation, especially when more or less magmatic differentiation, or the injection of one rock by another igneous rock, had taken place, was receiving more and more recognition. This action had recently received a beautiful illustration in the experiments of Mr. H. S. Hele-Shaw:—colouring-matter injected into flowing water curving round obstacles, and imitating in a remarkable way the foliation of gneissic and banded rocks. The Author had also proved in his paper that the structure now to be seen in rocks was sometimes the result of complex causes: the production of secondary mica being subsequently superinduced by pressure on a rock whose main structural features were due to causes operating prior to consolidation. Garnets were one of the most common products of contact-metamorphism, but they were also present in many igneous rocks as original constituents, as shown by their sometimes containing such igneous minerals as beryl; he therefore had no doubt that the Author was correct in regarding, as he understood him to do, the garnets in the rock described as original minerals.

Prof. Watts was glad to hear it conceded that the bulk of the Tremola Schists were originally igneous rocks. In reference to a remark made by the previous speaker, he wished to observe that while the earlier advocates of dynamo-metamorphism may have been wrong in attributing too much to pressure, all recent papers on the subject agreed that a great deal of the effect was due to this agency. To this rule the present paper was no exception.

Prof. Judd also spoke.

The Author expressed his thanks to the speakers for the reception which they had given to his paper, and stated that he did hold the garnets to be original minerals, for they frequently occurred in igneous rocks in cases where there was a local deficiency of alkaline constituents. He by no means denied that pressure was an important agent in producing mineral change, yet he thought that these and many other rocks exhibited structures which could not be attributed to it, but must be due to fluxional movement during cooling, if they were not due to metamorphism of banded sediments.

28. *On the* Metamorphism *of a* Series *of* Grits *and* Shales *in* Northern Anglesey. By Charles Callaway, M.A., D.Sc., F.G.S. (Read May 18th, 1898.)

In a recent paper[1] read before this Society, I endeavoured to show that certain gneisses in Southern Anglesey were formed out of plutonic rocks. Fragments of these gneisses have been identified[2] in younger pre-Cambrian strata, lying to the north, and these, in their turn, yield an abundance of rounded derivatives[3] to the basal Palæozoic conglomerates of the island. These newer pre-Cambrians, which I have provisionally referred to the Pebidian system,[4] display great variations in their degree of crystallization. Hence arises one of the chief difficulties in unravelling the geology of Anglesey. It has become increasingly evident that the questions still in dispute in this complicated area can be settled only by (1) carefully mapping the ground in minute detail, and (2) determining the nature and degree of alteration which many of the rocks have undergone. Mr. Edward Greenly has devoted himself with great enthusiasm to the former task, and the first-fruits[5] of his work promise highly satisfactory results. The present paper is offered as a further contribution to the series of problems arising under the latter head. It is here proposed to examine a series of grits and shales in Northern Anglesey, and to show that they are transformed into true crystalline schists as we follow them in a southerly direction.

I. The Area described.

North and north-west of Amlwch the ground is much disturbed and mixed up with faulted fragments of Palæozoic strata. To avoid controversial topics,[6] I shall confine myself to a patch about 3 miles square, lying south-west of Amlwch, extending north and south from Llanfechell and Rhosbeirio to the boundary-fault near Melin Pant-y-Gwydd and Pant-y-Glo, and west and east from Mynyd Mechell to Bodewryd. Over this area the rocks appear to be unbroken by faults, and exposures are fairly abundant.

I originally[7] divided the rocks of this district, taking them from south to north, into (1) Chloritic Schists of Mynydd Mechell, (2) Llanfechell Grits, (3) Rhosbeirio Shales; and I am disposed to conclude that the strata form an ascending series. The usual dip

[1] Quart. Journ. Geol. Soc. vol. liii (1897) p. 349.
[2] *Ibid.* vol. xxxvii (1881) p. 235. [3] *Ibid.* vol. xl (1884) pp. 568, 571, 578.
[4] *Ibid.* vol. xxxvii (1881) p. 232. [5] *Ibid.* vol. lii (1896) p. 618.
[[6] I refer especially to the connexion alleged by Prof. Hughes to exist between these rocks and the fossiliferous strata at Porthwen ('Geol. of Anglesey,' Quart. Journ. Geol. Soc. vol. xxxvi, 1880, p. 237, & vol. xxxviii, 1882, p. 16), and to the subsequent criticisms of the Rev. J. F. Blake (Quart. Journ. Geol. Soc. vol. xliv, 1888, p. 521). See also Hughes in Rep. Brit. Assoc. (York) 1881, p. 644.]
[7] Quart. Journ. Geol. Soc. vol. xxxvii (1881) p. 223.

is to the north, or a little east of north, and there is a clear change in the nature of the sediment as we go northwards. The lowest group is highly quartzose and gritty. In the middle, around Llanfechell, there is a considerable admixture of softer beds, which I have described as hypometamorphic shales; while at the summit of the series the shaly strata predominate, with gritty seams in subordinate proportion. The almost uniform northerly dip might of course have been produced by excessive pressure causing overfolding or overthrust, but of this there is no evidence, and it may be fairly concluded that the series is regular and ascending from south to north. This, however, is a minor point, and has no material bearing on my main contention.

II. The Metamorphism as seen in the Field.

The highest beds are well exposed in quarries and natural sections around Rhosbeirio. They consist of purple, yellow, and pale-green shales,[1] with intercalated bands of grit. The dip is at moderate angles, and there are no signs of contortion or dislocation. A slight glistening on lamination-surfaces indicates some alteration, and suggests the use of the term 'hypometamorphic.'

Beds of an intermediate character form the underlying horizon. They can be studied around Llanfechell. The grits do not greatly differ from those at Rhosbeirio, but the softer seams display a distinct micaceous or chloritic lustre. Similar beds are exposed along the easterly strike at Nant-y-Cyntin. Farther east, a short distance south of Rhosbeirio, rocks resembling the Rhosbeirio Shales and Grits are seen in a quarry at Bodewryd Newydd. They are slightly contorted in places, and these contorted seams are more schist-like than the shales.

The lowest beds of the series are conspicuously gritty. Indeed, they were originally described by Ramsay[2] as 'foliated grits.' Intercalated with the coarser seams are bands of a well-foliated micaceous or chloritic schist, the micaceous constituent evidently predominating. Near Cas Clock, for example, the schist is highly foliated, and displays a silvery lustre. Nearly everywhere in these gritty rocks the contortion is strongly marked.

Excellent sections are exposed at Pant-y-Glo, and these may be taken as typical of the lowest series. They are also of critical importance, as bearing on the question of metamorphism. The strata consist predominantly of hard green grits, showing a laminated structure, and evidently much compressed. That they were once ordinary sediments will be shown by microscopic evidence. Intercalated with them are seams of perfectly foliated glistening schist. So closely associated are these schists with the grits that a common origin must be predicated for both.

[1] The partially volcanic origin of the Anglesey Pebidians was noticed in my paper in this Journal, vol. xxxvii (1881), and subsequently by the Rev. J. F. Blake, in 1888.

[2] Mem. Geol. Surv. vol. iii (1866) 'Geol. of North Wales,' p. 184.

It will have been noticed that the signs of compression and contortion become more marked as we descend in the series, and the suggestion arises that a causal connexion exists between the increased metamorphism and the increased pressure. This point will be discussed after the microscopic evidence has been presented.

III. Microscopic Evidence of the Metamorphism.

Some of the rocks of this area were microscopically described by Prof. Bonney in an Appendix [1] to one of my papers on the Archæan Geology of Anglesey. These specimens were placed by him in two distinct groups: (1) 'Slaty and other not highly altered Rocks,' (2) 'Chlorite Schists.' As the object of this paper is to prove that the latter are a more highly altered phase of the former, it will be well to reproduce Prof. Bonney's very succinct descriptions of a few of the varieties.

The following is fairly typical of the former group:—'47 (Llanfechell). A coarser fragmental rock with a rather streaky structure, not unlike some of those which occur in the Borrowdale Series, containing numerous microliths of the viridite group, some being certainly chlorite. The aspect of the rock suggests that it has undergone considerable pressure. Many of the embedded fragments are from about 0·03 to 0·06 inch in longer diameter. Among them quartz, felspar, altered biotite (?), and a chloritic quartz-schist may be recognized, detrital materials almost certainly derived from the older gneissic and schist-rocks of this region of North Wales. Other fragments of a less certain character are present, with grains of decomposed ilmenite or magnetite and of epidote, which perhaps has replaced some other mineral.'

This specimen belongs to the middle group, and is rather more crystalline than the gritty seams in the Rhosbeirio Shales.

The next two slides (45, 46) belong to the second division, and are placed by Prof. Bonney under the head of 'a group of highly altered, distinctly-foliated rocks, consisting mainly of rather minutely-crystalline chlorite and quartz.' Of No. 45 he writes:—'chloritic constituent rather minute,' and of No. 46, 'highly altered and markedly foliated.'

A series of slides from Rhosbeirio, Llanfechell, Pant-y-Glo, and intermediate localities, links together the fragmental rocks with the true schists. The gradation is seen in both the fragments and the matrix.

The fragments in the grits are mainly of quartz, but in some of the slides felspar, both twinned and untwinned, is fairly abundant. The bits of schist referred to by Prof. Bonney are rare, but flakes of a clear minutely granular rock are scattered here and there. The quartz is usually angular, and the felspar-crystals are rarely, if ever, unbroken. The shaly seams in the grits, as well as the Rhosbeirio Shales, often contain fragments of quartz and felspar, but they are usually very minute.

[1] Quart. Journ. Geol. Soc. vol. xxxvii (1881) pp. 232–234.

The change in the quartz consists chiefly in the replacement of the angular fragments by granular particles fitting into each other with foliate interlocking margins, as in a normal schist. This alteration sometimes takes place, even where there are but slight traces of pressure. The particles and fragments have evidently been softened by heat, and more or less compressed, the angularities being thus obliterated, and the grains moulded into each other and welded together. This change, of course, implies contact between the fragments. Where portions of the matrix remain between them the welding is less complete. Sometimes angular particles of clear mineral are entirely immersed in a soft matrix of mica or chlorite, and still retain their sharp outlines even in the most crystalline of the schists. This feature is of especial interest, since it furnishes us with evidence of an original clastic structure where we do not usually expect to find it.

In places were the rock has been intensely crushed and sheared, patches of fragmental quartz and felspar have been rolled out into distinct folia, sharply differentiated from the micaceous and chloritic matrix, which then ceases to exist *qua* matrix, and becomes a normal constituent in a true foliated schist.

The matrix, even in the least altered varieties of grit and shale, has undergone some alteration. It consists chiefly of a green mineral of the chlorite family, or of a minute felt-work of transparent mica, or of a mixture of the two. There is in some slides a moderate quantity of opaque dusty matter, presumably iron-oxide. Occasionally epidote is present.

The progressive change in the chlorite and the mica takes the form of enlargement. The streaks and blotches of the former grow larger; the films of the latter become larger, thicker, and more distinct, polarizing more and more clearly in the brilliant colours of a white mica.

The best microscopic specimens for the study of this question are from the quarries at Pant-y-Glo. Four slides have been cut. In all of them we can see that the quartz and felspar have assumed to a greater or less extent the mosaic structure, yet all the slides display distinct traces of a fragmental origin, wherever the matrix has kept the clear particles from touching each other. These are the two points which are chiefly kept in view in the following descriptions.

No. 450.[1]—More than three-fourths of this slide consists of quartz. Next come, in the order of their abundance, chlorite, epidote, opacite, and felspar. The quartz presents the chief points of interest. Large irregular fragments of it are scattered throughout the specimen, and all of them are angular and well-defined, but occasionally they pass, at one side, into granular aggregates. There is also present a great deal of minute quartz in the granular condition, the particles interlocking with sinuate contours, forming

[1] The numbers are those of the slides preserved in my cabinet.

aggregates similar to those just noticed. Mixed up with the chlorite and other interstitial matter, there is a fair proportion of quartz in very small angular fragments. It can hardly be doubted that the minutely granular aggregates consist of small fragments of quartz and a little felspar, which have coalesced under the influence of heat and pressure; while the angular particles embedded in the matrix are original fragments which have been kept asunder, and protected by their soft environment. The pressure to which this rock has been subjected has been comparatively slight.

No. 449.—This slide also is very quartzose, and the other constituents are similar, except that a little white mica is present, and

Fig. 1.—*Schist from Pant-y-Glo* (*No. 449*).

× 45.

[Alteration partial; quartz-fragments conspicuous, some of them tailing off into mosaic. The minute quartz is often coalescent. White mica (not fragmental) is present in small proportion.]

there is less epidote. This rock has been compressed to a moderate degree, so that a distinct schistosity is produced, and this is strongly accentuated by the mica. Many of the larger quartz-fragments are still quite sharp and angular, lying for the most part with their longer axes parallel to the foliation; but some of them have apparently been converted into granular mosaic. A few of them tail off in one direction into mosaic, as if the thinner end of the fragment had yielded to the heat, while the main part of it had resisted. Minute particles of quartz surrounded by matrix are still angular.

No. 448.—Alteration greater, and schistosity more strongly marked. Contortion very intense, some of the micaceous folia being twisted and sheared again and again within the length of $\frac{1}{8}$ inch. The quartz-seams are perfectly granular. Some of them extend across the slide, others form short lenticles. There are no large fragments in this specimen. The folia between the quartzose seams are highly micaceous and chloritic, and embedded in them are numerous minute bits of quartz, many of which are perfectly angular.

Fig. 2.—*Schist from Pant-y-Glo (No. 448).*

× 45.

[Alteration more advanced. A 'folium' of chlorite, white mica, and clastic quartz is seen to intervene between two folia of quartz-mosaic.]

No. 447.—Similar, but more micaceous. The minute quartz-fragments are much less abundant, but still quite evident. (See fig. 3, p. 380.)

It is possible that the granular quartzose aggregates in these slides contain some felspar, but the minuteness of the particles renders the application of optical tests extremely difficult. Hardly any fragmental felspar appears in the more schistose varieties.

I am not prepared to offer a complete theory on the genesis of the metamorphism. In a general way, it is true that the alteration has proceeded *pari passu* with the pressure. The most highly-metamorphosed varieties of schist are contorted on both the large and on the small scale, and sheared on the minute scale. Yet, on the other hand, one of the slides (450) [1] from the Pant-y-Glo section is hardly compressed at all, though much of the minute quartz has acquired the granular structure. It is true that the bulk of the rock in this locality is contorted, so that it may be suggested that the heat which took part in the alteration of No. 450 was generated by mechanical pressure. But this explanation will not cover the whole of the facts. The Rhosbeirio Shales exhibit signs of only very moderate pressure, yet the matrix has undergone considerable alteration, and some of the minute quartz has become granulated.

Fig. 3.—*Schist from Pant-y-Glo* (*No. 447*).

× 60.

[Alteration still more advanced. A few angular fragments of quartz are visible, however, in the contorted meshwork of chlorite and mica.]

While, therefore, it would seem that mechanical force has been concerned in producing the more intense metamorphism of the lower part of the series, I am not disposed to advance this as the sole cause of the changes produced. This uncertainty, however, does not affect my main thesis—that the Mynydd Mechell schists have been formed by the metamorphism of rocks which were at one time sedimentary strata, and not plutonic masses.

[1] Prof. Bonney was kind enough to examine some of the principal rock-sections of this series, and he expressed his general agreement with my conclusions. The uncompressed condition of No. 450 attracted his special attention, and led him to suggest extreme caution in theorizing.

IV. Summary.

(1) The crystalline schists of the region south-west of Amlwch have been formed out of grits and shales.

(2) The metamorphism is chiefly seen in the coalescence of angular fragments of quartz and felspar to form granular mosaic, and in the enlargement of the chloritic and micaceous films constituting the matrix of the fragments.

(3) The metamorphism is most intense where the rock has been subjected to the greatest pressure, but it has proceeded to a less advanced phase where pressure has been apparently wanting, and the causes of the metamorphism are therefore not completely ascertained.

Discussion.

Prof. Bonney said that his opinion, expressed to the Author, was simply founded on the slices sent to him, for he did not know the district; that as metamorphism was dependent partly on the composition, partly on the environment of rocks, it was possible that rocks considerably changed might occur with those rocks which were slightly metamorphosed. At the same time, allowance must be made for the illusory effect of thrust-faults.

Prof. Hughes said that he had many years ago brought before the Society reasons for believing that the beds now described by Dr. Callaway were sedimentary deposits altered by crush. In the shaly portions differential movements between the particles had produced silky slates. In the gritty portions, where the rock was of an unyielding character, the grains, which were only minute pebbles, indented one another. Where the shaly beds were thin and were contained between unyielding rocks, the freedom of vertica or other compensation-movements was restricted, and puckering instead of cleavage resulted. He thought that some of the beds contained much volcanic material which lent itself in different manner and degree to metamorphism, whether that was due chiefly to pressure or partly also to the heat evolved by the movements. He had also drawn attention to the fossils which were found in schists, similar in character to, if not of exactly the same age as, those which occurred on the northern coast of the island.

The Author said that he could not agree with the last speaker that slickensides were concerned with the metamorphism, or that the softer rocks were more highly altered than the harder—in fact, it was the more gritty bands that had undergone the greatest change

29. *The* Carboniferous Limestone *of the* Country *around* Llandudno (North Wales). By G. H. Morton, Esq., F.G.S. (Read May 4th, 1898.)

I. Great Orme's Head.

The Carboniferous Limestone, and the subdivisions into which it is divided in North Wales, were described in papers read before the British Association and the Liverpool Geological Society between the years 1870 and 1898. The most recent paper on 'The Carboniferous Limestone of the Vale of Clwyd,' is in the Proc. L'pool Geol. Soc. vol. viii, 1897–98. It contains a description of the subdivisions of the Limestone, including the Purple Sandstone, which consists of a series of sandstones and shales described by Mr. George Maw in 1865 as Permian,[1] and more recently by Mr. Aubrey Strahan in 1890 as Coal Measures.[2]

The following table shows the subdivisions that occur in the Vale of Clwyd, and in two other areas previously described. The Purple Sandstone is shown to be on the horizon of the highest subdivision of the Carboniferous Limestone in Flintshire and Denbighshire:—

Vale of Clwyd.	*Prestatyn and Holywell.*	*Mold and Llangollen.*
Purple Sandstone.	Upper Black Limestone.	Arenaceous Limestone.
Upper Grey Limestone.	Upper Grey Limestone.	Upper Grey Limestone.
Middle White Limestone.	Middle White Limestone.	Middle White Limestone.
Lower Brown Limestone.	Lower Brown Limestone.	Lower Brown Limestone.
Red Basement Beds.	Red Basement Beds.	Red Basement Beds.

The Great Orme's Head is a prominent headland on the seacoast of Caernarvonshire. It is separated from the mainland by an isthmus a mile in width and about 20 feet above Ordnance datum, and must have formed an island in post-Glacial times. Llandudno, the well-known watering-place, is situated on the southeast, and principally on the alluvial land. The Head is 2 miles in length from east to west, and 1 mile from north to south; it is bounded on the north and west by precipitous cliffs, which rise from the sea-level to an elevation of 200 or 300 feet. Along the southeastern side there is a fringe of Boulder Clay, but the limestone rises with a steep escarpment at 50 or 100 yards from the seamargin. On the terrace of drift are the ruins of Gogarth Abbey, about 50 feet above the sea. The highest point is close to the Telegraph, 679 feet above Ordnance datum; St. Tudno's Church, called after the patron saint of the Head, is near the northern cliff, and is 332½ feet above sea-level. At the extreme north is the Lighthouse, about 200 feet in elevation. A drive has been constructed all round the Head, varying from 100 to 200 feet above the sea along the face of the cliff. The surface on the top of the

[1] Rep. Brit. Assoc. (B'gham) 1865, p. 67; Geol. Mag. 1865, pp. 380 & 523.
[2] Mem. Geol. Surv. 1890, 'Geol. of Flint, Mold, & Ruthin,' p. 11.

Great Orme's Head is of an undulating character, and the limestone being continuously exposed in terraced cliffs, weathered surfaces, and quarries, the strata may be examined over the entire extent of the headland.

Mr. Robert Hunt, in his 'British Mining,' 1884, states that 'the Romans found copper in the Great Orme's Head, and worked it extensively. In Llandudno, when digging for the foundations of buildings, the modern excavators have come upon the soil of the Roman level, coloured by the washings of the ore.' He also states that implements of waterworn stone, horn, and bronze have been discovered on both the Great Orme's Head and at Llandudno. Copper seems to have been the principal, if not the only ore obtained, but the work was discontinued about 30 years ago. The mines were still worked in 1859, for in that year I obtained specimens of crystallized chalcopyrite or pearlspar from the miners. According to the map of the Geological Survey, there are four north-and-south lodes running parallel for about $\frac{1}{2}$ mile, and all within 200 yards from east to west. Sir A. Ramsay states that black shales were reached in the old mine-shafts, and possibly belonged to the Llandeilo or Bala Beds beneath the limestone.[1] This may have been at the depth of 400 or 500 feet, but the position of the shafts referred to is now unknown.

There is no plan of the outcrop of the lodes, and no information as to the workings is available at Llandudno. The only such ground-plan is one preserved at the Home Office, and it shows the four lodes running exactly north and south, with two cross-veins striking N.N.W. intersecting and heaving the older veins out of their course. Another cross-vein, running north-east, does not disturb the others, and they are all shown in the accompanying reduced copy (fig. 1, p. 384) from a tracing of the original plan, which also comprises two other plans, showing the heaving of the veins and the distribution of the ore. I am indebted to Prof. C. Le Neve Foster, H.M. Inspector of Mines, who resides at Llandudno, for facilities in obtaining access to the plan here described.

Mr. Hunt's description of the veins is the only published account, and from his work it appears that they were alone productive in the crystalline rock, and always associated with it, but the term 'dolomite' is not used. The crystalline and the non-crystalline beds, he states, alternate with much regularity, and the productive character of the veins changes with that of the rock. When the four principal veins are crossed by others, and the intersection occurs in the crystalline rock, the deposit of copper pyrites is greatest. The ore occurs all through the crystalline rock, but the veins can scarcely be traced far into the ordinary limestone, and this explains the occurrence of so many trial-holes which do not seem to have led to any profitable result. These holes were evidently sunk along the supposed northern prolongation of the four principal lodes; but although the limestone is often exposed, no veins or fissures are

[1] Mem. Geol. Surv. vol. iii, 'Geol. of North Wales,' 2nd ed. (1881) p. 308.

visible. The de̍bris from the old shafts consist principally of dolomite containing pearlspar, calcite, cerusite, chalcopyrite, malachite, and anthracite, associated with green carbonate of copper impregnating the dolomite and often coating the crystals of chalcopyrite.

Fig. 1.—*Plan of lodes at Great Orme's Head.*

[Scale: 1 inch=about 175 yards. The dotted oblique vein is small, and bears no copper, but has the effect of a cross-course on the north-and-south lodes.]

There are very few faults in the limestone, and they seem to have had little influence on the varying dip of the strata. To any one sailing round the Great Orme's Head the general horizontality of the strata is remarkable, except on the east, where the beds are seen to bend upwards at an angle of 30°, and expose the lowest in the cliffs about the Happy Valley, the Pier and the higher portion of Llandudno, and Pen Morfa Lodge. Along the northern cliff the beds generally dip to the east at angles of from 5° to 10°, but the inclination varies with the undulation of the strata, and the rocks are often seen to dip in other directions. The constant exposure of the limestone rendered it easy to work out the subdivisions, and to show the area of each on the map of Great Orme's Head (fig. 2, p. 386). Unfortunately, the actual base of the Carboniferous Limestone is not exposed, and the highest beds have been denuded. The following synopsis shows the subdivisions that occur and the probable thickness of each :—

			Feet
Upper Grey Limestone, with 18 feet of shale at the base			200
Middle White Limestone	Upper beds, with 20 feet of rubble and shale at the base.	300	550
	Lower beds, with 7 feet of black shale at the base.	250	
Lower Brown Limestone or Dolomite			400
			1150

Compared with the Carboniferous Limestone for 50 miles to the south-east this section is remarkable, for with the exception of the outcrop of Little Orme's Head the Lower Brown Limestone is not composed of dolomite, either about Llandulas, the Vale of Clwyd, or in the country around Holywell, Mold, and Llangollen. There is no indication of the Red Basement Beds around Llandudno, although they are well exposed near Llandulas and in Anglesey.

The highest beds of the Upper Grey Limestone at the top of the Head have been denuded, and there is no trace of the succeeding Upper Black Limestone of Prestatyn, or of the Purple Sandstone of the Vale of Clwyd, both of which are on about the same horizon.

(1) Lower Brown Limestone.

Although I have not been able to find the base of the limestone anywhere about Llandudno, Mr. H. C. Beasley happened to see an excavation for the foundation of a house, on the north side of Chapel Walks, in April 1886, and he recorded the following section of the beds, which dipped to the north-west:—

Section at Llandudno

	Feet
Thin sandy beds alternating with limestone	3 to 4
Soft calcareous sandstone, with plant-stem	1
Fine-grained limestone, with one or two subangular, hard, black pebbles	1 to 2
Breccia of subangular pebbles, very firmly cemented together—the upper surface of the bed very uneven	1
Limestone	?

The section seems to have been on the south side of the supposed fault running W.N.W. and nearly parallel with the 'Old Road' which runs up the hill from Llandudno. As no such section occurs on the beach about the Pier, it seems certain that the beds that were exposed are nearer the base of the Lower Brown Limestone, and that they may have been brought up by the fault just mentioned. It is fortunate that the observation was so carefully made, as there is only a remote chance of any such exposure being seen again. Mr. Beasley found the following fossils in the excavation:—*Bellerophon* sp., *Productus Cora*, *Spirifera glabra*, and *Lepidodendron* (?), and they were submitted to me for determination. In a 'Guide to Llandudno,' by John Heywood (undated), it is stated that 'In an old quarry, once a sea-beach, at the foot of Great Orme, near Church Walks, *Stigmaria* and *Lepidodendron* may be found *in situ*,' and this no doubt relates to the same exposure.

The Lower Brown Limestone or Dolomite is the lowest subdivision at Great Orme's Head. It is well exposed in the precipitous cliffs above Llandudno, on the road above the Pavilion to the Happy Valley, and at the Flagstaff 100 yards north of the Lodge. The rock varies from a coarse to a fine-grained dolomite, which in many places simulates a mass of coral, and there are frequent drusy cavities containing crystals of pearlspar. It closely resembles the Permian limestone of Sunderland, and is of the same massive and crystalline character.

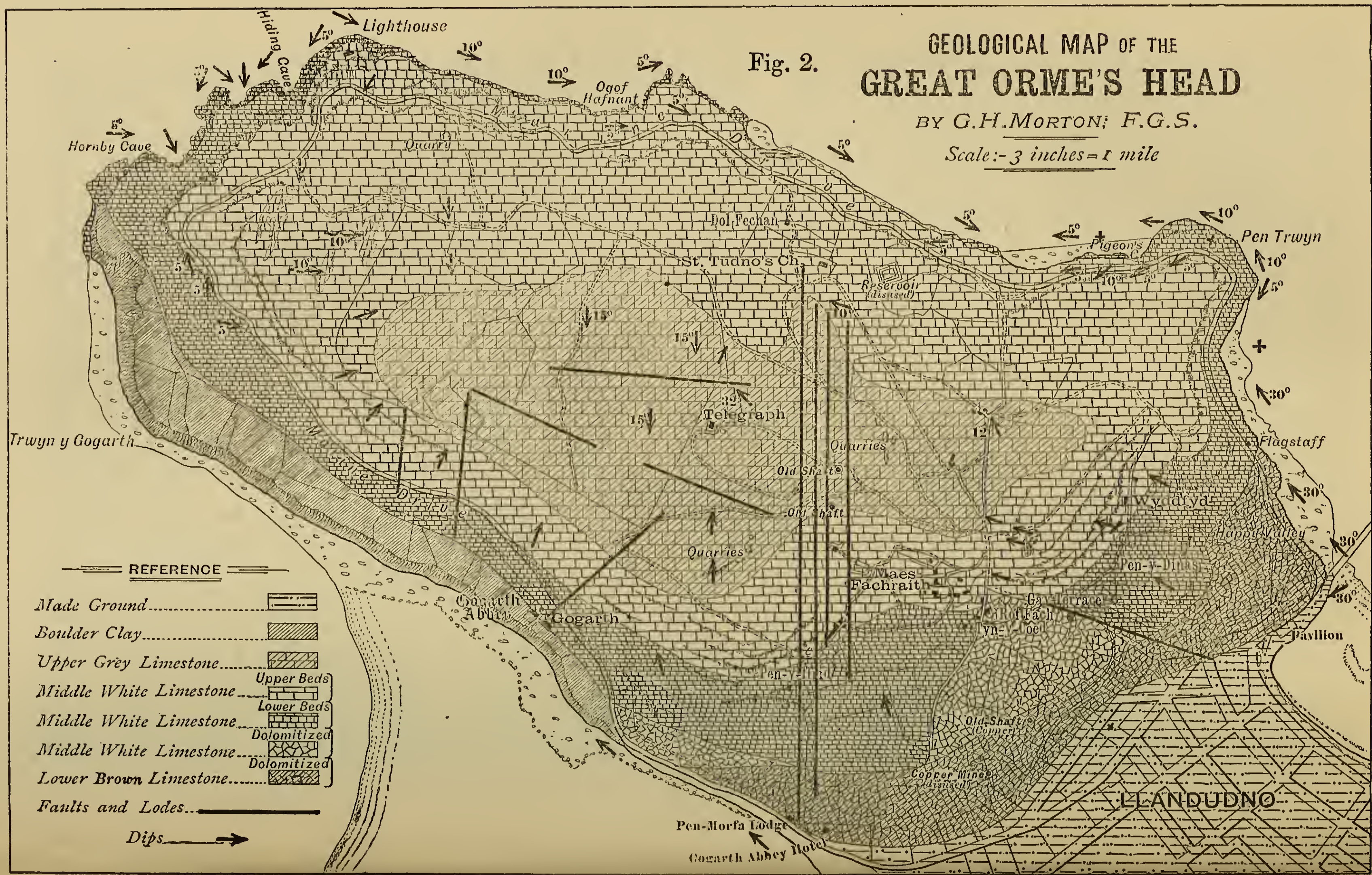


Fig. 2.
GEOLOGICAL MAP OF THE
GREAT ORME'S HEAD
BY G.H.MORTON; F.G.S.
Scale:- 3 inches = 1 mile
Lighthouse
Hiding Cave
Hornby Cave
Ogof Hafnant
Quarry
Dol Fechan
St. Tudno's Ch.
Reservoir (disused)
Pigeon's C.
Pen Trwyn
Telegraph
Quarries
Old Shaft
Trwyn y Gogarth
Flagstaff
Wyddfyd
Happy Valley
Pen-y-Dinas
Maes Fachraith
Gogarth Abbey
Gogarth
Tyn-y-Coed
Old Shaft (Copper)
Copper Mines (disused)
Pavilion
LLANDUDNO
Pen-Morfa Lodge
Gogarth Abbey Hotel
REFERENCE
Made Ground
Boulder Clay
Upper Grey Limestone
Middle White Limestone — Upper Beds
Middle White Limestone — Lower Beds
Middle White Limestone — Dolomitized
Lower Brown Limestone — Dolomitized
Faults and Lodes
Dips

The following analysis was kindly made for me by Mr. H. Fairrie at Dr. George Tate's College of Chemistry, Liverpool:—

	Per cent.
Lime	27·78
Magnesia	22·83
Iron protoxide (FeO)	·48
Iron sesquioxide (Fe_2O_3)	·59
Silica	·40
Water	·69
Carbon dioxide	47·23
	100·00

From the above the percentage of the carbonates is seen to be:—

Carbonate of lime	49·60
„ magnesia	47·95

The original bedding is preserved, but there is little or no shale between the beds. Fossils seldom occur, and then only in the upper surface of the beds, but at the bottom of the wooden steps down to the beach, just beyond the Pier, are two or three beds of limestone, interstratified with the dolomite, containing *Syringopora ramulosa* and the stems of encrinites. These are some of the lowest visible beds, and they dip 25° W.N.W., but those described as occurring at Chapel Walks must be under them. On the high ground above the Happy Valley the dip is 18° W., and on the Old Road, near Kenrick's Museum, it varies from 26° to 22°, and finally is 16° W., where it is covered by the succeeding subdivision

The thickness of the Lower Brown Limestone is about 400 feet between the Old Road and the Happy Valley, and it is succeeded by a grey shale and black limestone at the base of the Middle White Limestone. The shale is a well-defined horizon separating the two subdivisions, but farther south-west the dolomitization of the limestone has ascended and altered the lower beds of Middle White Limestone, as may be seen about Pen Morfa Lodge, and along the Old Road from Llandudno to Roft Fach, where the shale is absent and the dolomite and limestone alternate, the beds often changing horizontally from one rock into the other.

The Lower Brown Limestone has been extensively converted into dolomite after its original deposition. This is proved by the irregular horizon of the dolomitic rock about its upper limits, and its occurrence in lenticular masses in the two overlying subdivisions. It forms the filling of faults and string-courses in the limestone, and has evidently been altered long after the deposition and dislocation of the strata. The dolomite is intimately connected with the mineral veins, for on ascending from Llandudno by the Old Road that rock on the south-west extends nearly $\frac{1}{4}$ mile farther than on the north-east side, and suggests the occurrence of a considerable rather than an insignificant fault. The upthrow side of the fault is exposed south of a cottage at Roft Fach, where the striated surface hades 58° N., but the fault does not extend much farther up the hill where the limestone is continuously exposed.

No doubt the limestone on the south-west has been dolomitized by water containing magnesium carbonate, percolating through the strata from the fault or fracture supposed to run up the valley; but for some unknown cause it did not alter the limestone on the north-east side.

A few sections of the Middle White Limestone and Dolomite, from near Pen Morfa Lodge, were prepared for the microscope by Mr. Beasley, and proved to be either limestone with foraminifera or crystalline dolomite. None of them showed an intermediate condition or a passage from one rock into the other.

(2) Middle White Limestone.

The Middle White Limestone rests upon the Lower Brown Limestone, and is exposed over most of the Great Orme's Head. The clearest exposure of the lowest beds is between the Old Road and the Flagstaff quarry, north of the Pavilion, where the bed of shale, 7 feet thick, is the base and separates the two subdivisions. Above the shale there is a black limestone, about 18 feet in thickness, forming a conspicuous horizon along which the rock has been obtained for building purposes, on account of its occurrence in regular beds from 6 inches to 2 feet thick, with an inch or two of shale between them, allowing the stone to be easily worked. About 50 years ago the lofty cliffs were underquarried, until the obvious danger of the town being buried under a great fall of rock prevented further excavation.

The Middle White Limestone forms the main mass of the headland, and is about 550 feet in thickness. (In sailing round the coast the overlying subdivision can be scarcely seen, while the underlying subdivision occurs only in the cliffs about Llandudno and the lower part of the Happy Valley.) It is exposed in the massive beds forming the cliffs above and below the Marine Drive, where it nearly resembles the subdivision in other localities; it is of a light grey colour, though occasionally of a darker shade. The limestone contains very few partings of shale, some beds of red marl on both sides of the Old Road being exceptional. Near Pen Trwyn, west of the Drive, there is a conspicuous band of rubble and concretionary marl which separates the Middle White Limestone into a lower and an upper portion of nearly equal thickness, for a mile along the coast and inland to Roft Fach. This divisional line has been introduced in the map (fig. 2, p. 386), though it is difficult to define its exact horizon along the western side of the Head. There are, however, occasional concretionary beds about the north-western exposures of the limestone, and at the Lighthouse, at about the same horizon. The concretionary band at Pen Trwyn consists of red and yellow beds of marl and rubble 6 feet thick, with thin beds of limestone and a higher bed of marl, altogether about 20 feet thick, extending $\frac{1}{4}$ mile along the side of the Drive; and, as the limestone rises to the south, the marl and rubble cause a grass-covered slope round the precipitous crest of the cliffs above the Happy Valley. At Roft Fach the concretionary band of rubble and thin-bedded limestone is only 10 feet thick, and it cannot be traced farther west. Lenticular beds of dolomite occur in the limestone south-west of St. Tudno's Church, and in the steep cliffs above Gogarth, while south-west of the Head there are beds and dykes of dolomite along the side of the road; but chert is rare in the subdivision, if it be found at all.

About 20 feet from the top of the Middle White Limestone there are some beds of sandstone exposed in the large quarry west of Roft Fach. The sandstone is of irregular thickness, varying from 10 to 20 feet; it changes from a soft sandstone into a very hard arenaceous limestone, and contains occasional small quartz-pebbles. In colour it varies from white to red, though principally of a grey shade. This rock is on about the same horizon as the sandstone-conglomerate in Anglesey.

Although the base of the Middle Limestone is well defined by the bed of shale already described, and rests on massive beds of dolomite representing the Lower Brown Limestone in the Happy Valley, it is difficult to trace it farther west than the Old Road, in consequence of the conversion of its lower half into dolomite, as shown in the map (fig. 2, p. 386). The upper limit of the change is well seen in a section along the south side of a short road from Roft Fach. It exposes dolomite with limestone over it, string-courses of dolomite with limestone on the north and dolomite on the south side, and in another place a cluster of such strings of dolomite including fragments of unaltered limestone. The section seems to afford positive proof that the whole of the rock was originally limestone, and that long after its deposition it was converted into dolomite. It is also remarkable that the dark and more impure limestone was more readily changed than the white limestone, for the alteration is limited for the most part to the Lower Brown Limestone, the dark beds at the base of the Middle White, and to portions of the Upper Grey Limestone. At Pen Morfa Lodge the cliffs present lofty masses of dolomite, while farther along the Marine Drive beds of limestone are interstratified with it, and finally the dolomite ceases to occur.

The lodes and faults shown on the map are not distinguished from each other, for several of them are dislocations of the strata that have been worked for ore. The four parallel lodes may be faults, but there is no proof of such a conclusion: it seems probable that they were fissures which originated with the bending of the strata, and that they formed channels for conveying water containing magnesium carbonate, which altered the limestone along their boundary-walls, sometimes for a considerable distance. Pearl-spar, copper-pyrites, and other minerals were afterwards deposited in the open fissures, principally in the dolomitized portions and about the intersections of the veins. From an examination of specimens collected from the old mine-heaps it seems that the crystals of pearlspar were always deposited first, then usually the chalcopyrite, and finally the calcite. The anthracite was probably introduced as a liquid bitumen, which afterwards lost its volatile hydrocarbon constituents.

A list of the fossils found in the Middle White Limestone is appended (see pp. 392–393). They were all found in the 7 feet of black shale at the base, or in the limestone within 20 feet above it, with the exception of *Bellerophon costatus*, *Edmondia sulcata*, and *Cytherella æqualis*, obtained from about the middle of the subdivision.

(3) Upper Grey Limestone.

The Upper Grey Limestone is the highest subdivision of the Carboniferous Limestone. It occurs on the top of Great Orme's Head, occupying an elliptical area of about a mile from east to west, and half that from north to south. It covers a depression in the Middle White Limestone, and has a general dip towards the centre. The base on the south-east is a thick bed of grey shale, clearly exposed at the top of the 'Old Road' from Llandudno, about 450 feet above Ordnance datum, and the following is a section of the beds: these dip about 10° N.W., but they are well exposed only on the strike:—

	Ft.	In.
Thin limestone	1	6
Grey shale	6	0
Impure limestone	2	0
Grey shale	9	0
	18	6

Fossils are numerous in the shale, and include *Orthis Michelini*, *Productus giganteus*, *Pr. longispinus*, *Spirifera bisulcata*, *Sp. lineata*, and *Terebratula hastata*. The shale may be traced along the surface of the ground for about 100 yards to the westward, where it becomes covered with débris from the old mines; but it does not seem to be at the base of the subdivision for a much greater distance. In the absence of the thick shale, the lowest strata consist of thinly-bedded black limestone in bands about a foot in thickness, interstratified with black shale from 9 to 12 inches thick, both being well exposed in a series of quarries 300 yards south of the Telegraph. Along the outcrop of the lowest beds in other places the Upper Grey Limestone consists of thin beds of black limestone with little shale between them. The limestone worked in the quarries is about 40 feet thick, and is taken down to Llandudno and used for rough building purposes, instead of that formerly obtained from the base of the Middle White Limestone, which it resembles. The dip of the beds is 15° N., and the limestone is crowded with *Productus giganteus*, thousands of which may be seen of all sizes, while in the shale *Pr. margaritaceus*, a rare species in other localities, is very abundant. Many other fossils occur: these are tabulated in the appended list, pp. 392, 393. *Athyris ambigua* is a rare variety figured by Davidson.[1]

[1] Suppl. 'Carb. Brachiopoda,' Monogr. Palæont. Soc. p. 283, pl. xxxiv, figs. 10 & 11.

The limestone forming the ridge (on which the Telegraph stands) a little to the north of the quarries is on the opposite side of the fault and lode shown on the map. This fault is the axis of a synclinal, for the beds in the ridge dip 20° south, and are higher than those exposed in the quarries. The limestone occurs in thicker beds, and contains pink sandy shales, while those of the usual black colour are less frequent. In many places it has been altered into dolomite, while in others it retains its ordinary appearance, and contains the usual fossils, the most common being *Productus giganteus*. The dolomite occurs in irregular beds, lenticular masses, dykes, and veins, and the alteration seems confined to the limestone in the vicinity of the lodes. Chert is of common occurrence, filling fissures, and forming concretions around *Productus giganteus*. The chert is most conspicuous near mineral veins, but it does not occur in anything like such large masses as the dolomite.

There is another fault about 100 yards north of the Telegraph, running nearly due east and west, as shown in the map (fig. 2, p. 386). It is evidently a mineral vein, and must have been worked many years ago, for there are traces of buildings, washing-floors, and excavations along its course. South of the fault on the upcast side there is a cliff nearly 40 feet high, and a more gradual ascent for 100 feet higher to the site of the Telegraph. The limestone forming the cliff occurs in thick beds, dips 32° W.N.W., is much weathered, and traversed by several fissures which seem to have been excavated by miners in search of ore. North of the fault the lower beds of the subdivision occur, and there are indications of the Middle White Limestone cropping up along that side of the fault.

The thickness of the Upper Grey Limestone is estimated at about 200 feet on Great Orme's Head, the highest beds having been denuded. It was found impossible, however, to measure this limestone exactly, on account of its occurrence in the depression described, and the uncertain influence of the faults and lodes which could not be separately indicated on the map.

II. Little Orme's Head.

The Carboniferous Limestone forms Little Orme's Head, and embraces an area of about 4 square miles, being double that of Great Orme's Head. It forms two distinct ranges of hills, that on the north extending from Eglwys Rhos to the sea, 2 miles by $\frac{3}{4}$ mile, including Little Orme's Head proper, the greatest elevation being about 400 feet. The southern range extends 3 miles from Bod-y-Sgallen to the sea, and includes Bryn Dinarth, a hill 400 feet high, which is separated from the main mass of the range by a narrow alluvial valley. These two ranges of hills afford very similar exposures of the Lower Brown Limestone, more or less converted into irregular beds of dolomite, with the Middle White Limestone resting upon it, but without a trace of the Upper Grey Limestone, all of which has been denuded away. The most important geological feature is that the limestone of the northern range dips

List of Fossils from the Carboniferous Limestone near Llandudno.

R.=Rare. | C.=Common.
O.=Occasional. | V.C.=Very common.

	Lower Brown Limestone.	Middle White Limestone, Great Orme's Head.	Middle White Limestone, Little Orme's Head.	Upper Grey Limestone.
Actinoceras giganteum, Sow.	...	...	...	R.
Orthoceras filiferum, Phill.	...	...	...	R.
,, sp.	...	...	...	R.
Solenocheilus sp.	...	...	...	R.
Bellerophon costatus, Phill.	...	R.	R.	
,, sp.	R.			
Euomphalus Dionysia, Goldf.	...	R.	O.	R.
,, *pentangulatus*, Sow.	...	...	...	R.
Edmondia sulcata, Phill.	...	R.		
Pinna flabelliformis, Mart.	...	...	...	R.
Athyris ambigua, Sow.	...	...	...	O.*
,, *expansa*, Phill.	...	O.	...	O.
,, *planosulcata*, Phill.	...	R.	...	O.
Chonetes papilionacea, Phill.	...	C.		
,, *hardrensis*, Phill.	...	...	...	O.
Orthis Michelini, Léveillé	...	C.	...	O.
,, *resupinata*, Mart.	...	...	O.	R.
Productus Cora, D'Orb.	R.	C.	O.	O.
,, *comoides*	C.			
,, *fimbriatus*, Sow.	...	...	O.	
,, *giganteus*, Mart.	...	C.	O.	V.C.
,, *latissimus*, Sow.	...	...	...	O.
,, *longispinus*, Sow.	...	C.	...	C.
,, *margaritaceus*, Phill.	...	...	...	V.C.
,, *Martini*, Sow.	...	...	O.	
,, *princeps*, M'Coy	...	...	R.	
,, *punctatus*, Mart.	...	O.	O.	O.
,, *semireticulatus*, Mart.	...	C.	O.	C.
Rhynchonella acuminata, Mart.	...	...	O.	
Spirifera bisulcata, Sow.	...	...	O.	C.
,, *duplicicosta*, Phill.	...	...	O.	
,, *glabra*, Mart.	R.	...	O.	C.
,, *grandicostata*, M'Coy	...	...	R.	
,, *humerosa*, Phill.	...	R.	...	R.
,, *lineata*, Mart.	..	O.	C.	O.
,, *rotundata*, Sow.	...	R.		
,, *striata*, Mart.	...	...	O.	
,, *triangularis*, Mart.	...	...	...	R.*
Spiriferina laminosa, M'Coy	...	...	...	R.*

* Species obtained from a small quarry 400 yards to the north-east.

LIST OF FOSSILS (*continued*).

	Lower Brown Limestone.	Middle White Limestone, Great Orme's Head.	Middle White Limestone, Little Orme's Head.	Upper Grey Limestone.
Streptorhynchus crenistria, Phill.	...	R.		
Terebratula gillingensis, Dav.	...	...	O.	
„ *hastata*, Sow.	...	R.	...	R.
Fenestella plebeia, M'Coy........	...	R.		
Rhabdomeson gracile, Phill.	...	...	...	R.
Bairdia plebeia, Reuss	...	R.		
Cytherella æqualis, J. & K.	...	R.		
Griffithides seminiferus, Phill.	...	R.	...	R.
Leperditia Okeni, Münst.	...	R.		
Serpulites carbonarius, M'Coy	...	...	...	R.
Alveolites septosa, Flem.	...	O.		
Chætetes tumidus, Phill.	...	...	...	R.
Cyathophyllum Stutchburyi, M.-Edw.	...	C.	...	O.
Lithostrotion irregulare, M'Coy	...	...	O.	O.
,, *Martini*, M.-Edw.	...	O.	...	O.
,, *M'Coyanum*, M.-Edw.	...	...	...	O.
,, *Portlocki*, M.-Edw.	...	O.	...	O.
Lonsdaleia duplicata, Mart.	...	O.		
Syringopora geniculata, Phill.	...	C.	...	O.
„ *ramulosa*, Goldf.................... ..	O.	O.		
Zaphrentis Enniskilleni, M.-Edw. & H..........	...	O.		
Endothyra ammonoides, Brady	...	C.	C.	C.
,, *Bowmani*, Phill.	...	C.	C.	C.
Nodosinella sp.	...	C.	C.	

Nearly all the common and very common species found in the Middle White Limestone occur in the Upper Grey Limestone, and as with few exceptions they are from near the base of the subdivision, there is a difference in the horizon of 500 feet. Most of those at Great Orme's Head were found in the black shale at the base, and it seems that the occurrence of particular species depends more on the lithological character of the beds than on the horizon at which they occur. The relative number in which each species occurs refers to the Llandudno area alone.

south-east, while that of the southern dips north-west towards the intervening valley of Crenddyn, coloured as Millstone Grit on the Geological Survey map. As the valley is a synclinal 2 miles long and nearly a mile wide, the Upper Grey Limestone might be expected to occur in it, but that subdivision has not been found.

South-east of Eglwys Rhos there is a very confined area of red and yellow sandstone about Bod-y-Sgallen, resembling the Purple Sandstone of the Vale of Clwyd, though partly coloured as limestone and partly as Millstone Grit on the Geological Survey map. The names of all the places to which reference is made are derived from the 6-inch Ordnance map.

The most important exposure of the Carboniferous Limestone on Little Orme's Head is along the north-western escarpment of the northern range, visible from the parade and the rising ground above Llandudno. Two large quarries are prominent on the steep slope of the hill at Nant-y-Gammer, and both are worked in the Lower Brown Limestone, while the ridges along the top are formed of the lower beds of the Middle White Limestone. The limestone of both subdivisions dips about 15° south-east.

The base of the Lower Brown Limestone is not exposed, but the Caradoc or Bala Beds are seen about $\frac{1}{2}$ mile to the south-west, and no doubt occur much nearer the bottom of the hill. The limestone is exposed in an excavation below the lowest of the two quarries, and exhibits the waterworn sides of a large cavern or swallow-hole about 35 yards across, from which the roof has been excavated during quarrying or mining operations. The rock occurs in thick beds, and must be at or very near the base of the Lower Brown Limestone. In the quarries higher up, the limestone occurs in much thinner beds, these being only from 3 to 9 inches thick about the floor of the upper one, but thicker towards the top.

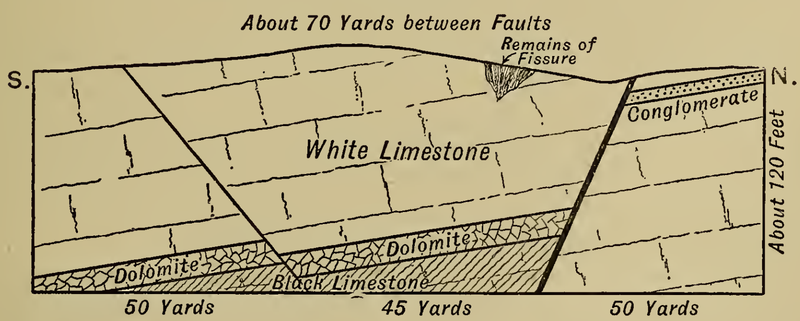
In the upper quarry, where the limestone is 60 or 70 feet thick, a large portion has been converted into dolomite in a very irregular manner. In some places the dolomite occurs in patches, and in other instances in beds which alternate with the limestone. A bed of limestone often runs against a fault or joint, on the other side of which it has been converted into dolomite. About the top of the quarry the dolomite is from 10 to 20 feet thick, but the thickness varies continuously throughout the exposure. Immediately north of these quarries a small one is worked in the limestone on the roadside, and a fault or fissure about 5 feet in breadth, running north-west or north-north-west through it, contains a filling of dolomite, thus proving that the alteration occurred after the limestone had been faulted and thrown into its present position.

The colour of the Lower Brown Limestone is dark grey, but it is often partially stained dark red, and is thus easily recognized in walls about the south of Llandudno. The dolomite is of a yellow or buff colour, and is used for rough building-purposes, rockeries, and road-metal. No fossils were seen in either the limestone or the dolomite, which weathers to a brown colour, resembles sandstone in texture, and disintegrates rapidly. The thickness of the subdivision is about 250 feet. Half a mile east, the Lower Brown Limestone is again exposed at the bottom of Mynydd Pentre with the succeeding subdivision over it.

The Middle White Limestone occurs above the Lower Brown Limestone along the crest of the hill at Nant-y-Gammer, and dips to the south-east. It is well exposed above Bodafon and at the 'Old Tower,' where the surface begins to descend with the dip, and the eroded beds occur over a considerable area. Lower down, the limestone is covered with plantations and fields as it reaches the valley below. It continues along the strike and forms the terraced hill of Mynydd Pentre, where the exposures are continuous, and the general dip about 20° to the south-east. On the north there is a depression of the surface, traversed by an important fault between Mynydd Pentre and Little Orme's Head, and running north-west and south-east. The Middle White Limestone then rises again, and forms the bold and precipitous headland 400 feet above the sea. The occurrence of the fault is evident, as the elevation of the base of the Lower Brown Limestone is 300 or 400 feet higher at Mynydd Pentre than it would have been in the absence of a fault.

A large quarry has been opened in recent years, by the Little Orme's Head Limestone Company, along the 100-foot contour-line on the north-eastern coast of the headland. The mural face of the quarry is along the dip-slope, and from 80 to 120 feet in elevation, with a dip of from 20° to 25° S.S.E., but the bedding of the massive limestone is somewhat obscure and varies in different places. The section towards the southern end of the quarry shows two faults, one of which has fractured a bed of dolomite, and the other has thrown up a bed of brecciated conglomerate. The dolomite is 14 feet thick, and the conglomerate 7 feet; the latter contains quartzite-pebbles. It must be below the dolomite, and probably near the base of the subdivision. The two faults run nearly due east and west, the principal one throwing up the conglomerate-bed at least 100 feet to the north. Quartzite-pebbles have been dragged down the fault, and are mixed up with the limestone-breccia, which also contains hard grit, sandstone, and red shale.

Fig. 3.—*Quarry at Little Orme's Head, in the Middle White Limestone.*



The dislocation of the dolomite by the small fault is remarkable, but, as the throw is only 9 feet, this fracture may be more recent than the general faulting of the Carboniferous Limestone. It is, however, quite possible that the dolomitization may have occurred along the bed after it was fractured. The bed probably possessed some affinity for the magnesium carbonate, a condition that might be expected on both sides of the fault. The dolomite is coarse-grained on one side of the fault, and fine-grained on the other. Mr. Robert Storey, the manager of the quarry, informed me that when the cliff-side was first worked no dolomite was observed, but that it was penetrated afterwards. On excavating 12 feet through the dolomite, the bed was found to change at a joint into ordinary limestone; while beneath, the rock is darker than anywhere else in the quarry, as shown in the section (fig. 3, p. 395).

The following analysis of the white limestone in the quarry shows how small is the amount of magnesium carbonate that it contains :—

	Per cent.
Carbonate of lime	98·92
Carbonate of magnesia	0·38
Oxides of iron and alumina	0·20
Sulphate of lime	trace
Insoluble siliceous matter	0·50
	100·00

Few fossils occur in the limestone, but Mr. Storey has preserved most of those that were found in the quarry, and they are tabulated in the list of species on pp. 392–393, which includes some of my own collecting.

The Lower Brown Limestone must occur below the floor of the quarry, north of the principal fault. It is probably represented along the inaccessible base of the cliffs just above the range of the tides, for a bed of dolomite about 30 feet in thickness crops out on the west side of Porth Dyniewyd, the little bay at the extreme north of the headland, 200 yards from the quarry, where copper is reported to have been found immediately above the sea-level.

At the north-eastern corner of the Head there is a remarkable boss of limestone, named Trwyn-y-Fuwch, the top of which is 100 feet above the sea, and it appears to have slipped down from a corresponding recess in the cliffs about 100 feet higher. The principal reason for this conclusion is that the obscure bedding in the fallen mass is nearly on end, and the limestone is quite unconnected with the adjacent cliffs. The fall seems to have occurred in pre-Glacial times, for there is a deposit of red earth containing fragments of chert, and a bed of fine-grained white sand covered with Boulder Clay, 150 yards wide, between the isolated mass and the cliffs from which it is supposed to have fallen. Mr. Storey came independently to the same conclusion, and I am much indebted to him for the facilities which he afforded me when at the quarry.

Along the worked face of the excavations there were several fissures, probably widened joints in the rock filled with red drift. About 7 years ago one of these was found to contain the teeth and bones of bear, hyæna, rhinoceros, and other mammalia a few feet above the floor of the quarry,[1] while some 30 or 40 feet higher a human skull was found, and near the top of the cliff a bronze spear-head 12 inches in length. All these objects had probably fallen or had been washed into the fissure at different times, from pre-Glacial to Recent.

[1] These were presented to the Liverpool Free Public Museum, but seem to have been lost.

The southern range of hills extends from Bod-y-Sgallen for 3 miles in a north-easterly direction, but does not appear to have any definite name. It presents exactly the same geological structure as that already described, the subdivisions consisting of the Lower Brown Limestone with the Middle White Limestone resting upon it. The only difference is that the dip is reversed, so that while the limestone in the northern range dips south-east, that of the southern range dips north-west, and there is a synclinal valley about a mile in width between them. Along the south-east of the valley the Middle White Limestone everywhere dips about 20° or 25° to the north-west. Over a considerable area the surface descends with the dip to the valley until covered by the cultivated land, and there is no indication of the Upper Grey Limestone in any part of the valley.

West of Pabo there are three large quarries, the one nearest that place being excavated in the side of a conical hill, and, except in colour, it presents a striking resemblance to several of the breached volcanoes of Auvergne. The limestone in this quarry is of a massive character, 90 feet thick, and traversed by joints which give it the appearance of being vertical. At the base of the quarry the limestone assumes a darker colour, is thin-bedded, and represents the Lower Brown Limestone, 30 feet thick, in which I saw several specimens of *Productus comoides*, but none in the overlying subdivision.

The Lower Brown Limestone has a continuous outcrop along the south-east of the range, and the base occurs parallel with the road at Llangwstenin Hall. Half a mile farther north there is a quarry where a black shale, having much the appearance of lignite, occurs a few feet above the level of the road. It is from 3 to 6 inches thick, but only extends for 10 yards, with a dip of 18° N.N.E., and must be near the base of the subdivision. There are beds of impure limestone above the black shale, and beds of dolomite 14 feet thick below it. The limestone rests unconformably upon the Wenlock Shale, and there is an alluvial valley along the east of the road.

Bryn Dinarth, or Bryn Euryn (named after the ancient British entrenchment at the top), is the conspicuous hill east of the valley, which separates it from the portion of the southern range already described, and is only a mile from Colwyn Bay. It is formed of the Middle White Limestone resting upon the Lower Brown Limestone, as in the hills on the west. On the north, the Middle White Limestone descends from the summit of the hill, which is 427 feet high, to the north of Llandrilloyn Rhos Church, and forms all the upper part of the hill with the exception of the semicircular ridge of Lower Brown Limestone, which crops out to the south. The Middle White Limestone exhibits its usual massive character : it is quarried at the northern end of the hill, where it dips 16° north-west, and is of a light colour. Another quarry on the east, just above the 200-foot contour-line, shows the white limestone 20 feet thick, resting on the dark grey beds of the inferior subdivision 40 feet in thickness, with a dip of 17° north-west.

The Lower Brown Limestone is mostly of a dark grey, but frequently of a red colour, as already described at Nant-y-Gammer (p. 394), though a considerable portion has been converted into dolomite, which, when weathered, might be easily mistaken for buff or brown sandstone. The lower part of the subdivision is obscured by a deep talus of red earth containing angular fragments of dolomite and limestone, derived principally from the breaking down and decomposition of the dolomite in the cliffs above, so that the exact base is uncertain. It must be, however, a little below the 300-foot contour on the 6-inch map, and consequently much above the base of the Lower Brown Limestone along the outcrop in any of the other hills that have been described.

The Wenlock Shale beneath is exposed only about the road and railway along the south of the hill, where it dips 45° north-east, and is about 50 feet above Ordnance datum, but probably extends much higher. All the slope of the hill below the overhanging cliffs, about 200 feet, is a talus which covers the steep escarpment of the Wenlock Shale, and the base of Lower Brown Limestone which rests upon it.

The Purple Sandstone of the Vale of Clwyd appears to be exposed in three localities in the valley east of Eglwys Rhos, the most important being a quarry in a plantation a short distance north-north-east of Bod-y-Sgallen. The colour varies from deep red to yellow, and the red becomes brighter on exposure to the weather. A great quantity of the stone has been used in the neighbourhood, and it is well exposed on the surface of the road leading to the outbuildings west of Bod-y-Sgallen, but the Hall is on the Lower Brown Limestone. In the quarry the dip is only 3° or 4° north, and about 30 feet of the sandstone is exposed.

There is another exposure on the road at Greengate Covert, as shown by the dip S.S.E. (Millstone Grit) on the Geological Survey map, the other being coloured as limestone. Mr. H. C. Beasley informed me that he had seen the sandstone in the watercourse, $\frac{1}{4}$ mile to the west, by the side of the road, but the place was so thickly covered with vegetation that I could not find it.

The relation of the sandstone to the limestone is not shown in any of the exposures, but that it has been let down by faults seems certain, and it probably rests upon the Upper Grey Limestone. The occurrence of limestone at Crogfryn renders it difficult to suggest the position of the boundary-line on the west; yet there must be faults north and south of the sandstone, which probably extends some distance up the Crenddyn Valley, but how far is uncertain.

III. Remarks on the Dolomite.

The dolomitization of the Carboniferous Limestone attracted the attention of geologists many years ago, and Prof. Phillips described the metamorphism of the formation about Kettlewell in Yorkshire.[1] The most important paper on the subject is that 'On the Character

[1] 'Geol. of Yorks: pt. ii (1836), Mountain Limestone District,' p. 26.

& Mode of Occurrence of the Dolomitic Rocks of Kilkenny,' by Mr. Andrew Wyley,[1] in which he described the alteration of parts of the Carboniferous Limestone into dolomite in a very capricious manner along the beds, and sometimes enclosing large masses of unaltered limestone, the change being always exceedingly abrupt. He described dykes of dolomite between joints, where it has lost all traces of the original stratification, and others where the bedding can be traced across from the limestone on each side. Mr. Wyley was of opinion that the metamorphism was produced by the passage upwards from great depths of water containing magnesium carbonate; that the alteration took place after the deposition of the Permian Limestone, and that both formations were dolomitized by the same upflow of magnesia, and at the same time.

If I was correct, in my paper on 'The Carboniferous Limestone of the Vale of Clwyd,'[2] in assigning the faulting of that formation in North Wales to the end of the Triassic, the metamorphism may have been produced in the Jurassic Period. In Kilkenny the alteration extends over a considerable area, but around Llandudno the dolomite may be seen presenting the most interesting variations within an area of a few square miles, and it is remarkable that it has not been described before.

In Kilkenny there are beds of limestone containing from 3 to 6 per cent. of magnesium carbonate, but around Llandudno the limestone contains only a mere trace of it. No dolomite occurs in the Vale of Clwyd, but in the Upper Grey Limestone at Penmon (Anglesey) there is a bed 30 feet in thickness.

Discussion.

Dr. Sorby said that, being convinced that in many cases dolomite had been formed by the replacement of half the carbonate of lime in limestones by carbonate of magnesia, he had been anxious to produce this change artificially, but so far had not succeeded. He had been able, at a fairly high temperature, to replace entirely the carbonate of lime; but not merely one half so as to form true dolomite. Sundry experiments, which have now been going on for 36 years, show that in some cases such long-continued action will produce changes which a few years fail to produce; and perhaps the formation of true dolomite depends on a very long-continued action at the ordinary temperature.

Dr. Hicks said that the Society was to be congratulated on receiving this further evidence of careful and original work from one who had been for so many years an active Fellow of the Society. No one had done so much as the Author, in North Wales, in working out the fossil-zones in the Carboniferous rocks, and the new fact now brought forward that the 'Lower Brown Limestone' has,

[1] Journ. Geol. Soc. Dublin, vol. vi (1854) p. 109.
[2] Proc. L'pool Geol. Soc. vol. viii (1897–98) p. 32.

in the areas referred to, been converted into dolomite appears hitherto to have been overlooked.

Mr. Strahan remarked on the excellence of the field-work upon which this paper was founded. The dolomite had been compared by the Author with a Permian rock: it differed, however, in being an alteration-product. The alteration in this and other cases affected the limestone most capriciously, converting it into an aggregate of crystals and completely obliterating the organic structures. Moreover it frequently accompanied faults, as in the case of the 'dun limestones' of the North of England. The percentage of magnesium carbonate had been stated by the Author as 48, but this seemed considerably too high for an ordinary dolomite. It might have been thought that the Trias, with the Dolomitic Conglomerate at its base, had been the source of the magnesia; but, as a matter of fact, the usual alteration effected by the Red Rocks had been the conversion of the limestone into hæmatite. Moreover, the Dolomitic Conglomerate was often almost devoid of magnesium carbonate. On the other hand, the dolomitization frequently accompanied faults which may, at some former period, have conducted underground water from the Coal Measures into the limestone. It was interesting to note that the rock found by the Author to lie upon the limestone differed from the purple sandstones which occupied that position in the Vale of Clwyd, as well, of course, as from the chert-beds of Flintshire. He congratulated the Author on his excellent results.

Mr. Marr also spoke.

The Author, in reply, stated that the subjects brought forward by the speakers would take up too much time for comment, and unfortunately he had not been able to hear all that had been said. He was much pleased with the interest taken in the paper, for he had not been able to read the whole of it, and some details had of necessity been omitted.

30. Petalocrinus, *Weller & Davidson*. By F. A. Bather, Esq., M.A., F.G.S. (Read April 20th, 1898.)

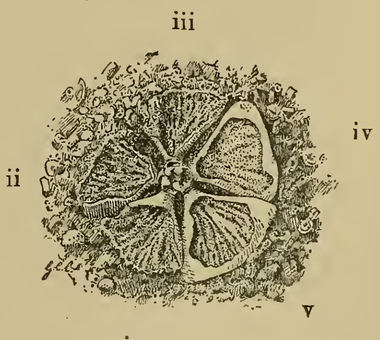
[Plates XXV & XXVI.]

Contents.

I. History of the Genus.

Among the geological collections from Gotland, preserved in the Riksmuseum at Stockholm, there have long been some curious fan-like objects, obviously echinodermal, but beyond that of doubtful significance. Study of these in September 1890 led to the conclusion that they were crinoidal; not cup-plates, however, as some had supposed, but dichotomous arms in each of which the branches were fused together, forming what may be termed an 'arm-fan.' Although it seemed probable that they were of Inadunate affinities, they were not, in the absence of more precise evidence, described in Part I of 'The Crinoidea of Gotland' (Kongl. Sv. Vet.-Akad. Handl. vol. xxv, No. 2, Dec. 1893). Fortunately, about this time Mrs. A. D. Davidson, now of Whiting (Ind.), discovered in the contemporaneous rocks of Iowa similar fossils, two of which retained the five arm-fans in their natural position, like the petals of a dog-rose around a small calyx (text-fig. 1). These were shown to me by Mrs. Davidson on her visit to England in the summer of 1891, and proved the correctness of my surmise concerning the Gotland fossils. The Iowa specimens, however, were taken back to America, and subsequently submitted by their owner to the Assistant in Palæontologic Geology at the University of Chicago, Mr. Stuart Weller, who prepared a paper entitled '*Petalocrinus mirabilis* (n. sp.) and a New American Fauna.'[1]

Fig. 1.—Petalocrinus mirabilis, *specimen* g. *Arm-fans arbitrarily numbered* i–v. (*Drawn by Mr. G. C. Chubb from a photograph and a plaster cast.*)



[Nat. size.]

[1] Journ. of Geol. vol. iv (1896) pp. 166–173.

Now that Mrs. Davidson's more complete individuals have been described, and the genus erected on their broader basis, it is time to describe the three species found in Gotland. The knowledge gained from them may then be applied to the elucidation of the special difficulties presented by the American specimens, and to the establishment in our classification of the family Petalocrinidæ, which, though suggested, was neither defined nor discussed in the paper just mentioned. Mr. Stuart Weller has obtained from various American localities fresh material of the species described by him and of two other species, and it was his intention to publish a supplementary paper with some revision of his previous work. He has, however, with the utmost generosity, placed his material in my hands for description, and helped me with notes, photographs, and plaster casts. Mrs. Davidson, too, was so good as to bring the type-specimens and other material to London with her in June 1897, in order that my study might be as complete as possible. This kindness from America fully repays the patience of seven years. But if there be any value in this paper, thanks are due not only to Mrs. Davidson and Mr. Weller, but to Prof. Gustaf Lindström for affording every facility for the examination of the specimens in the Riksmuseum at Stockholm, to my wife for much assistance in the wearisome preparation of those specimens, and to Mr. Gustaf Wenman for the pains that he has taken in the production of the plate illustrating them.

II. Geological Relations of *Petalocrinus*.

The species herein described are :—

P. mirabilis, Weller ; Niagara Limestone : Jones Co. (Iowa).
P. inferior, n. sp. ,, ,, ,, ,,
P. longus, n. sp. ,, ,, St. Paul (Indiana).
P. visbycensis, n. sp. ; beds **b** & **c** (Lindström) : north of Wisby (Gotland).
,, (senior) ; upper part of **c** : Westergarn (Gotland).
P. angustus, n. sp. ; junction of **b** & **c** ; north of Wisby (Gotland).
P. expansus, n. sp. ; base of **f** : Wisby (Gotland).

P. inferior and *P. mirabilis* are both found near Monticello, but not in absolutely the same locality, and the former, according to Mr. Weller, is at a slightly lower horizon. *P. visbycensis* and *P. angustus* are found in the clay along the shore north of Wisby ; it is not possible to refer each specimen to a definite horizon, but they may, generally speaking, be regarded as occurring at a horizon equivalent to the junction of the Llandovery and Wenlock series in England, or the Clinton and Niagara groups in North America. Since a species is also found at the base of Lindström's bed **f** (that is, somewhere about the Lower Ludlow of England and the Onondaga of North America), it follows that the known range of the genus extends both earlier and later in Gotland than in Iowa and Indiana.

Mr. Weller, in 1896, when still ignorant of the occurrence of

Petalocrinus in Gotland (although I had told Mrs. Davidson of it), used the supposed resemblance of this genus to *Crotalocrinus* as an argument for the homotaxis of the Niagara Limestone with the Gotland Limestone, which he classed with the Wenlock. The Gotland Limestone, however, or at least that portion of it in which *Crotalocrinus* is abundant, is bed **f** of Lindström, and is taken by that eminent palæontologist as the equivalent of our Aymestry rather than our Wenlock Limestone. Even without the occurrence of *Petalocrinus* itself in lower beds of the Gotland series, Mr. Weller's argument could have no great force, for the resemblance to *Crotalocrinus* is quite superficial and does not imply 'bonds of relationship.' But the actual facts of geological distribution at present prove no more than was better established on other grounds, *e. g.* by Mr. Weller's own description of *Goniophyllum pyramidale*, Hisinger, *mutatio secunda*, Lindström, from the same horizon and locality as *P. mirabilis.* In Gotland *mutatio secunda* occurs, according to Lindström (1882), in marly limestone (**d**) above the clay: that is to say, at precisely that horizon from which *Petalocrinus* is as yet unknown in Europe, the horizon of the Wenlock Limestone. It is right to mention here that on Dec. 21st, 1895, the late Charles Wachsmuth wrote to me that he had received 'an external natural mould from the Niagara of Chicago' which he referred to *Crotalocrinus.* This was confirmed by a squeeze taken from another specimen from the same beds, and kindly sent to me on Feb. 18th, 1898, by Mr. Weller. The species, however, cannot be determined, so that the specimens have but slight bearing on questions of synchronism. Therefore, with due remembrance of the imperfect and homotaxial nature of our correlation, the species of *Petalocrinus* may be arranged in the following geological order:—

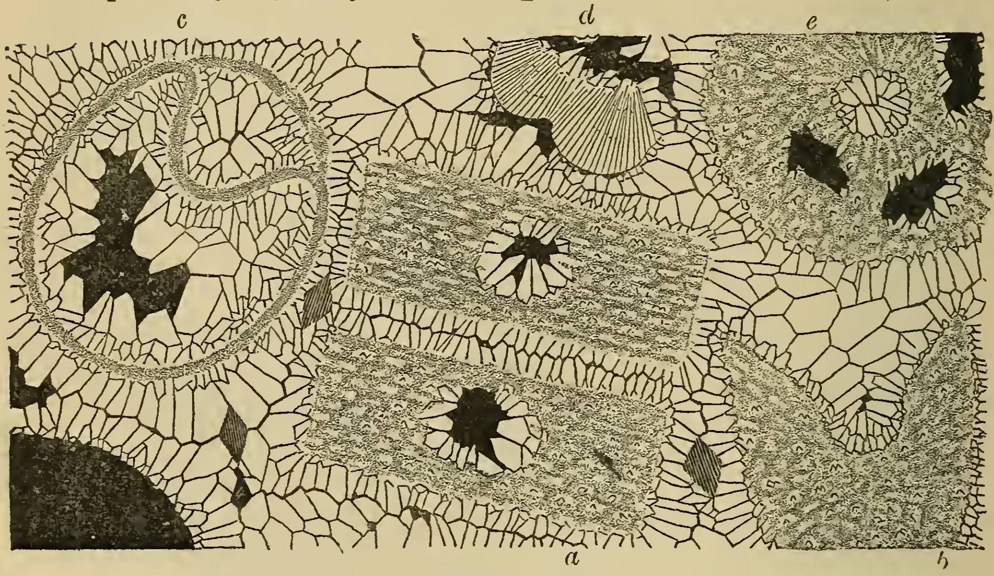
Silurian (Lapworth).	Europe.	North America.
Upper	*P. expansus.*	
Middle		*P. longus, P. mirabilis,*
"		*P. inferior.*
Lower	*P. visbycensis* (senior).	
"	*P. visbycensis, P. angustus.*	

It is probable that the publication of this paper will bring to light specimens in England: search for them should be made among collections, not of crinoids, but of brachiopods, especially among specimens of *Rhynchotreta cuneata* and similar Rhynchonelloids; some coral-fragments, as of the associated *Palæocyclus porpita* or species of *Ptychophyllum*, might, if partially exposed, be confused easily with an arm-fan. In fact, *P. major*, Weller, turns out to be an *Omphyma*, as explained on p. 407.

III. Description of Material.

P. mirabilis.—All the specimens are in an iron-stained siliceous rock, splitting into rough slabs. This is entirely composed of the remains of corals, crinoids, a few brachiopods, and bryozoa, all organisms with a calcareous skeleton; originally, therefore, the rock must have been a pure or nearly pure limestone. Whether this subsequently became dolomitized, as was the case with most of the Niagara Limestone of Illinois, Iowa, and Wisconsin, cannot be determined from the hand-specimens examined, since they show no trace of dolomite-crystals, even in thin sections under the microscope. It seems more probable that the first change was due to silicification, in the form of a gradual molecular replacement of the calcareous stereom[1] of the constituent fossils, beginning with the outer layer of each ossicle or fragment. Thus, in the case of a crinoid stem, the silicifying fluid bathed the outside of the stem, the walls of the axial canal from which the soft contents had previously decayed, and the narrow interstices between the columnals formerly filled with ligament. The supply of silica then decreased, and acidulated water passing through leached out any remaining stereom from the inner portions of each fragment. There were thus left a number of hollow boxes, as it were, formed of silica.

Fig. 2.—*Microscope-section of matrix of* Petalocrinus mirabilis, *specimen* **j**. (*Cut by Mr. F. Chapman. Brit. Mus. E 6635.*)



× 30 diam.

[The drawing is diagrammatic, especially in so far as the crinoid-fragments have been selected from different parts of the original preparation; it represents the section as seen by polarized light, nicols crossed. *a*, columnal cut longitudinally, showing axial canal; *b*, brachial cut transversely; *c*, brachial and covering-plates cut transversely; *d*, chalcedony; *e*, columnal cut transversely. Between all these, and in the cavities formed by solution, are minute crystals of quartz, while minuter crystals are in the meshes of the stereom, which also is silicified. The black areas represent spaces. The brachials certainly, and the columnals possibly, do not belong to *Petalocrinus* itself.]

[1] Stereom, any hard tissue, forming skeletal structures in Metazoa Invertebrata and in Protozoa: 'Nature,' vol. xliii (Feb. 12th, 1891) p. 345.

With the disappearance of all the carbonate of lime, water did not cease to penetrate the rock, but continued to deposit silica, partly as quartz, filling up all the minute spaces in the stereom, lining the cavities, and cementing the fragments, partly as chalcedonic mammillations on the inner walls of the hollow boxes, thus obscuring details of structure that might otherwise have been preserved with surprising clearness. The original replacing silica, the crystalline infilling, and the chalcedony are all shown in text-fig. 2, p. 404.

The larger fossils, therefore, are neither casts nor impressions, but when perfect resemble externally the original skeleton in everything except their chemical and physical composition, and consequent soapy feel. Often, however, this exterior is roughened by deposit of silica or marked with the concentric rings of beekite formation. But the fossils, being but thin and hollow cases, empty shows, rarely are perfect, and we see their interior. The effect of this is often somewhat that of an impression, and from it one may take a wax squeeze simulating the characters of the original outer shape. Text-fig. 1 (p. 401) shows the outer casing partly preserved on the dorsal side of the arm-fans numbered iv & v, while it is almost entirely removed from arm-fan iii. The exterior of the basals is also preserved, but one sees the interior of most of the radials, especially in radius i. The diverging ridges seen inside the arm-fans represent grooves on the ventral surface, and this is also the case with Pl. XXVI, figs. 44 & 46.

The need for this detailed explanation of the mode of petrifaction was proved by the difficulty of interpreting Mr. Weller's description and photographic process-engravings without such explanation. A similar mode of preservation was described in my paper on some *Eugeniacrini* from the 'Weisser Jura ε' of Streitberg (Quart. Journ. Geol. Soc. vol. xlv, 1889, pp. 359–362).

The specimens studied are the following:—

Specimens which Mrs. Davidson has deposited on loan in the Walker Museum, University of Chicago, but which she kindly withdrew temporarily for me to examine at leisure, namely:

(**a**) Cotype.[1] Weller & Davidson, *op. cit.* pl. vi, fig. 2. Crown, and proximal columnal, dorsal view. (Pl. XXVI, figs. 41–43.)

(**b**) Cotype. Weller & Davidson, *op. cit.* pl. vi, fig. 5. Single arm-fan in matrix, ventral view; part of dorsal surface and facet exposed.

(**c**) Portions of five arms, in place around a cup which is not exposed; dorsal view, but the dorsal wall and inner substance of the arm-plates are removed; numerous column-fragments and isolated columnals, possibly belonging to the species, are close by. (Pl. XXVI, figs. 48–50.)

[1] In this paper the word 'type' and its compounds are used in the senses proposed by Oldfield Thomas ('Suggestions for the more definite Use of the Word Type, etc.,' Proc. Zool. Soc. 1893, pp. 241, 242) and elaborated by C. Schuchert ('What is a Type, etc.,' Science, n. s. vol. v, pp. 636–640, April 23rd, 1897).

Specimens belonging to the Walker Museum, and lent me through the kindness of Mr. Stuart Weller, namely:—

(**d**) U.C. 4449. Crown and proximal columnal, dorsal view, more obscure than Pl. XXVI, figs. 38 & 39; alongside are remains of two other arms, dorsal view. (Pl. XXVI, fig. 44.)

(**e**) U.C. 4449. Single arm-fan, dorsal view, most of dorsal surface removed; facet well shown.

(**f**) U.C. 4735. A large slab of silicified rock (37 × 12-16 cm.) covered on both sides with remains of *Petalocrinus*. On the side which the general weathering and lichenous growth show to be the upper, there are two crowns, (**f** 1) 30 mm. and (**f** 2) 15 mm. in diameter, and remains of at least nine other arm-fans, all seen from the dorsal surface. The underside contains the remains of at least twelve arm-fans seen from the ventral surface, and four seen from the dorsal surface. There are in the slab various columnals and a few brachials of other crinoid genera, none capable of determination. The mass of the slab is made up of coral-fragments: *Halysites*, *Favosites*, etc. (Pl. XXVI, figs. 37, 45–47.)

Besides these, I have been furnished, through the kindness of Mr. Stuart Weller, with plaster casts of:—

(**g**) Cotype. Weller & Davidson, *op. cit.* pl. vi, fig. 3. A crown seen from the dorsal side, the cup not very well preserved. Also a photograph of this. (Text-fig. 1, p. 401.)

(**h**) Cotype, Weller & Davidson, *op. cit.* pl. vi, fig. 4. An arm-fan from the dorsal side, with dorsal surface removed, so that the floors of the grooves are exposed as rounded ridges.

(**i**) An arm-fan similar to **h**.

Finally, there are in the British Museum (Nat. Hist.):—

(**j**) E 6634. Portion of a slab similar to **f**, containing on one side an arm-fan in dorsal aspect, dorsal surface almost entirely removed and floors of grooves exposed; and on the other side two fragments of arm-fans similarly preserved. Presented by Mrs. Davidson. The microsection, text-fig. 2 (p. 404), was cut from this.

(**k**) E 6636. Arm-fan in siliceous matrix, dorsal aspect. Presented by Mr. Stuart Weller. (Pl. XXVI, fig. 40.)

(**l**) E 6637. Arm-fan in siliceous matrix, ventral aspect. Presented by Mr. Stuart Weller. (Pl. XXVI, figs. 51–56.)

P. longus.—One arm-fan, registered U.C. 4512, preserved in the Walker Museum, and lent by Mr. Weller, who collected it at St. Paul (Ind.), 1896. The state of preservation appears somewhat similar to that of *P. mirabilis*, but the specimen is free from matrix, and apparently silicified throughout. Rather more than the distal right-hand corner is broken away, at an angle similar to that followed by the Gotland specimens when they fracture; but the line of cleavage is not so regular. (Pl. XXVI, figs. 58–65, & text-figs. 11, 12, p. 432.)

P. inferior.—U.C. 4736, in the Walker Museum, found close to the locality of *P. mirabilis*, but at a slightly lower horizon, by Mr. Weller, who kindly forwarded me the specimen. The matrix is a loose dolomitized limestone, in which the calcareous fragments, echinodermal and other, are not wholly dissolved out. The specimen is an impression of an arm-fan, in which ridges represent natural casts of the arm-grooves. There are two fractures, and the margins are worn away. (Pl. XXVI, fig. 57, & text-fig. 10, p. 427.)

P. visbycensis.—The specimens are all composed of calcspar well preserved in a blue shale; they are usually dark in colour.

Specimens in the Riksmuseum, Stockholm:—Twenty-three arm-fans or portions of arm-fans, lettered **a**–**w**; details of some are given with the measurements (p. 423). (Pl. XXV, figs. 1–11 & 16–25, & text-fig. 8, p. 423.)

Specimens in the British Museum (Nat. Hist.):—

(**x**) E 6638; an arm-fan on matrix, ventral surface exposed; it is slightly worn at the distal and proximal ends (text-fig. 8 **x**, p. 423).

(**y**) E 6639; small arm-fan, somewhat weathered.

(**z**) E 6640; proximal portion of an arm-fan.

P. visbycensis (senior).—A single arm-fan on a matrix of hard calcareous shale, ventral surface exposed; Riksmuseum, Stockholm (Pl. XXV, figs. 12–15, & text-fig. 9, p. 424).

P. angustus.—A single arm-fan, the proximal end broken away, especially on the left side; Riksmuseum, Stockholm (Pl. XXV, figs. 26–32).

P. expansus.—A single arm-fan on spathose limestone, ventral surface and facet exposed; slightly weathered; Riksmuseum, Stockholm (Pl. XXV, figs. 33–36, & text-figs. 13, 14, p. 435).

'*P.* (?) *major*.'—Holotype and topotype, both belonging to Mrs. Davidson, and kindly withdrawn by her from the Walker Museum.

Mr. Weller wrote to me on Nov. 10th, 1896:—'I am convinced that the specimen I described as *P.* (?) *major* is nothing but a form of coral. Additional specimens secured this summer seem to make this certain.' Examination of these specimens suggests that the species is most closely allied to *Omphyma turbinatum* (Linn.).

IV. Anatomical Description of the Genus.

The cup, stem, and first primibrach are known only in *P. mirabilis*, but there is no reason to suppose that they were essentially different in the other species. The arm-fans of all species are known, and it is on them that specific diagnoses must be based; their structure in *P. mirabilis* and *P. visbycensis*, which differ but slightly, may be taken as the norm of the genus [1]; they are more

[1] On the zoological application of the word norm, see F. A. Bather, 'Postscript on the Terminology of Types,' Science, n. s. vol. v, pp. 843–44, May 28th, 1897.

readily studied in *P. visbycensis*, and the description will be based chiefly on that species.

The Dorsal Cup is bowl-shaped; flattened dorsally, with slightly concave base; subpentagonal in outline, owing to the lateral position of the radial facets, and very slightly excavate in the interradii; low, the height being about half the width. The measurements of five specimens are given in the table on p. 430.

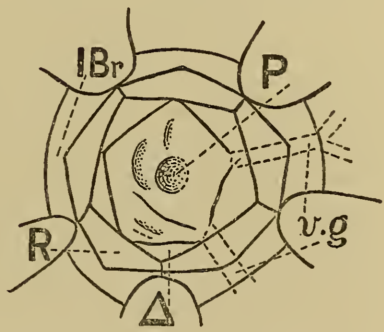
The cup was described by Mr. Weller as composed of radials and basals only, *i. e.* as that of a typical Monocyclic Inadunate crinoid, and he compared it to the cup of *Platycrinus*. This is in fact the appearance presented by **d** and **f** 2; but in those specimens the sutures are very obscure. In **g**, to judge from the photographs and plaster cast, the plates are clearly separate, and the basals appear not to come right up to the abactinal centre, but to leave a concavity a little larger than the space occupied by the proximal columnal, which does not seem to be present in the specimen (text-fig. 1, p. 401). This appearance is pronounced in specimen **a**, and here the interbasal sutures are distinctly seen to stop before reaching the columnal, while in the interradii arbitrarily designated iii–iv, iv–v in Pl. XXVI, fig. 42, obvious sutures are seen dividing the basals from the depressed area round the stem-attachment; in this area itself an interradial suture can be distinguished clearly in interradius iv–v, less clearly in interradius iii–iv. Although the surface is corrugated by the petrifying processes above described, there is no room for doubt as to the correctness of this description; and it was independently confirmed by two unprejudiced observers, Mr. H. W. Burrows and Mr. G. F. Harris, whose accuracy is well known to palæontologists. The important conclusion follows that the base is dicyclic, there being a circlet of infrabasals, minute but distinct, largely covered by the proximal columnal, and perhaps partly fused, but not into a single plate.

Basals (BB) 5; pentagonal, slightly wider than high, subequal. Owing to the absence of anals from the cup it cannot be seen whether there is any differentiation of a posterior side; in **a** the basal in interradius ii–iii is perhaps the largest, those in iv–v and v–i being smaller than the rest. The proximal portions of the basals are included in the central concavity.

Radials (RR) 5, subequal; height to base of facet about $\frac{2}{3}$ width. They are of the shield-shape usual in Inadunate crinoids; their proximal portions enter the flattened dorsal area; thence the plates curve upwards to the facet, but the curve is more pronounced in the interradii, so that the radials project towards the facet, the plane of which is almost parallel to the vertical axis of the cup, but a little sloping outwards ventro-dorsally. Taking the width of the radial as 100, the average width of the facet is relatively:—in **f** 1, 55·5; in **a**, 80; in **d**, 65·2; in **g**, 77. The specimens are here arranged in order of size, and it is seen that this considerable variation can scarcely be due to difference in age. There is also variation between the facets of an individual, though less in amount, as seen from the table of measurements on p. 429. The articular surface of the radial facet is exposed in no specimen, and its nature must be inferred from the facet of the arm-fan; it is safe to say that it was pierced by the axial canal.

The Tegmen is not clearly visible in any specimen. The cup of **a** is tilted slightly on one side, so that one can look a little underneath. Despite Mr. Weller's statement, 'No interradials observed on the dorsal aspect of the calyx,' there is seen in interradii i–ii and ii–iii a pronounced plate, just at the level of the arms and passing up on to the tegmen (Pl. XXVI, fig. 43). The wax squeeze taken from the impression of the tegmen in **f** 1 (Pl. XXVI, fig. 45 & text-fig. 3) shows that the first primibrachs abut on five radially-disposed plates. These, which are probably radials, project, in a slight angle, to the middle line of the primibrachs, but their inner, adoral margins are straight. They abut on one another by short sides. Therefore in this view they appear pentagonal. Between the radials and the oral centre, but interradially disposed, are subtriangular plates, probably one in each interradius, with their apices meeting the interradial sutures. These plates are interambulacral and are the same as the interradial plates seen in **a**. They may be homologized with the five subtriangular plates of the Cyathocrinoid tegmen, which have been spoken of in my papers as deltoids, and which, in opposition to P. H. Carpenter and Messrs. Wachsmuth & Springer, I believe to represent orals.[1] The other smaller plates of the tegmen are probably ambulacrals, but their arrangement cannot well be distinguished. The wax squeeze seems to show one or two traces of grooves, leading from the brachials, across the supposed radials, to a pronounced but narrow depression in the centre. This latter is no doubt the peristome, and, in the animal, may have been covered by plates; one cannot infer otherwise from the peculiar state of preservation of the fossil. The anus is not to be detected.

Fig. 3.—*Diagram of the tegmen of* Petalocrinus mirabilis, *to explain Pl. XXVI, fig. 45.*



P, peristome; *v.g*, ventral groove; Δ, deltoid; R, radial; IBr, first primibrach.

Mr. Weller, in his paper, spoke of 'the anal side.' In reply to a question, he wrote on May 5th, 1896:—'My only reason . . . . was the apparent slightly greater width between the two arm-bases and the slightly larger basal plate on the same side.' This refers, as he explained by a diagram, to that interradius on specimen **a** here marked iii–iv. Were this a constant feature, Mr. Weller's

[1] See especially 'Suggested Terms in Crinoid Morphology,' Ann. Mag. Nat. Hist. ser. 6, vol. ix (1892) p. 63; 'Brit. Foss. Crin.—VIII: *Cyathocrinus*,' *ibid.* p. 225; and 'Crinoidea of Gotland: I,' 1893, on p. 111 and elsewhere.

inference might be justified; but he continues, 'the other specimen [namely, **g**] does not show any appreciable difference in the different sides.' The measurements tabulated on p. 430 confirm Mr. Weller's second statement more readily than his first. Although there is variation in the width between the arm-bases, in no case can one interradius be selected as conspicuously wider than the others. At the same time, in specimens **d**, **f** 1, **f** 2, and possibly **g**, one interradius is distinctly narrower than the others, and might plausibly be regarded either as one of the anterolateral interradii, or as the right posterior. This, however, is not the case with **a**.

The Arms consist each of two parts: a first primibrach (IBr_1), which rests on the radial facet, and an arm-fan, which rests on the first primibrach.

The first primibrach is barely ·5 mm. high, with its proximal and distal margins parallel, of the same width as the facet of R and of the arm-fan, and, so far as can be seen, of the same thickness on both dorsal and ventral margins (except perhaps for the slight reëntrant angle on the ventral surface, already mentioned as seen in the impression of the tegmen in **f** 1). First primibrachs are seen also in **a** and **d**, and less clearly in **f** 2 and **g**. They were no doubt always present in *P. mirabilis*, and probably in other species. Their articular surfaces are unknown, but the structure of the distal one can be inferred from the facet of the arm-fan.

The Arm-fan, as seen from the ventral surface, roughly resembles a folding fan, opened to a varying extent in different individuals, and still more in different species. Seen from the dorsal surface it is like an oar-blade or paddle. The sides do not meet in a point, but become parallel at a short distance from the proximal end, forming as it were a short handle to the fan or paddle. Also at the distal end the sides usually curve inwards, especially in old individuals.

The angle of any arm-fan is defined as the angle at which lines drawn parallel to the general direction of the diverging sides, exclusive of the incurved distal region, meet one another. In *P. visbycensis* the angle varies from 70° to 93°, the average in observed specimens being 82° 24′, while in more than half the specimens it falls between 80° and 85°: that is, the mode equals the mean.[1] In *P. mirabilis* the angle varies from 51° to 83°, the average in thirty-one observed specimens being 71°, while in more than half the specimens it falls between 71° and 78°: that is, the mode is a larger angle than the mean. In *P. inferior* the angle is about 70°; in *P. longus*, 38°; in *P. angustus*, 38°; in *P. expansus*, 90°; in *P. visbycensis* (senior), about 88°.

[1] Geologists unfamiliar with the rising flood of zoological literature on Variation may be referred to W. Bateson, 'Materials for the Study of Variation,' London, 1894; and Karl Pearson, 'The Chances of Death,' 2 vols., London & New York, 1897. Those works contain explanations of many terms and methods used in the present investigation.

The grooves on the ventral surface of the arm-fan are proved by their mode of branching, and by various structures described in due course, to represent the ventral grooves of originally separate arm-branches.

The grooves do not simply radiate from the proximal end, as do the grooves of a fan or of the test of some brachiopods, but dichotomize according to a plan that is approximately the same for all species, and still more the same for all individuals of each species. This dichotomy may be described in language similar to that used in describing ordinary free arms, the difference being that one is unable to insert the numbers of the brachials in each series, since no trace of the original joints is retained.

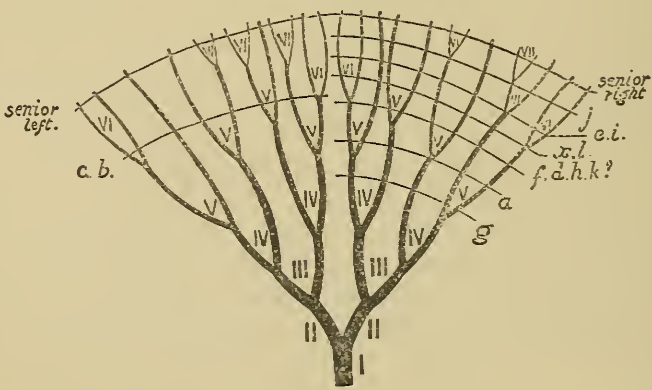
In *P. mirabilis*, *P. visbycensis*, and *P. inferior* the grooves (or arm-branches) divide almost immediately on entering the fan, so that a distinct ridge runs down the middle of each fan, dividing it into two similar halves. The secundibrach region is quite short, and the groove forks again almost at once.

In fans of *P. mirabilis*, nearly, if not absolutely, without exception, the two main divisions of the fan are almost precisely similar, that is, the arm-fan is bilaterally symmetrical. Moreover, so far as number is concerned, the branching is perfectly regular or 'isotomous'; there are always 2 IIBr grooves, 4 IIIBr, 8 IVBr, and 16 VBr, these last being the finials; or, as Mr. Weller puts it, there are '16 ambulacral grooves at the distal edge of each arm.' This number is stated by Mr. Weller in a letter to be invariable; and the specimens submitted to me confirm his statement. Though isotomous in respect of number and bilateral symmetry, the forking of the III, IV, and V Br series takes place at unequal levels. For example, confining our attention to the right-hand half of any fan (as viewed from the ventral surface), we see that the right-hand or outer IIIBr groove forks before the left-hand or inner groove; whereas, of the two IVBr branches springing from the latter, it is always that on the left which forks first. This may be reduced to rule. In any crinoid arm all the portion borne by any one axillary may be termed a 'dichotom,' and the line bisecting that axillary may be regarded as the median axis of the said dichotom; branches next to the median axis will be mediad with respect to that particular dichotom. If these terms be applied to *Petalocrinus*, the law governing the branching may be stated thus: in each dichotom that groove is first to branch which is farthest from the median axis of the preceding dichotom. This, though subject to minor modifications in the various species, is the law for the whole genus. It is but another mode of expressing the law that governs the branching of all primitive, non-pinnulate, simply dichotomous arms, and is the regular law for all Cyathocrinoidea that have more than two arm-branches. On p. 156 of 'The Crinoidea of Gotland: Part I.,' the law was thus expressed: 'the series towards the middle of each dichotom contain more ossicles than the outer branches.' The facts upon which the law was based are given in various parts of that paper, and on p. 219 of

'British Fossil Crinoids—VIII: *Cyathocrinus,*' Ann. Mag. Nat. Hist. ser. 6, vol. ix (1892).

In *P. visbucensis* the bilateral symmetry of the arm-fan is, as shown by text-fig. 4, more subject to variation. This is due partly to the fact that the bifurcations in each half do not always take place at the same level, partly to the different number of branchings that may occur in each division. The latter difference may depend to some extent on the different ages of the specimens; but the relation is not quite regular, since the levels at which the various branchings take place vary slightly in different specimens. Text-fig. 4 represents actual observed stages between the youngest known, with 5 branches, and the oldest known with 22. This shows perfect obedience to the law already stated, which was in fact inferred originally from this very diagram, the American specimens serving only to confirm it.

Fig. 4.—*Diagram showing branching of grooves in arm-fan of* Petalocrinus visbycensis.



[The letters refer to the specimens, and the lines drawn across represent the distal margin of each. Thus the diagram also shows the stages of growth. Since the right and left halves correspond, except in *P. visbycensis* (senior), the line is only drawn half way across.]

A total of 28 finials was reached by *P. inferior,* and possibly by *P. visbycensis* (senior). *P. expansus* and *P. longus* also have 28 and 27 finials respectively; but in their case the high number is attained, not by continuous regular dichotomy, but by a remarkable meristic variation, which may be defined as the addition or intercalation of another half-fan. This is fully described under those species (pp. 431 & 434). I cannot recall a similar variation among Cyathocrinoidea, but certain crinoids in which the arms are pinnulate and normally bifurcate once, often have one ramus forking again, so that the arm has 3 rami. This varies in individuals and even in the rays of an individual.[1] The unique type-specimens of *P. expansus* and *P. longus* may therefore be abnormal arm-fans; but their specific independence depends on other characters than this abnormality.

[1] A case of this kind was discussed in 'Brit. Foss. Crin.—V: *Botryocrinus,*' Ann. Mag. Nat. Hist. ser. 6, vol. vii (1891) pp. 404–405.

The sides in *P. visbycensis* and *P. angustus* are not quite straight or quite curved, but follow the contour of the branching arm (Pl. XXV, fig. 31). This is not obvious in the other species; but in them the lateral edges are rarely well enough preserved to show it, if it did occur.

The ventral surface of the arm-fan, taken as a whole, is slightly convex; the amount of convexity varies in the species and, to some extent, in individuals (Pl. XXV, figs. 5, 12, 16, 30, 33, & Pl. XXVI, figs. 51, 65).

The dorsal surface has a slight concavity in the middle region, corresponding to the ventral convexity; but proximally and on all the margins it is convexly rounded towards the edges, except where the facet comes. In *P. visbycensis* portions of the dorsal surface are often raised in irregular lumps or swellings, apparently due to a deposit of stereom secondary to that of the original brachials (see text-fig. 6, p. 418). This secondary stereom is often arranged in lines of growth, vaguely concentric with the distal margin (as seen in specimens **c**, **d**, **e**, Pl. XXV, figs. 7 & 29), and it is covered with a fine shagreen ornament (well seen in **c**, **e**, **g**, and **j**, Pl. XXV, fig. 23). Towards the distal margin the secondary stereom is less thick or entirely absent, and the original branching of the arms is often shadowed forth on the back by slight depressions; this is well shown in the young specimen **g** (Pl. XXV, fig. 2), and it is here seen that the depressions correspond with the ridges on the ventral surface. The secondary stereom appears first on these depressions; its successive layers did not cover the whole of the preceding ones, but each layer was more distal, so that an imbrication is visible in the lines of growth, the later and more distal layers overlapping the earlier proximal ones. On the dorsal surface of specimen **e** (Pl. XXV, fig. 7), near the distal margin, is the valve of a small *Beyrichia*; this appears to have become partially overgrown around the edges by the secondary deposit. The dorsal surface is not visible in any other species, except *P. mirabilis* and *P. longus*, and in them there is no evidence of growth-lines or shagreen ornament; such irregularity as occasionally occurs seems due to mineralization and weathering.

Further evidence of original free branching is afforded by the distal margin. This, in many specimens, instead of forming a regular curve, is slightly excavate or depressed, either in the medial region between the two halves of the arms (as, for example, *P. visbycensis*, specimen **f**, Pl. XXV, fig. 4; *P. mirabilis*, specimen **l**, Pl. XXVI, fig. 52; *P. expansus*, Pl. XXV, fig. 34; *P. angustus*, Pl. XXV, fig. 31), or in each half, in the axis of the second dichotom (as, for example, *P. visbycensis*, specimen **w**), or more irregularly (as *P. visbycensis*, specimen **b**). Thus a slightly-lobed outline is often seen in *P. visbycensis*, but hardly at all, and never to so great an extent, in *P. mirabilis*. This lobation is merely an exaggeration of what is seen in many specimens of *P. visbycensis* and some of *P. mirabilis*, namely, fine indentations at the distal ends of the ridges. This is not to be confused with the slight crenulation or scalloping of the distal edge due to the accentuation of the distal ends of the grooves by weathering, a process that destroys the indentation of the ridges. This indentation is continuous with the depressions on the dorsal surface, and also passes on to the distal ends of the ventral ridges, even when the ridges themselves are narrow and rounded for the greater part of their course. A well-preserved distal margin of an arm-fan thus reminds one of the edge of a roof formed of concave tiles, . When the ridge is broad, the depression often passes for some distance along its ventral surface, making it slightly concave.

There is considerable variation in the width of the ventral ridges, both absolutely, and relatively to the grooves. Thus in *P. longus* some ridges are almost knife-edged (or, as will be seen, it would be better to say 'saw-edged'), having in parts a width of ·2 mm.; while in *P. expansus* a width of 1·9 mm., nearly 10 times as much, has been noted. There is variation, not only between species, but between individuals of a species, between ridges of an individual, and between different regions of the same ridge. This is exemplified by the following study of *P. visbycensis*:—First, in each individual, while the grooves remain of approximately the same width, only tapering gradually distalwards, the ridges widen distalwards up to each branching, when they rapidly become narrow again: this is well shown in **g** and **h** (Pl. XXV, figs. 1 & 8). Again, in some individuals the ridges are far wider than in others. Thus in **j** the ridges are quite sharp in appearance, varying in width from ·2 to ·6 mm., while the normal width of the grooves tapers from about ·7 to ·5 mm. In **e** the ridges are of about the same width as in **j**, but they are not so high, and the grooves are not quite so wide, so that the ridges do not seem so sharp (Pl. XXV, fig. 6). In **c**, the width of the ridge varies from ·4 to 1 mm., while the normal width of the grooves is about ·5 mm. In **p**, the width of the ridges varies from ·5 to ·9 mm., and the normal width of the grooves is also ·9 mm. (Pl. XXV, fig. 9). The greatest width of a ridge found is in the fragment lettered **m**, where the width of the ridges between the outer IVBr on each side attains 1·5 mm.; the width of the grooves at this level is ·75 mm.

Since the sides of the grooves slope inwards, it might be suggested that this variation in the width of the ridges of different specimens was due to the greater or less wearing down of the specimens; but this is negatived by the preservation of notches for the covering-plates, as described in the sequel. It might also be thought that some variation was due to the different ages of the specimens: if the arms were not fused together, then the sides of the proximal brachials would undoubtedly grow wider at the same time as the whole arm increased in length; and the corresponding mode of growth in *Petalocrinus* would be an increase in the width of the ridges by intussusception. A comparison of young specimens with old does not, however, lend colour to this supposition: the ridges and grooves at their first appearance have a width similar to that obtaining in more developed specimens. For instance, in the young specimen **a**, the width of a ridge is actually half as great again as in the much older specimen **e**; while the width of the ridges and grooves in **g** is as great as, or greater than, in **f** and **e** (Pl. XXV, figs. 1, 4, & 6). The difference in size that does come about is in the width of the facet, and to a less extent in the width of the grooves of the I and II Br. This, however, is produced purely by lateral accretion: there is no intussusception, nor even any absorption of stereom; as the facet widens, so also the outer ridges increase in width and height at their proximal ends.

The narrower ridges appear to have rounded upper surfaces; but the broader ridges are flat or slightly concave, and their edges appear sharp and square. The variation in the ridges, as between species, will be more fittingly discussed under the heads of the species themselves.

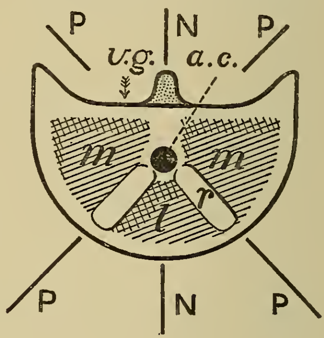
Mention has just been made of covering-plates (ambulacrals). None have yet been found in any of the Gotland species. It is just conceivable that a minute mass, apparently of stereom, that seems to roof over a little piece of one groove in *P. longus* may represent one or two such plates (see p. 433). They certainly are not preserved in any other of the American specimens. Frequently, however, one can distinguish, along the sides of the grooves, notches apparently for their reception. The following description applies to *P. visbycensis*, in which the notches were first observed and studied. In the flattened ridges they are not visible from above, but when the ridges are viewed from the side, with a strong light directed down the grooves, then the notches can be seen immediately under the straight edge of the ridge. Of these notches $4\frac{1}{2}$ go to 1 mm. in specimen **p** (Pl. XXV, fig. 25). In the forms with narrower rounded ridges the notches are visible from above, since they lie on the edges of the ridges. In specimen **e** about 4 notches go to 1 mm. (Pl. XXV, fig. 24). The notches on one side of a ridge alternate with those on the other side, and it appears also that the notches on one side of a groove alternate with those on the other side. This alternating arrangement would be a natural outcome of the alternation of the covering-plates. We infer, then, that there were ambulacrals alternating as usual, with a width of ·25 or ·22 mm., and somewhat closely articulated to the sides of the arm-groove. Their absence in the case of arms that could not be folded up, that became separated from the calyx after death, and that lay about on the sea-floor, is nothing more than is usual.

Notches for covering-plates are also seen in *P. angustus*, where they are very clear (Pl. XXV, figs. 26 & 27), in *P. mirabilis*, where they are usually obscure (Pl. XXVI, fig. 55), and in *P. longus*, where they are seen most clearly on the thin regions of the ridges, and give them a saw-like appearance (Pl. XXVI, figs. 61 & 62). A rabbet or ledge, apparently for the support of the covering-plates, is occasionally to be distinguished a little below the ventral edge of a ridge; as, for example, in *P. longus* (Pl. XXVI, fig. 62).

In *P. mirabilis* **f1**, the arm numbered ii has lost, in its right-hand half, a portion of the floor of the grooves, thus exposing what lay on the ventral surface of the arm. Here are seen some eighteen clearly-outlined depressions, apparently the traces of plates. A wax squeeze (Pl. XXVI, fig. 47) indicates that they are covering-plates alternating over the grooves, and resting on their edges in such a way that, if continued, the whole ventral surface of the arm-fan would have been covered by a plating of minute alternating ambulacrals. They do not form quite regular biserial rows, but occasional smaller plates appear intercalated.

At the proximal end of the arm-fan is a well-marked facet, which in *P. mirabilis* we know to be for articulation with the preceding IBr_1; in other species there may have been more IBr, or the arm-fan may have articulated immediately with the radial, but neither of these suppositions is probable. The following description applies to *P. visbycensis* (Pl. XXV, figs. 16–22, & text-fig. 5). The plane of the facet forms, with the plane tangential to the main surface of the arm, an angle of 55° in **f**, 60° in **j**, 61° in **g**, 65° in **c**, and 69° in **d**. The facet is bounded above by a straight line, merging at either end into angular processes formed by the ends of the outer side-walls of the outermost grooves. This line marks the widest part of the facet. The dorsal contour is a curve, circular or elliptical according to the ratio of depth to width of the facet, which ratio, as shown by the measurements in the table (p. 422), varies from $\frac{1}{2}$ to $\frac{3}{4}$. In the median vertical line of the facet, about $\frac{1}{3}$ the distance from the ventral margin, opens the axial canal (*a.c.* in text-fig. 5). In well-preserved adult specimens the lower margin of the facet is raised in a slight rim. From the axial canal down towards this rim run two strongly-marked but short ridges, each at an angle of about 45° with the vertical (*r* in text-fig. 5). The ridges are broad, and their upper surfaces are seen in **d** to slope slightly inwards to the median line of the facet. There are thus marked out on the facet three depressed areas, of which the median dorsal one (*l* in text-fig. 5) is the deepest, and by homology with recent crinoids may be regarded as the ligament-fossa. The two lateral areas (*m* in text-fig. 5) are separated one from another by a very slight elevation ventral to the axial canal, and may be called muscle-fossæ. The ridges are less marked in the young, but the fossæ can always be distinguished.

Fig. 5.—Petalocrinus. *Diagram of arm-facet.*



This form of facet may be compared with the trifascial articulation between certain brachials of *Bathycrinus*.[1] It seems to follow from it that the arm-fan was not capable of much movement in the vertical plane normal for other crinoids (**N** in text-fig. 5); indeed, such movement was hardly needed, since the rigid fans could not have folded up over the tegmen, and would also have got in each other's way if vertically depressed beneath a certain level. On the other hand, this articulation lent itself to movement towards right or

[1] See P. H. Carpenter, *Challenger* Report on Stalked Crinoids (1884), pp. 8 & 9.

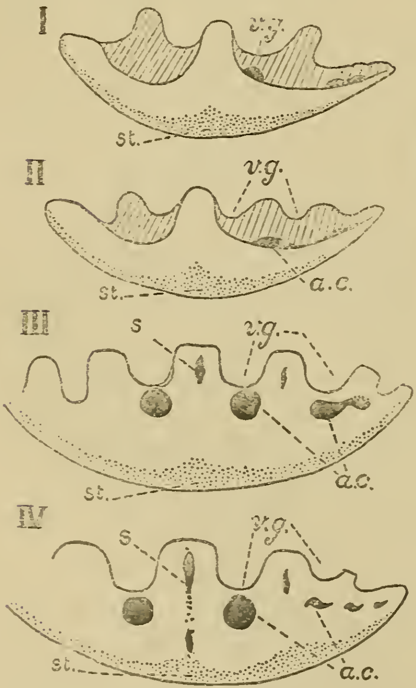
left in a plane inclined 45° to the vertical (**P, P** in text-fig. 5); and it was perhaps in this way that the arms closed.

In *P. mirabilis* the facet has a similar structure, but the petrifying processes have not preserved it so perfectly. It is seen in specimens **e** and **b** (Pl. XXVI, fig. 53), and its single axial canal is visible from the interior of the arm-fan in that arm of specimen **c** which is numbered iv. The better preserved crowns of this species confirm the foregoing inferences from the structure of the facet. The normal position of the armsis shown in **d** (Pl. XXVI, fig. 38); they spread out almost regularly from the cup, in such a way that no part of the fan rises above the tegmen, but the convex curve brings their distal ends fully 2 mm. below the base of the cup. In **f** 2 (Pl. XXVI, fig. 37) the concavity of the crown in its dorsal aspect is still greater: the width of the crown is 15 mm., and the arm-fans bend to 2 mm. below the base; the height of the cup being 2 mm., the total depth of the curve, from arc to chord, is 4 in 15. In many specimens one arm-fan often overlaps another on one of its sides: specimen **g** (text-fig. 1, p. 401) shows arm-fan i overlapping arm-fan ii; in specimen **d** (Pl. XXVI, fig. 38), arm-fan i overlaps arm-fan v; in specimen **f** 1 (Pl. XXVI, fig. 46), arm-fan iii overlaps ii. The appearance suggests a screw-propeller, and in life this resemblance may occasionally have been still greater.

The opening of the axial canal in the facet is, as a rule, single and circular, as in *P. mirabilis*, specimen **e**. But in *P. mirabilis*, specimen **b**, the axial canal is rather wider than high, while in the type of *P. longus* it appears as though split in two vertical slits, which lie in a slight depression (Pl. XXVI, fig. 59). These appearances are emphasized in two specimens of *P. visbycensis* (**i** & **m**), the proximal ends of which have considerable interest. Specimen **i** (Pl. XXV, fig. 21) may have been affected by weathering, but of fracture there are no traces; in it two of the ventral grooves come right to the proximal end: in fact, one might even say that four grooves come to the edge of the facet. Consequently two axial canals are visible, underlying the two grooves of the first dichotom. In the middle of this facet is a rather sharp vertical depression, which corresponds to the middle of the median ventral ridge, and is prolonged for 3 mm. on its upper surface as a distinct, though slight and not quite continuous, groove. In **m** (Pl. XXV, fig. 22) it is clear that the abnormality has not been produced either by weathering or fracture, but that the proximal end has a natural surface of union. This surface is shaped like a facet, but broader (3 mm. wide, and 1·5 mm. from the bottom of the grooves to the dorsal margin); and the angle which it makes with the ventral surface of the fan is similar to that of an ordinary facet. Four ventral grooves come right up to, and are cut short at, its ventral margin, and below each of these opens an axial canal. Dorsal to the line of the four axial canals is a very slight elevation, hardly to be called a ridge, while between this and the outer rim is a slight depression. It is probably a correct description of this abnormality to say that the arm has broken off along the suture between certain of the IIIBr; and one infers from the regularity of the curve that the brachials were arranged in regularly concentric rings, just as they are in *Crotalocrinus*, and in the proximal series of *Enallocrinus punctatus* and *Gissocrinus campanula* (see 'Crinoidea of Gotland, I,' pl. ix, fig. 294).

The axial canals are thus proved to branch with the ventral grooves, and to extend with them at least as far as the IIIBr. That they continue to run along to the distal ends of the grooves, even of adult specimens, has been proved by study of *P. visbycensis*. First, transverse sections made by grinding (specimen **n**, Pl. XXV, fig. 11 & text-fig. 6), or natural cleavage-fractures across the arm-fan in more distal regions (specimens **j** & **p**, Pl. XXV, fig. 10), enable one to see the axial canals, usually as dark spots, underneath the grooves. Secondly, some specimens (such as **h** and **i**, Pl. XXV, fig. 8), when seen from above, show holes through the floor of the ventral grooves into the underlying axial canals. Thirdly, in grinding the horizontal section (specimen **w**, text-fig. 7), one could, in

Fig. 6.—Petalocrinus visbycensis. *Series of sections across the proximal end of specimen* **n**.



I is the most proximal, IV the most distal.

v.g., ventral groove; *a.c.*, axial canal; *s*, trace of original suture between arm-branches; *st.*, secondary stereom.

The actual appearance of a stage in grinding slightly more distal than IV is shown in Pl. XXV, fig. 11. The course of the grooves is shown in text-fig. 8, **n** (p. 423). Magnified about 16 diam.

Fig. 7.—Petalocrinus visbycensis. *Horizontal section of arm-fan, specimen* **w**.

The lighter parts represent the translucent stereom; the broad, branching, darker parts (*v.g*) are the ventral grooves, or grooves + axial canals, filled with matrix; the light markings (*b*) in the middle of some of these latter represent portions of the stereom bridging over the axial canals; the dark markings (*s*) are the pigmented traces of the stroma originally filling the sutures between the arm-branches. The misty appearance of the middle of the drawing shows that, owing to the curvature of the fan, the above-mentioned structures here give place to the dorsal stereom. Drawn by Mr. G. Wenman. [× 4 diam.]

places, distinguish the dark lines caused by axial canals, which were ground through from the dorsal side before the ventral grooves themselves were reached. Sometimes, however, towards the distal margin, it appears that the canals were not completely separated from the grooves, this separation being, as is usual among Inadunata, a subsequent process caused by stereom growing in from either side and meeting in the middle so as to shut off the axial nerve from the other organs contained in the ventral groove. This is prettily shown by the broken surface of specimen **p** (Pl. XXV, fig. 10). Here the canals on the right are cut across more proximally than those on the left. Canal i is completely closed in; ii is also closed in, but there can be seen at the bottom of the ventral groove a little notch indicating the line along which the two halves of the stereom-bridge have met; iii is less far advanced, in that the stereom-bridge is only about halfway across; while in iv the axial canal is only distinguishable as a narrower **U**-shaped tongue at the bottom of the ventral groove. These stages may be compared with various figures of brachials of *Gissocrinus* given in 'The Crinoidea of Gotland, I,' as, for example, stage ii, with figs. 289, 299, 338, & 358; stage iii, with figs. 270 & 333; stage iv, with figs. 300, 311, 319, 332, & 366. Many specimens show a line along the floor of the grooves, caused by the imperfect union of the two sides of the stereom-bridge. On the other hand, the bridge sometimes appears to rise a little along the middle line, so that in the horizontal section a thin strip of the stereom (*b* in text-fig. 7, p. 418) appears to lie in the middle of the ventral groove.

These conclusions are confirmed by specimens of other species. In the type of *P. angustus* the proximal end is broken and shows two axial canals, which, however, are rather wide, since they are just branching into four. In *P. mirabilis*, specimen **d** 2, the distal ends of the grooves have a section like that of groove iv in Pl. XXV, fig. 10 (Pl. XXVI. fig. 44). The type of *P. longus* shows the canals coming to light on the distal margin, the line on the floor of the ventral groove, and the breakings through the floor of the groove (Pl. XXVI, fig. 64). The axial canals were not mentioned in the original description of the genus.

In describing the facet of *P. visbycensis*, specimen **i**, mention was made of a sharp median vertical depression, continued on to the median ventral ridge. The meaning of this may be gathered from the horizontal section of **w** (text-fig. 7). In this are plainly visible fine dark lines running along the middle of the ridges. These doubtless represent the original spaces between the primitively independent arm-branches; in other words, the sutures along which they fused. The suture (*s*) is more pronounced in the median ridge, that is, between the two main divisions of the arm. Here also one sees evident traces of it in *P. visbycensis*, specimen **n**; and consecutive transverse sections showed its gradual commencement and increase in size distalwards (text-fig. 6). In *P. angustus* the ridges are marked along their middle lines by dots of black pigment, which appear to be traces of the original connective tissue along the sutures between the branches. These dots are not shown in Pl. XXV, fig. 31, which aims at representing form alone.

The Stem is known only in *P. mirabilis*. A single columnal attached to the cup is seen in specimens **a**, **d**, and **f** 2, but is quite obscure in the two latter. In **a** (Pl. XXVI, fig. 42) it appears to be subangular, but the direction of the angles is not easy to determine owing to the irregularity of the silicified surface; it is quite a low ossicle, with a width of about 1 mm.; its lumen is very small, and appears obscurely pentagonal with radial angles. In specimen **c** the dorsal cup is covered by very hard matrix, consisting of silicified crinoid fragments. Above the abactinal centre is seen the articular surface of a columnal, similar to those of **a**, **d**, and **f** 2, and certainly belonging to this crown. Apparently it is subpentagonal with interradial angles, but the edges are rounded and irregular, so that one cannot feel certain as to this point. The diameter of this columnal is 1 mm.; the diameter of its lumen ·25 mm. At 4·5 mm. from here, lying interradially, between the arms numbered i and ii, are five columnals, still united one to another, and connected with the central one by fragments of others (Pl. XXVI, fig. 50). The length of the fragment of five is 5·2 mm.: that is, the height of a columnal is 1·04 mm.; its width is 1 mm. Another columnar fragment of five ossicles lies in a radial direction at the distal margin of the arm numbered ii; its measurements are similar to those of the other fragment. A few other columnals of similar appearance, but much worn, are scattered in the neighbourhood. Although there are remains of at least one other crinoid genus close by, these columnals are shown by their size and position to belong to the individual of *Petalocrinus*. In this case the stem cannot possibly have been less than 22 mm. long; but it was probably longer, since the width of the crown is 33 mm. The columnals in the first fragment of five show a marked depression at half the height, as though each columnal had been formed by the fusion of two. The sutures are slightly and irregularly crenulate. The articular surface of one of the scattered columnals (Pl. XXVI, fig. 49) shows radiating striæ; others are smoother, with slight depressions (Pl. XXVI, fig. 48), sometimes giving a subpentagonal outline to the articular surface, which normally is circular.

The orientation of the angles of the stem and of its lumen in all these specimens can hardly be determined with sufficient certainty to base on it any argument as to the presence or absence of infrabasals; but there certainly is nothing in the appearance that conflicts with the idea that the crinoid had a dicyclic or pseudo-monocyclic base, with the downward prolongations of the chambered organ radial in position.

V. Systematic Description of Genus and Species.

While it is possible to include in our generic diagnosis the characters of the calyx, which was probably the same in all species, the deficiency of material prevents us from basing the diagnoses of the species on more than the arm-fans. This, it is probable, conceals no great error, since experience teaches that in highly-modified genera or families (as, for example, *Herpetocrinus*, Calceocrinidæ, Eucalyptocrinidæ), the structures in which greatest differences between species are manifest are those in which the principal modifications characterizing the genera have taken place. This statement does not apply (under classifications based on the premisses usually accepted) to genera in the beaten track, that do not diverge widely from the common path (such as *Cyathocrinus*, *Pentacrinus*, and *Platycrinus*), for in them the criteria are usually small differences of ornament or of measurement, to human intelligence often unimportant, and stigmatized as 'useless characters.'

Species of this latter type owe their differentiating features, in many cases, to difference of ancestry. They go in crowds, each heterogeneous in origin, but moulded to a generic pattern by common conditions, and passing sheep-like from the fold of one genus into that of another. Species of the former type belong to a vigorous and sportive strain, started in a few individuals, and speedily overleaping the barriers of the flock; the essential features of the ancestor are preserved, and the race, after running rapidly through its extravagant changes, becomes extinct, as though its energy were spent. The variations produced have been of no advantage; they have broken against, rather than been shaped by, the inevitable shears of selective circumstance.

Application of the foregoing to the aberrant *Petalocrinus* suggests that the arms, as they are the structures most divergent from the normal crinoid type, will also be those in which variations suitable for discrimination of species are likeliest to occur.

For the present, ordinal and family characters need not be discussed, but the differentiating features of *Petalocrinus*, described at length in the preceding pages, may be formulated in the following—

Generic Diagnosis.—Base dicyclic; IBB minute (probably fused to 3); BB 5; RR 5. Arms inadunate, distinct; each composed of IBr_1, united to R by perforate articulation, and an arm-fan, similarly united to IBr_1 and formed by the anchylosis of all dorsal elements of a non-pinnulate dichotomous arm from Iax onward. Tegmen solid, containing 5 large iAmb (=deltoids or orals). Stem subcircular in section.

Genotype: *P. mirabilis*.

P. visbycensis, n. sp.
(Pl. XXV, figs. 1–25.)

Angle of arm-fan 70° to 93°, usually 80° to 85°; fan bilaterally symmetrical in shape, but not quite so in arrangement of grooves; finials 10 to 22; ventral surface of fan gently convex; dorsal surface slightly concave, with growth-lines and shagreen ornament; ridges usually as wide as, or rather less wide than the grooves, often flat-topped.

Type: Specimen **e**, Riksmuseum, Stockholm (Pl. XXV, figs. 5, 6, 7, 17, 23 & 24). Paratypes in Riksmuseum and British Museum.

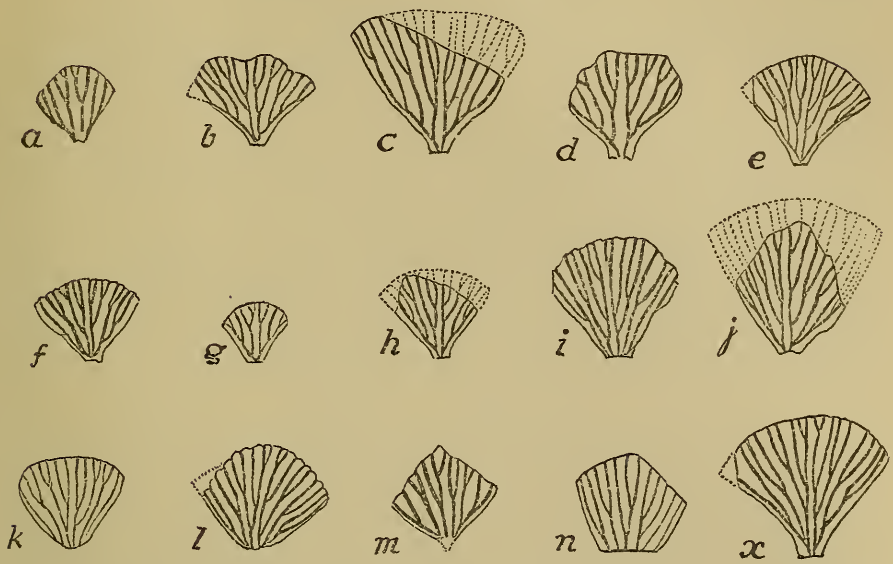
Locality: Shore north of Wisby (Gotland).

Horizon: Lower Silurian (as explained on p. 403). Beds **b** & **c** of Lindström.

Measurements of Specimens of *Petalocrinus visbycensis* (in millimetres).

	a	b	c	d	e	f	g	h	i	j	k	l	m	s	v	x
Length from ventral edge of facet	8·4	10	17 ?	12 ?	11·75	8·75	6 8	10 ?	14·75 ?	?	11 ?	12 ?	?	10 ?	9·75	15
Greatest width	8 ?	12·1	20 ?	11·75 ?	13·2 ?	10·8	6·5	11 ?	14·75 ?	?	12 ?	13 ?	?	12 ?	9·75	17
Width of facet	1	2	2·2	2·5	2·2	1·75	1	1·9	?	3	?	?	3	1·55	1·75	1·9
Depth of facet	·75	1·1 ?	1·6	1·5	1·5	1·25	·75	1·1	?	2	?	?	2	1·2	1·2	?
Thickness at distal end of arm	1·5	1·4	1 ?	1·1	1	·9	·9	1	1	?	?	1	?	·75	1·1	?
Number of finial grooves	12	18	18 ?	15	20	16	11	16 ?	22 ?	20 ?	16	18	?	16 ?	16 ?	20 ?
Angle of fan	76°	93°	81°	85°	76°	81°	70°	80°	82°	83°	?	89°	84°	87°	83°	86°
Angle of facet	?	?	65°	69°	?	55°	61°	?	?	60°	?	?	?	?	?	?

Fig. 8.—Petalocrinus visbycensis. *Tracings of arm-fans, partly restored.* (*Nat. size.*)



Notes on the specimens of which measurements are tabulated on p. 422.

a. The four admedian finials are only just beginning.
b. The distal edge is curiously lobed, not by fracture, and the median ridge is not in the line of greatest length.
c. There may have been more than eighteen finials. The thickness about the middle of the arm-fan is 1·3 mm.
d. The distal margin is irregular, perhaps imperfect. This may account for the uneven number of branches.
e. A perfect specimen; the Type.
f. A perfect specimen.
g. ,, ,,
h. Restored in the drawing. The number of brachials may well have been 18.
i. Much weathered, both at the ends and sides.
j is broken at the distal end, so that measurements of length cannot be given. Twenty branches can be seen; there may have been more. The thickness about the middle of the arm-fan is 2·1 mm.
k is weathered and rounded, and the facet quite lost.
l has lost its facet and a bit of its right-hand distal corner (left-hand as seen in the drawing).
m is broken at the distal end, and the proximal end appears to constitute an abnormal facet.
s has lost the distal right-hand quarter.
v has lost the distal left-hand quarter.
x lies on the matrix, so that only the ventral surface is exposed; it is slightly worn all over, especially towards the margins.

So complete a description of the arm-fan of *P. visbycensis* has been given under the head of general anatomy that repetition is needless.

Relations to other Species.—The only species with which the present one is likely to be confused are *P. mirabilis* and *P. inferior*. Were it not for the shagreen ornament and growth-lines, not always clearly seen even in *P. visbycensis*, and perhaps only absent from *P. mirabilis* in consequence of the mode of preservation, one might perhaps hit upon an arm-fan of *P. visbycensis* indistinguishable from one of *P. mirabilis*. This led me at first to regard both as a single species, and as differing mainly in the manner of fossilization. More careful study and more material has shown that, not only are the limits of variation in the Gotland specimens much wider than in those from America, but the norm (the acme of the variation-curve, the mode, as Prof. Karl Pearson calls it) is different in each set. This important fact once brought out, should not be obscured by confusing the two groups under one name.

No adult specimen of *P. visbycensis* is known to have more than 22 finials, whereas the type of *P. inferior* has 28. This, with the differing convexity, is quite enough to distinguish the species, so far as present material permits a judgment to be formed.

P. visbycensis (senior).

(Pl. XXV, figs. 12–15; text-fig. 9.)

Angle of arm-fan about 83°; fan bilaterally symmetrical in shape, but the distal branches do not correspond in the two halves; finials 24 to 28 (?); ventral surface gently convex, less so than in normal *P. visbycensis*; dorsal surface not seen; ridges for the most part wider than the grooves and flat-topped.

Type: Unique specimen in Riksmuseum, Stockholm.

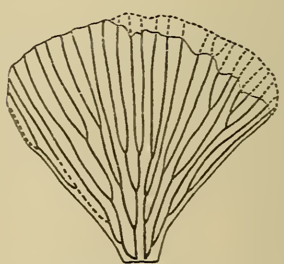
Locality: Westergarn (Gotland).

Horizon: Lower Silurian; upper part of bed **c** of Lindström.

Measurements of Specimen.—Length from ventral edge of facet, along middle ridge, 25·25 mm. Greatest length, which is in the right (left in ventral aspect) arm-branch, 27 mm. Length of side, 25 mm. Width, from median ridge to right (left in ventral aspect) side, 15·5 mm.; this doubled would be 31 mm., but in consequence of the loss of the distal edge of the left side, the actual width is 29·5. Width of facet, about 4 mm. Depth, about 2·25 mm.

Number of finials: in the left arm-branch 11, possibly 12, but since the distal margin of this arm is gone, there may well have been one or two more: in the right arm-branch, 13; but since this branch is imperfect on the outer edge, there may have been one more. The actual total of finials seen is 24, but the total in the perfect arm-fan may have reached 28. In any case 18 branches reach the level of VI Br, and three or four of these may well have become VII Br.

Fig. 9.—P. visbycensis (senior). *Tracing of arm-fan, partly restored.*



[Nat. size.]

Angle of arm-fan in proximal region is nearly 83°, but in the distal region is reduced to 70°, owing to the inward curvature of the sides. Angle of facet indeterminable.

In the proximal region the ridges are no thicker than in average specimens of *P. visbycensis*, and the arms branch neither more nor less. Towards the distal margin branching is less rapid, and this is correlated with the less angle of the fan; but since the arm does continue to increase in width, the ridges widen, and in some cases attain a breadth of 1·6 mm.

The characters in which this specimen differs from normal specimens of *P. visbycensis* all appear to be those of old age, namely, increase of grooves distally, and more particularly the irregularity of the increase combined with lessened angle of arm-fan and widening of ridges, also greater flatness of ventral surface. All these characters, except the number of the finials, are opposed to those of *P. inferior*, which there is no reason to regard as anything but a normal adult. Therefore, though the present specimen could not be included in *P. visbycensis* without disturbing the diagnosis, it seems better not to separate it as a distinct species, but to regard it as gerontic. This raises another question: Is it simply gerontic or phylogerontic? In other words: Is it a senile individual of the ordinary *P. visbycensis*-type, or is it a mutation that has acquired senile characters by acceleration of development? The large size of the specimen favours the former view; the fact that it comes from a higher horizon is not incompatible with the latter. Should further specimens be obtained from the same horizon and all found with these gerontic characters, then the form must be regarded as a phylogerontic mutation. For the present it may be distinguished merely by the addition of 'senior.'

P. angustus, n. sp.

(Pl. XXV, figs. 26–32.)

Angle of arm-fan 38°; fan bilaterally symmetrical in shape and number of grooves, but the levels of the branchings differ greatly in the two halves; finials 10; ventral surface of fan very slightly convex, except at distal margin; dorsal surface slightly concave along middle line, convex towards sides, with clear growth-lines and shagreen ornament; ridges much narrower than grooves, with crenulate tops.

Type: Unique specimen in Riksmuseum, Stockholm.

Locality: Shore north of Wisby (Gotland).

Horizon: Lower Silurian, bed **b** or **c** of Lindström.

Measurements of Specimen.—The proximal end is broken away, especially on the left side (right in ventral aspect). Length of median ridge preserved, 15·25 mm.; length of right side, 15·75 mm.; probable length from ventral edge of facet to distal margin, 16·5 mm. Greatest width of fan, 9 mm., occurs at 3·5 mm. from the middle of the distal margin; width at margin, about 8·6 mm. Width, depth, and angle of facet unknown.

Number of finials 10; and the distal narrowing of the fan shows that there would have been no more branching had the specimen attained even greater length.

Normal width of grooves, ·9 mm.; of ridges, ·5 mm.

Notes on the Specimen.—The law of branching is that of the genus, but the median ridge does not divide the specimen into similar halves, although the number of branches in each is equal. This is because branchings of the same order and nature do not take place at the same level, but all the branches of the right (left in ventral aspect) arm-half occur from 1 to 2 mm. more proximally than those of the left half. This arrangement considerably diminishes the width of the arm-fan, since in no two ridges do the broader regions occur at the same level.

The ventral surface is rather less convex in both directions than is that of *P. visbycensis*. The dorsal surface is slightly hollowed along a median triangular area with proximal apex. The lines of deposit of secondary stereom on the dorsal surface are well-marked, and the shagreen ornament follows the lines. At the distal end are depressions marking the original arm-branches; the distal margin also shows clearly the concavity of the ridges.

The notches for covering-plates are particularly clear; they lie, not at the sides of the ridge, nor precisely on its edge, but on the upper surface close to the edge; consequently the edge itself is almost straight, and the notches appear as one turns the specimen from side to side. The dots of pigment along the ridges have been discussed on pp. 419, 420.

Relations to other Species.—In dorsal aspect the angle of the arm-fan might suggest comparison with *P. longus*; but the number and arrangement of arm-grooves is quite different. The specimen cannot be considered as an undeveloped or aberrant *P. visbycensis*: it is longer than most individuals of that species, yet has no more finials than the youngest known; on the other hand, the number of finials and the narrowness of the fan are not due to mere loss of certain branches, but both form part of a consistent scheme of structure. These features separate the species still more strongly from the others known.

P. inferior, n. sp.

(Pl. XXVI, fig. 57; text-fig. 10.)

Angle of arm-fan about 70°; fan bilaterally symmetrical in shape and, apparently, in arrangement of grooves; finials 28; ventral surface of fan convex; dorsal surface not seen; ridges apparently less wide than grooves.

Type: Unique specimen in the Walker Museum, University of Chicago, registered U.C. 4736.

Locality: Near Monticello, Jones Co., Ia. (U.S.A.).

Horizon: Niagara Limestone, lower beds.

Approximate Measurements of Specimen.—Length, 18 mm. Greatest width, 19·6 mm. Width of facet, (?) 2·75 mm.; depth unknown.

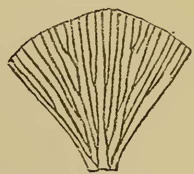
Number of finials visible: 12 on right side (left in text-fig. 10, which is reversed so as to make it comparable with the other diagrams), 13 on left side. Total visible, 25. There were probably 14 on either side, making 28 in all.

Angle of fan about 70°; it cannot be estimated very easily, as the sides are missing. Angle of facet unknown.

Ridges and grooves widen distalwards. At the distal margin five mediad ridges with their grooves have a united width of 4·2 mm., and four external ridges and grooves have a united width of 4·5 mm.

The concavity of the specimen (*i. e.* convexity of the ventral surface) is marked and equable.

Fig. 10. — Petalocrinus inferior. *Restored tracing of arm-fan.*



[Nat. size.]

Relations to other Species.—The number of finials separates this from *P. mirabilis* with 16, and *P. visbycensis*, with at most 22. From *P. visbycensis* senior, which has about the same number of finials, it differs in its regularity of branching and absence of senile characters. The length and width of the fan have about the same proportion as in *P. visbycensis*, but in *P. inferior* the width of the facet was probably greater, and the width of the grooves and ridges slightly less (in consequence of their greater number).

P. mirabilis, Weller.

(Pl. XXVI, figs. 37–56.)

Angle of arm-fan 51° to 83°, usually 71° to 78°; fan bilaterally symmetrical in shape and arrangement of grooves; finials 16; ventral surface of fan convex, more so than in *P. visbycensis*; dorsal surface slightly concave or flattened, no growth-lines or ornament seen; ridges usually less wide than grooves, and with rounded tops.

No specimen was selected as holotype by the author of the species.

Co-types are specimens **a**, **b**, collection of Mrs. A. D. Davidson, deposited on loan in the Walker Museum, University of Chicago, and specimens **g** and **h** in that Museum.

Meta-types are specimens **d**, **e**, **f**, **i** in the Walker Museum; **j**, **k**, **l** in the British Museum; and **c** in the Davidson Collection. For details, see pp. 405, 406.

Locality: Near Monticello, Jones Co., Ia. (U.S.A.).

Horizon: Niagara Limestone, upper beds.

Measurements: For those of the arm-fans, see the following table:—

Measurements of Arm-fans of *Petalocrinus mirabilis* (in millimetres).

	a i.	a ii.	a iii.	a iv.	a v.	b	c i.	c ii.	c iii.	c iv.	c v.	d i.	d ii.	d iii.	d iv.	d v.	e	f1 i.	f1 ii.
Length from ventral edge of facet ...	10 +	10 ?	10·2	10 +	?	11	13 ?	14 ?	13 ?	Broken off quite short.	Broken off short.	7·6	7·75	7·75	?	8	13·2	12	12
Greatest width	?	?	10 ?	?	?	12	14 ?	13·5 ?	Left half missing.			10	10	?	?	?	14·5	15	15
Width of facet	2·4	2·5	2·4	2·2	2·5	2·3	?	?				1·5	1·5	1·6	1·5	1·6	2·3	2	?
Depth of facet	?	2	?	?	?	1·3	?	?				?	?	?	?	?	1·5	?	?
Number of finial grooves	?	?	?	?	?	16	16	16				?	?	?	?	16	16	16 ?	15 ?
Angle of arm-fan	66°	55°	51°	61°	?	61°	74·5°	75°				73°	79°	78°	?	?	71·5°	83°	81°
Width of grooves + ridges at distal margin ..	?	?	?	?	?	1	1	1 ?				?	?	?	?	1	1	?	1·2

MEASUREMENTS OF ARM-FANS OF *PETALOCRINUS MIRABILIS* (CONT.).

	f1 iii.	f1 iv.	f1 v.	f2 i.	f2 ii.	f2 iii.	f2 iv.	f2 v.	f3	g i.	g ii.	g iii.	g iv.	g v.	h	i	j	k	l
Length from ventral edge of facet ...	?	13 ?	13·5	6	5·4	6·5	6·5	Not preserved.	?	10 ?	10 ?	10 ?	10	10	11	14 +	14·5	12 ?	8·5
Greatest width	15	14·1	15	7	?	7	7·5		12·3	10 ?	10 ?	10 ?	11·5	11·5	12·2	16 +	16	13 ?	9·5
Width of facet	2	2	2	1·5	1·2	1·5	1·5		?	2	2	2	2	2	1·5	?	2·5 ?	1 ?	2
Depth of facet	?	?	?	?	?	?	?		?	?	?	?	?	?	?	?	?	?	1·5 ?
Number of finial grooves	16	16 ?	16	?	?	?	?		16	?	?	?	?	16 ?	16	16	16	?	16
Angle of arm-fan	83°	75°	73·5°	73°	81°	71°	77°		58° ?	58°	61°	74°	80°	54° ?	73°	73°	72°	71°	75°
Width of grooves + ridges at distal margin ..	?	?	?	?	?	?	?		1	?	?	?	?	?	·85	1·25	1	?	·75

The thickness at the distal end of the arm-fans can rarely be observed; in **b** it is 1 mm.; in **d**, arm i about 1 mm.; and in **l** it is 1·2 mm. The angle that the facet makes with the ventral surface of the fan can be estimated only in **b**, where it is 83°; in **e**, where it is 75°; and in l, where it is 78°.

The first primibrach, seen only in this species, has a height along the dorsal line of ·5 mm. in specimens **a** and **d**, and has the same width as the facet of the radials and the arm-fans. Towards the ventral surface its height decreases.

The ridges between the grooves sometimes widen considerably at the distal end, as in **b**, but there is no sign of branching beyond 16 finials. The ridges are generally rounded, narrower than the grooves, and, when favourably preserved, display notches for covering-plates alternating on either side (as in specimen **b**). The covering-plates are not preserved, but one seems to see their impressions in specimen **f** 1, arm ii, as previously described on pp. 415, 416 (Pl. XXVI, fig. 47).

Measurements of Dorsal Cups (in millimetres).

	a	d	f 1	f 2	g
Height	3	1·6	?	2	?
Width from R to IR	6	4·4	6	3·25	4
Basals, height	1·3	1	?	?	?
,, width	1·7	?	?	?	1·2
Radials, height	2	1·5	?	?	?
,, width	3	2·3	3·6	?	?
Column, width	1	1	?	·5	?
Width between arms i–ii	2·5	2 ?	2·2	·75	1
,, ,, ,, ii–iii	2·5	1·7	2·5	1	1·2
,, ,, ,, iii–iv	2	1·5	2	1	1
,, ,, ,, iv–v	2·5	1·1	1·6	1	·5
,, ,, ,, v–i	2	1·5	2·5	1	1
Greatest width of crown	26·5	20·5	31	13·5	22

The dorsal cup, since it is known only in this species, has been described in detail under the head of 'General Anatomy.' In specimen **a** it is tilted a little on one side, exposing portions of the tegmen (Pl. XXVI, fig. 43); the sutures are fairly distinct. In **c** the cup is doubtless present, but covered by matrix. In **d** (Pl. XXVI, fig. 38) the cup is clear, but the sutures less distinct than in **a**. In **f** (Pl. XXVI, fig. 46) the cup is removed, and only the impression of the tegmen marks its former presence. In **f** 2 (Pl. XXVI, fig. 37) the sutures of the small cup cannot be distinguished: either they were anchylosed in life, or have been obscured by petrification. In **g** (text-fig. 1, p. 401) some of the cup-plates have been broken away, and only their outer casings left, as explained in the 'Description of Material' (p. 405).

The columnals are known only in this species, and, as shown in specimen **c** (Pl. XXVI, figs. 48–50), have already been described under the head of 'General Anatomy' (p. 420). Single columnals are also seen, attached to the cup in specimens **a**, **d**, & **f** 2, but not in **g**.

Relations to other Species.—From *P. inferior* this differs in the smaller number of finial grooves. From *P. visbycensis* it differs in the constancy of its branching; the more restricted limits of the angle of the arm-fan, which tends to be a smaller angle, as explained under *P. visbycensis*; the greater convexity of the ventral surface; and the less width of the ridges, as a rule. With the other species comparison is unnecessary.

P. longus, n. sp.

(Pl. XXVI, figs. 58–65; text-figs. 11 & 12, p. 432.).

Angle of arm-fan, 38°; fan divided into two unequal portions, different in the number and arrangement of their grooves, by a ridge to the right of the middle line in ventral aspect; the left-hand portion represents two normal halves, each smaller than the right-hand portion; finials: 10 in right-hand, 7 in middle, and 8 (preserved, ? 10) in left-hand portion; ventral surface of fan almost flat, bending dorsalwards slightly at proximal end; dorsal surface flat, no growth-lines or ornament seen; ridges mostly very narrow, with serrate tops.

Type: Unique specimen in the Walker Museum, University of Chicago, registered U.C. 4512.

Locality: St. Paul, Ind. (U.S.A.).

Horizon: Niagara Limestone.

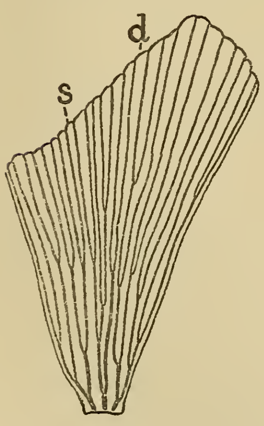
Measurements of Specimen.—Length from ventral edge of facet, 34·5 mm. Greatest width, 24 mm. Width of facet, 3·25 mm. Depth of facet, 1·9 mm. Thickness at distal end of arm, 1 mm. Number of finial grooves, (26 or 27) 25 preserved. Angle of arm-fan, 38°. Angle of facet, 72°.

The branching of this arm-fan is complicated; in discussing it, the terms 'right' and 'left' will be used to correspond with 'right' and 'left' of text-figs. 11 & 12 (p. 432), & Pl. XXVI, fig. 60, which represent the specimen in its ventral aspect.

First, we notice that the arm-fan is divided into two portions, differing in size and in the number of their branches, by a ridge (*d*) to the right of the middle line. Further, the left and larger of these two portions is again unequally divided by a ridge (*s*) that comes nearly, but not quite, to the proximal end of the fan. A normal arm-fan begins with a single and obvious bifurcation of the grooves—that is, with two grooves corresponding to IIBr. Here, however, it is hardly possible to distinguish the forking on either side of ridge *s* as being of a different order from the forking on either side of ridge *d*. Theoretically it may be so: that is, the pair of initial grooves on the left may represent IIIBr; but it simplifies matters to take the two portions on the left as each equivalent to the single one on the right of *d*, and to describe their initial grooves as IIBr. The diagram (text-fig. 12) therefore represents the arm-fan as composed of three portions, L, M, and R, separated by the two ridges *s* and *d*, and each beginning with IIBr.

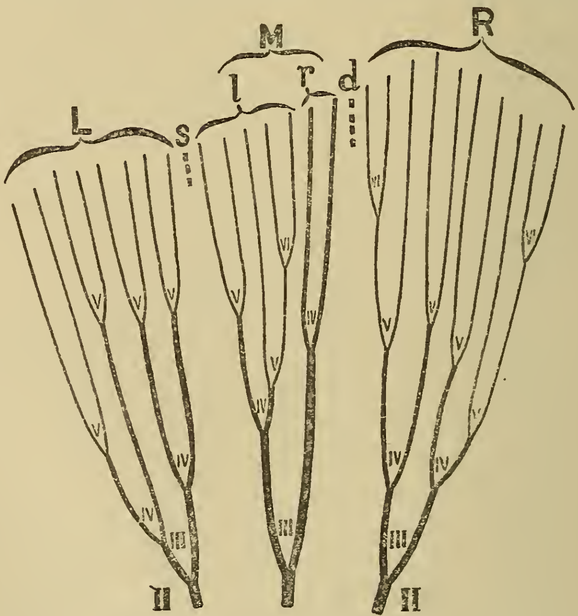
In portion R the branchings follow the law for the genus. There are ten finials, of which the two internal and the two external (using those terms throughout with reference to the whole fan) are VIBr, the others being VBr. The finials, especially the VBr, are very long, some occupying fully three-quarters the length of the fan. The ridges are narrowest about halfway down the arm, and thence gradually widen distalwards. Thus a single ridge narrows from ·4 to ·2 mm., and then widens to ·5 mm. The grooves, which are usually about ·5 mm. wide, may be compressed to ·25 mm., and widen distally to ·65 mm. The ridges are always narrower than the immediately adjacent regions of the grooves that they separate.

Fig. 11. — Petalocrinus longus. *Outline and branching of arm-fan*, × 2 *diam.*



s & *d*, sinistral and dextral ridges; L, M, & R, left, median, and right portions; *l* & *r*, left and right subdivisions of M.

Fig. 12.—*Hypothetical diagram of the same.*



In portion L the branchings follow the law for the genus, except that two rami of one dichotom (the internal IVBr, *i. e.* next portion M) both branch at the same level. The preserved finials are all VBr; but since a large part is missing at the distal end, we are free to suggest that the internal branch probably, and the external almost certainly, forked again. In that case the finials of portion L would precisely correspond to those of portion R.

Portion M is abnormal in its branching: first, in that it does not dichotomize into divisions that are at all equal, but forks into a left division with five finials (*l*), and a right division with two finials (*r*); secondly, in that the levels at which branching takes place cannot be harmonized with the law for the genus, and especially in the fact that the right-hand branch arising from the left IIIBr, forks again so soon as almost to produce the appearance of a trichotomy. The interpretation consequent on thrice-repeated examination of this particular area results in the numbering of the finials from left to right as V, V, V, VI, VI, IV, IV; this does not agree with either of the other portions in any respect, nor is such an arrangement found in any normal half of an arm-fan. Matters are not made clearer by any other interpretation that might possibly be put on portion M.

One may, therefore, describe the peculiar structure of this arm-fan as due to the intercalation of an abnormal portion (M) between two normal halves (L and R), M being derived by the abnormal branching of IIBr in L. This of course is no explanation, and it is indeed difficult to conceive a cause that could produce such variation in a structure so compact and usually so symmetrical, especially as the superficial symmetry of outline has not been disturbed.

Although the branching of the right-hand half is theoretically almost identical with that of the left-hand half, yet a practical difference is obvious in that so many of the dichotoms begin at the same level. There are in fact four adjacent finial dichotoms, three in this half and one in the intercalated portion, all of which start almost on the same line; one result of this is a sudden and marked thinning of the ridges in this region. The ridges are finely crenulate, and owing to the narrowness of some of the ridges, the crenulations meet right across, so that the edge is almost saw-like. In portion M, near the proximal end of the long finial, third from the left, there appear to be a few covering-plates preserved. They are inserted in the crenulations, and are much depressed. In some ridges there is a slight projection or rabbet below the crenulations, and this probably served to support the covering-plates. The axial canals are exposed at the distal ends of the grooves, as shown in Pl. XXVI, figs. 63 & 64.

The ventral surface of the arm is almost flat, but bends downward at the proximal end (Pl. XXVI, fig. 65).

The distal edge is very slightly scalloped at the ends of the grooves, while the ends of the ridges are almost flat, and do not show the slight indentation observed in *P. mirabilis.*

The dorsal surface (Pl. XXVI, fig. 58) is almost flat, rounded off along the two sides, especially at their proximal ends. It is covered with curious raised markings, like flat, irregularly anastomosing bands. These are probably due to mineralization and weathering. There are no traces of lines of growth or of shagreen ornament.

The facet (Pl. XXVI, fig. 59) is semicircular, widening outward at the upper angles. The axial canal, which lies in the middle, is split into two vertical slits, and lies in a slight depression, on either side of which, dorsad of the canal, is a scarcely perceptible swelling, corresponding to the two ridges in *P. visbycensis.*

Relations to other Species.—In the angle of the arm-fan *P. longus* resembles *P. angustus*; but, even apart from its greater size and abnormal construction, it is exactly the opposite of *P. angustus* in its mode of branching. Whereas in the latter species the branching is accommodated to the narrowness of the fan, in *P. longus* it is as unaccommodating as can be, and the numerous branches are squeezed into the constricted space by the narrowing of both grooves and ridges. In its tripartite division and the resultant greater number of its branches, *P. longus* is the analogue of *P. expansus*; but whereas in that species the fan is increased in width, not merely by the number of grooves but by the breadth of the intervening ridges, in *P. longus* the width of fan, grooves, and ridges is diminished. As regards the other species, even if we disregard the abnormality and the angle of the fan, there remain as clear differences the mode and number of branchings, the narrowness of grooves and ridges, and the length of the fan.

P. expansus, n. sp.

(Pl. XXV, figs. 33–36; text-figs. 13 & 14, p. 435.)

Angle of arm-fan, 90°; fan divisible into three portions, each corresponding to half a normal arm-fan; finials in each third 9–10, total preserved 28; ventral surface of fan flat, bending dorsalwards very slightly at proximal end; dorsal surface not seen, no trace of ornament on portions visible; ridges much wider than grooves, and flat-topped.

Type: Unique specimen in Riksmuseum, Stockholm.

Locality: Wisby (Gotland).

Horizon: Upper Silurian, base of bed **f** of Lindström.

Measurements of Specimen.—Length along ridge *d*, 21·25 mm.; length along ridge *s*, 18·9 mm.; greatest length, which is immediately right of *d*, 24 mm.; greatest length of portion left of *s*, 20·5 mm.; width of specimen, as preserved, 22·5 mm.; width of specimen, as restored, 28·5 mm.; width of portion left of *s*, as restored, 10 mm.; width of portion right of *s*, as restored, 18·5 mm.; width of facet, 3·5 mm.; depth of facet, 1·9 mm.; normal width of groove, ·8 mm.; greatest and least width of ridge *d*, 1·5 and ·5 mm.; greatest and least width of ridge *s*, 1·9 and ·9 mm.

The branching of this arm-fan is comparable with that in the type-specimen of *P. longus*, and may be described in a similar manner by dividing the ventral surface into portions L, M, and R, separated by ridges *s* and *d* (text-fig. 14).

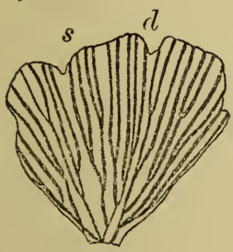
A difference is at once seen in the closer connexion of L and M, since the initial groove of L obviously arises from the IIBr groove of M. So long as this fact is duly recognized, it will facilitate description to regard the initial groove of each portion as IIBr, as was done in *P. longus*.

The 9 finials of L may thus be termed, reading from left to right: VI, VI, V, V, V, V, V, V, V. Similarly the 9 finials of M are: V, V, V, V, V*, V, V, VI, VI; while the 10 finials of R are: VI, VI, V, V, VI*, VI*, V, V, V, V. In each portion the branching

* VI*, VI* are produced by the forking of the branch corresponding to V*.

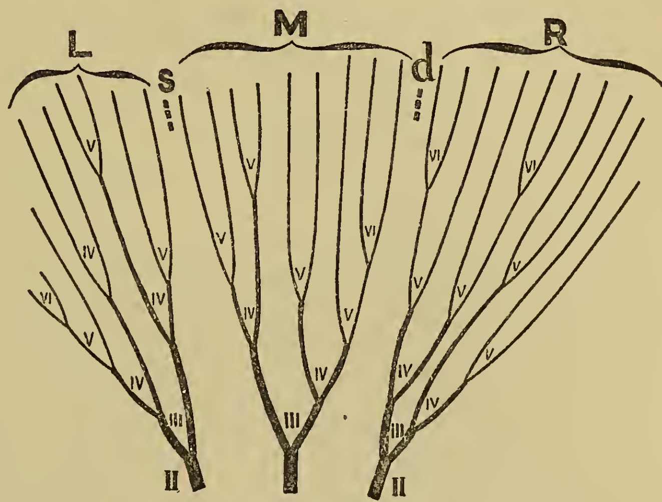
follows the law for the genus. We may describe the complete fan as consisting of a normal fan divided into two almost symmetrical halves M and R by the ridge *d*, and of another normal half-fan L of the same size and character budded off from M and separated from it by the ridge *s*. M and R differ only in the additional forking of one branch in R, as denoted above by the asterisks. Or

Fig. 13. — Petalocrinus expansus. *Tracing of arm-fan.*



[Nat. size.]

Fig. 14.—*Diagram of the same.*



we may regard L and M as forming two halves of a normal fan, absolutely symmetrical about the ridge *s*, so far as number of branchings is concerned; in this case R is the added half-fan arising immediately from IBr. The one thing that we cannot do is to regard the portion M as the intercalated one, as we found best in *P. longus*; the abnormality or the trend of evolution, whichever it be, is different in kind in the two cases.

The ventral surface of the arm-fan is almost quite flat, sloping downwards only at the proximal end and the distal margin. Ridges *s* and *d* are very broad and flat, of irregular width, and deeply excavate at the distal end. Ridge *s* shows clear traces of a furrow, the original line of fusion, in both its proximal and its distal region; and it is this which favours the view that L is the added half-fan. The broad and flat appearance of the other ridges is in part due to weathering, but in any case their width increases towards the distal end. There are no traces of covering-plates.

Relations to other Species.—That there is no real resemblance to *P. longus* has been shown already. The only question is whether we are not dealing with an abnormal variation of *P. visbycensis*; and were the difference confined merely to the addition of a half-arm, or even were this accompanied by some thinning of the ridges to compensate for the increased width, one might answer that question in the affirmative. But the variations with which the abnormality is correlated are not such as appear natural consequences of it; they are greater width and flatness of the grooves, and greater flatness of the fan as a whole. So marked are these features that they alone would suffice to distinguish the species. They are gerontic characters, as already explained under *P. visbycensis* (senior), but in this case they affect the whole fan to a far greater extent, and must be considered as phylogerontic, a view which consists thoroughly with the geological horizon of the specimen.

VI. The Affinities of *Petalocrinus*.

The arm-fan of *Petalocrinus*, considered by itself, presents a problem that the most accomplished specialist could hardly be expected to solve offhand. The solution here proposed was reached only with labour and patience; and even when confirmed by Mrs. Davidson's fortunate discovery of a complete crown, there were many details still obscure to those who had only the American specimens for study.

That the arm-fan has arisen by fusion of the branches of a dichotomous, non-pinnulate arm, is proved by the evidence given in detail above, namely: the law of branching of the grooves, the same as the law of arm-branching in a Cyathocrinoid; the emphasis of the dorsal depressions that correspond to the ventral ridges as they near the distal edge; the undulating outline of the distal edge, connected with the concavity of the ventral surface of the ridges, especially in the distal region; the lobation of the fan in correspondence with the dichotoms; the fine furrows sometimes seen on the ventral surface of the ridges, pigmented in *P. angustus*, and appearing in many sections, both horizontal and transverse, as fine black lines indicative of pre-existing soft tissue; the greater definiteness of this line along the median ridge, that is, between the two main rami or half-arms; the axial canals passing under the grooves, branching with them, and often merging into them at the distal end; the notches for covering-plates, if not traces of the actual plates. In the arm-fan as it at present exists, however, the original branches are very thoroughly fused, not merely by the lateral union of the brachials, accompanied by their fusion in a vertical direction, but also by the deposit of secondary stereom. The closeness of the ultimate connexion appears from the facts that fracture of the arm-fan always takes place along planes at a definite angle to the sagittal plane, and that the cleavage-planes cut cleanly across all the ridges and grooves. The whole arm-fan, therefore, constitutes, like any single ossicle of an echinoderm, a crystallographic unit.

Dichotomous arms following the regular law of arm-branching are more common among Dicyclica than Monocyclica; but to which of these Sub-Classes *Petalocrinus* belongs must be decided by the structure of the cup. This, it is claimed, shows a dicyclic base.

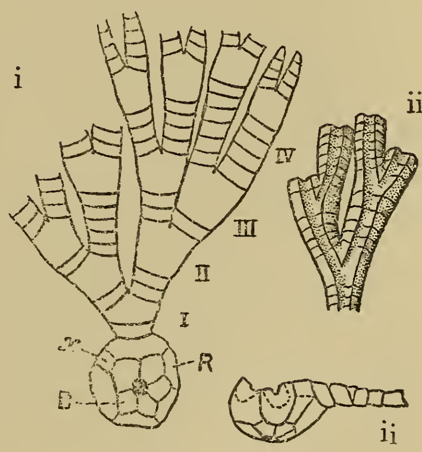
The simple structure of the cup, and the relation of the first primibrachs to the radials, proves that *Petalocrinus* belongs to the Order Dicyclica Inadunata.

The solidity of the tegmen, and the apparent prominence of five interradially-situated plates, lead one to refer the genus to the Sub-Order Cyathocrinoidea rather than to the Dendrocrinoidea.

Among Cyathocrinoidea the family Cyathocrinidæ is that which has already been mentioned as presenting certain resemblances; but the apparent absence from the cup of an anal plate prevents us from placing *Petalocrinus* actually within that family; so far as that is concerned, it agrees better with Codiacrinidæ, which are descendants of Cyathocrinidæ. The peculiar structure of the arms seems, however, to justify the erection of a separate family for *Petalocrinus*, as was in fact proposed by the founders of the genus.

Search must next be made among Cyathocrinidæ for a genus from which *Petalocrinus* may have sprung. This appears to be afforded by *Gissocrinus*, or still better by the subgenus *Arachnocrinus*, which is the chief American representative of the genus (text-fig. 15). The dorsal cup of *Arachnocrinus* is rounded and depressed; the infrabasals, which may be 3, as in the normal *Gissocrinus*, are as minute and as hard to distinguish as in *Petalocrinus*. The radial facet is almost vertical, and the arms come off at right angles to the vertical axis of the calyx, and continue in that plane for some distance. The same is the case with *Gissocrinus incurvatus* of Gotland, which, though intimately connected with undoubted *Gissocrini*, was in part doubtfully referred to *Arachnocrinus* by Wachsmuth & Springer, whose action was discussed on p. 168 of 'The Crinoidea of Gotland: I.'

Fig. 15.—Arachnocrinus bulbosus. *Diagrams adapted from J. Hall, Fifteenth Rep. State Cab. Nat. Hist. N.Y. pl. i, figs. 19, 20, & 21 (1862).*



(i) Basal view, with part of one arm shown. *B*, basal circlet; *R*, radial circlet; *x*, anal; I–IV, series of brachials. (ii) View from left post. radius, a small part of right post. arm remains attached (iii) Ventral view of a portion of an arm, showing the deep grooves and their bifurcation within the axillaries. [$\times \frac{4}{3}$.]

The difficulty of the comparison with *Arachnocrinus* lies in the lateral origin and horizontal position of the anal tube in that genus. I have tried to convince myself that certain elongate masses seen between some arm-fans in one or two specimens of *Petalocrinus* might represent fragments of a similarly placed anal tube, but without success. Negative evidence, however, is not fatal to the comparison, and we are not bound to postulate an anal tube in every *Arachnocrinus* or descendant thereof. A single species of *Cyathocrinus* may have an anal tube in some individuals and a mere opening through the tegmen in others. It may also be noticed that the anal plate in the dorsal cup of *Arachnocrinus* is usually smaller and less regular than in *Cyathocrinus*, as shown in text-fig. 15.

As concerns the arm-structure, I pointed out five years ago, with no thought of *Petalocrinus* in my mind, that in *Gissocrinus typus* and *G. campanula* the proximal brachials of each arm were disposed very regularly, lay close against one another laterally, had flattened sides, and appeared (perhaps were) laterally united by suture ('Crinoidea of Gotland: I,' pp. 157, 162). Text-fig. 15, reproduced from J. Hall, shows a feature that has not hitherto been noticed: if the drawing be correct, then in this species, *Arachnocrinus bulbosus*, the axillaries are compound plates; thus the apparent Iax consist of the true Iax and the right and left $IIBr_1$; this follows not only from the disproportionate length of the axillaries, but from the notch in their upper angles, representing the original division between the right and left brachials.

Gissocrinus, including *Arachnocrinus*, is then a genus that tends in the direction of *Petalocrinus*, as regards the structure of both dorsal cup and arms. If not the actual ancestor, it at least suggests the manner of evolution.

Petalocrinus has been compared by Mr. Weller with *Crotalocrinus*, on the ground of its arm-structure, and with *Platycrinus* from the appearance of the dorsal cup. The latter comparison is untenable if the base be dicyclic; in any case the evolution of arm-structure in *Platycrinus* and its allies was in the direction of biserial, pinnulate, slightly branched arms, right away from the structure of *Petalocrinus*. The arms of *Crotalocrinus* resemble those of *Petalocrinus* in so far as the branches are laterally united. The union, however, is by loose suture, is restricted to the distal ends of each ossicle, and is combined with great flexibility of the whole arm-net thus produced. The relation of the arm-net to the cup is also different from that of the arm-fan: by the partial atrophy or vertical compression of many proximal brachials, IIBr, and even IIIBr or IVBr, come to rest on the upper surface of the radial, while their corresponding ambulacrals are incorporated in the tegmen. The stages of this development are seen in *Enallocrinus*, as pointed out by Wachsmuth & Springer.[1] But from those writers I have always differed, in that I have believed this to indicate the evolution of the Crotalocrinidæ from the Cyathocrinidæ. Into this discussion, for which I have long been collecting materials, it is impossible now to enter. It is enough to have shown that the Petalocrinidæ and Crotalocrinidæ are related only in so far as they proceed from one starting-point along asymptotic paths.

The family Petalocrinidæ, hitherto undefined, may be diagnosed thus:—Cyathocrinoidea in which IBB are minute and probably fused, and in which the branches of each arm, from Iax to the finials inclusive, are fused into a rigid arm-fan, articulating with the cup by means of a free IBr_1.

[1] '*Crotalocrinus*: its Structure & Zoological Position,' Proc. Acad. Nat. Sci. Philad. 1888, pp. 364–390, pls. xix & xx.

VII. Summary.

This paper discusses the Silurian Crinoid genus *Petalocrinus*, Weller & Davidson, 1896, on the evidence of all the original material from Iowa, and of further material from Iowa, Indiana, and Gotland.

Petalocrinus is shown to have a dicyclic base, not monocyclic, as originally described. The structure of the tegmen is shown to be that of the Cyathocrinoidea. The arm-fans, characteristic of the genus, are proved to have been formed by fusion of the branches of an arm of Cyathocrinid type. In them are described for the first time axial canals, covering-plates, the articular facet, and various minor structures. The species *P.* (?) *major*, Weller, is shown to be an *Omphyma*; but *P. mirabilis*, Weller, the genotype, is redescribed, and with it five new species—*P. inferior* and *P. longus* from Iowa; *P. visbycensis*, *P. angustus*, and *P. expansus* (as well as a possible mutation, *P. visbycensis* senior) from Gotland. The family Petalocrinidæ, at present including only this genus, is diagnosed, and arguments are offered for its descent from Cyathocrinidæ, probably by way of *Arachnocrinus*.

EXPLANATION OF PLATES XXV & XXVI.

[All figures are twice the natural size (that is, ×2 diameters), except where the contrary is stated.]

Plate XXV.

Specimens from Gotland, drawn by Gustaf Wenman.

Petalocrinus visbycensis (p. 421).

Fig. 1. (g) Ventral view; shows scalloping of edge, and perfect ridges.
2. (g) Dorsal view; shows depressions corresponding to ventral ridges.
3. (g) Distal end, ventral surface upwards; shows indentation of ridges.
4. (f) Ventral view; shows perfect ridges with notched edges.
5. (e) Type. Distal end, ventral surface upwards. (*Cf.* fig. 3 & text-fig. 8, p. 423.)
6. (e) „ Ventral view; shows nearly perfect ridges with notched edges.
7. (e) „ Dorsal view; shows shagreen ornament, growth-lines, scalloped distal margin, and a *Beyrichia* embedded in secondary stereom.
8. (h) Ventral view; shows grooves opening in places into the axial canal. × 5 diam.
9. (p) Ventral view; the axial canals for the most part confluent with the grooves. × 5 diam.
10. (p) Proximal end of fragment; showing grooves I, II, III, IV, as explained on p. 419. × 5 diam.
11. (n) Proximal end ground down; for interpretation, see text-fig. 6 on p. 418. × 6 diam.
12. (senior) Elevation, as seen from distal end, showing transverse curvature. (*Cf.* fig. 33.)
13. („) Ventral view. (*Cf.* text-fig. 9, p. 424.)
14. („) Articular facet, left bottom portion broken.
15. („) Section along line of fracture *a–b*; shows traces of original sutures in middle of ridges. × 5 diam.

Fig. 16. (c) From true right side (left side of ventral view); showing angle of facet and longitudinal curvature. The distal corner on the other side is broken (see text-fig. 8, c, p. 423). × 4 diam.
17. (c) Articular facet; shows axial canal and diverging downwardly-directed ridges. × 4 diam.
18. (d) Articular facet, as in fig. 17; shows also apparent slight striation of dorsal margin. × 4 diam.
19. (j) Proximal end, from true left side, showing angle of facet.
20. (j) Articular facet. × 4 diam. (*Cf.* text-fig. 5, p. 416.)
21. (i) Abnormal facet, with two axial canals, and trace of original suture in median ridge. × 6 diam.
22. (m) Abnormal facet, with four axial canals in a concavity. × 6 diam.
23. (e) Type. Shagreen ornament on dorsal surface. × 10 diam.
24. (e) „ A ridge, seen from the side, showing notches for covering-plates. × 10 diam.
25. (p) A ridge, seen from the side, showing flat top and lateral notches. × 10 diam.

Petalocrinus angustus. Type (p. 425).

Fig. 26. Two ridges, seen from the side, three-quarter view; notches for covering-plates. × 10 diam.
27. One ridge seen from above, showing alternation of notches. × 10 diam.
28. Distal end. (*Cf.* figs. 3 & 5.)
29. Distal half, from true left side, showing lines of growth. × 6 diam.
30. From true right side; showing flatness of fan.
31. Ventral view; the traces of pigment are not shown, for the sake of clearness.
32. Dorsal view, showing growth-lines, shagreen ornament, and depressions corresponding with ventral ridges.

Petalocrinus expansus. Type (p. 434).

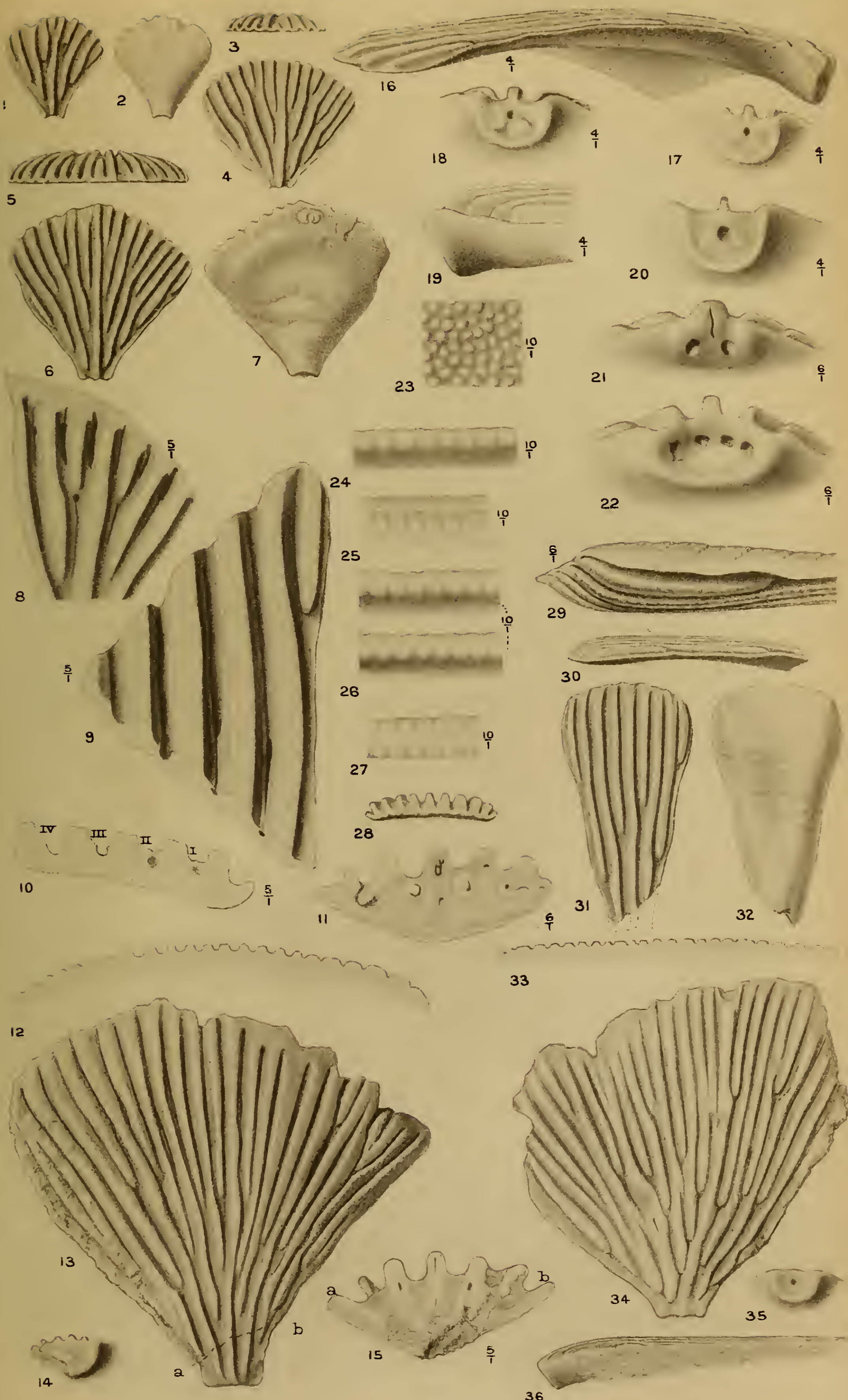
Fig. 33. Elevation, as seen from the distal end, showing transverse curvature almost flat.
34. Ventral view (*Cf.* text-figs. 13 & 14, p. 435).
35. Articular facet, much worn.
36. From true left side, to show angle of facet and absence of longitudinal curvature.

Plate XXVI.

Specimens from Iowa and Indiana, drawn by the Author, with some help from photographs and sketches by J. Green.

Petalocrinus mirabilis (p. 427).

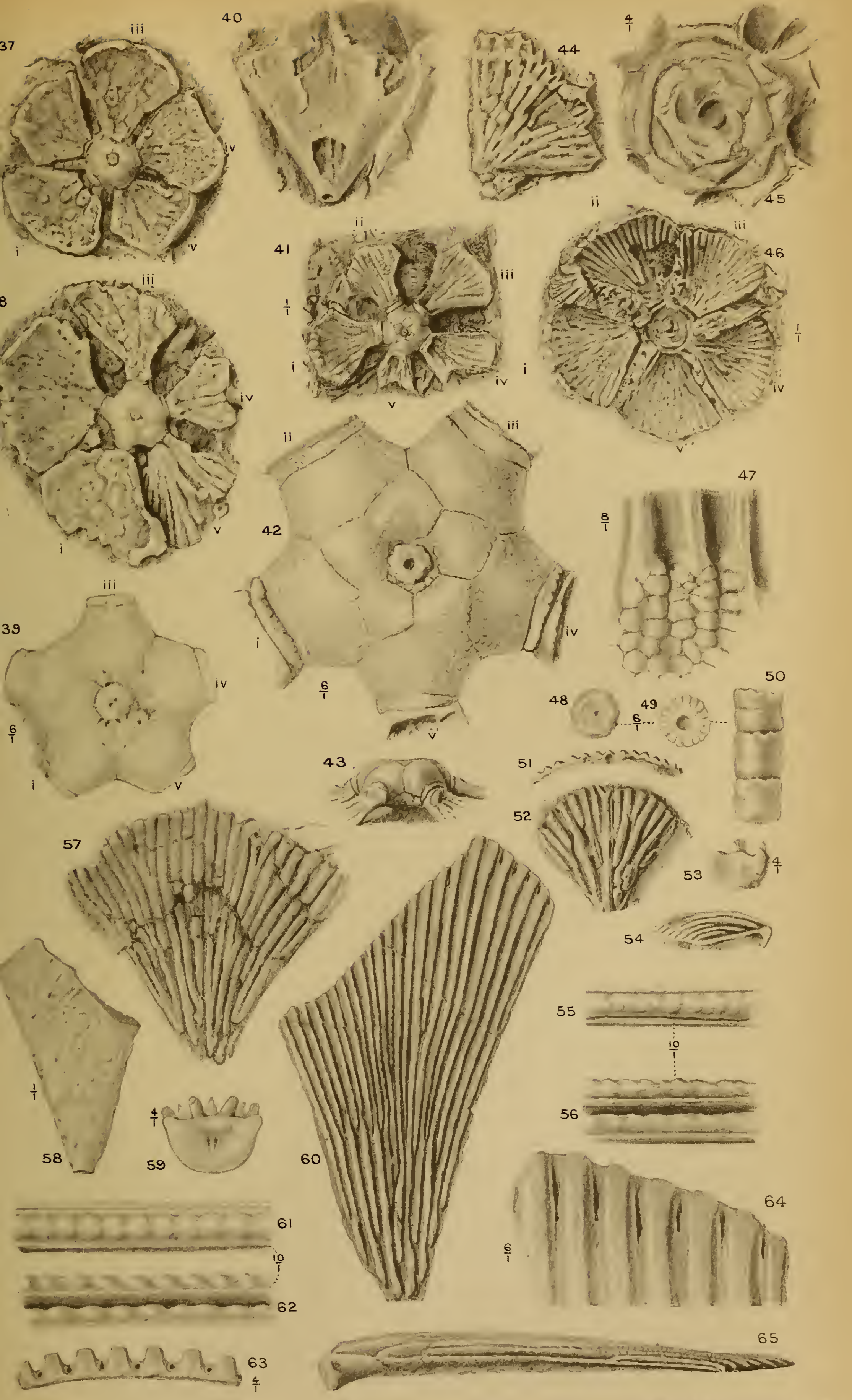
Fig. 37. (f 2) Dorsal view; the arm-fans arbitrarily numbered i–v.
38. (d 1) Dorsal view; the arm-fans arbitrarily numbered i–v.
39. (d 1) Dorsal cup, in the same orientation. × 6 diam.
40. (k) Dorsal view of an arm-fan; the dorsal surface removed in parts, exposing the cavity of the fossil and the floor of the ventral surface.
41. (a) Dorsal view; the arm-fans arbitrarily numbered i–v. Nat. size.
42. (a) Dorsal view of dorsal cup, in the same orientation, showing columnal, IBB, BB, RR, and IBr. × 6 diam.
43. (a) Dorsal cup, from interradius i–ii; showing portion of tegmen.
44. (d 2) An arm-fan from which the dorsal surface has been removed, seen in dorsal view, showing the floor of the grooves, here seen as ridges, and the scalloping of their ends.
45. (f 1) Ventral view of a wax squeeze taken from the impression of the tegmen. For interpretation, see text-fig. 3, p. 409. × 4 diam.



G. Wenman, del.

PETALOCRINUS from GOTLAND

BEMROSE & SONS LTD DERBY & LONDON



PETALOCRINUS from N. AMERICA.

Fig. 46. (f 1) Dorsal view of a crown from which the dorsal cup has been removed. The arm-fans show the floor of the grooves as ridges. A portion broken away in arm-fan ii exposes impressions of covering-plates. Nat. size.

47. (f 1) Ventral view of a wax squeeze taken from the impressions of ridges and covering-plates beneath the broken portion of arm-fan ii. The grooves are exposed in the upper part of the drawing, but hidden by covering-plates in its lower part. × 8 diam. (See p. 416.)

48. (c) Joint-surface of a columnal showing minute lumen in a slight concavity, and subpentagonal bevelling of edges. × 6 diam.

49. (c) Joint-surface of a columnal, striated, with lumen more definite than in fig. 48. × 6 diam.

50. (c) Side view of three columnals, showing the crenulation of the sutures. × 6 diam.

51. (1) Distal end, ventral surface upwards; shows considerable indentation of the median ridge.

52. (1) Ventral view.

53. (1) Articular facet. × 4 diam.

54. (1) From true right side.

55. (1) A ridge from above, showing notches for covering-plates. × 10 diam.

56. (1) Two ridges from the side, three-quarter view. × 10 diam.

Petalocrinus inferior (p. 426).

Fig. 57. Type. The impression of the ventral surface. (*Cf.* text-fig. 10, p. 427.)

Petalocrinus longus. Type (p. 431).

Fig. 58. Dorsal view. Nat. size.

59. Articular facet, showing double axial canal. × 4 diam.

60. Ventral view. (*Cf.* text-figs. 11 & 12, p. 432.)

61. A ridge from above, showing notches for covering-plates. × 10 diam.

62. Two ridges from the side, three-quarter view. × 10 diam.

63. Distal view of perfect upper corner of the fan, showing axial canals. × 4 diam.

64. Ventral view of perfect distal corner of the fan, showing axial canals emerging. × 6 diam.

65. From true left side, showing angle of facet and slight longitudinal curvature.

Discussion.

Dr. G. J. Hinde complimented the Author on the very successful manner in which, with such imperfectly preserved materials, he had elucidated the structural characters and affinities of this peculiar genus of crinoids. An examination of the specimens exhibited satisfactorily confirmed the interpretations given of them by the Author.

Dr. H. Woodward also spoke.

The Author thanked the Fellows for their reception of his paper, and was glad to find that it met with the approval of those who had overcome similar difficulties. He drew attention to another specimen exhibited by him, the first Silurian crinoid from Australia, named *Hapalocrinus Victoriæ*, and lent by Mr. T. Hall, of Melbourne University.

31. *On the* Grouping *of some* Divisions *of so-called* 'Jurassic' Time. By S. S. Buckman, Esq., F.G.S. (Read April 6th, 1898.)

Contents.

Introduction.

A considerable portion of this paper was written before the appearance of a communication on Dundry Hill.[1] A reference to the ideas set forth in this paper will be found in that communication, in Table IV, facing p. 696.

[When this paper was first presented to the Society the Author had designated the Ages by the terms Bathonian, Bajocian, etc., proposing, in effect, to continue the usage carried out in the communication above mentioned, to employ these terms for chronological purposes only. They have been used formerly, as for instance by Renevier, for both stratigraphical and chronological divisions:—Bathonian Stage or Bathonian Age.

However, it was pointed out to the Author that this plan would lead to confusion; and he then proposed to use, as distinctly chronological terms for Ages, names taken from dominant ammonite-genera. There is an advantage in this plan, seeing that the chronological divisions are based entirely upon zoological phenomena. And there was an admitted disadvantage in retaining for chronological purposes names such as Bathonian, Bajocian, etc., taken from places where particular strata were developed.

But the change has a wider effect if a congruous series of terms is to be produced. Jurassic is equally open to the same objection as Bathonian, and it will require to be replaced by a term taken from some zoological phenomenon. The divisions of Jurassic—Eo- and Neojurassic—fall into the same category; they may be easily replaced by such terms as Arietidan and Stepheoceratidan Epochs, which appropriately mark the changes of the ammonite-fauna. Jurassic and Triassic it is not so easy to replace; so, for the present, they remain. They are strictly stratigraphical terms; but they are used in this paper with inverted commas for chronological purposes. Thus 'Jurassic' Period denotes really the period

[1] 'Dundry Hill,' by S. S. Buckman & E. Wilson, Quart. Journ. Geol. Soc. vol. lii (1896) pp. 669–720.

during which the strata of the Jurassic System were deposited. On the other hand Mesozoic is a chronological, and not applicable as a stratigraphical, term.

This note is inserted for the purpose of explaining the reason for the changes introduced since the paper was read before the Society. They are only changes of name; the principle of the paper remains the same.—June, 1898.]

I. General Considerations.

In the present communication I have two main purposes in view. The first is to demonstrate the application of the chronological system of nomenclature in regard to a certain portion of time; the second is to construct what may be called a geological calendar, in order that those who are collecting fossils may be able to date the species which they find. Particularly do I give this for the benefit of those who are concerned with the biological aspect of palæontology, to whom a knowledge of the exact succession of organic beings in time is an important feature, to enable them to study the evolution.

It may be noted, with one or two exceptions, to be dealt with later, that all the hemeral names are taken from the names of ammonites. For the divisions of Mesozoic time this plan would be adopted so far as possible; and it needs no defence, for Haug remarks with regard to the zonal work of Oppel, Quenstedt, Neumayr, and others:—'L'importance des ammonites pour l'établissement du parallélisme des couches était reconnue, et en même temps se trouvait posé le principe que les autres fossiles marins, tels que gastropodes, lamellibranches, brachiopodes, échinodermes, ne devaient intervenir qu'en seconde ligne dans les assimilations. Quant aux caractères lithologiques, ils étaient naturellement refoulés tout-à-fait à l'arrière-plan.'[1]

Thus the next step in the arrangement follows by logical necessity upon this one; for if the ammonites are recognized as the best indicators of the faunal sequence, and since the chronological subdivisions depend upon this sequence, then the further grouping of the chronological subdivisions must be controlled by the zoological affinities of the ammonites. For instance, the shortest geological time-division is a hemera: that is, the time during which a particular species—generally in Mesozoic chronology, of an ammonite—had dominant existence. A longer space of time contains so many hemeræ; it is at present designated by the very faulty title of 'an Age'; but it is obvious that, as the hemera depends on the ammonite-species, an 'Age' must depend on the duration of allied series of ammonite-species. In the present state of ammonite-nomenclature the duration of an Age is dependent upon the duration of an ammonite-family, or at any rate, if not the whole period of duration, at least that portion of time during which the family was of the greatest importance as a constituent of the ammonite-fauna. In other words, as a family has its periods of

[1] Article 'Jurassique' in 'La Grande Encyclopédie,' Paris, 1894, p. 325.

rise, of maturity, and of decline (or, in scientific language, its epacme, acme, and paracme), so the duration of the Age would be principally governed by the period of acme, and would be less concerned with the epacmastic and paracmastic periods of the same family; because during any one such period should be found the acme of another family.

Following on this again as a logical conclusion is the recognition that any time-division larger than an Age must depend upon the duration in time of allied ammonite-families. When it is found that a certain number of ammonite-families allied from a zoological and evolutionary point of view flourish and disappear, to be succeeded in a similar manner by another quite distinct group of ammonite-families similarly allied among themselves, then it is obvious that, so far as is practicable, the time-division which embraces so many Ages should correspond to the period of time marked by this zoological phenomenon, and that the end of this time-division and the beginning of the next should coincide, as far as practicable, with the time when the one family-group has declined so low as to become unimportant, while a succeeding family-group has risen to importance.

Such are the theoretical considerations which should guide the application of a chronological scale. Their practical application, however, may not fully conform to the theoretical premisses because, in the first place, our knowledge of the faunas is very incomplete, even in connexion with the most fully-explored regions; and secondly, the faunal successions (as known to us) do not follow with that faultless regularity which would be necessary for the complete fulfilment of the conditions laid down. All that is possible, therefore, is to so arrange the chronological scale that while it expresses what we do know, it shall be able to show good reason for the arrangement where the actual facts of faunal succession do not possess the regularity which would be desired to make the arrangement perfect and indisputable.

The first point for consideration, therefore, is the date at which that division of the Mesozoic Era to be known as the 'Jurassic' Period should commence. Hitherto the stratigraphical division between Triassic and Jurassic deposits has been generally made at the base of the *planorbis*-zone. The change of lithic conditions and the incoming of ammonites in many places seem to make this horizon peculiarly distinct; but in a chronological scale these matters have not the least weight: the only thing to be taken into consideration is the zoological relationship of the ammonite-fauna of the pre-*rotiformis* hemeræ in comparison with the fauna of its successors and predecessors. First there are three genera in the pre-*rotiformis* hemeræ which are closely allied to one another—*Psiloceras*, *Wæhneroceras*, and *Schlotheimia*. If these genera were the parents of the forms which dominate the *rotiformis* and succeeding hemeræ, then it would be correct to place the pre-*rotiformis* hemeræ with their successors; but in my opinion they are not the progenitors: the genera of the *rotiformis* and later hemeræ are an entirely distinct series, of different descent. This, I am aware, is an extremely heterodox view, because *Psiloceras planorbis* is considered as the radical whence the Jurassic ammonites have sprung.[1] However, I read the affinities of this ammonite (*planorbis*) differently. It is, in my opinion, a decadent form which has attained to the smooth stage after its ancestors had passed through a ribbed stage, and of this ribbed stage it shows traces itself in the obscure costæ of its inner whorls. Its ancestors, I consider, were slowly-coiled costate species, like *tortile* or *Johnstoni*[2]; and, in fact, these species are the vigorous continuations of the same stock from which *planorbis* is a decadent offshoot. With these species it agrees in another character, namely, that the inner lobes are dependent, and point in an oblique manner across the whorl towards the periphery; but this is just the character which is not found in the Arietidæ, as I should define them, and on the absence of this character in the Arietidæ dominating the Asteroceratan Age I rely to show that they are not the descendants of *Psiloceras*.

Another view of the descent of *Psiloceras planorbis* has been taken by Mojsisovics: he considers it to be the descendant of *Monophyllites Clio*, a Triassic species from what he calls the 'Juvavische Stufe.' Although this might rather favour the chronological arrangement for which I argue, yet there are, to my mind, insuperable difficulties against its acceptance. The weightiest of these is that *Monophyllites Clio* does not, according to Mojsisovics's own figures, show that dependent character of the inner portion of the suture-line which obtains in *Psiloceras planorbis*. How then is it that *Psiloceras planorbis* shows this character, which it shares with other species? But there is a further objection: *Monophyllites Clio* does not show those ribs which should be found in a parent of *Psiloceras planorbis*, according to the evidence of the inner whorls of the latter species.

There still remains a large series of species in the pre-*rotiformis* hemeræ, which have been called *Arietites* or Arietidæ, and this might be thought to tell against my view; but in connexion with these species certain essential details have been disregarded. Thus Hyatt places in his genus *Caloceras* not only species such as *liassicum* and *tortile* (which have complex suture-lines with the inner portions strongly dependent, and the inner lobes pointing obliquely, across the whorl towards the periphery), but also species such as *raricostatum*, which have a simple suture-line running straight across the whorl and not dependent. Here there are species not only of two genera, but really of two families. *Caloceras* must be restricted to the first; Bayle's *Echioceras* is used for the second—the *raricostatum*

[1] '*Psiloceras planorbis* is a radical derived from *Ps. caliphyllum* or else from pre-existing Triassic ancestors, and the absence of a complete series connecting it or *Ps. caliphyllum* with *Gymnites* of the Trias is evidently due to the absence of an equally complete series of formations,' Hyatt, 'Genesis of the Arietidæ,' Smiths. Contrib. Knowledge, vol. xxvi (1889) No. 673, p. 117.

[2] Compare possibly *Ammonites lævidorsatus*, von Hauer, 'Nachtr. zur Kenntn. der Ceph. Fauna d. Hallstätter Schichten,' Sitzungsber. k. Akad. Wissensch. Wien, vol. xli (1860) pl. iii, figs. 9 & 10.

series.[1] *Caloceras*[2] must be removed from the Arietidæ on account of its septation; and because of this very character it forms with the genera *Psiloceras*, *Wœhneroceras*, and *Schlotheimia* a well-marked family, Psiloceratidæ, which flourished during the Caloceratan Age (time of Hettangian Stage) and almost completely came to an end in the hemera *marmoreæ*.

As to the exact connexion of this family with the particularly Triassic ammonites there is at present considerable doubt. In outward form they seem to be near many of them; but outward form in ammonite-classification and genealogy cannot be trusted, though Mojsisovics gives us only this and too few suture-lines upon which to form opinions. Then there is a great paucity of described species from the Rhætic[3] and from the underlying beds of the zone of *Sirenites Argonautæ*. As to the ammonites of this zone, Mojsisovics says that most of them are undeterminable owing to their bad preservation. But upon a consideration of the ammonite-fauna I venture to say that the Caloceratan Age should be regarded as the close of the 'Triassic' Period; that there is at the close of the Caloceratan Age quite a new departure in regard to the ammonite-fauna—an incursion of a new series, which, forming two families, Arietidæ and Hildoceratidæ, holds dominant sway throughout the Arietidan Epoch (time of Eojurassic Series); and that the greatest faunal break between the 'Triassic' and 'Jurassic' Periods occurs at this date, when the Psiloceratidæ give place to the Arietidæ.

As to the sedimentary change which occurred towards the end of the 'Triassic' Period, I wish to protest against the assumption of its contemporaneity. The argument for such an assumption usually travels in a circle—that the change of sediment marks the close of the Trias, therefore, *ipso facto*, wherever the change occurs is the close of the Trias, because of the change; and so the inference is that the sedimentary change was contemporaneous. But this takes for granted the very point which has to be proved, namely, that the change was contemporaneous; and the only proof of such contemporaneity can be given by palæontology.

Even if the contemporaneity of the change were proved, it need not affect the biological aspect of the case, which is that the

[1] The following species belong to Bayle's genus *Echioceras*:—*raricostatum*, d'Orb., the type; *Patti*, Dumortier; *Bodleyi*, Dum. (*non* J. Buckm.); *armentale*, Dum.; *Pauli*, Dum.; *Oosteri*, Dum.; *tardecrescens*, Dum. (*non* Hauer); *jejunum*, Dum.; *viticola*, Dum.; *Edmundi*, Dum.; *vellicatum*, Dum.; *Nodotianum*, d'Orb.; *Macdonelli*, Portlock; *aplanatum*, Hyatt; and, somewhat doubtfully, *carusense*, d'Orb.; *Newberryi*, Hyatt; *æduense*, Dum.

[2] Many of the species of *Caloceras* are figured by Wähner from the *marmorea*-beds of the North-eastern Alps, and the same peculiarity of septation is noticeable in them—the dependent, obliquely-directed inner lobes; see 'Beitr. tieferen Zonen d. unt. Lias in d. nordöstl. Alpen,' Pal. Oesterreich-Ungarns.

[3] I fully anticipate that the results of future work will show that the beds now called Rhætic are not strictly contemporaneous deposits, but that the case will prove similar to that of the 'Midford Sands' in connexion with Lias and Oolite respectively—namely, that what is Lias in one place is called Rhætic elsewhere, and what again is Rhætic in another place is called Juvavische Stufe somewhere else.

essentially 'Jurassic' ammonite-fauna did not begin to hold dominant sway until after the sedimentary change had been completed, and that ammonites of a different stock lived while the change was in progress (and in some districts after it was completed), occupying the new areas which the changed conditions had opened up for them.

What therefore it is justifiable to say is this—that during the last few hemeræ of the 'Triassic' Period there occurred certain local physical changes, as a consequence of which the sea occupied the areas of certain large inland lakes; and that thus the ammonites of the 'Triassic' Period could extend themselves over a wider area. So it is that the ammonite invasion makes a noticeable feature in the fauna of certain districts, and, being connected with a lithic change which has preceded it by a longer or shorter period in different cases, to it has been ascribed an undue prominence. But such a faunal feature, simply an accident of colonization owing to the opening up of new territory, is not of universal chronological importance, especially when the chronological data depend on the biological features connected with the rise and fall of particular ammonite-families.

Such, then, are the considerations which have induced the proposition—that if the biological affinities of the ammonites be correctly understood, the 'Jurassic' Period should be regarded as commencing at the beginning of the *rotiformis* hemera, and its first subdivision should be the Asteroceratan Age (time of Sinemurian Stage).

II. The Ages of the 'Jurassic' Period.

It is proposed to divide the 'Jurassic' Period into two Epochs —Arietidan and Stepheoceratidan—for reasons which will be seen presently. The Arietidan Epoch is divisible on biological grounds into four Ages, in the following manner:—

(*a*) First is the Asteroceratan Age, comprising seven hemeræ; and the Arietidæ, as now defined, excluding the Psiloceratidæ and *Echioceras*, dominate it entirely. They die away with some suddenness during the hemera *oxynoti*; and very few species of the family survive into the next Age.

(*b*) The succeeding space of time is the Deroceratan Age, and some strata called Lower Lias, besides all those called Middle Lias, were deposited during its continuance. The Deroceratan Age comprises seven hemeræ; but there is no permanent predominance of any particular family or genus during that time.

In the first hemera the species of *Echioceras* are dominant. Hitherto this genus has been regarded as one of the Arietidæ; but it is very obvious from the simplicity of its suture-line, from the uncarinate or merely subcarinate periphery of *Echioceras raricostatum*, from the depressed and not compressed whorls of this species, that a new departure has commenced, and that a new, less developed stock has come into prominent existence The ancestors of *Echioceras* must on these grounds be sought, not among the carinate compressed-whorled Arietidæ, but in a non-carinate, depressed-whorled, slowly-coiled, costate species, and certainly a species with a simple suture-line not dependent with regard to its inner lobes. Such would be the ancestor of *Echioceras*, a genus to be regarded as one of the forerunners of the Hildoceratidæ, which attain to so much importance later; and with that family it should be classed. Certainly *Echioceras* is only a migrant from some main stock existing in some unknown locality—perhaps a pelagic series. It soon runs its course, but other migrants from this stock appear at disconnected intervals during this Age; while after its close the ammonite-fauna consists almost entirely of successive migrant waves of Hildoceratidæ, their similarity to each other indicating a common origin.

The hemera which succeeds that of *raricostatum* is dominated by an entirely different series of ammonites—the genus *Deroceras* of the family Deroceratidæ, whose descendants, the Stepheoceratidæ, attain so much importance in the Stepheoceratidan Epoch.

The two following hemeræ saw the dominance of another family —the Polymorphidæ—in the genera *Uptonia*[1] and *Cycloceras*. Possibly as belonging to the same family, or more likely to the Deroceratidæ, may be reckoned the dominant genus of the next hemera—namely *Liparoceras*.[2] Two more hemeræ remain, and these witness the incursion of yet another family, the Amaltheidæ, and the remarkably sudden disappearance of this branch of it with the close of the hemera *spinati*.

The Deroceratan Age, therefore, is not dominated throughout its duration by any one family. Suitably, however, it begins with the replacement of the Arietidæ by the new series *Echioceras*,[3] and ends with the disappearance of the Amaltheidæ to permit of the next age commencing with the new incursions which dominate it.

(*c*) The succeeding Age is the Harpoceratan, consisting of ten hemeræ, and during nearly the whole time it is dominated by genera of Hildoceratidæ. During the earlier hemeræ the genera *Dactylioceras* and its allies—descendants of *Deroceras*—play a somewhat important part; but then they become insignificant, and almost disappear with the close of the hemera *bifrontis*,[4] while successive waves of Hildoceratidæ continue to be dominant until the hemera *dispansi*. At the close of this the Hildoceratidæ practically disappear for a time, and their place is taken by *Dumortieria*, a genus

[1] See p. 453.

[2] There may be more than one series in *Liparoceras*; they may be homœomorphs, descendants of genera belonging to the two families.

[3] It may be noticed that Haug divides the Charmouthian (strata of Deroceratan Age) from the Sinemurian (strata of Asteroceratan Age) at the base of the *raricostatum*-zone, but for a totally different reason—a stratigraphical one—namely that 'la trangression du Lias moyen paraît commencer avec la zone à *Caloceras raricostatum*.' (Article 'Jurassique' in 'La Grande Encyclopédie,' Paris, 1894, p. 326.)

[4] The idea that *Dactylioceras* is the forerunner of *Perisphinctes* cannot be too strongly condemned—as a study of the suture-lines is sufficient to show, or better still, a study of the inner whorls of *Perisphinctes*. That genus is the non-tuberculate degenerative of *Stepheoceras* (*Stephanoceras*).

of the Polymorphidæ. With the disappearance of the *Dumortieriæ* the Harpoceratan Age is fittingly brought to a close.

Here I would pause to say a few words concerning the Harpoceratan Age, on account of my treatment of its stratigraphical equivalent Toarcian [Stage] in a former paper 'On the Cotteswold, Midford, & Yeovil Sands.'[1] At that time, treating the term Toarcian in a somewhat different way—namely, from a mixed stratigraphical and palæontological point of view—I proposed that the Toarcian, during which the Hildoceratidæ were dominant, should include all the strata which were deposited during what are now called Harpoceratan and Ludwigian Ages, divided, however, into Lower Toarcian from *falciferum* to *opalinum*, and Upper Toarcian from *Murchisonæ* to *concavum* (see p. 473 of that paper).

Now, the dominance of the Hildoceratidæ throughout the Harpoceratan and Ludwigian Ages is even more fully confirmed to-day than when I wrote the paper just quoted, owing to our better knowledge of the affinities of ammonite-species. But this predomi nance suffers interruption during two hemeræ, when *Dumortieriæ* of the family Polymorphidæ hold nearly undisputed sway. If this interruption were to be disregarded, and the term Harpoceratan (time of Toarcian Stage) were to be applied to the whole space of time dominated by the Hildoceratidæ, the result would be an Age nearly twice as long as any of the others; and this would be highly undesirable. Therefore it is advisable to take note of the interruption in the dominance of the Hildoceratidæ, and to consider this event as a chronological landmark. As in the case of the Deroceratan Age ending with the incursion of the Amaltheidæ, so it is advisable that the Harpoceratan Age should have similar treatment, and be regarded as coming to a close with the incursion of the *Dumortieriæ*. Consequently the Ludwigian Age should begin when the Hildoceratidæ resume their sway. By this means the two Ages, Harpoceratan and Ludwigian, are brought to be of duration compatible with the length of time occupied by other Ages.

(*d*) The Ludwigian Age consists of six hemeræ, and it is dominated almost entirely by the Hildoceratidæ—a fact uniting it closely to the Harpoceratan Age. Further the Hildoceratidæ are, of all ammonite-families, the nearest allied to the Arietidæ of the Sinemurian ; and thus the biological features of the Ludwigian Age are similar to those of the preceding Ages. Noticeable during a portion of this Age is another attempt on the part of the Deroceratidæ to become established, in the case of *Hammatoceras* and *Erycites* ; these, however, never become of any considerable specific importance compared with the Hildoceratidæ. But the close of the Ludwigian Age is marked by the influx of another series of Amaltheidæ, namely the Sonnininæ.

As to the close of the Ludwigian Age, it is not continued in the present arrangement to include the hemera *discitæ*, wherein the final disappearance, so far as we know at present, of the Hildo-

[1] Quart. Journ. Geol. Soc. vol. xlv (1889) p. 440

ceratidæ takes place. It is true that this disappearance is very important, because with the disappearance of the Hildoceratidæ ends the dominance of that type of ammonite known as Arietidæ and Hildoceratidæ. Then with a short period of dominance of the Sonnininæ there comes the dominance, at any rate for the remainder of 'Jurassic' time, of an entirely different series—a very much more elaborately-developed ammonite—a descendant of the Deroceratidæ, which several times endeavoured to become dominant before—namely, the Stepheoceratidæ. However, in the *discitæ* hemera the Sonnininæ become dominant, so that both in individual size and in number of species they entirely overshadow the last remnants of the Hildoceratidæ. From a zoological point of view the Sonnininæ are the most important; and on this ground it is now proposed that the Ludwigian Age and the Arietidan Period should terminate with the close of the hemera *concavi*.

The Stepheoceratidan Epoch commences with the Sonninian Age (*e*), comprising five hemeræ during which the Sonnininæ are in their acme and their paracme. In the first four hemeræ they are certainly dominant; in the last they are few in numbers and small in size, and the importance of the Stepheoceratidæ which have accompanied them throughout is at last firmly established. The Sonninian Age is fittingly brought to a close with the final disappearance of the Sonnininæ in the hemera *Blagdeni*.

The Parkinsonian Age (*f*) commences with the first appearance of those peripherally-sulcate Stepheoceratidæ, hitherto called *Cosmoceras*, and now *Cosmoceras* and *Parkinsonia*, which play so important a part in the succeeding hemeræ. But, as to the suitable subdivisions of Parkinsonian time, we are in this country under difficulties, because of the non-ammonitiferous nature of the deposits. For this reason I have inserted in Tables I & II two names of brachiopoda as hemeral designators, but they are only intended for use until it can be certainly shown during what ammonite-hemera they lived. As to the time when the Parkinsonian Age should close, I do not feel competent to express an opinion: it must depend entirely on the ammonite-evidence, and be regulated by the time of disappearance of some portion of the essentially Parkinsonian fauna, or the incoming of a new fauna.

It may be remarked, however, that from the Sonninian Age onwards it would appear that all the ammonite-fauna, excluding the Lytocerataceæ, consists of two main families, the Stepheoceratidæ and the Oppelidæ. Developments of certain genera of these families may attain sufficient importance to be given family rank, but that will not alter the facts of the case, that after the Sonninian Age there are found no more members of the families Arietidæ, Hildoceratidæ,[1] Polymorphidæ, nor apparently of the Amaltheidæ.

1 The most Hildoceratoid genera of the Stepheoceratidan Epoch—namely *Hecticoceras* and *Lunuloceras*—are placed by Bonarelli in the family Oppelidæ. This is most likely the true reading of their affinities; see Boll. Soc. Malac. Ital. vol. xviii, p. 77.

Renevier's Chronographic Subdivisions.[2]	Chronological Terms. Ages.	Chronological Terms. Epochs.
Bathonien	...rkinsonian Age.	Stepheocera-tidan Epoch.
Bajocien............	...ninian Age.	
Aalénien	...lwigian Age.	Arietidan Epoch.
Toarcien	...arpoceratan Age.	
Pliensbachien	...oceratan Age.	
Sinémurien	...roceratan Age.	
Hettangien	...oceratan Age.	
Rhétien (as a divi-sion of Jurassic).		

...ical terms. They are on... ...ccording to faunal contents, they are
...uthorities have as to the... ...o locality.—June 16th, 1898.]
...-rendu VIème Congr. Gé... ...n i e n may qualify Stage or Age.]

TABLE I.

Stratigraphical Terms as used by certain Authors.[1]		Renevier's Chronographic Subdivisions.[2]	Approximate Zonal Terms used by Wright.	Chronological Terms. Proposed Hemeral Names.	Full Title of Distinctive Fossil.	Chronological Terms. Ages.	Epochs.
				Hemera.			
GREAT OOLITE SERIES.	Cornbrash. Forest Marble. Bradford Clay.			*disci.*	*Oppelia* (?) *discus.*		
				(*coarctatæ.*)	*Dictyothyris coarctata.*		
	Great Oolite. Stonesfield Slate. Fuller's Earth.	Bathonien		(*maxillatæ.*)	*Terebratula maxillata.*		
				subcontracti.	*Macrocephalites subcontractus.*	Parkinsonian Age.	
INFERIOR OOLITE SERIES.	Inferior Oolite: Upper Division.		Parkinsoni	*fuscæ.*	*Oppelia fusca.*		Stepheoceratidan Epoch.
				zigzag.	'*Stephoceras*' *zigzag.*		
				Truellii.	*Strigoceras Truellii.*		
				Garantianæ.	*Parkinsonia Garantiana.*		
				niortensis.	,, *niortensis.*		
		Bajocien		*Blagdeni.*	*Cœloceras Blagdeni.*		
				Sauzei.	'*Sphæroceras*' *Sauzei.*		
			Humphriesianum	*Witchelliæ* sp.	*Witchellia* sp.		
	Inferior Oolite: Lower Division.			*Sonniniæ* sp.	*Sonninia* sp.	Sonninian Age.	
				discitæ.	*Hyperlioceras discites.*		
				concavi.	'*Lioceras*' *concavum.*		
				bradfordensis.	*Brasilia bradfordensis.*		
	Northampton Sands.	Aalénien	Murchisonæ	*Murchisonæ.*	*Ludwigia Murchisonæ.*		
				scissi.	*Tmetoceras scissum.*	Ludwigian Age.	
			Opalinum	*opaliniformis.*	'*Lioceras*' *opaliniforme*, sp. nov.		
	Yeovil Sands.			*aalensis.*	*Grammoceras aalense.*		
				Moorei.	*Dumortieria Moorei.*		
	Midford Sands.		Jurensis	*Dumortieriæ* sp.	,, sp.		
				dispansi.	*Grammoceras dispansum.*		
	Striatulus-Shales (Yorkshire).			*Struckmanni.*	,, *Struckmanni.*		
				striatuli.	,, *striatulum.*	Harpoceratan Age.	
UPPER LIAS[3]	Cotteswold Sands.	Toarcien		*variabilis.*	*Haugia variabilis.*		
			Commune	*Lilliæ* sp.	*Lillia* sp.		
				bifrontis.	*Hildoceras bifrons.*		
	Upper Lias Shales.		Serpentinum	*falciferi.*	*Harpoceras falciferum.*		
			(Zone of *A. annulatus*, Tate & Blake)	*acuti.*	*Grammoceras* (?) *acutum.*		Arietidan Epoch.
			Spinatum				
MIDDLE LIAS	Marlstone and Sands.			*spinati.*	*Paltopleuroceras spinatum.*		
			Margaritatus	*margaritati.*	*Amaltheus margaritatus.*		
		Pliensbachien	Striatum	*striati.*	*Liparoceras striatum.*		
			Ibex	*Valdani.*	*Cycloceras Valdani.*	Deroceratan Age.	
	Lower Lias Clays.		Jamesoni	*Jamesoni.*	*Uptonia Jamesoni.*		
				armati.	*Deroceras armatum.*		
			Raricostatum	*raricostati.*	*Echioceras raricostatum.*		
			Oxynotus	*oxynoti.*	*Oxynoticeras oxynotus.*		
			Obtusum	*stellaris.*	*Asteroceras stellare.*		
				obtusi.	,, *obtusum.*		
			Turneri	*Turneri.*	*Arietites Turneri.*		
LOWER LIAS		Sinémurien	(Zone of *Pentr. tuberculatus*, auct.).	*Birchi.*	*Microderoceras Birchi.*	Asteroceratan Age.	
	Lower Lias Limestones.		(Upper *Bucklandi*, auct.).	*gmuendensis.*	*Coroniceras gmuendense.*		
			Bucklandi (Lower *Bucklandi*, auct.).	*rotiformis.*	,, *rotiforme.*		
				marmoreæ.	*Schlotheimia marmorea.*		
		Hettangien	Angulatum (?*A. laqueus*-zone, Reynès).	*megastomatos.*	*Wæhneroceras megastoma.*	Calceratan Age.	
			Planorbis	*planorbis.*	*Psiloceras planorbis.*		
TRIAS	Rhætic.	Rhétien (as a division of Jurassic).					

[1] [I take no responsibility for the stratigraphical terms. They are only placed here to give a rough guidance; and, with the exception of the Sands which are placed according to faunal contents, they are interpreted from the very different views which authorities have as to their use. In fact, any one term differs greatly in application, even by the same author, according to locality.—June 16th, 1898.]

[2] ['Chronographe géologique,' 2nd ed., Compte-rendu VIème Congr. Géol. Intern. Zürich, 1894. His subdivisions are both stratigraphical and chronological, for Bathonien may qualify Stage or Age.]

[3] [The arenaceous Midford and Cotteswold Sands have been ranged in the Inferior Oolite Series by certain authors, whereas their argillaceous equivalents in other places have been called Lias.]

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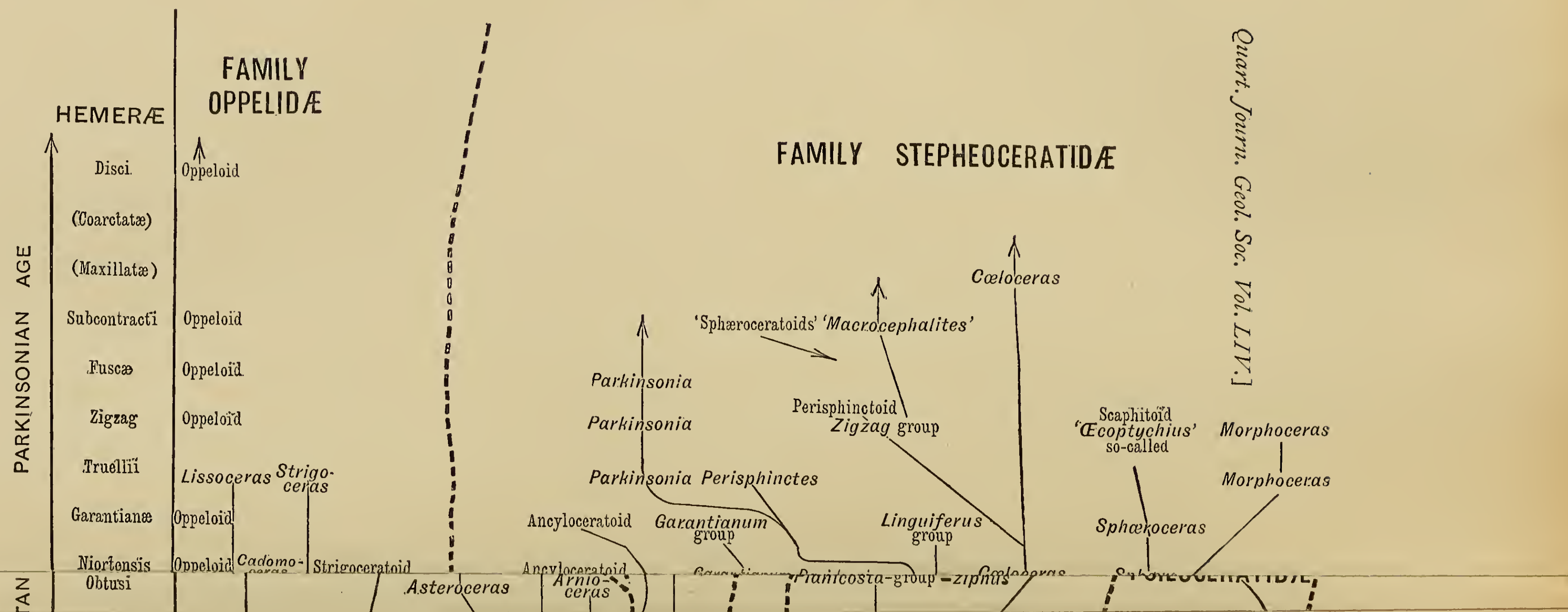
TABLE II.—AMMONITE-GENEALOGY.



Certainly such generic names as *Oxynotoceras* and *Amaltheus* are used for species of the Stepheoceratidan Epoch; but this use is founded only on external similarity, and not on a study of genetic affinities.[1] There seems therefore no reason to divide the 'Jurassic' Period into more than two Epochs: the earlier dominated by ammonites of the Arietidæ and Hildoceratidæ, which are closely allied to one another; and the later dominated by the far more highly developed Stepheoceratidæ, in company with the Oppelidæ.

III. The Divisions of a Portion of 'Jurassic' Time (with Table I).

Facing p. 450 is a table of time-divisions in illustration of the foregoing remarks. It will also serve as a definite time-table whereby the dates of the different 'Jurassic' species may be recorded —a matter of great importance for the study of palæontology.

IV. A Genealogy of some 'Jurassic' Ammonite Genera (with Table II, facing p. 451).

In order to illustrate the remarks which have been made concerning the divisions of 'Jurassic' time and their dependence on ammonite-evolution, a table of ammonite-genealogy has been constructed. However theoretical the ammonite-genealogy may appear—and it is not claimed as more than an approximate sketch of the probable lines of evolution—yet the table does present certain facts, namely, the times of occurrence of certain particular genera. It is as a record thereof that it is put forward. But on its interpretation an opinion is expressed, and that opinion is connected with the proposed method of subdividing 'Jurassic' time.

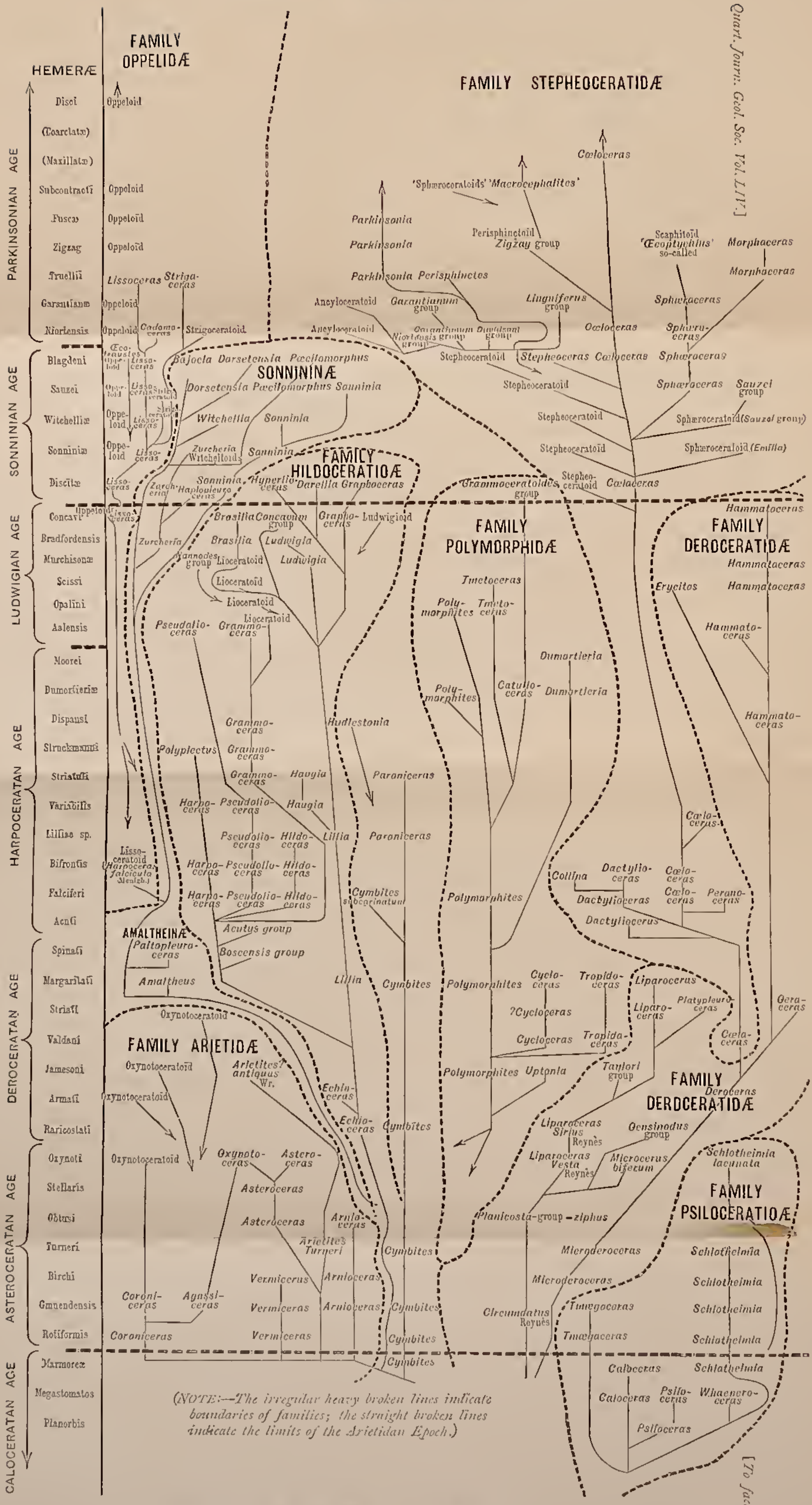
A comparison of this genealogical table with others, and the reasons for its differences therefrom, cannot be given in the present paper.

It may be remarked that the species of ammonites yet undescribed are very numerous, that of the described species only a small portion are treated with detail sufficient for genealogical purposes, and that therefore the data for genealogical work are often very insufficient. And when all the discovered species have been figured and described with full details, they will be only a portion of the total fauna which must have been in existence. So that genealogical data cannot be expected to be complete even then, though they may be sufficient for the purpose.

Attention may be called to the fact that in the same family a genus of ammonites farther removed from the assumed parent

[1] Something more than a crenulate carina is required to warrant the attribution of the *cordatus*-series to *Amaltheus* or to the Amaltheidæ. Their ontogeny and septal details must be considered, and the series will possibly be found to belong to the Stepheoceratidæ, not so very distant from *Parkinsonia*, etc.

TABLE II.—AMMONITE-GENEALOGY.



(NOTE:—The irregular heavy broken lines indicate boundaries of families; the straight broken lines indicate the limits of the Arietidan Epoch.)

[For 'Whaeneroceras' read 'Wæhneroceras'; for 'Emilia' read 'Emileia'; for 'Linguiferus' read 'linguiferum.]

[To face p. 451.

stock makes its appearance before another genus showing less removal therefrom. Or, put in another way, a genus showing a mature stage with greater dissimilarity to its young stage occurs before a genus showing a mature stage with less dissimilarity, which is equivalent to saying that the more phylogenetically-developed genus occurs before the less phylogenetically-developed genus.[1]

Instances may be given :—*Amaltheus* before *Paltopleuroceras*, *Dactylioceras* before *Stepheoceras*, and *Stepheoceras* before *Cœloceras Blagdeni*, as also the case of *Strigoceras* and Strigoceratoids mentioned later (p. 460, 3rd footnote).

In other cases a later genus is more developed in some respects and less in others than a preceding allied genus, showing that the preceding genus is scarcely the exact ancestor of the succeeding one, for instance *Ludwigia* and *Graphoceras*. A similar principle is noticeable among the genera of Hildoceratidæ as a whole—the earlier genera are sometimes more developed in some respects than the later. This is probably very much the case with the successive series which have been marked in Table II as Oppeloids. They are, possibly, often successive offshoots from less modified forms, not descendants from one another. Therefore I have not joined them in the table. The same may hold good with other stocks, even to a greater extent than I have indicated.

V. Notes on certain Generic Names.

In connexion with the Table of ammonite-genealogy the opportunity is taken to propose certain new generic names, to emend others which require modification, and to make certain remarks concerning particular appellations.

Genus Arietites, Waagen, emend.

[Type: *Arietites Turneri*, J. de C. Sow.]

This is merely a matter of arrangement. Waagen's *Arietites* was practically preoccupied by Hyatt's genera *Asteroceras*, *Arnioceras*, etc., and is therefore inapplicable to any of the species which belong to them. However, *Turneri* does not seem to fall into that category. Certainly it has been placed in *Asteroceras*, but that is partly because its specific identification has been so often incorrect. It is really quite distinguishable from *Asteroceras* on account of the mode of ribbing, especially the long forward projection of the costæ on the peripheral area.

Instead of proposing a new generic name, it seems feasible to use *Arietites* in a definitely restricted sense—applicable to a species which was not generically appropriated at the time when the name was proposed. Then *Turneri* becomes the type in this sense.

[1] A want of exact technical terms is felt here. More phylogenetically-developed may denote a series which is retrogressive, or which exhibits what are technically called phyl-hypostrophic characters in the race—hypostrophic in the individual. See 'Human Evolution,' Nat. Sci. vol. x (1897) p. 188.

There is a further reason in this. There is a family Arietidæ, and yet practically no genus *Arietites*.

It seems probable that Sowerby's plate ('Min. Conch.' pl. ccccli) contains species belonging to two genera. The upper figure is now taken as the type of *Turneri*.

Genus Oxynotoceras, Hyatt.

The compressed species of the Arietidan Epoch, which are generally classed as *Oxynotoceras*, are, as their septal details show, certainly polygenetic homœomorphs—the terminal lines of different genera. Most of them are possibly extreme developments of different genera of the Arietidæ; but there is also a possibility that one or more species may be developments of *Schlotheimia*, and so belong to the family Psiloceratidæ.

These matters can be settled only by long and careful working out of ontogenetic and septal details. Mere outward form is of no value in the matter of affinity.

Genus Uptonia, S. Buckm.

[Type: *Uptonia*[1] *Jamesoni* (J. de C. Sow.).]

The characters of this genus are that the spinous stage is never strongly developed, but that it only takes the form of small knobs upon the costæ; and that earlier or later, according to the degree of development, these knobs disappear, giving place to a strong costate stage. So a somewhat rotiform shape and strong, distant, straight costæ become the prominent features of the genus.

Hitherto *Jamesoni* has been regarded as a *Dumortieria*, but it and its series are separable therefrom on account of a more ornate septation.

Genus Paltopleuroceras,[2] S. Buckm.

[Type: *Paltopleuroceras spinatum* (Bruguière).]

This is merely a necessary alteration of name. *Ammonites spinatus* and allied species have been hitherto known as *Pleuroceras*; but that name is in prior use. The present description has reference to the strongly-projected character of the costæ on the peripheral area—the way in which they appear to be thrown forward.

There are several species of this genus, but they have hitherto been classed as '*spinatus* and varieties.' The mode of growth, the bisulcate periphery, and the simpler suture-line effectually separate the genus from *Amaltheus*.

[1] In compliment to Mr. Charles Upton, who has explored the *Jamesoni*-beds both in the South of England and in Scotland.

[2] παλτός, hurled.

Genus CŒLOCERAS, Hyatt.

It seems to me desirable to take *Ammonites pettus*, Quenst., as the type of this genus, and to restrict its use to those species showing the similar characters of a broad periphery, nearly flat from spine to spine, of depressed whorls, and crater-like umbilicus: that is, if, as would appear to be the case, these characters are due to direct descent, and are not independent developments in different series. These characters attain their maximum development in *Blagdeni*, Sow., and the same form of shell is found to characterize the young of the *Brocchi*-group, of the *Deslongchampsi*-group, of the *Humphriesianum*-group, and even the infant stages of *Parkinsonia* and its allies. These facts seem to indicate that *Cœloceras* is the radical form from which these others are offshoots.

The principal species of the genus as now constituted would be *Cœloceras pettus* (Quenst.), *C. Blagdeni* (Sow.), *C. Banksi* (Sow.), and *C. coronatum*, Brug. (d'Orb.). *Ammonites centaurus*, d'Orb., of the Deroceratan stage, is also related; but exactly in what manner is not easy to say at present.

Genus STEPHEOCERAS, S. Buckm.

This is only an alteration of the name *Stephanoceras*, because that was preoccupied when proposed by Waagen. The type-species, however, remains the same—namely, *Stepheoceras Humphriesianum* (Sow.). The distinction from *Cœloceras* is principally one of development—namely, that the broad flat periphery gives place at an early age to a rounded and narrower periphery. The broad flat periphery only yields to the arched periphery in *Cœloceras* in the gerontic stage (see *C. Banksi*); but in *Stepheoceras* the change takes place in immaturity. Thus what is only a gerontic and occasional feature in *Cœloceras* becomes the ephebic and regular character of *Stepheoceras*. Almost accompanying this feature is another—the recession of the inner margin from the line of tubercles, whereby in old *Cœloceras*, and in certain Stepheocerata, a so-called 'abnormal' body-chamber is produced,[1] but as growth proceeds on the same lines, and in other species the change takes place at an earlier age, what is a so-called 'abnormal body-chamber' at the time of the change becomes a perfectly normal feature, with almost imperceptible recession.

Thus there are really three styles of umbilication in *Stepheoceras*:—1st, in the immature whorls, up to a time which varies with the species, regular concentric umbilication, with the inner margin of the overlapping whorl in contact with the spines of its predecessor; 2nd, a period when the umbilication becomes excentric, owing to recession of the inner margin from the line of spines; 3rd, a period of renewed concentric umbilication, when practically the whorls coil concentrically, so far as each is concerned with the other, but all of them coil at a distance from the line of spines, so that the

[1] See d'Orbigny, 'Céph. Terr. Jurass.' pl. cxxxiv, *Ammonites Humphriesianus*.

concentric coiling in the latter case differs from that of the first, and is the result of the change brought about by a period of excentric coiling.

These stages may be seen in *Ammonites Humphriesianus*, d'Orb., pl. cxxxiv:—1st stage, all whorls, except the last ¼ whorl; 2nd stage, last ¼ whorl. In *A. Humphriesianus*, d'Orb., pl. cxxxiii (*Bayleanus*, Oppel), reduced one-third:—1st stage, about first four whorls; 2nd stage, about the next whorl, when the shape of the whorl gradually changes from depressed to compressed, and becomes narrower; 3rd stage, the rest of the fossil.

I desire to direct especial attention to these figures, because some remarks of mine in this connexion appear to have been misunderstood. I would also direct attention to *Morphoceras* as a descendant of *Sphæroceras*, where *Sphæroceras* shows the beginning of excentric umbilication. *Morphoceras dimorphum* shows excentric umbilication with compression of the whorl, tending to become again concentric, and *Morph.* '*polymorphum*' (d'Orb., pl. cxxiv, figs. 5 & 6) shows the further development of this renewed concentricity. I claim that the same change of coiling which produced *Stepheoceras* from *Cœloceras*, and *Morphoceras* from *Sphæroceras*, also produced the Arietidæ, etc., from *Cymbites*. Further, that it is a mistake to regard *Cymbites* as a senile form incapable of producing descendants because of its abnormal body-chamber, and to class it with admittedly senile forms such as *Cadomoceras*, *Œcoptychius*, *Œcotraustes*, etc.—as grave a mistake as it would be to regard the want of teeth in a baby's mouth as the same phenomenon as their absence from the mouth of an old man.

In regard to the evolution of *Stepheoceras*, it may be remarked that the same method which produces the true *Stepheoceras* from *Cœloceras* is repeated again and again to produce other similar series as degeneratives of *Cœloceras*. Hitherto all these forms have been called *Stephanoceras*; but in reality they are heterogenetic or polygenetic series, agreeing only in the fact of being in a certain stage of development—the stage when the broad periphery gives place to the narrower one.

Similarly, the present use of *Perisphinctes* means only polygenetic series of degeneratives from *Stepheoceras* and allied forms —series which have lost the spinal ornaments. *Sphæroceras* is really used also in a similar manner; and it may be noted that if the broad periphery be retained, but becomes arched with increase of inclusion the while, forms called *Sphæroceras* and *Emileia* are produced. Later, in these forms is seen the process of decrease of inclusion resulting in *Morphoceras*, on the one hand, and *Emileia polymera* on the other. But when this decrease of inclusion takes place *pari passu* with the reduction of the breadth and the arching of the periphery, then are produced what have been called *Stephanoceras*: to one series of which, the *Humphriesianum*-group, the name *Stepheoceras* is now appended, in lieu of *Stephanoceras*, which must lapse altogether on account of prior use.

Genus Emileia,[1] S. Buckm.

[Type: *Emileia Brocchi* (Sow.).]

A Sphæroceratoid ammonite-series distinguished from the true *Sphæroceras* by (1) very complicated septa; (2) obtuse-ended primary costæ, in the form of elongate knobs; (3) the loss in phylogenetic development of the spheroidal form and the assumption of a more discoidal or rotiform shape—as, for example, in *Emileia polymera* (Waagen).

The developmental feature noticed under (3) is the result of the earlier inheritance of the 'excentric' mode of coiling. Lateral compression of the whorl proceeds in company with a decreasing degree of envelopment.

Genus Œcoptychius, Neumayr.

I have noted in the genealogical Table (II, facing p. 451) a Scaphitoid so-called '*Œcoptychius*,' its date being the early part of the Parkinsonian Age. An *Œcoptychius Grossouvrei*, from 'Bajocien supérieur, Sully,' has recently been figured and described by M. Brasil.[2] A specimen of this species has been in my cabinet some 15 years, collected by Mr. F. Stubbington, from Broad Windsor—top beds—evidently from the deposits of the *zigzag* hemera. I gave it a MS. name as a new species of *Œcoptychius*. But with my present knowledge of homœomorphous forms I doubt the correctness of the designation.

The species certainly has a remarkable likeness to the *Œcoptychius refractus*, Rein.,[3] which is the type of Neumayr's genus. But that is a Kellaways species; and *Grossouvrei*, to belong to the same genus, must have been the ancestor of *refractus*. This involves the supposition that this peculiar distorted form remained with little alteration or modification for a very long time, during which a whole series of distorted forms ought to be found connecting *Grossouvrei* and *refractus*. In my opinion, such direct genetic connexion is doubtful, and I regard the similar shape of these species as the independent results of similar causes. *Grossouvrei* is apparently the refracted form of *Sphæroceras*, and possibly the final representative of that particular line. *Refractus* seems to be the distorted form of another series, because it shows what *Grossouvrei* does not, a subsulcate periphery,[4] so that it is, possibly, the refracted form of a peripherally-sulcate series allied to *Parkinsonia*. These species are heterogenetic homœomorphs.

This homœomorphy goes even farther: for Quenstedt figures[5] a

[1] In compliment to M. Émile Haug.

[2] Brasil, 'Céph. nouveaux,' Bull. Soc. géol. Normand. vol. xvi (1893) p. 45 & pl. iv, figs. 12 & 13.

[3] Reinecke is the author of the specific name, not de Haan, who is generally credited with it. Reinecke forestalled him by 7 years.

[4] *Teste* d'Orbigny. The ribs are distinctly interrupted on the periphery.

[5] 'Amm. Schwäbisch. Jura,' vol. i (1885), p. 368 & pl. xlvi, fig. 7.

Scaphitoid—'*Scaphites bifurcatus*' from the Upper Lias; and that is presumably a refracted *Dactylioceras*.

These Scaphitoid forms are important, because, from phenomena exhibited by them and by injured ammonites, it seems possible to state as a biological law that there is a tendency to hypostrophy —to revert to ancestral conditions upon any disturbance of individual economy. Such disturbance may be: (1) sudden, such as an injury, and therefore local in action, restricted to the part affected; (2) long continued, such as unfavourable environment, and therefore general, affecting the whole shell. The law is the same in each case, and the results are similar: in the first case, a local hypostrophy in the parts affected; in the second case, general hypostrophy. The acquirement in the second case is transmitted to posterity; but in the first the evidence of transmission is less certain: attention may be drawn, however, to the case of *Asteroceras Slatteri* (Wright).

The shape of *Œcoptychius refractus* and *Œc. Grossouvrei* may be regarded as the result of the efforts of a coiled cone to revert to the ancestral form of a straight cone; and the struggle between the tendency to coil and the tendency to straighten produces the peculiar shape. As there is no sign of local injury which would reveal itself in displacement of the costæ, the only conclusion would seem to be that the forms are due to unfavourable environments.

The Scaphitoid shape is, however, only an exaggerated exhibition of the same process as that which produced the so-called abnormal body-whorls—the tendency to excentric coiling. The different degrees may be noted in *Gervillii*, *bullatus*, and *refractus*.

In another family may be compared a series ending in *Cadomoceras*, which, after all, denotes Scaphitoids (see p. 460).

Note.—Of course the important point to establish is whether *Grossouvrei* be a degenerative of *Sphæroceras*, and *refractus* a heterochronous homœomorphous degenerative of another series. If *Grossouvrei* be not the ancestor of *refractus*, it cannot bear the name *Œcoptychius*. Whether it have another generic name than *Sphæroceras* is the merest matter of detail, but if it be only a form of expression of a decadent *Sphæroceras*, it is doubtful whether another generic name is required. The less decadent forms of *Sphæroceras* are distinguished as *Morphoceras*.

Family Hildoceratidæ.

I make the following notes concerning certain genera in this family, but it may be remarked that all its genera will require very considerable revision. This is now in preparation, in connexion with my monograph on the 'Inf. Oolite Ammonites' (Palæont. Soc.).

It has been found that the curvature of the ribs in the species of this family affords a generic criterion of the first importance. This subject has not hitherto received sufficient attention, but in the figures now being prepared in connexion with the monograph, it is intended to give an outline of the rib-curve in all cases.

Genus Lioceras, Hyatt.

[Type: *Lioceras opalinum*, Reinecke.]

The species which I placed under this generic name in my monograph will have to undergo considerable revision. Though they have a certain similarity of external form, they differ appreciably in the trend of their costæ (or striæ) and to a certain extent in septal details.

Further, there are several species similar to *opalinum*, even to the possession of the fine hair-like striæ; but on strict examination these species are found to have differences of rib-flexure. In some instances they existed at different dates, in other cases they were contemporaneous; but they have caused great geological confusion.

And then the question arises, which among these very similar forms is really the true *opalinum*? For it is *opalinum* and its ancestors which constitute the genus *Lioceras*. And Reinecke's figure of *opalinum* is, in connexion with such similar forms as these, very difficult to interpret, as the drawing is by no means exact enough for the purpose.

The subject will be more definitely treated in the forthcoming part of the monograph, but I would now note that the specimen figured as *opalinum* in that work, pl. xiii, figs. 1 & 2, will be separated from *opalinum* as a distinct species by the name *opaliniforme*, and also as a distinct genus. This will explain the use of the term *opaliniformis* in the hemeral Table (I); and in the genealogical Table (II) it is entered as Lioceratoid.

Genus Brasilia,[1] S. Buckm.

[Type: *Brasilia bradfordensis*,[2] S. Buckm.]

The flexure of the rib is the distinguishing character of this genus: the curvature is different from that which obtains in the *opalinum*-group—true *Lioceras*.

Genus Graphoceras,[3] S. Buckm.

[Type: *Graphoceras v-scriptum*,[4] S. Buckm.]

The V-shaped costæ which suggested the specific name separate the type and other species as a genus distinct from any hitherto-named genus of the family Hildoceratidæ.

[1] In honour of M. Louis Brasil, who has done good work among the Jurassic ammonites of Normandy.

[2] Monogr. Palæont. Soc. 'Inf. Ool. Amm.' pt. i (1887) pl. iv, figs. 5 & 6.

[3] γράφος, what is written, a letter.

[4] *Op. supra cit.* pt. ii (1888) pl. x, figs. 5 & 6.

Genus Darellia,[1] S. Buckm.
[Type: *Darellia semicostata*, nom. nov.[2]]

The costæ are something between V-shaped and biarcuate in curvature, and they are associated with a carinate-tabulate periphery. The features of the periphery are similar to those of *Hyperlioceras*, but the rib-curvature is quite different: in that genus there is a long peripheral projection. The features of the periphery distinguish this genus from *Graphoceras*, and so does the rib-curve.

Specimens figured as the immature forms of *Hyperlioceras Walkeri*, namely those depicted in pl. xvi, figs. 3, 4, 5 & 6 of the monograph (pt. iii, 1889), are shown by their rib-curve to belong to this genus. They are generically and specifically distinct from *Hyperlioceras Walkeri*, and it is proposed to distinguish them as *Darellia polita*—separable from *Darellia semicostata* by a smaller umbilicus.

In order to make the generic names which are used in the genealogical Table (II) more intelligible and easier for reference, a list of them is now appended, with certain illustrative species.

VI. List of Genera arranged under Families.

Opposite the generic names are placed the names of certain illustrative species. In most cases the name which stands first may be considered as the type-species.

Family AMALTHEIDÆ.

Subfamily Amaltheinæ.

Genus.	Species.
Amaltheus.	*margaritatus, nudus.*
Paltopleuroceras.	*spinatum, hawskerense.*

Subfamily Sonnininæ.

Genus.	Species.
Bajocia.	*Farcyi.*
Dorsetensia.	*Edouardiana.*
Haplopleuroceras.	*subspinatum.*
Pœcilomorphus.	*cycloides.*
Sonninia.	*propinquans, Sowerbyi.*
Witchellia.	*læviuscula.*
Zurcheria.	*Ubaldi, pugnax.*

Family ARIETIDÆ.

Genus.	Species.
Agassiceras.	*Scipionianum, Gaudryi.*
Arietites.	*Turneri.*
Arnioceras.	*semicostatum, Hartmanni.*
Asteroceras.	*obtusum, stellare.*
Coroniceras.	*rotiforme, Bucklandi.*
Oxynotoceras.	*oxynotus.*

[1] In honour of Mr. Darell Stephens, F.G.S., to whose assiduous collecting in the Inferior Oolite of the Sherborne district science is indebted for a knowledge of many new species.

[2] *Lioceras decipiens*, var. *intermedium* (?), Monogr. Palæont. Soc. Inf. Ool. Amm.,' pt. ii (1888) pl. xii, figs. 10 & 11.

Family DEROCERATIDÆ.[1]

Genus.	Species.
	densinodus-group.
Deroceras.	*armatum, Davœi.*
Erycites.	*fallax, gonionotus.*
Hammatoceras.	*insigne, amplectens.*
Liparoceras.	*Henleyi, capricornus.*
Microceras.	*biferum.*
Microderoceras.	*Birchi.*
	planicosta-group.
Platypleuroceras.	*latœcosta.*
	Taylori-group.

Family HILDOCERATIDÆ.

Genus.	Species.
	acutus-group.
	boscensis-group.
Brasilia.	*bradfordensis.*
	concavum-group.
Darellia.	*semicostata*, nov.
Grammoceras.	*striatulum, aalense.*
Graphoceras.	v-*scriptum.*
Harpoceras.	*falciferum, Strangwaysi.*
Haugia.	*variabilis, jugosa.*
Hildoceras.	*bifrons, serpentinum.*
Hyperlioceras.	*discites, Walkeri.*
Lillia.	*Lilli, tirolensis.*
Lioceras.	*opalinum.*
Ludwigia.	*Murchisonœ.*
	nannodes-group.
Polyplectus.	*discoides.*

Family OPPELIDÆ.

Genus.	Species.
Cadomoceras.[2]	*cadomense.*
Lissoceras.	*oolithicum.*
Œcotraustes.	*genicularis.*
Oppelia.	*subradiata.*
Strigoceras.[3]	*Truellii.*

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[1] There are three fairly distinct series in this family :—(1) *Liparoceras*, etc.; (2) *Deroceras*, etc.; (3) *Hammatoceras*, etc. In *Hammatoceras* a strong carina is developed, and the species have considerable external similarity to *Sonninia*. The suture-line, however, is very distinct, and attests the relationship with Deroceratan forms. ('Descent of *Sonninia* & *Hammatoceras*,' Quart. Journ. Geol. Soc. vol. xlv, 1889, p. 651.)

[2] This denotes an extreme gerontic form—possibly a degenerative offshoot of *Lissoceras*. But there are homœomorphous species, almost certainly polygenetic, and certainly heterochronous. Their similarity has caused much mistaken identification; this similarity, coupled with difference in date, has made much trouble in matters of stratigraphy.

[3] With regard to *Strigoceras* and Strigoceratoid forms there seems to be a remarkable development of closely similar forms 3 times over. The first series of Strigoceratoids lived during the *Witchelliœ* sp. hemera. They disappear; but during the *niortensis* hemera there lived another very similar series. Then during the *Truellii* hemera there appeared another series, apparently at first less developed than any of their forerunners, but ultimately developing to become very similar to them.

Family POLYMORPHIDÆ.

Genus.	Species.
Catulloceras.	*Dumortieri, Leesbergi.*
Cycloceras.	*Valdani, Maugenesti.*
Dumortieria.	*Levesquei, radians.*
	grammoceratoides-group.
Tmetoceras.	*scissum.*
Tropidoceras.	*Masseanum.*
Uptonia.	*Jamesoni, Reynardi.*

Family PSILOCERATIDÆ.

Genus.	Species.
Caloceras.	*torus, Johnstoni, liassicum.*
Psiloceras.	*planorbis.*
Schlotheimia.	*angulata, marmorea.*
Tmægoceras.	*latesulcatum.*
Wæhneroceras.	*tenerum, megastoma.*

Family — ? —— Radical Stock.

Genus.	Species.
Cymbites.	*globosus.*
Hudlestonia.[1]	*affinis, Sinon.*
Paroniceras.	*sternale.*

Family STEPHEOCERATIDÆ.

Genus.	Species.
Cœloceras.	*pettus, Blagdeni.*
Collina.	*gemma.*
Dactylioceras.	*commune, annulatum.*
	Davidsoni-group.
Emileia.	*Brocchi, polymera.*
	Garantianum-group.
	linguiferum-group.
Macrocephalites.	*macrocephalus.*
Morphoceras.	*pseudoanceps, dimorphum.*
	niortensis-group.
Parkinsonia.	*Parkinsoni.*
Perisphinctes.	*Martinsii.*
Peronoceras.	*fibulatum.*
	Sauzei-group.
Sphæroceras.	*Gervillii, Brongniarti.*
Stepheoceras.	*Humphriesianum.*
	zigzag-group.

The inclusion of a generic name does not imply the expression of any opinion as to its validity or otherwise. Nor does the mention of an ammonite-group imply that it is entitled necessarily to generic rank.

Quenstedt's *Psilonoticeras*, *Arieticeras*, etc., are really invalid, because they were admittedly proposed as mere modifications of existing names—of *Psiloceras* and *Arietites* respectively.

Munier-Chalmas's *Cadomites* and *Normannites*, of the family Stepheoceratidæ, were names given for supposed sexual features.

[1] The affinities of *Hudlestonia* must be considered very doubtful. It is possibly an extreme development of the radical stock. There is another similar series—the *staufensis*-group, its horizon given as *Murchisonæ* zone, its date perhaps *scissi* or *Murchisonæ* hemera—which may be another extreme development.

VII. Summary.

This paper contains the following:—

(1) An argument that chronological divisions in geology should depend on faunal features.

(2) The proposition that 'Jurassic' chronology should be governed by the phenomena of ammonite-development.

(3) The opinion that the 'Jurassic' Period should be divided into two epochs, Arietidan and Stepheoceratidan, and that the first should commence with the Asteroceratan Age and end with the Ludwigian.

(4) A hemeral time-table whereby species may be dated.

(5) A genealogy of some 'Jurassic' ammonites to illustrate the chronological remarks.

(6) Notes on certain generic names and the proposal of some new generic titles.

(7) A list of the genera to which reference has been made, arranged under families.

Discussion.

Mr. H. B. Woodward remarked that most geologists would agree that two sets of divisional names were needful: one to indicate chronology, and the other to indicate the stratigraphical formations. Stratigraphical names could not be interfered with by Mr. Buckman's paper. He need only refer to Prof. Lapworth's detailed work in the Southern Uplands to show how important were stratigraphical names; and he had no doubt that they would last for ever. The changes of grouping proposed by the Author were such as should be considered over a wide area. A worker paying special attention to *Belemnites* would probably arrive at very different conclusions. Moreover, the diagram exhibited by the Author showed no special reason for making chronological divisions at any one stage more than another. He felt strongly that the paper was one that should have been submitted to the International Geological Congress, rather than to the Geological Society.

Prof. Seeley regarded the Author's labours in endeavouring to trace the phylogeny and affinities of ammonites as a valuable contribution to palæontology. The attempt to classify the Lower Secondary strata by this evidence might be less important than the diagrammatic demonstration of the periods of time during which characters of external form and internal structure were distributed in the ammonite-tribe. It was usual to find that species appeared prior to the physical changes which brought in the rocks which those species distinguished by their abundance. He trusted that the Author would maintain the familiar nomenclature of the Oolites as the basis for his stratigraphical language, since the paper appeared to be an attempt to trace the influence of stratigraphical conditions on the distribution of palæontological characters in an important group of fossils.

The President also spoke.

32. *The* GRAPTOLITE-FAUNA *of the* SKIDDAW SLATES. By Miss G. L. ELLES, Newnham College, Cambridge. (Communicated by J. E. MARR, Esq., M.A., F.R.S., F.G.S. Read May 4th, 1898.)

[PLATE XXVII.]

CONTENTS.

I. INTRODUCTION.

THE term Skiddaw Slates is the name given to all the sedimentary and contemporaneous volcanic deposits of the Lake District and its neighbourhood, which lie below the Borrowdale Volcanic Series. Mr. Marr has shown (Geol. Mag. 1894, p. 122) that the main outcrop of these beds lies north of the mass of volcanic rocks which constitute the central hills of Cumbria. This outcrop seems to be continued in a south-south-easterly direction across the eastern end of Ulleswater to Shap, though it is partly covered by a deposit of Carboniferous Conglomerate.

Another mass of Skiddaw Slate forms the hill of Black Cone in the south of Cumberland, and a small outcrop also occurs near Dalton-in-Furness.* The same rocks appear to be extensively developed in the Isle of Man, though the beds there seem to be unfossiliferous.

East of the Lake District the Skiddaw Slates are again found in the Cross Fell Inlier, and have been mapped in the small inlier of Teesdale.

The beds are always much contorted and faulted, and greatly affected by cleavage; also in certain places they have been extensively altered by the protrusion of igneous rocks through them.

The largest collections of fossils have been made in the Keswick district, where the beds have been well worked by local observers. Some of these are well preserved, but the best fossils, as a whole, come from the Cross Fell Inlier. The following are the chief localities from which fossils have been obtained:—

(1) KESWICK DISTRICT. Randal Crag, Carlside Edge, and White House Fell (Skiddaw), Barf, Outerside, Bassenthwaite Common, Saddleback, Glenderamakin Valley, Troutbeck.
(2) ULLESWATER DISTRICT. Aik Beck, Pooley = Eggbeck.
(3) SHAP DISTRICT. Thornship Beck.
(4) CROSS FELL DISTRICT. Ellergill, Milburn.

At Mr. Marr's request I undertook the description of the graptolite-fauna of these beds. My intention at first was to confine myself to a description of the specimens in the splendid collection of Skiddaw Slate fossils in the Woodwardian Museum at Cambridge, which now includes that made by the late Mr. Kinsey-Dover, of Keswick. I soon found, however, that it would be impossible to do this without repeated reference to specimens elsewhere, and it therefore seemed best to make the work as comprehensive as possible, by including a description of all specimens of interest in whatever collections they might be. This I have been enabled to do, owing to the great kindness of the many collectors of Skiddaw Slate fossils. In the following pages therefore, though the Woodwardian Museum Collection forms the main basis of my work, reference will constantly be made to other collections, especially to those of Prof. H. A. Nicholson, Mr. J. Postlethwaite, and the Collection of the Keswick Museum of Local Natural History.

For some time the graptolite-fauna of the Skiddaw Slates has been considered of especial interest, as possessing affinities with the fauna of the Quebec Group of Canada, though the exact relationships have never been worked out. As I hope to be able to show, the fauna is also very closely related to that of the Swedish *Phyllograptus*-skiffer, though it probably includes also a fauna from beds at a lower and higher horizon.

In the descriptions of the species, I have not entered into any detail when a species has been already figured and described, unless the Skiddaw Slate forms show some differences from the type. When it has been possible, I have given a full description of the structure of the proximal end, as I believe this to be a point of the greatest importance. In many cases few, if any, structural details can be made out, but in others the specimens are preserved in relief in iron pyrites, and show more detail than has been noticed by the authors who have previously described them. The absence of any remarks concerning structure may be taken to mean that the specimens were not sufficieutly well preserved for such to be made.

In a few cases generic descriptions have been modified in accordance with the results of recent work, and in some cases also, for similar reasons, a modification has been made in the description of a species, or a fuller description given than that already in existence.

II. Previous Literature on the Skiddaw Slates.

(*a*) Stratigraphical.

1820, 1832. The earliest account of the Skiddaw Slates is that given by Otley in 1820, in the Lonsdale Magazine, vol. i, p. 433, the next being that of Prof. Sedgwick, published in Proc.

Geol. Soc. vol. i, p. 399. In this paper the author described briefly the range and extent of the Skiddaw Slates as then recognized, and gave some account of their lithological characters. He stated that they contain no organic remains;
1848. but he subsequently (1848) called attention to the discovery of two graptolites, and a few so-called fucoids (Quart. Journ. Geol. Soc. vol. iv, p. 223). He concluded that these are the earliest forms of life, and regarded the Skiddaw Slates as representing beds below the *Lingula*-Flags of Wales.
1863. The first detailed account of these rocks was given by Harkness in his paper on 'The Skiddaw Slate Series' (Quart. Journ. Geol. Soc. vol. xix, pp. 113–135). There he described fully the various districts in which the Skiddaw Slates are exposed, and their variation in lithological character in different localities. He also gave sections illustrating the relationships of these beds to others in the district. In conclusion, he referred the Skiddaw Slates to the Lower Llandeilo, that is, to the rocks which, in the Shelve area, overlie the Tremadoc and underlie the main mass of the Llandeilo (= Arenig in modern nomenclature).
1876. The next paper of importance is the Geological Survey Memoir on the Northern Part of the English Lake District, written by J. Clifton Ward. He gave a general account of the different rocks to which the term Skiddaw Slates has been applied, and the alteration that these have undergone from various causes. Below the Volcanic Series the sequence given by him is as follows (*op. cit.* p. 47):—

Interbedded volcanic strata and Skiddaw Slates.
(5) Black slates of Skiddaw.
(4) Gritty beds of Gatesgarth (Buttermere), Latterbarrow, Tongue Beck (Skiddaw), Watch Hill, and Great Cockup.
(3) Dark slates.
(2) Sandstone series of Grasmoor and Whiteside.
(1) Dark slates, Kirk Stile, between Loweswater and Crummock.

He regarded (5) as Upper Arenig, (4) as Middle Arenig, (3) as Tremadoc, and (2) and (1) as the equivalents of the *Lingula*-Flags.
1879. This opinion Clifton Ward subsequently emphasized in a paper in Geol. Mag. 1879, pp. 49 & 110, where (on p. 124) he summed up the evidence as follows:—'The physical evidence inclines one to believe that the Skiddaw Slates include the Arenig Slates, the Arenig Grit, the Tremadoc Slates, and the *Lingula*-Flags.' His conclusions were based entirely on physical evidence, and, in accordance with the custom of that time, the palæontological evidence was absolutely neglected; nevertheless, subsequent palæontological work bears out his views in general, though the actual divisions made by him do not now hold good.

1894. Of the more recent papers, the most complete is that of Marr, who, utilizing palæontological evidence, divides the beds as follows (Geol. Mag. 1894, p. 128):—

2. (d) Milburn Beds = Uppermost Arenig or Lower Llandeilo.
   (c) Ellergill Beds.
   (b) *Tetragraptus*-beds. { Upper, with *Didymograptus nanus*. Lower.
   (a) *Dichograptus*-beds.
1. *Bryograptus*-beds. = Tremadoc Slates.

1897. The following is the sequence adopted by the officers of the Geological Survey in their recent memoir, 'Geology of the Country between Appleby, Ullswater, and Haweswater' (p. 34):—

5. Milburn Group. } Equivalents of the lower part of the Borrowdale Series.
4. Ellergill Beds. }
3. Upper Skiddaw Slates.
2. Watch Hill Grits (Arenig Grit).
1. Lower Skiddaw Slates and Grassmoor Grits.

The rocks are regarded as the representatives of everything between the Middle Cambrian and the Upper Arenig rocks of Wales.

(*b*) Palæontological.

1848. In 1848 Prof. Sedgwick described the earliest organisms that were found in the Skiddaw Slates (Quart. Journ. Geol. Soc. vol. iv, p. 223). These were two graptolites which he referred to *Graptolites sagittarius* (His.) and *Gr. latus* (M'Coy), and four so-called fucoids.

1863. No further additions were made till Salter gave a list in his palæontological appendix to Harkness's paper 'On the Skiddaw Slate Series' (Quart. Journ. Geol. Soc. vol. xix, p. 135). In this he gave a list of 17 species of graptolites, and he also figured some of the forms. Several of these determinations were erroneous, due no doubt to the fragmentary condition of the specimens, and only a few of them find a place in a modern list.

1868. Nicholson's paper on 'The Graptolites of the Skiddaw Series' (Quart. Journ. Geol. Soc. vol. xxiv, pp. 125–145) was the first systematic memoir on the fauna of these beds. The descriptive part of it is exclusively devoted to graptolites, which, as he justly remarks, form by far the most important part of the fauna. He raised the number of species to 24 (omitting several of Salter's), and the number of genera to 8—*Dichograpsus*, *Tetragrapsus*, *Phyllograpsus*, *Didymograpsus*, *Diplograpsus*, *Pleurograpsus*, *Graptolites*, and *Dendrograpsus (?)*.

The advance made in our knowledge of the graptolites in general has affected many of the names and identifications adopted in that paper. Nicholson's view, as there given—namely, that all the forms from the Skiddaw Slates referred to the genus *Monograptus* (*Graptolithus*) were merely fragments of compound graptolites—is in accord with the general opinion of geologists of the present day, the genus *Monograptus* being wholly unknown in the Skiddaw Slates. His hesitation in admitting the genus *Dendrograptus* has also been justified by the fact that no true *Dendrograptus* is yet known from these beds. Some of the forms referred to *Dichograptus* in that paper have since been made the types of new genera by Nicholson or others, thus:—

Dichograpsus multiplex is now known as *Temnograptus multiplex.*
Dichograpsus reticulatus is now known as *Schizograptus reticulatus.*
Dichograpsus Logani is now known as *Loganograptus Logani.*
Dichograpsus antennarius is now known as *Cryptograptus antennarius.*

Again, Nicholson has subsequently erected one of the forms there referred to *Didymograpsus caduceus*, Salt., into a new species *D. gibberulus*, and his *D. serratulus* (Hall) has become *D. Nicholsoni*, Lapw.

Finally, it is very probable that other forms referred to by him are included in the present list under a different name. Thus:

His *Didymograpsus sextans* may be the *Dicellograptus moffatensis* His *Didymograpsus geminus* is the *Didymograptus indentus* His *Diplograpsus mucronatus* may be the *Cryptograptus Hopkinsoni*	of the present paper.

Since Nicholson wrote that paper, he has himself described several new genera and species both in the Geol. Mag. and the Ann. & Mag. Nat. Hist., and Lapworth has also added to the list.

1894. In Geol. Mag. 1894, pp. 123–124, Marr gives the most complete list that has hitherto appeared. He enumerates 46 species, belonging to 21 genera. Of these I reject both the genera *Janograptus* and *Ctenograptus*, the former because I think the determination was erroneous, and the latter because I do not consider that the form in question is a graptolite at all. I have also doubts as to the nature of *Thamnograptus*, but include it for the present.

The species '*Tetragraptus fruticosus*' (Hall) I have never seen in the Skiddaw Slates, though there are two species allied to it occurring in the beds, with which I think it has been confused. I am also inclined to think that large specimens of *Didymograptus bifidus* (Hall) have been wrongly referred to *D. Murchisoni* (Bœck.), and I consider that *Dichograptus Sedgwickii*, Salt., is identical with *D. octobrachiatus* (Hall). This reduces Marr's list to 41 species, belonging to 19 genera. To these I add 18 species and 3 genera, bringing the total up to 59 species belonging to 22 genera; but of these 7 species have never been previously recorded in this country (they are indicated by an asterisk in the following list) and 7 are new to science. The following are the genera and species of graptolites at present known from the Skiddaw Slates:—

Fam. Dichograptidæ (Lapw.).

Genus 1. *Bryograptus*, Lapw.
Sp. (a) *Br. ramosus*, Brögger, var. *cumbrensis* nov.
(b) *Br. Kjerulfi*,* Lapw.
(c) *Br.* cf. *Callavei*, Lapw.
Genus 2. *Clonograptus*, Hall.
Sp. (a) *Cl. flexilis* (Hall).
(b) *Cl.* cf. *tenellus** (Linnarsson).
(c) *Cl.* sp.
Genus 3. *Loganograptus*, Hall.
Sp. *L. Logani*, Hall:
various types.
Genus 4. *Temnograptus*, Nich.
Sp. *T. multiplex*, Nich.
Genus 5. *Pleurograptus*, Nich.
Sp. *Pl. vagans*, Nich.
Genus 6. *Trochograptus*, Holm.
Sp. *Tr. diffusus*,* Holm.
Genus 7. *Pterograptus*, Holm.
Sp. *Pt.* sp.*
Genus 8. *Schizograptus*, Nich.
Sp. *Sch. reticulatus*, Nich.
Sch. tardifurcatus, sp. nov.
Genus 9. *Trichograptus*, Nich.
Sp. *Tr. fragilis*, Nich.
Genus 10. *Dichograptus*, Salt.
Sp. *D. octobrachiatus* (Hall):
various types.
D. separatus, sp. nov.
Genus 11. *Tetragraptus*, Salt.
Sp. (a) *T. Bigsbyi* (Hall).
(b) *T. crucifer* (Hall).
(c) *T. Headi* (Hall).
(d) *T. pendens*, sp. nov.
(e) *T. Postlethwaitii*, sp. nov.
(f) *T. quadribrachiatus* (Hall).
(g) *T. serra* (Brongn.).
Genus 12. *Phyllograptus*, Hall.
Sp. (a) *Ph. Anna*, Hall.
(b) *Ph. angustifolius*, Hall.
(c) *Ph. ilicifolius*, Hall.
(d) *Ph.* ——, var. *grandis* nov.
(e) *Ph. typus*, Hall.
Genus 13. *Didymograptus*, M'Coy.
Sp. (a) *D. affinis*, Nich.
(b) *D. bifidus* (Hall).
(c) *D. extensus*, Hall.
(d) *D. fasciculatus*, Nich.
(e) *D. gibberulus*, Nich.
(f) *D. gracilis*,* Törnq.
(g) *D. indentus* (Hall).
(h) *D.* ——, var. *nanus*, Hopk. & Lapw.
(i) *D. Nicholsoni*, Lapw.
(k) *D. nitidus* (Hall).
(l) *D. patulus* (Hall).
(m) *D. V-fractus*, Salt.
(n) *D. V-fractus*, var. *volucer*, H. O. Nich.
Genus 14. *Azygograptus*, Nich. & Lapw.
Sp. (a) *A. Lapworthi*, Nich.
(b) *A. cœlebs*, Lapw.
(c) *A. suecicus*,* Moberg.

Fam. Nemagraptidæ, Hopk.
Genus *Leptograptus*, Lapw.
Sp. *L.* sp.

Fam. Dicranograptidæ, Lapw.
Genus *Dicellograptus*, Hopk.
Sp. *D. moffatensis* (Carr.).

Fam. Diplograptidæ, Lapw.
Genus 1. *Diplograptus*, M'Coy.
Sp. (a) *D. dentatus* (Brongn.)
(b) *D. teretiusculus* (His.)
(c) *D. appendiculatus*,* Törnq. MS.
Genus 2. *Climacograptus*, Hall.
Sp. *Cl. Scharenbergi*, Lapw.
Genus 3. *Cryptograptus*, Lapw.
Sp. (a) *Cr. Hopkinsoni* (Nich.).
(b) *Cr. antennarius*, Hall.
(c) *Cr. tricornis* (Carr.).

Fam. Glossograptidæ, Lapw.
Genus *Glossograptus*, Emmons.
Sp. (a) *Gl. armatus* (Nich.).
(b) *Gl. Hincksii* (Hopk.).
(c) *Gl. fimbriatus* (Hopk.).

Fam. Retiolitidæ, Lapw.
Genus *Trigonograptus*, Nich.
Sp. (a) *Tr. ensiformis* (Hall).
(b) *Tr. lanceolatus*, Nich.

Fam. ?
Genus *Thamnograptus*, Nich.
Sp. *Th. Doveri*, Nich.

III. Description of Genera and Species.

Genus *Bryograptus*, Lapw.

(*b*) Bryograptus Kjerulfi, Lapw. (Fig. 1, p. 470.)

1880. *Br. Kjerulfi*, Lapw. Ann. Mag. Nat. Hist. ser. 5, vol. v, p. 164 & pl. v, fig. 22.
1882. *Br. Kjerulfi*, Brögger, 'Die silur. Etagen 2 u. 3 im Christiania-Gebiet,' p. 37 & pl. xii, fig. 20*a*.

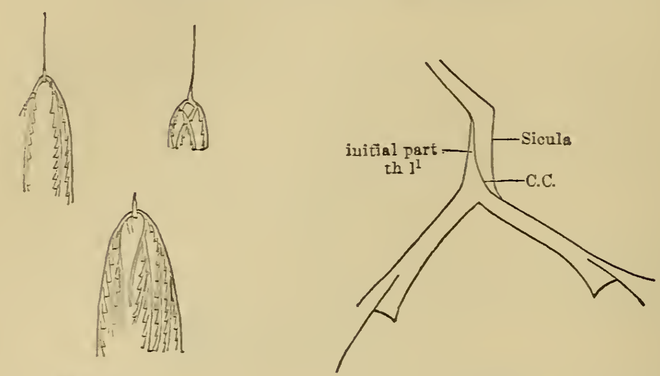
'The rhabdosoma consists of two slender primary stipes diverging from a conspicuous sicula at a small angle. From the inner margin of these there originate two or more compound secondary stipes. These are symmetrically disposed, and the earliest ones arise near the sicula. The thecæ number twenty to the inch (eight in 10 mm.); they overlap for less than one-third of their length, and are inclined at an angle of about 20°. Their outer walls are curved, and the cells widen slightly in the direction of the aperture, which is concave. The apertural angle is about 110°.'

The sicula of this species is decidedly large, being commonly $\frac{1}{16}$ inch in length (about 1·5 mm.). From its apex a fine thread-like prolongation is often seen to extend; this is without doubt the virgula ('nema' of Lapworth).

Lapworth gives the angle of divergence of this species as 40° but it often appears larger, owing to the mode of preservation of the form.

The species is characterized by its shrub-like form, and by the fact that the primary stipes have a tendency to run parallel to each other, after the first divergence, in a manner which forcibly suggests the habit of the later 'tuning-fork' graptolites.

Fig. 1.—*Bryograptus Kjerulfi.*



Nat. size. [Coll. Postlethwaite.]

×10. [Coll. Brend.]

Occurrence.—With *Bryograptus ramosus* var. *cumbrensis* in Lower Skiddaw Slates.

Locality.—Barf, near Keswick.

(*c*) Bryograptus cf. Callavei, Lapw.

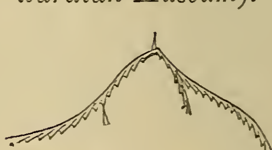
1880. ? *Br. Callavei,* Lapw. Ann. Mag. Nat. Hist. ser. 5, vol. v, p. 165 & pl. v, fig. 21.

This form seems to be closely related to *Br. Callavei*, Lapw., though it presents some minor differences.

'The rhabdosoma consists of two very slender flexuous primary stipes, which diverge from the sicula at a rather wide angle. From the inner margins of the primary stipes secondary branches are given off. These are unsymmetrically disposed. The thecæ number twenty-five to the inch (eleven in 10 mm.); they are in contact with each other $\frac{1}{3}$–$\frac{1}{2}$ their length, and are long narrow tubes of uniform width throughout their length. They are about 5 times as long as wide, and are inclined at an angle of 20°. Their outer walls are straight. The apertures are straight, but oblique to general direction of stipe; the apertural angle is about 105°.'

Unfortunately, only one specimen of this form has been found, and in this there are only two secondary branches, and even these are incomplete. It seems to be a very slender form, the maximum width being only $\frac{1}{40}$ inch (·63 mm.). The sicula is less conspicuous than in the other *Bryograpti* known from the Skiddaw Slates; it does not exceed $\frac{1}{24}$ inch in length (1·05 mm.).

Fig. 2.—Bryograptus Callavei (*coll. Woodwardian Museum*).



[Nat. size.]

This specimen appears to differ from the typical *Br. Callavei* in (1) wider divergence of stipes; (2) greater number of thecæ to the inch, twenty-eight instead of twenty.

The specimen was figured by Marr (Geol. Mag. 1894, p. 130, fig. 6).

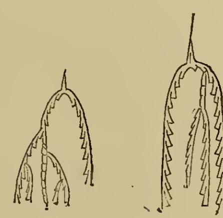
Occurrence.—Lower Skiddaw Slates.

Locality.—Barf, near Keswick.

(*a*) Bryograptus ramosus, Brögger, var. cumbrensis nov.

The rhabdosoma consists of two slender primary stipes diverging from a large ($\frac{1}{16}$ inch, 1·58 mm.) and clearly defined sicula at a small angle. The virgula is sometimes well preserved. From the inner margins of the primary stipes originate two or more compound secondary branches. These are unsymmetrically disposed, and may arise near the sicula or quite remote from it. The thecæ number twenty-four to the inch (nine to ten in 10 mm.); they are widest at their apertures; their outer walls are straight or very slightly curved. They are in contact with each other for rather less than half their length, and are inclined at an angle of about 20°. The apertures are concave, and the apertural angle varies between 115° and 120°.

Fig. 3.—*Bryograptus ramosus* var. *cumbrensis*.



Nat. size.

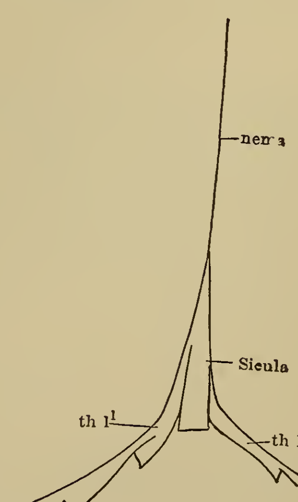
[Colls. Postlethwaite & Woodwardian Mus.]

The irregular and unsymmetrical branching shows the near relationship of this form to Brögger's typical *Br. ramosus*. But in the variety here described the secondary branches may be near the sicula or remote from it, whereas Brögger states that in the typical form they are always remote. This variety, then, differs from the typical form

(1) In the position of the irregularly disposed secondary branches.

(2) In the number of thecæ to the inch; Brögger's type having forty to fifty in the inch (sixteen to twenty in 10 mm.), whereas in this variety the number never exceeds twenty-four (nine to ten in 10 mm.).

Fig. 4.—*Diagram showing the point of origin of the earliest theca* (*see also fig. 1, p. 470*).



[×10.]

Br. ramosus var. *cumbrensis* differs from *Br. Kjerulfi*, Lapw., to which it has sometimes a superficial resemblance,

(1) In unsymmetrical branching.

(2) In the character of the cells, and their number to the inch.

The specimens now placed in this new variety were in 1894 provisionally referred by Mr. Marr to *Br. ramosus*, Brögger.[1] A closer examination has, however, convinced me that all the Skiddaw Slate forms resembling *Br. ramosus* should be regarded as a distinct variety of that species, and in this opinion Mr. Marr himself now concurs.

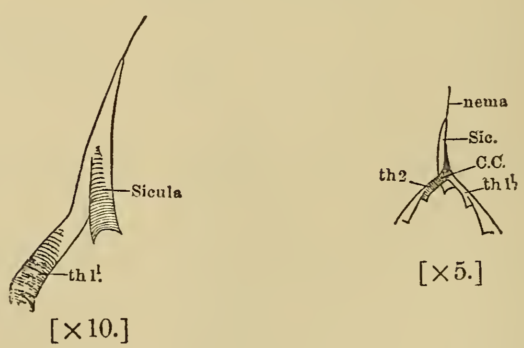
Occurrence.—The variety occurs in the Lower Skiddaw Slates associated with *Br. Kjerulfi*, and I have seen one specimen on a slab containing *Tetragraptus Bigsbyi* (Hall).

Locality.—Barf, near Keswick.

Note on the Structure of *Bryograptus*.

The examination of several specimens of *Bryograptus* in different stages of growth, preserved in many ways and in various positions, has convinced me that the stipes originate from the sicula in a manner which is in all respects identical with that described for *Didymograptus*.

Fig. 5.—*Stages in the development of* Bryograptus (*coll. W. A. Brend*).



The 'initial bud' in *Br. ramosus* var. *cumbrensis*, and I believe also in *Br. Kjerulfi*, arises on the left side of the sicula at a point about midway between apex and aperture. It then grows down towards the aperture of the sicula, closely adpressed to it, and before it diverges there is developed from it what seems to be the connecting-canal; this grows obliquely across the back of the sicula, and ultimately gives rise to the first theca of the right primary stipe. The phylogenetic value of this will be discussed later.

Genus *Clonograptus*, Hall.

The branching in this genus differs from that of *Dichograptus* and *Loganograptus*, in that the ultimate dichotomous division takes place at a greater distance from the point of first dichotomy.

[1] Geol. Mag. 1894, p. 130.

(*a*) CLONOGRAPTUS FLEXILIS (Hall).

1858. *Graptolithus flexilis*, Hall, Geol. Surv. Canada Rep. 1857, p. 119.
1865. *Graptolithus flexilis*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 103 & pl. x, figs. 3–9.
1873. *Clonograptus flexilis*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. xi, p. 138.

A slab in the British Museum (Nat. Hist.) shows three specimens referable to this species, and two of these are exceedingly good.[1]

The dichotomy takes place at fairly distant intervals, the distance increasing with remoteness from the base. The larger of the two good specimens has seventeen ultimate stipes, but these are by no means all of the same order.

(1) From the lower right-hand stipe of the 2nd order, four branches of the 5th order and two of the 4th order arise as the result of repeated dichotomous division.[2]
(2) From the upper right-hand stipe of the 2nd order only two stipes of the 5th order are developed; the others are of the 4th order, and show no signs of further division.
(3) From the upper left-hand stipe of the 2nd order no branches of a higher order than 4 are developed, and these persist as long single stipes.
(4) From the lower left-hand stipe of the 2nd order only two long stipes of the 3rd order are developed.

This may be graphically represented thus:—

$$4^{V}+2^{IV}+2^{V}+3^{IV}+4^{IV}+2^{III}=6^{V}+9^{IV}+2^{III}=17.$$

The formula for a typical *Clonograptus* should be

$$8^{V}+8^{V}+8^{V}+8^{V}=32.$$

There has been therefore considerable atrophy.

In the smaller of the two specimens there are only thirteen ultimate stipes, and none of an order higher than 4:—

(*a*) Order 2 gives rise by dichotomous division to four stipes of order $4=4^{IV}$.
(*b*) Order 2 „ „ „ two stipes of order 4 and one of order $3=2^{IV}+1^{III}$.
(*c*) Order 2 „ „ „ two stipes of order $3=2^{III}$.
(*d*) Order 2 „ „ „ four stipes of order $4=4^{IV}$.

Total: $10^{IV}+3^{III}=13$.

The stipes are all slender and flexuous; they increase in width from their origin up to a maximum of $\frac{1}{24}$ inch (1·05 mm.).

The thecæ are clearly seen on several of the stipes, and on stipes

[1] [Since writing the above I have had reason to doubt that these specimens came from the Lake District; but as the species unquestionably occurs at Barf, the description is allowed to stand.]

[2] The so-called 'funicle' is regarded as consisting of two stipes of the 1st order, in accordance with recent work. Compare the description of *Tetragraptus quadribrachiatus* (Hall), p. 485.

of every order. They number about twenty-five to the inch (ten in 10 mm.). They are narrow tubes, with slightly curved walls, and are four times as long as wide; they are inclined at an angle of about 30°, and are in contact for half their length. These apertures are straight, and are perpendicular to the general direction of the stipe.

In no specimen have I observed a disc.

Locality.—Unknown.

(*b*) Clonograptus cf. tenellus (Linnarsson).

1871. *Dichograptus (?) tenellus*, Linnarsson, Öfv. Kongl. Vet. Ak. Förh. Stockholm, vol. xxviii, no. 6, p. 795.

1876. *Dichograptus tenellus*, Linnarsson, Geol. Mag. dec. 2, vol. iii, p. 242.

1892. *Clonograptus tenellus*, Moberg, Geol. Fören. Stockholm Förhandl. vol. xiv, p. 89 & pl. ii, figs. 1–3.

A slab on which are two specimens of a species closely resembling Linnarsson's *Cl. tenellus* is in Mr. Postlethwaite's collection; it was shown to Prof. Lapworth some years ago, and he then said that it seemed to him to be identical with a form occurring in the Tremadoc Beds of North Wales.

The best specimen is by no means perfect, but it is well preserved; it shows the two stipes of the 1st order, and three out of the four stipes which arise from these by dichotomous division. The other stipe is embedded, and only two out of the three are seen to divide further. Stipes of 5 orders are visible within a length of $1\frac{1}{4}$ inch (31·7 mm.). The angle between the stipes of order 2 is 90°, between those of order 3, 75°, those of order 4, 60°, and those of order 5, 50°. The branches become longer as they reach a higher order: in other words, the distance between the points of dichotomy increases with remoteness from the base.

The species is very slender; it never exceeds $\frac{1}{50}$ inch (·5 mm.) in width, including the thecæ. The stipes are very slightly flexuous. The thecæ number twenty to the inch (five in 10 mm.); they are inclined at a very low angle, and are in contact for a very short distance at their base; their outer wall is straight or very slightly curved. The apertures are concave, submucronate, and very slightly oblique to the general direction of the stipe. The species is characterized by its extreme tenuity.

Locality & Horizon.—Barf. Lower Skiddaw Slates.

(*c*) Clonograptus sp.

On many slabs of the Skiddaw Slates I have observed several dichotomously-divided stipes of what I believe to be a species of *Clonograptus*, though in their fragmentary condition specific determination is not possible. For the most part, they appear to be the ultimate stipes; they are slender, flexuous, and rather delicate, having a maximum width of not more than $\frac{1}{24}$ inch (1·05 mm.).

The thecæ are very clearly seen; they are long narrow tubes, of uniform width, numbering twenty to the inch (eight in 10 mm.). They are in contact for two-thirds of their length, and have straight apertures, which are situated perpendicularly to the general direction of the stipe.

Occurrence.—In the Middle Skiddaw Slates, associated with *Dichograptus octobrachiatus.*

Localities.—Barf; Randal Crag, Skiddaw; Slape Crags, above Hope Gill, Brackenthwaite; Carlside Edge; Bassenthwaite Sand-beds.

Genus *Loganograptus* (Hall) modified.

The description of the genus *Loganograptus* given by Hall ran as follows:—

'Polypary consisting of more than eight simple stipes proceeding from a single axis, with a distinct broad corneous disc.' (See 'Introd. to the Study of Graptolitidæ,' 20th Ann. Rep. N.Y. State Cab. Nat. Hist. 1867, p. 226.)

This definition requires modification, for it would seem to imply that the presence of a disc is essential, and that the number of stipes is sufficient ground for separating the form from *Dichograptus.* This does not seem to be the case:—

(1) Forms are known precisely similar in every detail, with the exception of the disc. It seems likely, therefore, either that the disc has perished during preservation, or was only developed to meet special needs, and consequently its presence is not of generic value.

(2) The number of stipes is not an important distinction, but rather the capacity in *Loganograptus* for greater dichotomy.

A complete *Dichograptus*, as, for example, a typical *D. octobrachiatus* (Hall), is a form in which dichotomy can occur only twice in all. In *Loganograptus*, on the other hand, dichotomy may take place three, four, or more times. In both genera it always takes place near the base.

The number of stipes varies with the completeness of the dichotomy; a form may have only six stipes, and yet be referable to the genus *Loganograptus*, as I shall show. I am not aware that a greater number of stipes than thirty-two has ever been recorded. The various other numbers that are met with are the result of failure of complete dichotomy. A specimen before me has only seven stipes, and yet it must be referred to *Loganograptus*, since it shows a greater capacity for dichotomy than is ever shown by *Dichograptus.* In this form all four stipes of the 2nd order are developed, but only two of these undergo further division, so that only four stipes of the 3rd order are produced; of these only one undergoes further division. The number, therefore, is made up as follows:—

$$2^{\text{II}}+3^{\text{III}}+2^{\text{IV}}=7.$$

Similarly, it is possible to have a *Loganograptus* with only six stipes; in this case three out of the four stipes of the 2nd order persist as single stipes; the fourth divides dichotomously, giving rise to two stipes of the 3rd order, one of which persists, and one is again dichotomously divided:

$$3^{II}+1^{III}+2^{IV}=6.$$

The definition of *Loganograptus* should run thus:—

Rhabdosoma typically symmetrical; short branches of the 1st order arise on either side of the sicula, and these, by repeated dichotomous division, give rise to a form whose branches vary in number 6–32– —? Dichotomy never takes place less than 3 times. Disc may be present or absent.

LOGANOGRAPTUS LOGANI, Hall.

1858. *Graptolithus Logani*, Hall, Geol. Surv. Canada Rep. 1857, p. 115.
1865. *Graptolithus Logani*, Hall, 'Grapt. of Quebec Group,' Geol. Surv. Canada, dec. 2, p. 100 & pl. ix, figs. 1–9.
1867. *Loganograptus Logani*, Hall, 'Introd. Study Graptolitidæ,' N.Y. State Cab. Nat. Hist. 20th Ann. Rep. p. 226.

This species is abundant in the Skiddaw Slates, but none of the specimens that I have seen possess more than sixteen stipes; and there are specimens with twelve, ten, nine, eight, and seven stipes respectively. All dichotomy takes place within $\frac{1}{6}$ inch (4·23 mm.) from the point of origin of the earliest stipes.

The stipes of the 1st order are about $\frac{1}{24}$ inch long (1·05 mm.), those of the 2nd order $\frac{1}{16}$ inch (1·5 mm.), and those of the 3rd order $\frac{1}{12}$ inch (2·1 mm.), while those of the 4th order may be 2 inches or more in length (50·8 mm.). These stipes are narrow at their origin, but widen to a maximum at $\frac{1}{16}$ inch (1·5 mm.).

The thecæ are twenty-two to twenty-four in the inch (eight to nine in 10 mm.), they are inclined at 35°, are free for about half their length, and have their apertures placed almost perpendicularly to the general direction of the stipe.

One specimen from Outerside now in the British Museum (Nat. Hist.) has sixteen stipes, and is figured by Nicholson.[1]

Occurrence.—Middle Skiddaw Slates.

Localities.—Randal Crag, Skiddaw; Barf; Outerside.

Genus *Trichograptus*, Nich.

TRICHOGRAPTUS FRAGILIS, Nich.

1869. *Dichograpsus fragilis*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. iv, p. 232 & pl. xi, figs. 1–3.
1876. *Trichograptus fragilis*, Nich. Geol. Mag. dec. 2, vol. iii, p. 248.

The only specimens of this delicate little species known to me are the types which are in the British Museum (Nat. Hist.). The species is very fragile, and is peculiar, in that of the four stipes of the 2nd order produced as a result of the dichotomy of the earliest stipes, the two upper ones are alone capable of further subdivision, the other two persisting as single stipes.

Nicholson regards the branches given off by the two upper stipes as lateral, and he therefore refers them all to the same order of branching—the 3rd order.

[1] 'Monograph of the British Graptolitidæ,' 1872, p. 109, fig. 52 *c*.

Occurrence.—Ellergill Beds = Upper Skiddaw Slates.

Localities.—Thornship Beck, near Shap; Ashlock Sike.

Note.—The foregoing distinction, between 'dichotomous' and 'lateral' branching, is arbitrary. In the above species, and some of those next to be described, I call the branching lateral when the original stipe continues to grow in the same direction after division as before, but dichotomous when continuation of growth in the original direction would bisect the angle between the two stipes resulting from such division. The appearance of the rhabdosoma in the two cases is very different.

I have been unable to determine whether such lateral branching results merely from the unequal instead of equal division of the common canal, which has been shown to occur in true 'dichotomy.'[1] It might conceivably be of a totally different nature, as, for example, the result of budding from one of the thecæ of the main stipe; but certainly in some cases the first view is the correct one.

Note on the Genera *Temnograptus*, Nich.: *Schizograptus*, Nich.; *Trochograptus*, Holm; *Holograptus*, Holm; and *Rouvilligraptus*, Barrois.—The species belonging to the genera *Temnograptus*, *Schizograptus*, and *Trochograptus*, which will now be described, are closely allied to each other and to the genera *Holograptus* and *Rouvilligraptus*. The appended table (I, p. 478) indicates some of the more important differences between them.

Genus *Temnograptus*, Nich.

Temnograptus multiplex, Nich. (Fig. 6, p. 479.)

1868. *Dichograpsus multiplex*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 129 & pl. vi, figs. 1–3.

1876. *Temnograptus multiplex*, Nich. Geol Mag. dec. 2, vol. iii. p. 248.

There is only one specimen of this species in the Woodwardian Museum, and if the branching is dichotomous, as it appears to be, there are at least six orders of stipes. These result from the dichotomous division of one of the stipes of the 2nd order; all the others are incomplete.

The stipes of the 1st order are short, being about $\frac{1}{8}$ inch in length; those of the 2nd order are rather longer than $\frac{1}{3}$ inch; the stipes of the remaining orders arise as a result of dichotomous division at intervals of about an inch.

The angles between the stipes diminish steadily as they get farther away from the base:—

Angle between two stipes	of Order 2=90°	(about)
,, ,,	of Order 3=75°	(about)
,, ,,	of Order 4=70°	(about)
,, ,,	of Order 5=50°	(about)
,, ,,	of Order 6=40°	(about)

This may or may not be a character of importance.

Occurrence.—Middle Skiddaw Slates.

Locality.—Near Peelwyke, Bassenthwaite.

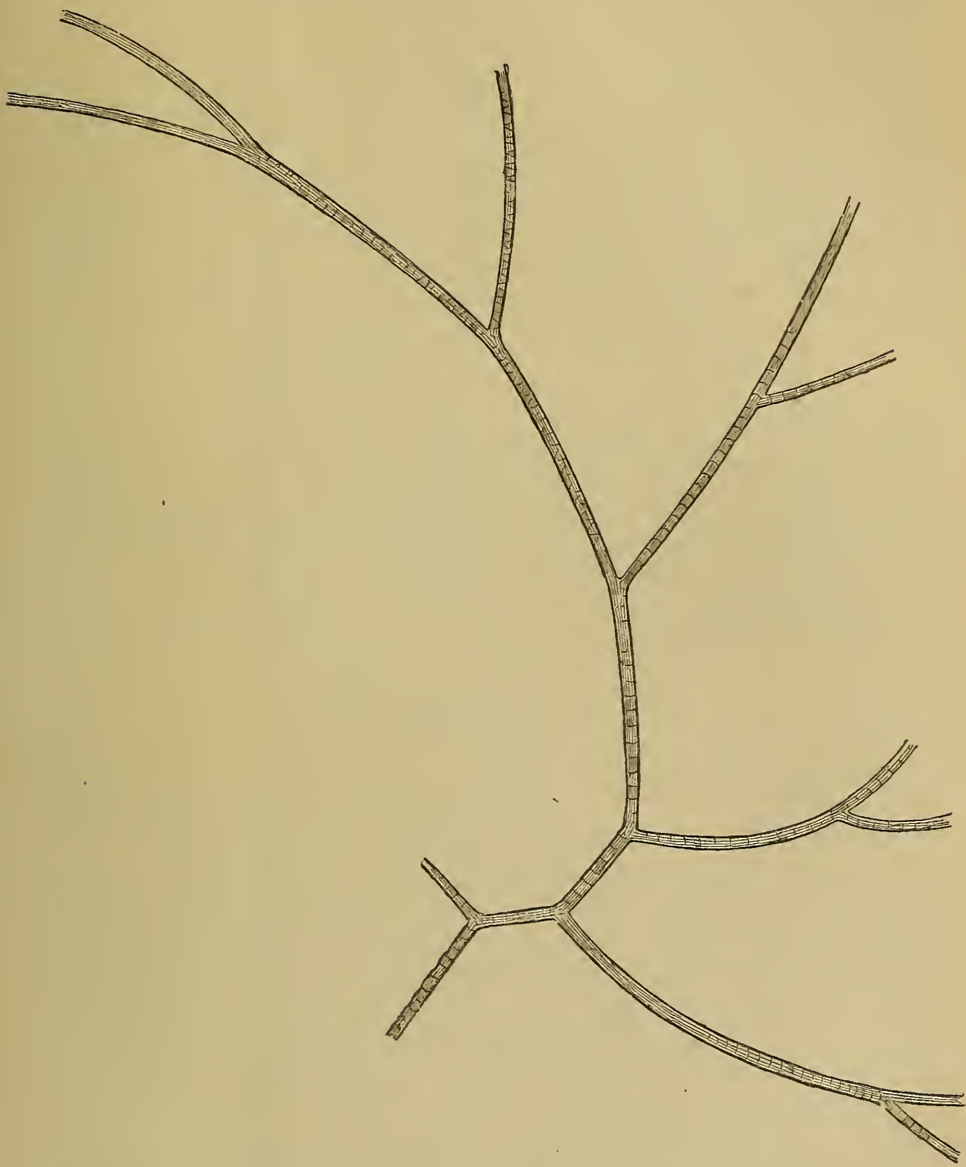
[1] Holm, Geol. Fören. Stockholm Förhandl. vol. xvii (1895) p. 319.

TABLE I.

COMPARATIVE TABLE SHOWING THE MORE IMPORTANT DIFFERENCES BETWEEN THE GENERA *SCHIZOGRAPTUS*, *TEMNOGRAPTUS*, *TROCHOGRAPTUS*, *HOLOGRAPTUS*, AND *ROUVILLIGRAPTUS*.

Schizograptus.	*Temnograptus.*	*Trochograptus.*	*Holograptus.*	*Rouvilligraptus.*
Stipes straight, slender, rigid.	Stipes slightly curved.	Stipes curved.	Stipes straight.	Stipes straight.
Stipes of 3 orders only.	Stipes of at least 6 orders probably indefinite.	Stipes of at least 5 orders.	Stipes of at least 4 orders.	Stipes of 4 orders.
Branching: (*a*) dichotomous. (*b*) lateral.	Branching: Dichotomous throughout.	Branching: (*a*) dichotomous. (*b*) lateral.	Branching: (*a*) dichotomous. (*b*) lateral.	Branching: (*a*) dichotomous. (*b*) lateral.
Branches all on same side, at regular intervals.	Dichotomous division at regular intervals.	Branches all on same side, at irregular intervals.	Branches on different sides, at irregular intervals.	Branches on different sides, at regular intervals.

Fig. 6.—Temnograptus multiplex, *Nich.; coll. Woodwardian Mus.*



[Nat. size. For description, see p. 477.]

Genus *Trochograptus*, Holm.

Trochograptus diffusus, Holm. [Pl. XXVII, facing p. 480.]

1881. *Trochograptus diffusus*, Holm, Öfv. Kongl. Vet. Akad. Stockholm Förh. vol. xxxviii, no. 9, p. 49 & pl. xiii.

There are two excellent specimens of this species in the Keswick Museum, labelled '*Pleurograptus vagans*,' Nich., a less perfect one in the Woodwardian Museum at Cambridge, which has been erroneously referred to *Temnograptus multiplex*, Nich., and another in Prof. Nicholson's private collection. One of the specimens in the Keswick Museum, in addition to many stipes of the 4th order, shows one of the 5th order, but in the other specimen there appears to be no stipe of a higher order than 4. The stipes of the 1st order divide dichotomously, but all subsequent branching appears to be lateral; the lateral stipes are always on the same side of the main stipe, and curve in the same direction. The branching takes place at very irregular intervals, but there appears to be sometimes a general plan that the distances between the stipes are greater the more remote the stipe is from the base. Thus in one specimen lateral branching traced along the main stipe takes place (*a*) after 1 inch (25·4 mm.), (*b*) after $1\frac{1}{4}$ inch (31·7 mm.), (*c*) after $1\frac{1}{2}$ inch (38 mm.). The angles between the stipes gradually decrease:—

(*a*) Angle between two stipes of Order 2=90°
(*b*) „ „ of Order 3=75°
(*c*) „ „ of Order 4=65°

There are twenty-five thecæ in the space of an inch (ten in 10 mm.). Both specimens in the Keswick Museum show a small square disc whose diameter is about $\frac{1}{4}$ inch (6·3 mm.); but the type-specimen has none, nor has the specimen in the Woodwardian Museum.

Occurrence.—Middle Skiddaw Slates.

Localities.—Scale Hill; Low Bridge, Whit Beck, near High Lorton; Grisedale Pike.

Genus *Schizograptus*, Nich.

SCHIZOGRAPTUS RETICULATUS, Nich.

1868. *Dichograpsus reticulatus*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 143, pl. v, figs. 4 & 5.
1876. *Schizograptus reticulatus*, Nich. Geol. Mag. dec. 2, vol. iii, p. 248.

The stipes in this species are characteristically straight and rigid, and the whole rhabdosoma resembles a branched *Tetragraptus* of the *quadribrachiatus*-type. There are branches of three orders only. The two stipes of the 1st order are very short, and measure together not more than $\frac{5}{12}$ inch (2·1 mm.); four stipes of the 2nd order arise from these as a result of dichotomous division. These constitute the main stipes of the rhabdosoma, and from these are given off lateral stipes nearly at right angles and all on the same side. The first stipe of the 3rd order is given off at a distance of about $\frac{1}{4}$ inch (6·3 mm.) from the point of dichotomy, and the second at a distance of $\frac{5}{12}$ inch (10·5 mm.) from the first. On one main stipe whose total length is 3 inches (76 mm.) only two lateral stipes are visible, and both these arise within the first $\frac{2}{3}$ inch of its length (17 mm.). On no stipe have I seen more than two stipes of the 3rd order; therefore it would seem likely that none were developed.

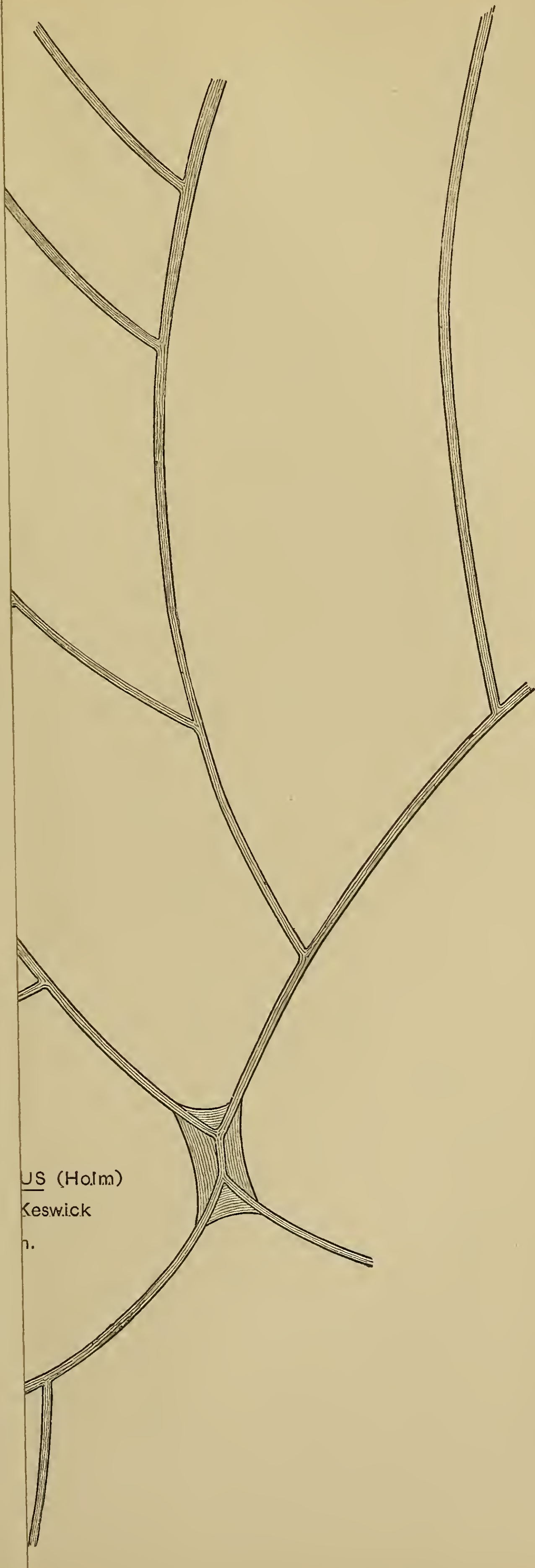
The thecæ number twenty-five to the inch (ten in the space of 10 mm.), and are inclined at a low angle.

Localities.—Scale Hill, near Crummock; Barf.

SCHIZOGRAPTUS TARDIFURCATUS, sp. nov. (Fig. 7, p. 481.)

This species is very closely allied to the foregoing. It also strongly recalls a *Tetragraptus* of the *quadribrachiatus*-type.

The rhabdosoma consists of two short branches of the 1st order



US (Holm)
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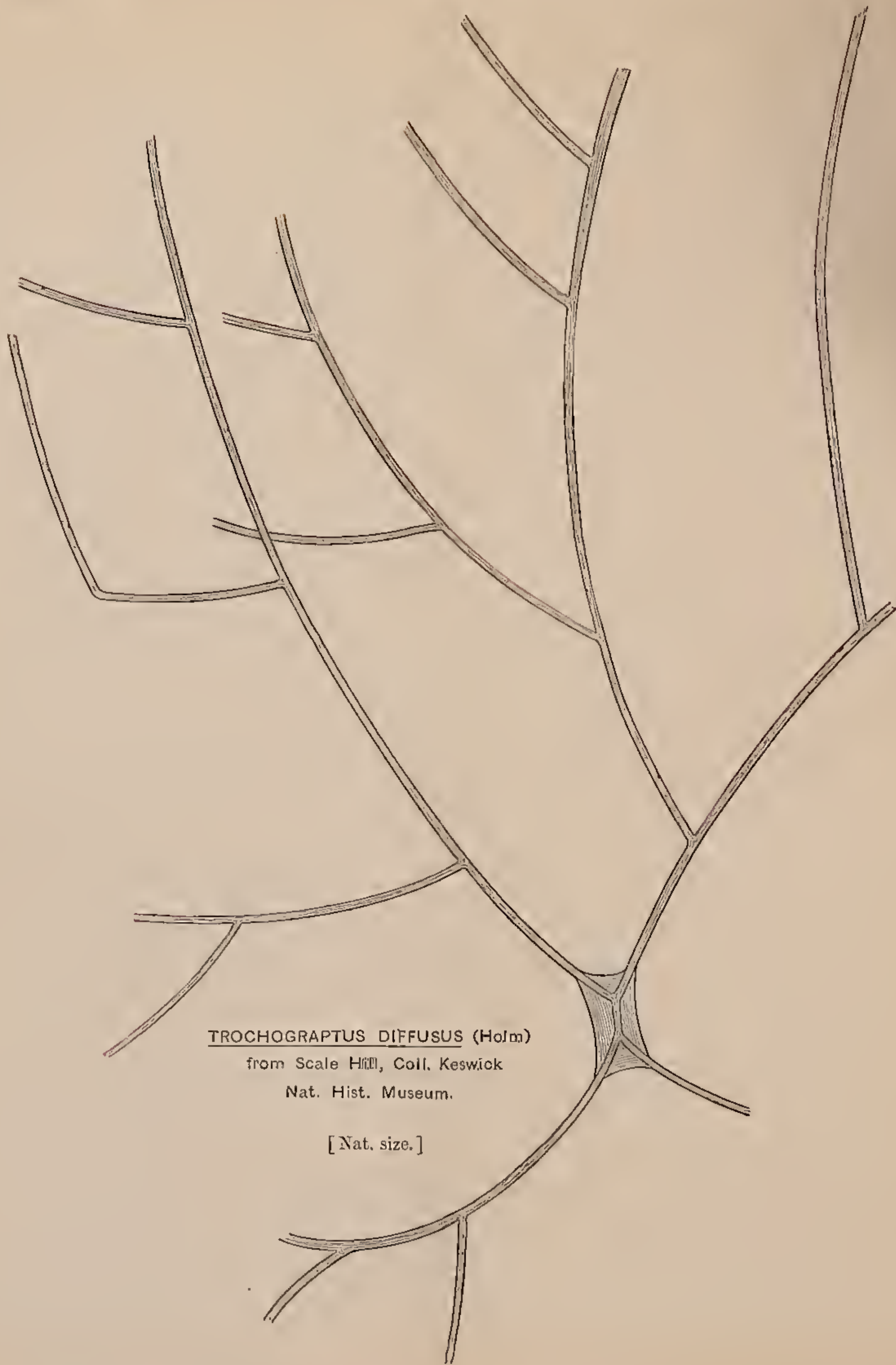
Quart. Journ. Geol. Soc. Vol. LIV, Pl. XXVII.

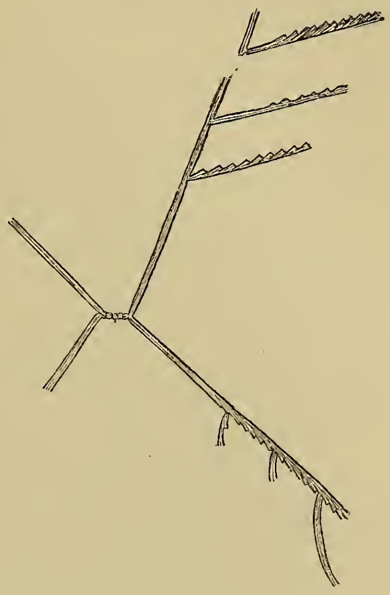


TROCHOGRAPTUS DIFFUSUS (Holm)
from Scale Hill, Coll. Keswick
Nat. Hist. Museum.

[Nat. size.]

measuring together $\frac{1}{12}$ inch (2·1 mm.); four stipes of the 2nd order are developed from these as a result of dichotomous division. These constitute the main stipes of the rhabdosoma. On each main stipe, at a distance of $\frac{7}{12}$ inch (14·7 mm.) from the point of dichotomy, the first lateral branch is given off at an angle of about 70°; a second lateral branch at a similar angle, at a distance of $\frac{1}{3}$ inch from the first (8·5 mm.); and a third at the same angle, and at a similar distance. There seems to be no further branching.

Fig. 7.—Schizograptus tardifurcatus, *sp. nov.* (*coll. Postlethwaite*).



[Nat. size.]

The length of the stipes is $1\frac{3}{4}$ to 2 inches (44 to 50 mm.), and the maximum width is $\frac{1}{24}$ inch (1·05 mm.).

All details regarding the thecæ are obscure, but they number twenty to the inch (eight in 10 mm.), are in contact for about half their length, and have oblique apertures.

The species differs from *Schizograptus reticulatus*,

(1) In having three branches of the 3rd order, and these situated closer together;

(2) In lateness of development of the lateral branches.

Locality.—Carlside Edge.

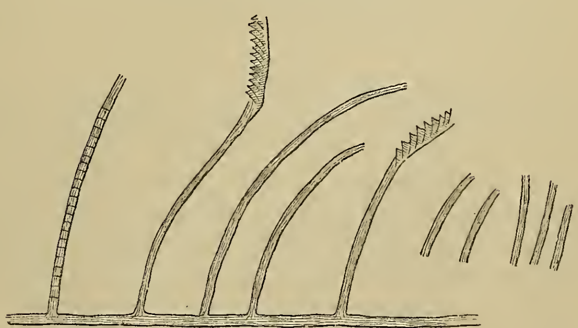
Genus *Pleurograptus*, Nich.

PLEUROGRAPTUS VAGANS, Nich.

1868. *Pleurograptus vagans*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 144, pl. vi, figs. 4 & 5.

The specimen is only a fragment, but it seems to be identical with that figured by Nicholson (*op. cit.* fig. 4). It shows a main stipe giving off a number of simple lateral stipes at an angle of about 60°. These are given off at irregular intervals, and from one side only; as many as ten may be counted, but of these only two show the

Fig. 8.—Pleurograptus vagans (*coll. Postlethwaite*).



[Nat size.]

characters of the thecæ clearly; the remaining stipes show the thecal apertures, or else the dorsal side of the stipe is turned towards the observer, and nothing is seen of the thecæ. The stipes are narrow at their origin, but widen to a maximum width of $\frac{1}{12}$ inch (2·1 mm.).

The thecæ are of the general *Dichograptus*-type; they number twenty-four to the inch (nine to ten in 10 mm.), are inclined at 55°, and are in contact for the greater part of their length. The apertures are submucronate, and are inclined to the general direction of the stipe at an angle of 130°.

The specimen is in Mr. Postlethwaite's collection.

Localities.—Carlside Edge; Scale Hill, near Crummock (type-specimen).

Genus *Pterograptus*, Holm.

Pterograptus (?) sp.

At Aik Beck there occur numerous broken stipes of a graptolite which seems more closely related to *Pterograptus*, Holm, than to any other known form. All the specimens that I have seen belong to Prof. H. A. Nicholson, by whom they were sent to me.

The stipes so often appear isolated that I am inclined to think that their attachment to the main stipe must have been of a very slender nature; this fact led me at first to think that the form was a new species belonging to the genus *Azygograptus*, until I developed out a specimen showing lateral stipes still attached to the main stipe.

The branching in this specimen and the general characters of the rhabdosoma (so far as I have been able to make them out) recall some Swedish specimens of *Pterograptus*, which differ from the species described by Holm. In view of the fragmentary condition in which the form occurs in the Skiddaw Slates I will not attempt a specific diagnosis, but will merely note the characters so far as I have been able to determine them.

Fig. 9.
Pterograptus (?): *coll. Nicholson.*

[Nat. size.]

All the stipes are alike, and gradually widen from their point of origin to a maximum width of $\frac{1}{48}$ inch (about ·5 mm.) opposite the apertures of the thecæ.

The branching appears to take place at fairly regular intervals along the main stipe, but is different from that of *Pterograptus elegans*, Holm. In that species branches are given off from each of the first seven thecæ on each main stipe, but in the form in the Skiddaw Slates there are at least three thecæ between the lateral stipes. The lateral stipes are given off alternately on each side of the main stipe. All the stipes are concavely curved, and the thecæ are always on the inside of the curve. These number between fifteen and twenty to the inch (seven to eight in 10 mm.); they are inclined at 20°, are in contact with each other for a very small fraction of their length, and their apertures are inclined to the general direction of the stipe at an angle of about 90°. The thecæ are about $\frac{1}{12}$ inch long (2·1 mm.) in the mature parts of the stipes, and are about 5 times as long as wide; their outer wall has commonly a very slight concave curvature.

Occurrence.—Ellergill Beds (?).

Locality.—Aik Beck, Pooley.

Genus *Dichograptus* (Salt.), modified.

Rhabdosoma bilaterally symmetrical. Two branches are developed on either side of the sicula; these divide dichotomously after a short distance giving rise to four branches of the second order, which are in their turn capable of dichotomous division at a short distance from the point of the first dichotomy. The stipes of the third order never divide again. A disc may be present or absent.

DICHOGRAPTUS OCTOBRACHIATUS (Hall).

1858. *Graptolithus octobrachiatus*, Hall, Geol. Surv. Canada Rep. 1857, p. 122.
1863. *Dichograpsus aranea*, Salt. Quart. Journ. Geol. Soc. vol. xix, p. 137, figs. 9 & 10.
1863. *Dichograpsus Sedgwickii*, Salt. *ibid.* fig. 11.
1865. *Graptolithus octobrachiatus*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 96, pl. vii, figs. 1–7 & pl. viii, figs. 1–4.
1868. *Dichograpsus octobrachiatus*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 129, pl. v, figs. 1 & 2.

In 1885 Hermann, in his paper 'Die Graptolithenfamilie Dichograptidæ,' described *D. Sedgwickii*, Salt., as a species distinct from *D. octobrachiatus* (Hall) since it has curved branches, and the thecæ are inclined at a rather lower angle. The curved branching is, I think, only the result of the mode of preservation; and certainly some specimens, which have their thecæ inclined at a high angle and therefore belong to *D. octobrachiatus*, have also apparently curved branches. Most of the specimens in the Woodwardian Museum and other collections are preserved with their dorsal side uppermost, and the thecæ are not well shown except in a few cases, and so all details of inclination are obscure. I am inclined to think that the species in question are one and the same, and therefore I include under the name *D. octobrachiatus* (Hall) both Salter's species, *D. aranea* and *D. Sedgwickii*.

There are many specimens of *D. octobrachiatus* (Hall) in the Woodwardian Museum, and the species seems to have been abundant in the Skiddaw Slates.

The form is very varied as regards the number of stipes. Perhaps the commonest form is that which has eight stipes of the 3rd order, and from this the species derives its name. Other individuals, agreeing in all respects except the number of stipes, have seven, six, or five stipes.

In the normal type with eight stipes of the 3rd order, there are four short stipes of the 2nd order, and two short stipes of the 1st order; both stipes of the 1st order, and all four of the 2nd order, undergo dichotomous division.

In the septad type (seven stipes) one of the stipes of the 2nd order fails to divide dichotomously, and persists as a single stipe: the other three stipes of the 2nd order dividing as in the normal type.

In the hexad type (six stipes), two of the stipes of the 2nd order show no dichotomous division, and in the pentad type (five stipes) only one stipe out of the four divides dichotomously. Obviously a further reduction gives rise to a form resembling a *Tetragraptus* of the *quadribrachiatus*-type. On this point more will be said later.

The stipes of the 1st order are about $\frac{1}{24}$ inch (1·05 mm.) in length, those of the 2nd order about $\frac{1}{16}$ inch (1·58 mm.), while those of the 3rd order are often very long, some attaining a length of from 5 to 6 inches (12·6 to 15 cm.); others, younger perhaps, barely exceed an inch (25·39 mm.) in length. The stipes are slender at their origin, but widen out to a maximum of $\frac{1}{8}$ inch (3·17 mm.) in the larger forms; naturally the smaller ones are not so wide as this.

The thecæ on the stipes of the 3rd order, which are the only ones clearly seen, number between twenty and twenty-four to the inch (eight to nine in 10 mm.); they are 4 times as long as wide, and are inclined at an angle of about 20° at their bases, curving so that near the aperture the cell makes an angle of 50° to 55° with the axis of the stipe. The thecæ are in contact for two-thirds of their length, and their apertures make an angle of 105° to 110° with the general direction of the stipe.

A disc may or may not be present, and when present varies greatly in size in different individuals.

Occurrence.—The species occurs in the Middle Skiddaw Slates, on slabs associated with *Didymograptus nitidus*, *D. patulus*, *D. gibberulus*, *D. V-fractus*, *Tetragraptus* sp.?, and *Loganograptus* (nonad type).

Localities.—Randal Crag, Skiddaw; Mire House, Skiddaw; Carlside Edge; Slape Crags, above Hope Gill, Brackenthwaite; Outerside; Braithwaite; Grisedale Pike.

Dichograptus separatus, sp. nov. (Fig. 10, p. 485.)

There are two slabs of this species in the Woodwardian Museum. It is a somewhat rigid and very slender form, and is characterized by the unusual length of the stipes of the 1st order, which are much longer than in any form of *Dichograptus* hitherto described. Each stipe must be fully $\frac{1}{8}$ inch (3·17 mm.) long, and thus what older authors would have regarded as the 'funicle' is $\frac{1}{4}$ inch (6.35 mm.) in length. The two stipes of the 2nd order make with each other an angle of 105°; these are rather less than $\frac{1}{8}$ inch in length;

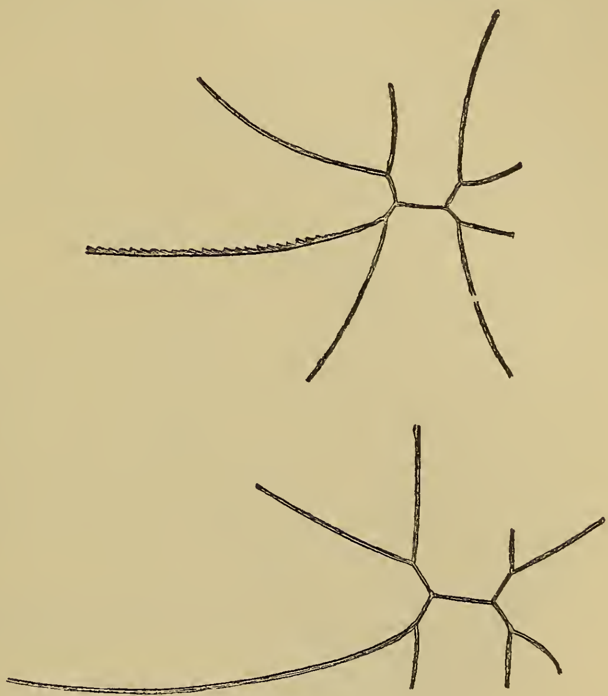
they then divide dichotomously, giving rise to the eight stipes of the 3rd order, which make with each other an angle of about 70°.[1] These stipes may be as much as 3 inches in length.

The whole rhabdosoma is very slender, never attaining a greater width than $\frac{1}{50}$ inch (·5 mm.).

The thecæ are not very clearly seen, but they seem to be closely set, and number thirty-two to the inch (thirteen in 10 mm.).

Locality.—Outerside.

Fig. 10.—Dichograptus separatus, *sp. nov.* (*coll. Woodwardian Mus.*).



[Nat. size.]

Genus *Tetragraptus*, Salt.

(*f*) Tetragraptus quadribrachiatus (Hall).

1858. *Graptolithus quadribrachiatus*, Hall, Geol. Surv. Canada Rep. 1857, p. 125.

1863. *Tetragrapsus crucialis*, Salt., Quart. Journ. Geol. Soc. vol. xix, p. 137, fig. 8 *b*.

1865. *Graptolithus quadribrachiatus*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 91, pl. v, figs. 1–5, & pl. vi, figs. 5, 6.

1868. *Tetragrapsus quadribrachiatus*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 131.

1875. *Tetragraptus quadribrachiatus*, Hopk. & Lapw. *ibid.* vol. xxxi, p. 649 & pl. xxxiii, figs. 9 *a* & *b*.

Tetragraptus quadribrachiatus (Hall) seems to be abundant in the Skiddaw Slates. There are specimens of all ages and sizes, but only a few are sufficiently well preserved to show the characters of the thecæ; the rest merely show the typical form of the species.

The ultimate stipes are generally straight and rigid; they are slender at their origin, and gradually increase up to a maximum width of $\frac{1}{12}$ inch (2·1 mm.) in the largest specimens, but often only $\frac{1}{20}$ to $\frac{1}{16}$ inch (1·2 to 1·5 mm.) in the forms that are of common occurrence.

[1] The above-mentioned angles of divergence refer only to one aspect of the rhabdosoma; this was the same in all the specimens known to me, and the angle was therefore constant.

There are twenty-four thecæ in the space of an inch (nine to ten in 10 mm.); they are free for one-third to half their length, and make with the general direction of the stipe an angle of 30° to 40°. The apertures are straight and nearly perpendicular, being inclined at an angle of 95° to 100°.

The total length of primary and secondary stipes before dichotomous division is about $\frac{1}{12}$ inch (2·1 mm.). This measurement represents the length of the so-called 'funicle' of earlier authors, a term, which as Holm has shown, is no longer applicable to the graptolites. It is evidently celluliferous in some specimens, and therefore, no doubt, in all.

Whether the length of these branches of the 1st order is the same on either side of the sicula I am not able to say with certainty; there is an appearance of symmetry in some aspects of the rhabdosoma, but this may be deceptive. It is unfortunate that, in almost every case, this part of the rhabdosoma is preserved so that the apertures of the cells are embedded in the rock, and only the dorsal walls of the stipes are turned towards the observer.

Occurrence.—This species is found in the Middle Skiddaw Slates in the following associations:—

(1) On a slab from Barf with *Didymograptus Nicholsoni*, Lapw.
(2) On a slab from Outerside with *Cryptograptus Hopkinsoni*, Nich.
(3) On a slab from Bassenthwaite Common with *Didymograptus gibberulus*, Nich.
(4) With *Tetragraptus crucifer* (Hall).

Localities.—Barf; Outerside; Bassenthwaite Common; Skiddaw; Randal Crag, Skiddaw; Carlside Edge, Skiddaw; Aiken Gill (Scawgill); Scale Hill, Crummock; north-east of Grisedale Pike.

(*c*) Tetragraptus Headi (Hall). (Fig. 11, p. 487.)

1858. *Graptolithus Headi*, Hall, Geol. Surv. Canada Rep. 1857, p. 127.
1865. *Graptolithus Headi*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 94 & pl. vi, fig. 8.
1868. *Tetragrapsus Headi*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 131.

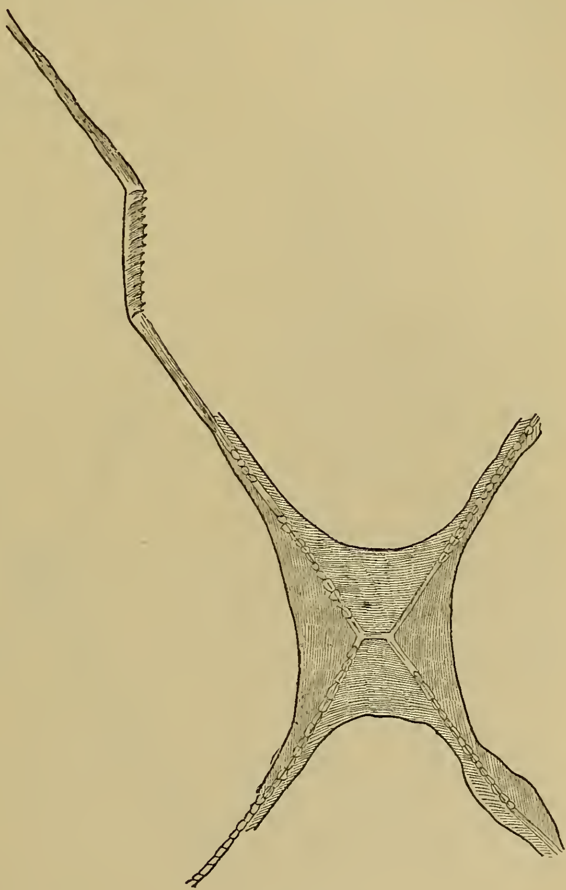
I have not seen many specimens of *Tetragraptus Headi* from the Skiddaw Slates; three, or possibly four, which should be referred to that species are in the Woodwardian Museum, but unfortunately the stipes in all these are preserved with their dorsal side uppermost, and nothing is seen of the thecæ. The best specimen found as yet is undoubtedly that in Mr. Postlethwaite's collection; this not only shows the disc well, but also one stipe is turned on its side for part of its length and reveals the thecæ.

The general form of the species is similar to that of *T. quadribrachiatus* (Hall), but the dichotomous division of the primary stipes seems to take place almost at once (in other words, the so-called 'funicle' is extremely short), and the stipes are wider than in that species. The disc is quadrangular, nearly square, and with more or less straight sides; in the largest specimen examined it was fully $\frac{2}{3}$ inch (17 mm.) square, but often it is not completely preserved; it is always slightly extended along the stipes. In the specimen in

Mr. Postlethwaite's collection there is a very prolonged 'alation' up the stipes, but this is not so pronounced in other specimens.

The stipes are narrow at their origin, but widen to a maximum of fully $\frac{1}{12}$ inch (2·1 mm.) when the thecæ are seen. The greatest length observed is $4\frac{1}{4}$ inches (12·2 cm.).

Fig. 11.—Tetragraptus Headi (*coll. Postlethwaite*).



[Nat. size.]

The thecæ number twenty-four in the space of an inch (nine to ten in 10 mm.); they are long curved tubes, and are inclined at an angle of about 40°; their apertures are situated obliquely to the general direction of the stipe.

There is another specimen in the Woodwardian Museum which has been referred to *T. alatus* (Hall). It is a small specimen, only two stipes are seen, and these do not exceed $\frac{1}{2}$ inch (12·7 mm.) in length. The disc is square and straight-sided, and measures $\frac{1}{3}$ inch (8·5 mm.) across each diameter. The membrane certainly does appear to envelope the stipes more or less completely, but I think that this must also be the case in young forms of *Tetragraptus Headi*.

The specimen is preserved so as to show the apertures of the thecæ facing the observer, and these number twenty-four to the inch (nine to ten in 10 mm.). Taking into consideration the form of the disc and the number of thecæ to the inch, I am inclined to think that this specimen is a young form of *Tetragraptus Headi*.

Occurrence.—The specimen in Mr. Postlethwaite's collection occurs on a slab on which there are also present *Didymograptus patulus* (Hall) and *D. gibberulus*, Nich.; it belongs probably to the upper part of the Middle Skiddaw Slates.

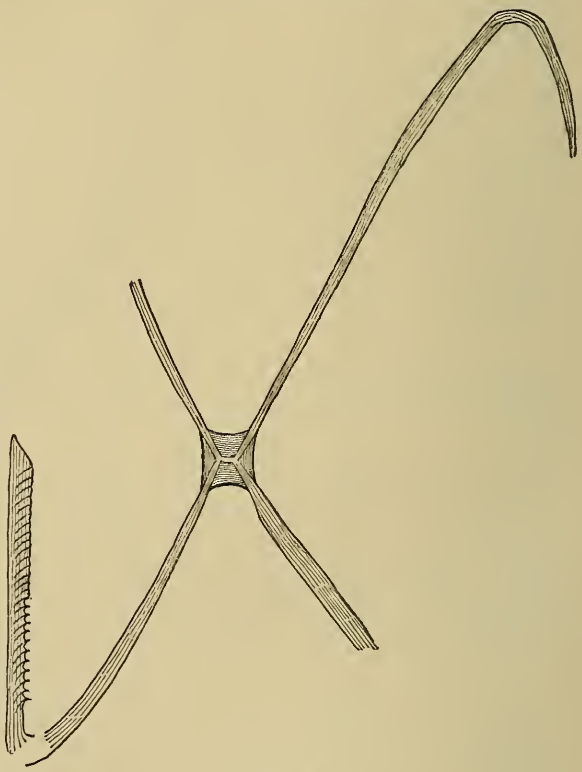
Localities.—South-western end of Randal Crag, Skiddaw. Nicholson also records a specimen from Barf, near Keswick.

(*b*) Tetragraptus crucifer (Hall).

1858. *Graptolithus crucifer*, Hall, Geol. Surv. Canada Rep. 1857, p. 125.
1865. *Graptolithus crucifer*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 92 & pl. v, fig. 10.
1868. *Tetragrapsus crucifer*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 144.

A specimen in Mr. Postlethwaite's collection is the only one known to me, therefore it would seem to be rare in the Skiddaw Slates. This one agrees very well with Hall's description.

Fig. 12.—Tetragraptus crucifer (*coll. Postlethwaite*).



[Nat. size.]

The general form is like *T. quadribrachiatus* (Hall), but the stipes widen very much more rapidly and are much stouter; and the disc is smaller and more oblong than it is in *Tetragraptus Headi* (Hall).

The stipes widen rapidly from their origin, and at the same time are turned over on to their sides so as to reveal their thecæ, though all details are obscure.

The maximum width observed in any stipe is fully $\frac{1}{6}$ inch (4·2 mm.); the greatest length is $3\frac{1}{4}$ inches (82·4 mm.).

The disc is small, quadrangular, and oblong, the greatest length being $\frac{1}{4}$ inch (6·3 mm.), the greatest width $\frac{1}{6}$ inch (4·2 mm.), and there is a very slight 'alation' up the stipes.

All details of the thecæ are obscure. There seem to be twenty-two apertures in the space of an inch (eight to nine in 10 mm.), and these are situated obliquely with regard to the general direction of the stipe.

Occurrence.—On this slab there are also specimens of *Azygograptus suecicus*, Moberg. The species also occurs with *Tetragraptus quadribrachiatus* (Hall).

Locality.—Barf, near Keswick.

(*a*) Tetragraptus Bigsbyi (Hall).

1853. *Didymograpsus caduceus*, Salt. (*pars*), Quart. Journ. Geol. Soc. vol. ix, p. 87, fig. 1 *a*.
1858. *Phyllograptus similis*, Hall, Geol. Surv. Canada Rep. 1857, p. 140.
1863. *Didymograpsus caduceus*, Salt.? Quart. Journ. Geol. Soc. vol. xix, p. 137, fig. 13 *b* (?).

1865. *Graptolithus Bigsbyi*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 86 & pl. xvi, figs. 22–30.

The specimens upon which Salter founded his species *Didymograptus caduceus* seem to have belonged to two distinct forms, *D. gibberulus*, Nich., and the *Tetragraptus* to which Hall later gave the name *Bigsbyi*. To avoid any confusion which might therefore arise, it appears wisest to adopt Hall's specific name in place of the older term.

This species is abundant in the Skiddaw Slates; it is characteristically small and never seems to exceed $\frac{3}{4}$ inch (19 mm.) in length, while specimens of less than $\frac{1}{2}$ inch (12·7 mm.) are more commonly found. The general form of the rhabdosoma may be described as a broad oval, truncated at its upper end in most specimens, but occasionally nearly complete, since there is a tendency on the part of some stipes to come together at their distal extremities, and in some cases actual fusion appears to have taken place.

The stipes are about $\frac{1}{24}$ inch (1·05 mm.) wide at their origin, but widen rapidly to a maximum width of $\frac{1}{8}$ inch (3·2 mm.), diminishing again at their distal ends. The stipes are distinctly broad in proportion to their length; their dorsal wall is nearly always concavely curved, though the amount of curvature varies greatly in different individuals.

The sicula is apparently about $\frac{1}{12}$ inch (2·1 mm.) in length, and the proximal part of the rhabdosoma bears a general resemblance to *Didymograptus gibberulus*, Nich. Holm's work on the structure of this species indicates that the earliest theca arises from the sicula near its apex, and the two stipes of the 1st order, constituting the 'funicle' of other authors, are reduced to a minimum, for dichotomous division appears to take place at once.[1]

The thecæ number between thirty-two and thirty-six to the inch (thirteen to fourteen in 10 mm.). They are at first nearly at right angles to the general direction of the stipe; those developed later have an initial angle of 40° to 50°, but curve so that the inclination near the aperture makes an angle of 60° to 70° with the axis. The thecæ are widest at their apertures, and are about 4 times as long as wide. The apertures are slightly concave and mucronate, and the apertural angle is about 140°.

Occurrence.—In the lowest part of the Middle Skiddaw Slates, with *Bryograptus ramosus* var. *cumbrensis*.

Localities.—Randal Crag, Gibraltar; White House Fell, Skiddaw; Bassenthwaite Sand-beds; Outerside; Troutbeck.

Note.—I have not been able to convince myself that the form provisionally named *inosculans* by Marr & Nicholson (Geol. Mag. 1895, p. 538). is really distinct from the species above described. There seems to be every intermediate stage between a form in which the stipes are distinctly separated and that in which complete fusion appears to have taken place, and the characters of the cells are in every case the same. In my opinion, the real intermediate form between *T. Bigsbyi* (Hall) and *Phyllograptus* is to be found

[1] Holm, 'Om *Didymograptus, Tetragraptus*, och *Phyllograptus*,' Geol. Fören. Stockholm Förhandl. vol. xvii (1895) p. 319.

in the *Tetragraptus phyllograptoides* of Swedish authors, in which the stipes are united for some little distance at their proximal ends, but are free above.

(*g*) Tetragraptus serra (Brongn.).

1828. *Fucoides serra*, Brongniart, 'Hist. Végét. Foss.' vol. i, p. 71, pl. vi, figs. 7 & 8.
1858. *Graptolithus bryonoides*, Hall, Geol. Surv. Canada Rep. 1857, p. 126.
1863. *Tetragrapsus* [*bryonoides*], Salt. Quart. Journ. Geol. Soc. vol. xix, p. 137, fig. 8.
1865. *Graptolithus bryonoides*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 84 & pl. iv, figs. 1–11.
1868. *Tetragrapsus bryonoides*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 131.
1875. *Tetragraptus serra*, Hopk. & Lapw. *ibid.* vol. xxxi, p. 650 & pl. xxxiii, fig. 10.

There seems little doubt that Brongniart's *Fucoides serra* is the same species that Hall described later as *Graptolithus bryonoides*; in fact, Hall himself acknowledges this ('Grapt. of Quebec Group,' p. 84), and therefore the older specific name should be retained.

The rhabdosoma presents great variation in form, owing to the different ways in which it has been preserved. Sometimes the stipes are spread out as in *T. quadribrachiatus*, at others they are directed obliquely upwards. The two stipes of the 1st order (so-called 'funicle') reach together a length of about $\frac{1}{12}$ inch (2·1 mm.). The stipes resulting from the dichotomous division of these attain sometimes an enormous length, one specimen in the Woodwardian Museum being about 9 inches (22·8 cm.) long, and another rather more than 7 inches (17·7 cm.); the commoner forms, however, do not exceed 2 inches (51 mm.) in length. These stipes are narrow at their origin, but widen rapidly, and are found to have attained their maximum width after the 3rd or 4th theca; they become narrower again at the extreme distal end, owing to the shortness of the thecæ at that point. The dorsal walls of the stipes may be straight or curved. The width is very different in different individuals; in some, the width at the origin of the stipes is $\frac{1}{24}$ inch (1·05 mm.), and the maximum width attained $\frac{1}{12}$ inch (2·1 mm.), but in the largest individuals the maximum width is fully $\frac{1}{6}$ inch (4·2 mm.).

The thecæ vary in number according to the place of measurement, size, and age of an individual; near the proximal end they may be twenty-six or even twenty-eight to the inch (ten to eleven in 10 mm.), but in the adult part of the rhabdosoma the number rarely exceeds twenty (eight in 10 mm.). The thecæ are long, somewhat curved, and are widest at their apertures; their length is about 3 times as great as their maximum width; they are inclined 40° to 50° (average 45°), and are free for about a quarter of their length. Their apertures are concave and circular, and are inclined to the general direction of the stipe at an angle of 110° to 120°.

The sicula is fairly large and conspicuous in some specimens; it measures $\frac{1}{12}$ inch (2·1 mm.).

The species may be distinguished from *Tetragraptus quadribrachiatus* (Hall) by (1) the very rapid widening of the stipes and (2) the greater width attained; and from *T. Bigsbyi* by (1) fewer cells in a given unit of length; (2) general form and greater size when mature.

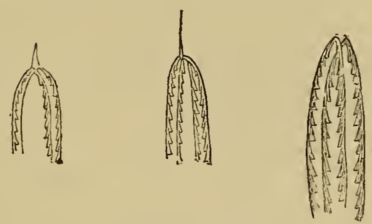
Occurrence.—Middle Skiddaw Slates.

Localities.—The species seems very abundant in the Skiddaw Slates; it is recorded from Randal Crag, Skiddaw; Bassenthwaite Sand-beds; Outerside; White House Fell, Skiddaw; east of Dodd Wood, Keswick; Barf, Frozen Gill; Gibraltar, Skiddaw.

(*d*) Tetragraptus pendens, sp. nov.

'Rhabdosoma small and very slender, consisting of two pairs of descending stipes, which after the first divergence are directed vertically downwards, and run nearly parallel to each other. The sicula is conspicuous and fairly long, being $\frac{1}{16}$ inch in length (1·58 mm.). The stipes are narrow and of uniform width throughout their length, never exceeding $\frac{1}{48}$ inch (·5 mm.); the inner margin is celluliferous. The cells are long narrow tubes of uniform width, and number between twenty and twenty-four in the space of an inch (eight to nine in 10 mm.); they are inclined 15° to 20° to the general direction of the stipe; their outer wall is straight, or may have a slight concave curvature near the proximal end. The cells are in contact with each other for rather less than half their length, which is commonly $\frac{1}{12}$ inch (2·1 mm.). Apertures straight, occupying more than half the total width of the rhabdosoma. Apertural angle about 120°.'

Fig. 13.—Tetragraptus pendens, *sp. nov.* (*coll. Postlethwaite*).



[Nat. size.]

This delicate little species is related to *Tetragraptus fruticosus* (Hall) by its general form, but may be readily distinguished from that species:—

(1) It is much more slender, and never seems to exceed $\frac{2}{3}$ inch in length.

(2) Its stipes are parallel and of uniform width, while those of *T. fruticosus* are divergent and increase gradually in width throughout their length.

(3) There are more cells in a given unit of length, twenty to twenty-four compared with fifteen.

(4) The cells are inclined at a very much lower angle, 15° instead of 38°.

From all other known species of *Tetragraptus* the present species is distinguished by its form.

Structure.—The development of the rhabdosoma appears to commence precisely in the way that Holm has described as characteristic of the genus *Didymograptus*,[1] but after the development of one cell each stipe undergoes dichotomous division, resulting in the production of two pairs of stipes, which appear to be similar in every respect.

Occurrence.—Middle Skiddaw Slates.

One specimen of this species occurs on a slab with *Azygograptus suecicus*, Moberg, another on a slab with *Didymograptus V-fractus*,

[1] *Op. jam cit.* Geol. Fören. Stockholm Förhandl. vol. xvii (1895) p. 319.

Salt., and a third on a slab which also bears *D. gibberulus*, Nich., and *Phyllograptus typus*, Hall. These fossils are all characteristic of the highest beds of the Swedish *Phyllograptus*-skiffer, from which horizon I have also seen a form of *Tetragraptus* similar to that just described.

Locality.—Barf, near Keswick.

(*e*) Tetragraptus Postlethwaitii, sp. nov.

This species belongs to what may be called the '*fruticosus*-type' of *Tetragrapti*. 'Rhabdosoma pendent; all the stipes directed vertically or obliquely downwards, narrowest at their origin, but widening somewhat rapidly to a maximum width of $\frac{1}{16}$ inch (1·58 mm.). Thecæ: long narrow tubes of uniform width, numbering between twenty-eight and thirty to an inch (eleven to twelve in 10 mm.); inclined at about 30°, with very slight concave curvature, and in contact for the greater part of their length. Apertures nearly straight, making an angle of about 130° with the general direction of the stipe.'

The species is large, and the stipes often attain considerable length; in one specimen a length of $3\frac{1}{2}$ inches (88·7 mm.) has been measured, but the width remains constant at $\frac{1}{16}$ inch (1·58 mm.) throughout the whole length.

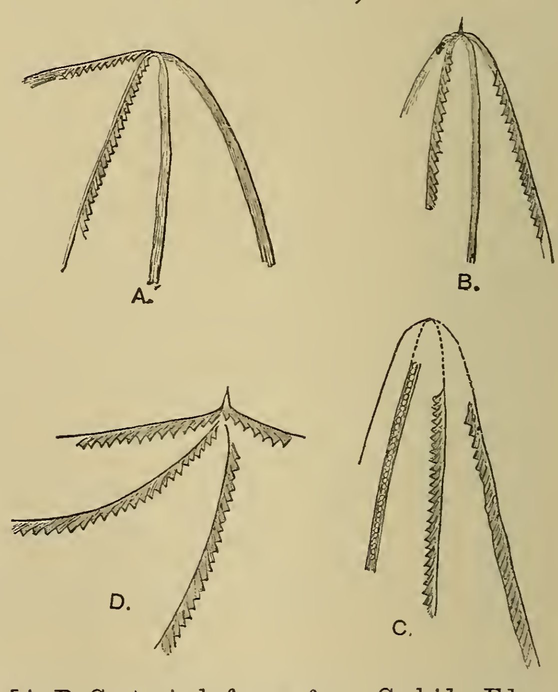
The dorsal walls of the stipes are commonly curved. All details of the proximal end are obscure.

The species differs from *Tetragraptus fruticosus* (Hall): (1) in the absence of gradual widening; (2) in the lower angle of inclination of the thecæ and the greater number in a given unit of length.

It differs from *T. pendens*, sp. nov.: (1) in its much larger size; (2) in the higher angle of inclination of the thecæ and the greater number in a given unit of length.

Some aspects of *T. quadribrachiatus* present a similar appearance, and from this form it may be distinguished by the characters of the thecæ.

Fig. 14.—Tetragraptus Postlethwaitii, *sp. nov.* (*colls. Postlethwaite and Woodwardian Mus.*).



[A, B, C=typical forms from Carlside Edge; D=a specimen doubtfully referable to this species, from Barf. All are shown of the natural size.]

Localities. — All the specimens known to me come from Carlside Edge or Barf, and all except one are in Mr. Postlethwaite's collection, the one other specimen belonging to Prof. Nicholson.

I name this species after my friend Mr. Postlethwaite, who first pointed the form out to me, and to whom all geologists owe a debt of gratitude for his arduous labours among the Skiddaw Slates.

Genus *Phyllograptus*, Hall.

(*c*) Phyllograptus ilicifolius, Hall.

1865. *Phyllograptus ilicifolius*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 121 & pl. xvi, figs. 1–10.

The rhabdosoma consists of four stipes, united so as to form two broad intersecting ovals, each of which is widest at its upper end. The rhabdosoma is about $\frac{1}{2}$ inch (12·7 mm.) long, and has a maximum width of $\frac{1}{4}$ to $\frac{1}{3}$ inch (6·4 to 7·5 mm.). The curvature of the thecæ in different parts of the rhabdosoma is very characteristic : near the proximal end they first ascend, and then curve out and down ; in the centre of the rhabdosoma they are so little curved that they appear almost horizontal ; while at the distal extremity they are directed outwards and upwards, and ultimately almost straight upwards. The thecæ number thirty-two to the inch (thirteen in 10 mm.) ; they are in contact throughout their length ; their apertures are concave, oblique, and distinctly mucronate.

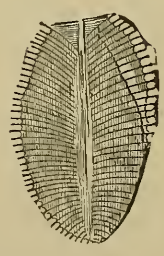
Occurrence.—With *Phyllograptus typus* in the Middle Skiddaw Slates (upper part).

Locality.—Randal Crag.

(*d*) Phyllograptus ilicifolius, Hall, var. grandis nov.

The general form of the rhabdosoma is the same as in the foregoing, and consists of four stipes united so as to form two broad intersecting ovals. The rhabdosoma is fully 1 inch (25·4 mm.) long, and has a maximum width of $\frac{7}{12}$ inch (14·7 mm.). The curvature of the thecæ and the number to the inch agree with *P. ilicifolius*. Growth-lines parallel to the thecal aperture are seen on several of the thecæ.

Fig. 15.—Phyllograptus ilicifolius, *var.* grandis *nov.* (*coll. Woodwardian Mus.*).



[Nat. size.]

The specimen upon which the above description is based is in the Woodwardian Museum ; it is very much larger than any specimen figured by Hall as belonging to the species *ilicifolius* ; in fact, it resembles most closely those figures which are enlarged 3 diameters. I have therefore designated it as a variety of Hall's species, and given it the name *grandis* to denote its unusual size.

Locality.—North-east of Sleet How, Keswick.

(*a*) Phyllograptus Anna, Hall.

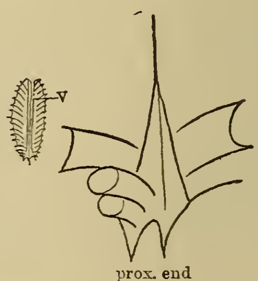
1865. *Phyllograptus Anna,* Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 124 & pl. xvi, figs. 11–16.

There are several specimens referable to this species, both in Mr. Postlethwaite's collection and in the Woodwardian Museum.

It is characterized by its small size, and the great number of thecæ in a given unit of length. These number between thirty-six and forty to the inch (fourteen to sixteen in 10 mm.). None of the specimens are as much as $\frac{1}{2}$ inch (12·7 mm.) in length; they appear to be commonly $\frac{5}{12}$ inch (10·5 mm.) long, and have a maximum width of $\frac{1}{5}$ inch (5·078 mm.), which is attained near the distal extremity of the rhabdosoma.

All the thecæ are curved, though the curvature is less in the middle than at the proximal and distal extremities of the rhabdosoma. The thecæ are in contact throughout their length.

Fig. 16.—Phyllograptus Anna (*coll. Woodwardian Mus.*).



[Nat. size, and a portion magnified 10 diam.]

One specimen in the Woodwardian Museum seems to show in some detail the structure of the proximal end. This is on the same general plan as that indicated by Holm for the species *angustifolius*. In this specimen one stipe has been completely removed, and the sicula and first theca are revealed. The sicula is very long; it measures $\frac{1}{12}$ inch (2·1 mm.). The first theca, which appears to arise close to its apex, resembles the sicula in form.

A virgula is seen coming from the apex of the sicula; it does not project beyond the distal extremity of the rhabdosoma. So far as I am aware, no virgula has hitherto been seen in the genus *Phyllograptus*.

Occurrence.—With *Phyllograptus angustifolius,* Hall, in the Middle Skiddaw Slates.

Localities.—Randal Crag, Skiddaw; Barf; Carlside Edge.

(*e*) Phyllograptus typus, Hall.

1858. *Phyllograptus typus,* Hall, Geol. Surv. Canada Rep. 1857, p. 137.

1865. *Phyllograptus typus,* Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 119 & pl. xv, figs. 1–12.

1868. *Phyllograpsus typus,* Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 133 & pl. v, fig. 16.

Hall has well described this form as 'elongate-ovate, or lanceolate, broad oval or obovate.' The form is exceedingly variable, as the following table of dimensions shows. The variation is largely dependent on the amount of curvature of the thecæ, which is very different in different individuals :—

Specimen and Locality.	Length. in.	Length. mm.	Width (Max.).* in.	Width (Max.).* mm.	No. of thecæ to inch.	No. in 10 mm.
A. Randal Crag (One slab)	$1\frac{1}{4}$	31·7	$\frac{1}{3}$	8·7	24	9–10
B. 1. Barf (One slab)	$2\frac{1}{4}$	57	$\frac{1}{4}$	6·3	24	9–10
B. 2. ,, (One slab)	2	50·6	$\frac{1}{4}$	6·3	24	9–10
B. 3. ,, (One slab)	$1\frac{1}{2}$	38	$+\frac{1}{4}$	7	26	10
C. ,,	$1\frac{1}{4}$	31·7	$\frac{1}{4}$	6·3	26	10
D. ,,	$\frac{7}{12}$	14·7	$\frac{3}{16}$	4·76	26	10
E. ,,	1	25·4	$-\frac{1}{3}$	8	24	9–10
F. ,,	$\frac{1}{3}$	8·7	$\frac{3}{16}$	4·76	24	9–10
64¹. ?	$1\frac{1}{3}$	34 1	$\frac{1}{4}$	6·3	26	10
².	1	25·4	$\frac{1}{4}$	6·3	24	9–10
³.	1	25·4	$\frac{1}{3}$	8·7	24	9–10
69. Outerside	?	...	$\frac{1}{3}$	8·7	24	9–10
76. Bassenthwaite Sand-beds	?	...	$\frac{5}{12}$	10·5	24	9–10

The species appears to be characterized by (1) the number of thecæ in a given unit of length; (2) the form of the aperture, which is equally extended at its upper and lower limits.

The thecæ are curved throughout the whole length of the rhabdosoma; they go out nearly horizontally in the proximal part, but curve back so that the aperture points downwards. The degree of curvature seems to vary somewhat, according to the aspect in which the rhabdosoma is viewed. The curvature is less in the middle of the stipe, and the line of the aperture becomes parallel to the general direction of the rhabdosoma; above this, the aperture becomes inclined, and the thecæ are inclined at a higher angle, which increases steadily towards the distal end, so that eventually in some forms the apertures of the cells lie almost perpendicular to the general direction of the rhabdosoma, a complete change in position having thus been effected. The thecæ number between twenty-four and twenty-six to the inch (nine to ten in 10 mm.); they never exceed twenty-six, and are far more commonly twenty-four. They are in contact throughout their length, and have slightly mucronate apertures.

The proximal end is not often well preserved, but two specimens show some details. In one the sicula and first theca can be made out; the sicula has a length of about $\frac{1}{16}$ inch (1·58 mm.); the first theca seems to be developed from near its apex, and closely resembles it in general form. Another specimen shows a view resembling that figured by Holm (*op. cit.* pl. xiii, fig. 2).

The larger forms of this species bear a superficial resemblance to *Phyllograptus angustifolius*, but are always broader, and the form of the aperture is distinctive.

Occurrence.—With *Didymograptus gibberulus*, Nich., *D. nitidus* (Hall), *Azygograptus suecicus*, Moberg, *Phyllograptus angustifolius*, Hall, *Dichograptus octobrachiatus* (Hall). It appears to be very

* In some specimens the maximum width is quite near the proximal end, in others it is nearer the middle of the rhabdosoma.

abundant in the Middle Skiddaw Slates (upper part) at several localities.

Localities.—Barf; Whiteside; Carlside; east of Dodd Wood; Randal Crag; Glenderamakin Valley; Mungrisedale.

(*b*) Phyllograptus angustifolius, Hall.

1858. *Phyllograptus angustifolius,* Hall, Geol. Surv. Canada Rep. 1857, p. 139.
1865. *Phyllograptus angustifolius,* Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 125 & pl. xvi, figs. 17–21.
1868. *Phyllograpsus angustifolius,* Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 132.

This species, like that just described, has a varied form, but it is never broadly ovate.

The curvature of the thecæ is very similar to that of *Ph. typus*, in so far as at the proximal end the thecæ come out nearly horizontally and then curve slightly back and down; but the subsequent curvature is far more uniform than is the case with *Ph. typus*, where there is an appreciable diminution in the centre of the rhabdosoma. The inclination of the thecæ increases steadily towards the distal end. The thecæ are more numerous than in *Ph. typus*: there are generally thirty in the space of an inch, though the number may be as low as twenty-eight or as high as thirty-two (eleven to thirteen in 10 mm.).

The form of the aperture with its long denticle is characteristic, there being a greater extension on the lower than on the upper side. The denticle may be as much as $1\frac{1}{2}$ times the width of the thecæ.

The dimensions of the species vary greatly in different individuals; the length may be anything up to 2 inches (50·7 mm.), and the width may be as great as $\frac{1}{3}$ inch (8·7 mm.), but is more commonly $\frac{1}{6}$ or $\frac{3}{16}$ inch (4·2 or 4·76 mm.).

In broader forms the species approaches *Phyllograptus typus*, but can be distinguished by (1) the form of the cell-aperture; (2) the greater number of cells in a given unit of length.

The greatest width is often attained near the base of a long specimen, and, in fact, the rhabdosoma is often wider at this point than at any subsequent point along its length.

Occurrence.—The species appears to be very abundant in the Middle Skiddaw Slates; it occurs on the same slabs as *Phyllograptus typus*, Hall, *Ph. Anna*, Hall, *Tetragraptus Bigsbyi* (Hall), *Didymograptus nitidus* (Hall), and *Dichograptus octobrachiatus* (Hall).

Localities.—Barf; Carlside; Whiteside; Randal Crag; Bassenthwaite Sand-beds; Knott Head, Whinlatter.

Genus *Didymograptus,* M'Coy.

(*e*) Didymograptus gibberulus, Nich. (Figs. 17 & 18, pp. 498, 499.)

1853. ? *Didymograpsus caduceus,* Salt. (*pars*) Quart. Journ. Geol. Soc. vol. ix, p. 87, fig. 1 *a*.
1863. ? *Didymograpsus caduceus,* Salt. *ibid.* vol. xix, p. 138, fig. (p. 137) 13 *a*, *b* ?
1875. *Didymograptus gibberulus,* Nich. Ann. Mag. Nat. Hist. ser. 4, vol. xvi, p. 271 & pl. vii. figs. 3, 3 *a* & 3 *b*.

1891. '*Didymograptus*' *gibberulus*, Moberg, Geol. Fören. Stockholm Förhandl. vol. xiii, p. 221.
1892. *Isograptus gibberulus*, Moberg, *ibid.* vol. xiv, p. 346 & pl. viii, figs. 3–7.
1895. *Didymograptus gibberulus*, Holm, *ibid.* vol. xvii, p. 334.

'Rhabdosoma bilateral, consisting of two fairly broad stipes which bend upwards from the sicula in gentle curves at an angle of 335° to 340°. Stipes widest at their origin, attaining commonly $\frac{1}{12}$ inch (2·1 mm.); there is a marked distinction towards the distal extremity, the stipe there seldom exceeding $\frac{1}{20}$ inch (1·26 mm.) in width.

'The thecæ number forty to the inch (sixteen in 10 mm.); the apertures of the earliest cellules are directed obliquely downwards, but the thecæ then curve in such a manner that they come to face horizontally outwards, and ultimately even upwards; they are then inclined to the general direction of the stipe at an angle of about 45°, and have an apertural angle of 130°. The thecæ are in contact for almost the whole of their length; in the proximal part of the rhabdosoma they are 4 times as long as wide, but in the distal part of the stipes they are very much shorter.'

This species is abundant in the Skiddaw Slates. There are very good specimens in the Woodwardian Museum, the Keswick Museum, and in Mr. Postlethwaite's collection. Three of the specimens in the Woodwardian Museum are Nicholson's types. Another is better preserved than any of these; it is in relief, and exhibits important structural details, to some of which reference has been recently made by Dr. Holm in his work on the Swedish specimens.

The species varies greatly in size and form, especially as regards the direction of the stipes. These varieties may be distinguished as follows:—

(1) Dorsal walls of stipes continuously curved, so that the distal extremities point towards each other;
(2) Dorsal walls of stipes straight; stipes almost parallel to each other;
(3) Dorsal walls straight; distal extremities of stipes directed away from each other.

In all these forms, however, details of structure are essentially the same, and there appears to be every gradation between the extreme types.

The species bears a superficial resemblance to some aspects of *Tetragraptus Bigsbyi* (Hall), in which only two stipes are seen. It should be readily distinguished from that species by the fact that in *T. Bigsbyi* the rhabdosoma is narrowest in its proximal part, whereas in *Didymograptus gibberulus* it is widest at this point.

Notes on Structure of Type-specimens and others.

(A) Obverse Side.[1]

1.—Impression of obverse (sicula-side) aspect of a specimen of

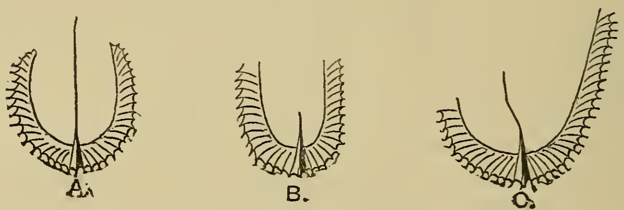
[1] For an explanation of the terms obverse aspect and reverse aspect, see my paper 'On the Subgenera *Petalograptus* & *Cephalograptus*,' Quart. Journ. Geol. Soc. vol. liii (1897) p. 189.

var. B (=Nicholson's fig. 3 *a*).—This specimen is about $\frac{1}{3}$ inch (8·7 mm.) long; the stipes certainly diverge more than Nicholson's figure indicates. I think that what he regarded as the 'two central cellules' must be the sicula and the earliest-formed theca, which so closely resembles the sicula in form.

The sicula is long and narrow for the greater part of its length, but widens somewhat abruptly near its aperture, where it attains a width of $\frac{1}{48}$ inch (·5 mm.). In length it commonly measures $\frac{1}{8}$ inch (3·2 mm.).

The earliest theca is seen on the right in this specimen; it originates from the sicula at a point very near the apex, and

Fig. 17.—*Variation in forms of* Didymograptus gibberulus, *Nich. Obverse aspect, nat. size.*



A = specimen from Bassenthwaite Sand-beds.
B & C = specimens from Randal Crag, Skiddaw.

[A & C are in the Keswick Nat. Hist. Museum, and B in the Woodwardian Museum.]

then grows downward. In general form it resembles the sicula very closely indeed; thus this species illustrates well the view held by some authors that the so-called 'sicula' is nothing but the earliest theca developed from a 'zooid germ.'

The first theca (adopting the usual nomenclature) is in contact with the sicula for almost its whole length, but they curve away from each other near their apertures, leaving a space between them. Lines of growth may be detected along their length, and especially near their apertures. The connecting-canal must be situated very high up and near the sicula-apex; for the theca which is developed second * (th. 1^2), that is, the first on the left of the sicula, seems to be nearly as long as the first on the right (th. 1^1): *cf.* structure of reverse aspect.

The length of the earliest thecæ is about $\frac{1}{12}$ inch (2·1 mm.); those developed later gradually diminish in length towards the distal extremities of the stipes, which thus come to have the appearance of being gently rounded off.

2.—The specimen figured by Nicholson as 3 *b* differs only from the above in that a filamentous thread is seen to proceed from the apex of the sicula; this, according to Wiman's recent work,† must be regarded as the true virgula.

* The nomenclature for the thecæ is the same as that adopted in my paper on *Petalograptus* & *Cephalograptus* already quoted.

† Wiman, 'Ueber Diplograptidæ, Lapw.,' Bull. Geol. Inst. Upsala, vol. i, no. 2 (1893) p. 97.

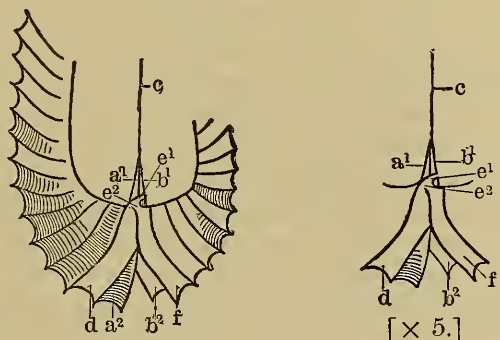
(B) Reverse Side.—This specimen is preserved in relief, and is ¼ inch (6·3 mm.) long.

In this view of the rhabdosoma the greater part of the sicula and the first theca are hidden by the growth of th. 1^2 and th. 2^1, so that there are only visible the apex of the sicula with the filamentous virgula and the initial part of theca 1^1, and, at the base, the apertures of the sicula and theca 1^1.

The connecting-canal between theca 1^1 and theca 1^2 is clearly seen, just below the apex of the sicula and rather above the level of the initial parts of the thecæ which have developed later. There appears also to be a connecting-canal (or something of an homologous nature) between theca 2^1 and theca 1^2. This would seem to indicate that theca 2^1 develops from theca 1^2, instead of developing normally from theca 1^1.

Unfortunately, I am unable to say for certain whether such is always the case in this species or not, for this is the only specimen that I have seen of this aspect of the rhabdosoma, sufficiently well preserved to show these details. It may be accidental. Development appears, at any rate, to have proceeded normally after the growth of the earliest thecæ, each theca of each series developing from the theca next to it on the side nearest the sicula. Growth-lines may be detected in places.

Fig. 18.—Didymograptus gibberulus, *Nich.; reverse aspect, coll. Woodwardian Museum.*



[× 5.] [× 5.]

[From White House Fell, Skiddaw.]

a^1 = apex of sicula.
a^2 = aperture of sicula.
b^1 = initial part of theca 1^1.
b^2 = aperture of theca 1^1.
c = virgula.
d = theca 1^2.
e^1 = connecting - canal between thecæ 1^1 & 1^2.
e^2 = connecting-canal (?) between thecæ 1^2 & 2^1.
f = theca 2^1.

In other particulars the structure of the rhabdosoma seems to be identical in both aspects.

Occurrence.—On slabs with *Didymograptus patulus* (Hall), *Azygograptus suecicus*, Moberg, and *Tetragraptus quadribrachiatus* (Hall), in Middle Skiddaw Slates.

Localities.—Randal Crag and White House Fell, Skiddaw; Bassenthwaite Common.

(*k*) Didymograptus nitidus (Hall). (Figs. 19 & 20, pp. 500, 501.)

1858. *Graptolithus nitidus*, Hall, Geol. Surv. Canada Rep. 1857, p. 129.
1865. *Graptolithus nitidus*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 69 & pl. i, figs. 1–9.
1868. *Didymograpsus nitidus*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 135.
1874. *Didymograptus nitidus*, Etheridge Jun., Ann. Mag. Nat. Hist. ser. 4, vol. xiv, p. 6 & pl. iii, fig. 20.

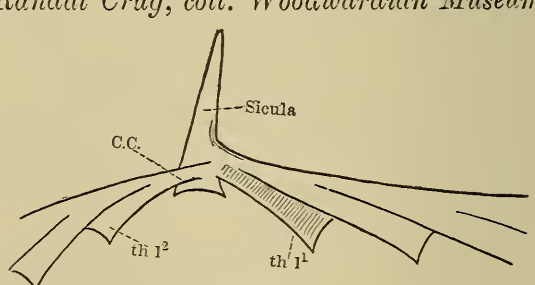
A species which resembles Hall's *D. nitidus* more closely than any other known graptolite is exceedingly abundant in parts of the Skiddaw Slates. In 1868 Nicholson observed the form, and noticed that it was not in all particulars identical with Hall's species. He stated that the English specimens were more closely related to the type that Hall had described and figured as a young form, and was inclined to think that they should be regarded as a distinct variety. Young forms of the species are certainly very abundant in the Skiddaw Slates, but there are also adult forms, and these seem to be very closely related to Hall's type. There are still certain minor differences, but these seem to me to be so unimportant that I cannot discern any necessity to distinguish them from the typical form under a varietal name.

Hall gives the angle of divergence as 175°; in our Skiddaw Slate forms it is often very much lower, the initial angle of divergence being in some cases only 130°. How far this is the result of preservation I am not prepared to say, but I am inclined to think that even in these stouter and more rigid graptolites the angle of divergence may be affected within certain limits, though hardly perhaps enough to account for the above discrepancy.

In the typical American form the stipes appear to proceed at once horizontally or very nearly so, but our English specimens show a greater variation in form. In some the stipes are directed downwards, in others horizontally or even upwards. The English species has also rather fewer thecæ in a given unit of length, twenty-eight to thirty-two in 1 inch (eleven to thirteen in 10 mm.), instead of thirty-two to thirty-four in 1 inch (thirteen to fourteen in 10 mm.); the greatest length observed in any stipe is 3 inches (76 mm.).

Notes on Structure.—The sicula is fairly conspicuous; it is usually about $\frac{1}{16}$ inch (1·58 mm.) in length, and is very slender in its apical part. It is often placed obliquely with regard to the stipes. The earliest theca (th. 1^1) arises from the sicula at some distance above the aperture on the left side. The connecting-canal is fairly oblique; it gives rise to the earliest theca of the secondary stipe (th. 1^2) in the normal manner. In some specimens the stipes diverge from each other at their origin at an angle of about 175°, their dorsal walls being straight; in others there would seem to be a tendency to grow at first downwards, the angle of divergence being about 130°; in exceptional cases this growth may be continued, but more frequently it is arrested after the development of six to ten thecæ on each stipe, the stipes then assuming the horizontal position. In this case the dorsal walls are at first curved, but subsequently straight.

Fig. 19.—Didymograptus nitidus; *from Randal Crag, coll. Woodwardian Museum.*



[× 10.]

In other cases again, where the downward growth is arrested,

Fig. 20.—*Diagram illustrating the variations in form of* Didymograptus nitidus.

the stipes are directed slightly but persistently upwards, and the dorsal wall is continuously curved. The stipes are narrowest at their origin, but widen rapidly, the maximum width being attained opposite theca 10.

In the largest specimens the width at the origin is about $\frac{1}{30}$ inch (·87 mm.), and the maximum width $\frac{1}{16}$ inch (1·58 mm.), but average specimens do not exceed $\frac{1}{24}$ inch (1·05 mm.) in width. The maximum width is maintained till near the distal extremity, where it diminishes owing to the partial development of the latest-formed thecæ; the stipe has thus the appearance of being rounded off. In some forms the thecæ appear like those figured for *D. constrictus* (Hall), but evidence would seem to show that this is merely the result of peculiar preservation, being due to lateral compression of the stipe.

The thecæ are $\frac{1}{16}$ to $\frac{1}{12}$ inch (1·58 to 2·1 mm.) long; they are narrow at their base, but widen towards their apertures, being often at that point nearly twice as wide as at their base. They are about 3 times as long as wide. The outer wall of the cell has a slight double curvature, near the base it is slightly concave, near the aperture slightly convex.

The thecæ number twenty-eight to thirty-two in an inch (eleven to thirteen in 10 mm.); they are in contact for half their length in the proximal part of the stipe: this increases to $\frac{2}{3}$ or $\frac{3}{4}$

nearer the distal end. They are inclined at an angle of 35° to 40°. The thecal apertures are very slightly concave, and they form with the general direction of the stipe an angle of 120°. One specimen shows the pustules at the thecal bases.

The English form, then, is characterized by (1) the variable curvature of the stipes; (2) the rapid increase in width from the initial point; and (3) the character of the thecæ and their number in a given unit of length.

Occurrence.—On one slab it occurs associated with *Tetragraptus quadribrachiatus* (Hall); it probably belongs to the Middle Skiddaw Slates.

Localities.—Randal Crag, Skiddaw; east of Longside; Barf; Bassenthwaite Sand-beds; Knott Head, Whinlatter Pass; Brundelhow Lead Mine; Gatesgill; below Raven Crag, west of Skiddaw.

(*i*) Didymograptus Nicholsoni, Lapw.

1868. *Didymograpsus serratulus*, Nich. (*non* Hall), Quart. Journ. Geol. Soc. vol. xxiv, p. 136.

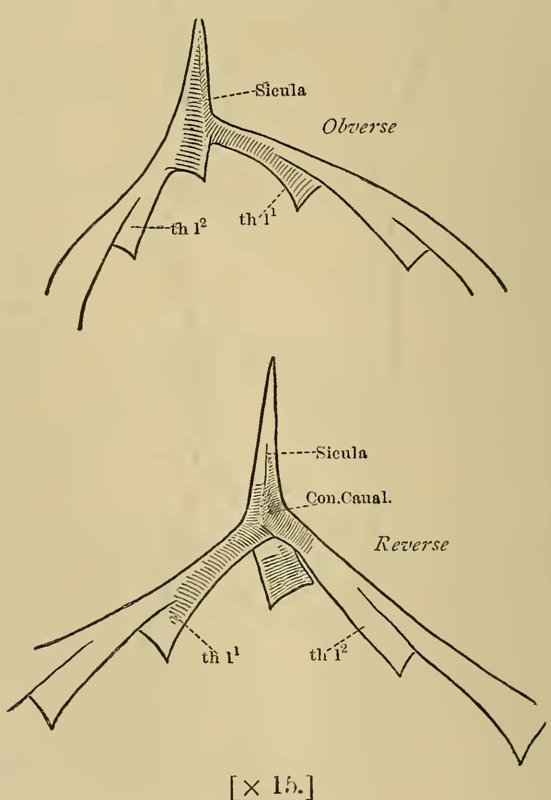
1870. *Didymograpsus serratulus*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. v, p. 343 & pl. vii, figs. 3–3 *d*.

1875. *Didymograptus Nicholsoni*, Lapw. & Hopk. Quart. Journ. Geol. Soc. vol. xxxi, p. 644 & pl. xxxiii, figs. 5 *a–d*.

The Skiddaw Slate specimens now referred to *D. Nicholsoni* were provisionally referred by Nicholson to *D. serratulus*. As Lapworth has shown, Hall's species differs from this in the number of thecæ in a given unit of length and in their shape. According to Hall's figure, there must be only sixteen thecæ in the space of 1 inch (six in 10 mm.) in *D. serratulus*, whereas in *D. Nicholsoni* there are twenty-six (rather more than ten in 10 mm.).

The original specimens obtained from the Skiddaw Slates are said to have been imperfect, but some specimens of the form collected from Barf and now in the Woodwardian Museum are very well preserved.

Fig. 21.—*Impression of* Didymograptus Nicholsoni *from Barf near Keswick; coll. Woodwardian Museum.*



The stipes are usually rigid, and their dorsal walls straight, but occasionally they may be slightly curved; in some individuals they are very long. The stipes widen slightly from their point of origin, but they are uniformly narrow for almost their entire length, never exceeding $\frac{1}{24}$ inch (1·05 mm.) and measuring commonly rather less.

Notes on Structure.—The sicula is $\frac{1}{16}$ inch (1·58 mm.) long; it is narrow, and does not widen much even in the direction of its aperture. The earliest theca (th. 1^1) arises about halfway up the sicula on the left side (obverse view). The general structure of the rhabdosoma is best seen in the reverse view. Theca 1^1 at once curves concavely outward, so that the sicula is free on the left side from the point of origin of theca 1^1 to its aperture. The connecting-canal is long and oblique, and theca 1^2 is closely adpressed to the right side of the sicula.

The angle at which the stipes diverge from each other varies from 110° to 130°. The outer walls of the earliest thecæ have a slight concave curvature, but in the thecæ developed nearer the distal end the walls are straight. The thecæ are in contact with each other for a short distance at their base; they are narrow tubes of uniform width, and are inclined to the general direction of the stipe at an angle which is usually about 25°, but may vary from 20° to 30° in differerent parts of the stipe.

The apertures of the thecæ are concave; they form with the axis of the stipe an angle of 100° to 105°. The thecæ are about 4 times as long as they are wide.

The species may be said to be characterized (1) by the rigidity of the stipes; (2) by the characters of the thecæ: (*a*) the nearly perpendicular aperture; (*b*) contact only at base; (*c*) low angle of inclination; (3) by the number of thecæ in a given unit of length.

Occurrence.—On one slab this species is associated with *Tetragraptus quadribrachiatus* (Hall), Middle Skiddaw Slates.

Localities.—Barf, near Keswick; Carlside Edge, Skiddaw; Outerside; Thornship Beck, Shap.

(*a*) Didymograptus affinis, Nich.

1863. *Didymograpsus* sp., Salt. Quart. Journ. Geol. Soc. vol. xix, p. 137, fig. 13*d*.
1869. *Didymograpsus affinis*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. iv, p. 240 & pl. xi, fig. 20.
1870. *Didymograpsus affinis*, Nich. *ibid.* vol. v, p. 343, fig. 4.

The specimens in the Woodwardian Museum which have been referred to this species should, in my opinion, have been referred to *Didymograptus Nicholsoni*, Lapw.; they do not resemble Nicholson's types.

In *D. affinis* the stipes rarely exceed $\frac{1}{50}$ inch (·5 mm.) in width. The cells are free for almost their whole length; they number eighteen to the inch, or perhaps twenty if the measurement be taken near the sicula (seven to eight in 10 mm.); they are inclined at a low angle, 15° to 20°, and their apertures are perpendicular to the general direction of the stipe.

The sicula is extremely minute, being about $\frac{1}{40}$ inch (·63 mm.) in length.

Localities.—Aik Beck, Pooley; recorded by Nicholson from Barf, Carlside Edge, and Ellergill.

(c) Didymograptus extensus (Hall).

1858. *Graptolithus extensus*, Hall, Geol. Surv. Canada Rep. 1857, p. 132.
1865. *Graptolithus extensus*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 80 & pl. ii, figs. 11–16.
1870. *Didymograpsus extensus*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. v, p. 341 & pl. vii, figs. 2 & 2 *a*.
1875. *Didymograptus extensus*, Lapw. & Hopk. Quart. Journ. Geol. Soc. vol. xxxi, p. 642 & pl. xxxiii, figs. 1 *a–d*.

This species does not seem to be at all abundant in the Skiddaw Slates, and all the specimens are so poorly preserved that very few details of structure can be made out.

The stipes are characteristically slender and flexuous; they diverge at a fairly constant angle of 150°, but have a distinct tendency to curve slightly upwards in their more distal portions.

Some specimens are known whose total length must have been at least 12 inches, and one of about this length from Randal Crag (Skiddaw) is now in the Woodwardian Museum.

The stipes increase in width very slowly from their origin up to a maximum which is attained not far from their distal ends; the decrease near the actual extremity is also gradual. The width of the stipes at their origin is generally about $\frac{1}{50}$ inch (·5 mm.); this increases up to a maximum of $\frac{1}{16}$ inch (1·58 mm.) in a few species, but more commonly they do not exceed $\frac{1}{24}$ inch (1·05 mm.).

There are twenty-four thecæ in the space of an inch (about nine or ten in 10 mm.); these are long narrow tubes of uniform width, which are 3 times as long as wide in the adult part of the stipes, but probably only twice as long nearer the sicula. The maximum thecal length is $\frac{1}{12}$ inch (2·1 mm.). They are free for one-third of their length distally, but for not more than a half in the proximal parts of the stipes, and are inclined at an angle of about 40°.

The thecal apertures are concave, and make with the axis of the stipe a variable angle of 100° to 115°.

Occurrence.—Middle Skiddaw Slates.

Localities.—Randal Crag, Skiddaw; below Raven Crag, west of Skiddaw; Outerside; Knockmurton, near Lamplugh Cross.

(l) Didymograptus patulus (Hall). (Figs. 22 & 23, p. 506.)

1858. *Graptolithus patulus*, Hall, Geol. Surv. Canada Rep. 1857, p. 131.
1863. *Didymograpsus hirundo*, Salt. Quart. Journ. Geol. Soc. vol. xix, p. 137, fig. 13 *f*.
1865. *Graptolithus patulus*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 71 & pl. i, figs. 10–15.
1868. *Didymograpsus patulus*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 135.
1870. *Didymograpsus patulus*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. v, p. 340 & pl. vii, fig. 1 *a*.
1875. *Didymograptus patulus*, Lapw. & Hopk. Quart. Journ. Geol. Soc. vol. xxxi, p. 644 & pl. xxxiii, figs. 4 *a–e*.

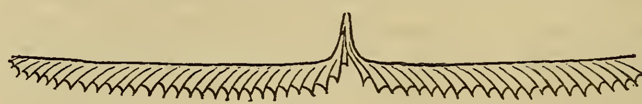
In this species the stipes diverge at a constant angle of 180°, and continue throughout their whole length in more or less of a straight line, though in some of the larger specimens there is a tendency to curve upwards at the distal extremities. Sometimes the stipes attain an enormous length. A slab in the Keswick Museum shows a large specimen, one stipe of which is complete and measures 12 inches (30·46 cm.) in length; the total length of this specimen must therefore have been originally at least 24 inches (61 cm.). Another specimen, now in the Woodwardian Museum, must have been at least 21 inches (53 cm.) in length. These are, so far as I know, the longest specimens on record. The stipes are of considerable width even at their origin, and may widen out to as much as $\frac{1}{8}$ inch (3·17 mm.). This is rather in excess of the measurement given by Hall, but he does not seem to have had such large specimens under his notice.

In none of my specimens have I noticed that the number of thecæ to the inch exceeds twenty-eight (eleven in 10 mm.); in fact, that number is only exceptionally attained near the proximal end when the thecæ are not typically developed, and even then the number is more commonly twenty-six (rather more than ten in 10 mm.). Nicholson gives thirty, thirty-two, thirty-four (twelve to fourteen in 10 mm.) for some Skiddaw Slate forms, and he also figures a specimen with concavely curved dorsal walls. None of my specimens show this character at all, and I should be inclined to refer Nicholson's figure to *Didymograptus nitidus* (Hall). The width of the stipe varies, due no doubt in part to the variation in the length of the thecæ and their inclination; in some young specimens the maximum width is therefore never attained. As a general rule the stipes are wide at their origin, and continue to widen slightly towards their distal ends; but immediately before the actual extremity is reached there is a diminution in width, owing to the partial development of the latest thecæ.

Structure of the proximal end.—The sicula attains a length of $\frac{1}{8}$ inch (3·17 mm.); this is rather long, though small in proportion to the size of the rhabdosoma. It is long and narrow, especially in the apical part: at its aperture it is $\frac{1}{48}$ inch (about ·5 mm.) in width. The first theca (th. 1^1) seems to originate very near the apex of the sicula; it grows at first closely adpressed to the sicula in a straight downward direction, but then curves away from the sicula, leaving it free near its aperture for about one-third of its length on the left side. The second theca (th. 1^2) also at first grows closely adpressed to the sicula; it seems to arise from the connecting-canal which is situated near the apex of the sicula. Theca 1^2 does not grow much farther down than theca 1^1, consequently the proximal part of the rhabdosoma in this species has an unusually symmetrical appearance. The apertures of the earliest thecæ are more nearly parallel to the direction of the stipe than those subsequently developed. In the obverse view the sicula is seen to be somewhat obliquely placed, but this is not so noticeable in the reverse view, when the right side and part of the aperture are concealed by the growth of theca 1^2.

Adult part.—The stipes are characteristically wide; the average width lying between $\frac{1}{10}$ and $\frac{1}{12}$ inch (2·5 and 2·1 mm.), but in the larger specimens referred to above the width is as much as $\frac{1}{8}$ inch (3·17 mm.).

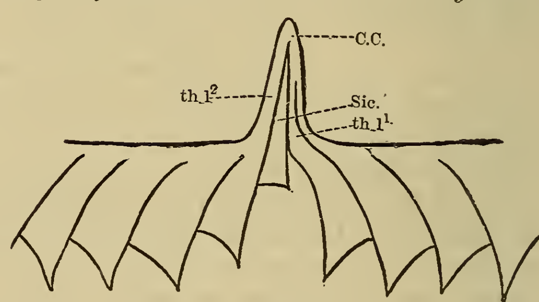
Fig. 22.—Didymograptus patulus, *reverse aspect; from Randal Crag, coll. Woodwardian Museum.*



[Nat. size.]

The thecæ number twenty-four to the inch (nine to ten in 10 mm.) as a general rule, but twenty-six or twenty-eight (ten to eleven in 10 mm.) may be counted near the proximal end. They are inclined at various angles in different parts of the stipe: near the proximal end they are inclined at about 45°; a little farther away from the sicula they curve so that, while the inclination at their bases is only 25°, their apertures make with the general direction of the stipe an angle of 60°. The thecæ are 3 times as long as wide, and are free for about a quarter of their length.

Fig. 23.—*A portion of the same, showing origin of th. 1¹, th. 1², and connecting-canal.*



[× 5.]

The apertures of the thecæ are concave and submucronate, and are inclined at a constant angle of about 130° in the mature part of the stipe: it is characteristic of the species that the anterior margin of each theca is vertically above the base of the second theca in advance. The thecæ usually show lines of growth parallel to their apertures.

Occurrence.—With *Didymograptus gibberulus*, Nich., and *Azygograptus suecicus*, Moberg, in the Middle Skiddaw Slates.

Localities.—Large specimens, and all the best ones, from Randal Crag; others from Outerside, Aik Beck, and Carlside Edge.

(*f*) Didymograptus gracilis, Törnq.

1890. *Didymograptus gracilis*, Törnq. 'Undersökn. öfv. Siljansområdets Grapt.' pt. i, Lunds Univ. Årsskrift, vol. xxvi, p. 17 & pl. i, figs. 9–12.

There can, I think, be no doubt that a specimen in Mr. Postlethwaite's collection should be referred to this graceful little form.

The species is extremely slender, and it is characteristic that the stipes appear to diverge from the sicula at markedly different levels. In the light of recent research this must mean that the connecting-canal is very oblique. The stipes diverge at an angle of 180°.

The earliest theca arises from the middle of the sicula and grows straight out, so that the stipe to which it gives rise appears to originate at that point; the theca (th. 1^2) from which the secondary stipe originates does not diverge from the sicula till close to the aperture, so that the secondary stipe appears to arise close to the aperture of the sicula.

The dorsal wall of each stipe shows a slight convex curvature. There are eighteen thecæ in the space of an inch (seven in 10 mm.).

I am not aware that *Didymograptus gracilis* has been recorded hitherto from this country.

Occurrence.—Middle Skiddaw Slates.

Locality.—Barf, near Keswick.

(*d*) Didymograptus fasciculatus, Nich.

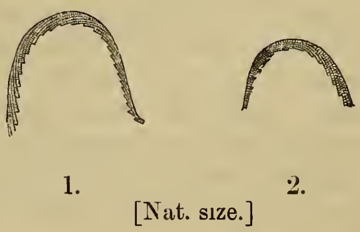
1869. *Didymograpsus fasciculatus*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. iv, p. 241 & pl. xi, figs. 21 & 22.
1870. *Didymograpsus fasciculatus*, Nich. *ibid.* vol. v, p. 344, figs. 5 *a* & *b*.

This species should be easily recognized, even in a fragmentary condition, because of its peculiar characters. All the specimens hitherto recorded belong to the Skiddaw Slates. None are perfect, showing at most the proximal end and one stipe. The two specimens in the Woodwardian Museum, which I believe to be referable to this species, are fragments of the distal parts of the stipes.

The dorsal wall of the stipe seems to be always convexly curved, but not always equally so. The stipe at first grows straight upwards, and then curves round; in some specimens the curvature is continued to such an extent that the distal portion of the stipe is parallel to the proximal part, but in others, after the first decided convex curve, the stipe runs very nearly straight.

The cells are peculiar and eminently characteristic; they number twenty-four in the space of an inch (nine to ten in 10 mm.) in the adult part of the stipe, and are exceedingly long and narrow, attaining sometimes a length of nearly $\frac{1}{4}$ inch (6·3 mm.). They are inclined at so low an angle (15°) that they seem to run nearly parallel to the back of the stipe; they are free only for the last fraction of their length, and have their apertures perpendicular to the axis of the stipe. In the proximal part of the rhabdosoma the cells are smaller, more distant, and are in contact with each other only for a small fraction of their length.

Fig. 24.—*Two specimens of* Didymograptus fasciculatus *sent by Prof. H. A. Nicholson, from Ellergill.*



1. 2.

[Nat. size.]

A perpendicular line dropped near the aperture of a cell will be seen to cut four different cells, and yet the maximum width of the stipe does not exceed $\frac{1}{24}$ inch (1·05 mm.) and is much narrower near the proximal end.

Occurrence.—Ellergill Beds=Upper Skiddaw Slates.

Localities.—Aik Beck, Pooley; Thornship Beck; Ellergill.

(*m*) DIDYMOGRAPTUS V-FRACTUS, Salt. (Figs. 25–28, pp. 508 & 509.)

1863. *Didymograpsus V-fractus*, Salt. Quart. Journ. Geol. Soc. vol. xix, p. 137, fig. 13 *e*.
1868. *Didymograpsus V-fractus*, Nich. *ibid.* vol. xxiv, p. 134.

'Rhabdosoma consisting of two stipes which, after proceeding downwards from the sicula for a short distance, bend abruptly outwards, so as to enclose a much more open angle of divergence. The dorsal wall of each stipe is at first convexly and then concavely curved. The thecæ number thirty-six to the inch (fourteen in 10 mm.); they are inclined 25° to 30°. They are long, narrow tubes, widest at their aperture, and have an apertural angle of 115°. The thecæ are in contact for half their length proximally, but for nearly two-thirds of their length in more distal portions of the stipe.'

A complete description of this form has never hitherto been given, though it has for a long time been recognized as a well-defined species. There are several good specimens of it, both in Mr. Postlethwaite's collection and in the Woodwardian Museum.

The general form of the species is as described above, but the examination of a number of specimens reveals considerable variation

Fig. 25.—Didymograptus V-fractus, *from Barf; coll. Woodwardian Museum.*

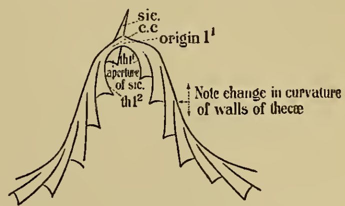
Nat. size.

[A=reverse aspect; B=obverse aspect.]

from the typical form, especially as regards the length of the V-part, and the direction taken by the stipes after the abrupt bend. In some cases the V-shaped part is narrow and rather long, in others it is small and the branches after the bend are exceedingly long; while in others again the initial angle of divergence is greater, and the change in direction less abrupt. Some forms indeed approach very nearly to Tullberg's *Didymograptus vacillans*, but the stipes of that species are of a more uniform width than in *D. V-fractus*.

Notes on Structure.—The sicula is long and narrow; it attains a length of $\frac{1}{16}$ inch (1·58 mm.) exclusive of the prolongation from its apex, which here, as in other forms, must be regarded as the true virgula. The sicula is not placed symmetrically with regard to the stipes; it is nearer the secondary stipe, *i. e.* the stipe with the second thecal series.

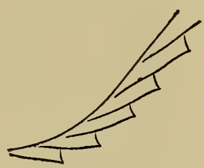
Fig. 26.—*Proximal end of* A, *enlarged to show the structure of the reverse side of the rhabdosoma and point of origin of th. 1*[1].



[× 5.]

The first theca (th. 1[1]) appears to originate from the sicula some distance above its aperture; it grows at first horizontally away from the sicula, which is thus seen in obverse aspect to be free on the left side near the aperture. In the obverse view theca 1[1] is seen on the left side; after growing horizontally it curves downwards. The connecting-canal is narrow and oblique. In the earlier part of its course theca 1[2] is, in reverse aspect, seen to be in close connexion with the apertural part of the sicula.

Fig. 27.—*More distal part of stipe of* A, *enlarged to show the character of the thecæ.*

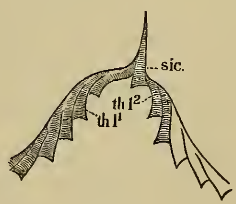


[× 5.]

The walls of the earliest developed thecæ are concavely curved. They are about $\frac{1}{24}$ inch (1·05 mm.) long; those developed later are longer.

The stipes are narrowest at their origin, but quickly attain their maximum width, $\frac{1}{24}$ inch (1·05 mm.), near the bend. In the largest specimens that I have seen the maximum width was $\frac{1}{16}$ inch (1·58 mm.), but $\frac{1}{20}$ inch (1·05 mm.) is more usual. The thecæ of the initial part of the rhabdosoma have their walls concavely curved, but after about three thecæ on the primary stipe and two on the secondary, this concave curvature begins to give place gradually to a slight convex curvature. The thecæ thus curve away from each other, and the general direction of the stipe is changed.

Fig. 28.—*Enlargement of portion of* B, *showing the point of origin of th. 1*[1], *and the generally unsymmetrical appearance of the stipes with regard to the position of the sicula.*



[× 5.]

The thecal walls in the distal portion of the stipes are nearly straight; he thecæ have a length of $\frac{1}{16}$ inch (1·58 mm.), and are 3 times as long as wide.

Occurrence.—Middle Skiddaw Slates.

Localities.—New Brow Quarry, Upper Lorton; Dodd, Brackenthwaite; Barf, near Keswick; Brunstock Scar.

(n) Didymograptus V-fractus var. volucer, H. O. Nich.

1890. *Didymograptus V-fractus* var. *volucer*, H. O. Nich. Geol. Mag. dec. iii, vol. vii, p. 342, fig. 3.

This variety agrees in general characters with the foregoing species, but the whole rhabdosoma is thicker, the basal angle narrower, and the V-part more prolonged. The bend is very abrupt, and the stipes thereafter run in a direction at right angles to their previous direction of growth.

Notes on Structure.—The sicula appears to resemble that of *Didymograptus V-fractus* both in position and form, and the details of the proximal end, so far as can be made out from the only two specimens known to me, seem to agree with that species.

The stipes are narrowest at their origin; they grow nearly parallel at first, and steadily increase in width up to the bend, where they are $\frac{1}{12}$ inch (2·1 mm.) wide. In the specimen in the Woodwardian Museum the width appears to be greatest at the bend, and then to diminish again towards the distal extremities of the stipes, but in Nicholson's specimen the width appears to be maintained along the horizontal part of the stipe.

In the V-part of the rhabdosoma the concave curvature of the thecal walls is apparent, and is continued for a longer distance than in *D. V-fractus*, being continued for the first seven thecæ at least.

The thecæ number thirty-six to the inch (fourteen in 10 mm.); in the V-part they are in contact for half their length, but in the horizontal part for fully two-thirds of their length.

Angle of inclination: (*a*) V-part = 25° to 30°; (*b*) horizontal part = 60° at curve to 40°.

Apertural angle: (*a*) V-part nearly perpendicular; (*b*) horizontal part = 120° to 125°.

The apertures are slightly mucronate. The thecæ are about 3 times as long as wide.

Occurrence (?). Locality.—Outerside.

(*g*) Didymograptus indentus (Hall).

1858. *Graptolithus indentus*, Hall, Geol. Surv. Canada Rep. 1857, p. 128.
1865. *Graptolithus indentus*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 74 & pl. i, fig. 20.
1875. *Didymograptus indentus*, Lapw. & Hopk. Quart. Journ. Geol. Soc. vol. xxxi, p. 647 & pl. xxxiii, figs. 7 *a–c*.

All the specimens of *D. indentus* (Hall) and the variety *nanus* from the Skiddaw Slates are badly preserved as regards the thecæ, and it is therefore in some cases rather difficult to distinguish between them, though the forms that are less than $\frac{1}{2}$ inch (12·7 mm.) long should probably be referred to the variety. When the number of thecæ can be counted the distinction can more readily be made. Both forms would seem to be present in the Skiddaw Slates, and to occur together in great abundance at certain localities, as, for instance, at Outerside and the Glenderamakin River.

In both forms the sicula is long and narrow, and occasionally shows the thread-like virgula proceeding from its apical extremity. The initial angle of divergence of the stipes is generally about 60°, but after the first divergence the stipes run more or less parallel to each other, though there is in some forms a tendency to close together at their distal ends.

In *D. indentus* (Hall) the stipes generally exceed 1 inch (25·39 mm.) in length, are parallel or subparallel, and have a uniform width of about $\frac{1}{24}$ inch (1·05 mm.). The sicula is long, $\frac{1}{10}$ inch (2·53 mm.), and the earliest developed theca appears to originate rather above the sicula-base and to be closely adpressed to it.

Very few details regarding the thecæ can be made out beyond their number, which is about twenty-five in the space of 1 inch (ten in 10 mm.).

Occurrence.—Upper Skiddaw Slates and top of Middle Skiddaw Slates.

Localities.—Outerside; Glenderamakin River; the Dodd, Skiddaw; Mosedale Beck, near Troutbeck.

(*h*) Didymograptus indentus var. nanus, Lapw.

1868. *Didymograpsus geminus*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 134 & pl. v, figs. 8 & 9.
1870. *Didymograpsus geminus*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. v, p. 346, fig. 6.
1875. *Didymograptus indentus* var. *nanus*, Hopk. & Lapw. Quart. Journ. Geol. Soc. vol. xxxi, p. 647, pl. xxxiii, fig. 7 *d* & pl. xxxv, figs. 4 *a–c*.

The specimens now assigned to this species were originally referred by Nicholson to *D. geminus* (His.), and he at the same time remarked that *D. indentus* (Hall) was probably a large example of it. The species in question is altogether different from Hisinger's, both in size and increase of width, and also in other more minute particulars. As Lapworth has pointed out, it is best considered as a dwarf variety of *D. indentus* (Hall), with which it agrees closely in everything except size and the number of thecæ in a given unit of length.

The character of the proximal end agrees in all particulars with *D. indentus* (Hall), but the stipes never exceed $\frac{1}{2}$ inch (12·7 mm.) in length, and are commonly narrower than in that species.

The thecæ seem to be far more numerous, being as many as thirty to thirty-six in the inch (twelve to fourteen in 10 mm.). The apertures, so far as can be seen, seem to be perpendicular to the general direction of the stipe.

Occurrence.—On one slab from Outerside it is associated with *Tetragraptus serra* (Brongn.). Middle and Upper Skiddaw Slates.

Localities.—Outerside; Glenderamakin River; Thornship Beck; Barf; Gatesgill; Mosedale Beck, near Troutbeck.

(*b*) Didymograptus bifidus (Hall).

1865. *Graptolithus bifidus*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 73, pl. i, figs. 16–18 & pl. iii, figs. 9 & 10.
1868. *Didymograpsus bifidus*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 136.
1870. *Didymograpsus bifidus*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. v, p. 346, fig. 7.
1875. *Didymograptus bifidus*, Hopk. & Lapw. Quart. Journ. Geol. Soc. vol. xxxi, p. 646 & pl. xxxiii, figs. 8 *a–e*.

Two forms of this species are known from the Skiddaw Slates: in one the stipes diverge at an angle of about 60°; in the other the base is more rounded, and the initial angle of divergence approaches a right angle. The ultimate angle included between the stipes in both forms is generally from 15° to 20°.

The stipes are never parallel, but are continuously divergent throughout their length, though I have never seen a specimen from the Skiddaw Slates in which the angle of divergence was as wide as that figured by Hall (*op. supra cit.* pl. iii, fig. 9). The stipes are narrow at their origin, being about $\frac{1}{20}$ inch (1·26 mm.) wide, but ultimately attain a maximum width of $\frac{1}{12}$ inch (2·1 mm.). No Skiddaw Slate specimen is known to me in which the width is as great as $\frac{1}{4}$ inch (6·3 mm.), the maximum dimension given by Hall. The greatest width is attained near the distal end of the stipes, after which there is a somewhat rapid diminution. The increased width is due to the fact that the thecæ augment steadily in length from the proximal to the distal portion of the stipes; but at the actual extremities the thecæ are only partially developed, and consequently a diminution in width again takes place. One result of this is to give a peculiar curvature to the celluliferous margins; these have at first a slight concave curvature, but subsequently the curve may be convex, or else curvature is continuously concave; the dorsal walls are at first convex, and then straight.

The thecæ number generally thirty-two to thirty-six in the inch (thirteen to fourteen in 10 mm.); they are long narrow tubes, and their length is about 4 times that of their width at the widest part; they are free for a third to a quarter of their length, and are inclined at an angle of about 45°. The apertures are concave and submucronate, and make an angle of about 125° with the general direction of the stipe.

When fully grown the rhabdosoma measures commonly about 1 inch (25·4 mm.) in length; one specimen from Thornship Beck is, however, $1\frac{1}{4}$ inch (31·7 mm.) long, and another from Ellergill must have been fully $1\frac{1}{2}$ inch (38 mm.) in length. From the appearance of the rhabdosoma in the obverse view, it would seem as if the earliest theca originated from the sicula slightly above its aperture, but in no specimen is the proximal end sufficiently well preserved to make this out with certainty.

The species is characterized by (1) the form of the stipe with straight dorsal wall and curved celluliferous margin; (2) the gradual widening of the stipes from the point of origin; and (3) the characters of the thecæ and their number to the inch.

Occurrence.—With *Diplograptus dentatus* (Brongn.) at Ellergill in the Ellergill Beds = Upper Skiddaw Slates.

Localities.—Barf; Doddick Fell; Saddleback; Outerside; Burstock Scar, Skiddaw; Thornship Beck, Shap; Ellergill; East Dodd Wood; Aik Beck, Pooley.

Genus *Azygograptus*, Nich. & Lapw.

1875. Nich. Ann. Mag. Nat. Hist. ser. 4, vol. xvi, p. 269.

The original description of the genus, which seems to have been founded on the characters of *Azygograptus Lapworthi*, Nich., requires some modification when the characters of the other species are taken into account. It can no longer be said that the stipe 'is developed from the central portion of the sicula on one side,' and hence the relationship to the Nemagraptidæ is no longer obvious. For my own part, I much prefer to regard it as belonging to the Dichograptidæ, since I consider it most closely related to the forms in that family. It has no connecting-canal, and, therefore, not more than one stipe can arise, but otherwise it closely resembles a *Didymograptus*. Holm has described a form which he believes to be intermediate between the *Didymograpti* and the *Azygograpti*; in this one stipe is developed and also a connecting-canal, from which, however, no second stipe arises. If this be the case, the *Azygograpti* are undeniably linked to the *Didymograpti*, and should, in my opinion, be included in the same family.

A modified definition of *Azygograptus* might be stated as follows:—'Rhabdosoma single, unilateral, consisting of a single stipe with cells on one side only. This stipe originates from the sicula at various levels.'

(*a*) Azygograptus Lapworthi, Nich.

1875. *Azygograptus Lapworthi*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. xvi, p. 269 & pl. vii, figs. 2–2 *c*.

Rhabdosoma consisting of a single curved stipe with cells on one side only. This stipe originates at a point rather more than half way down the sicula. The stipe makes with the sicula an angle of 110°.

The cells number twenty in 1 inch (eight in 10 mm.); they are long and narrow, and the width at the aperture is about twice as great as at the origin. Outer walls straight, or with very slight concave curvature in some of the earliest developed thecæ. Inclination 20°; the cells are in contact for a very short distance at their base. Cell-apertures straight, perpendicular to the general direction of the stipe.

The sicula is large and conspicuous when present, but many of the stipes seem to be broken off from the sicula at the point of connexion. It is $\frac{1}{20}$ inch (1·26 mm.) long (Nicholson gives $\frac{1}{24}$ inch =1·05 mm. as the length, but all the specimens that I have seen are slightly longer), and is always completely free at its apertural end for fully one-third of its length; the width at the aperture is about $\frac{1}{50}$ inch (·5 mm.). The apical part of the sicula occasionally shows transverse rings.

The stipe is very slender at its origin, the width opposite the aperture of the first theca not exceeding $\frac{1}{48}$ inch (about ·5 mm.)

but it gradually increases in width up to a maximum of $\frac{1}{24}$ inch (1·05 mm.). The stipe may be as much as 2 inches (50·7 mm.) long and is always concavely curved.

Locality and Horizon.—Hodgson How Quarry, near Portinscale (Middle Skiddaw Slates).

(*b*) Azygograptus cœlebs, Lapw.

1880. *Azygograptus cœlebs,* Lapw. Ann. Mag. Nat. Hist. ser. 5, vol. v, p. 159 & pl. v, figs. 16 *a–c*.

Rhabdosoma unilateral, consisting of a single stipe, which is very slightly curved and appears to originate from the major extremity of a small but clearly defined sicula. The stipe runs in a direction perpendicular to the long axis of the sicula.

The thecæ number twenty-five to the inch (ten in 10 mm.); they are narrow tubes expanding slightly in the direction of the aperture, inclined at an angle of 15°. Outer wall with very slight concave curvature. Thecæ in contact for a short distance at the base; some of the earliest developed thecæ may be in contact for as much as one-third of their length. The apertures of the thecæ are acute, straight, and face slightly inwards.

The sicula is well marked though small, $\frac{1}{30}$ inch (·87 mm.) long; it is wider than in *Az. Lapworthi.* The earliest theca appears to arise at the base of the sicula on the right, at least that is the point at which it curves away from the sicula; but from the structure it seems that it actually originated at a point considerably higher up the sicula, and grew closely adpressed to the sicula until near its aperture, when it took a sudden curve outwards. Perhaps this was to give greater strength of attachment to the sicula, which, as I have shown, is frequently broken off in *Az. Lapworthi* at the point of connexion with the stipe.

Lapworth states the maximum length of the stipe as 2 inches (50·7 mm.), but none of the specimens that have come under my notice have exceeded $\frac{1}{2}$ inch (12·7 mm.) in length. The maximum width is $\frac{1}{48}$ inch (about ·5 mm.); there is no marked increase from the point of origin.

Locality and Horizon.—Ellergill=Upper Skiddaw Slates.

(*c*) Azygograptus suecicus, Moberg. (Fig. 29, p. 515.)

1892. *Azygograptus suecicus,* Moberg, Geol. Fören. Stockh. Förhandl. vol. xiv, p. 342, pl. viii, figs. 1 & 2.

Rhabdosoma simple, consisting of one slightly curved stipe which originates in the angle between the aperture and the side of the sicula. The stipe makes with the conspicuous sicula an angle of 145°.

The cells number eighteen to the inch (seven in 10 mm.); they are long narrow tubes, in contact with each other for a short distance at their base, but in the more distal part of the stipe they may be in contact for as much as one-third of their length; they are inclined at an angle of 15°. The apertures of the thecæ are straight, acute, and perpendicular to the general direction of the stipe.

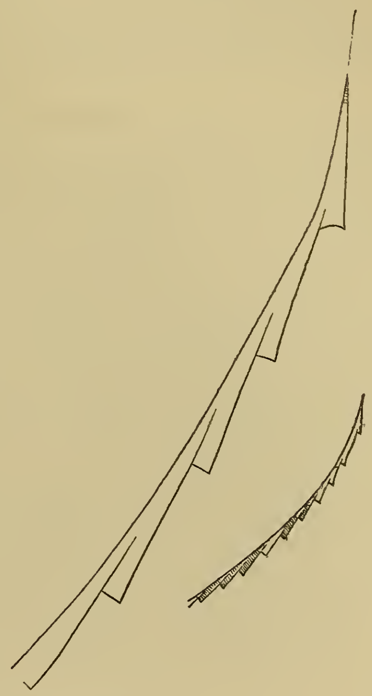
The sicula is very long and narrow, it is fully $\frac{1}{16}$ inch (1·58 mm.) long; the stipe arises close to the aperture and immediately grows out. It varies in length from $\frac{1}{2}$ to $1\frac{1}{2}$ inch (12·7 to 38 mm.); the maximum width, $\frac{1}{30}$ inch (·87 mm.), is attained almost at once; there is no perceptible increase after the two earliest thecæ.

The stipe has in general a more rigid look than in *Az. Lapworthi*, though it is often curved in its more distal part.

Occurrence.—On the same slab with *Didymograptus patulus* (Hall), *D. gibberulus*, Nich., and also in dense masses to the exclusion of other species (at Barf). Top of Middle Skiddaw Slates. This species had not hitherto been recorded from this country.

Localities.—Barf; north-east of Sleet How, west of Braithwaite; Carlside Edge.

Fig. 29.—Azygograptus suecicus *from Barf; coll. Woodwardian Museum.*



[× 10.] [× 2.]

	Az. Lapworthi	*Az. cœlebs*	*Az. suecicus*
Length of sicula	$\frac{1}{20}$ in. (1·26 mm.)	$\frac{1}{30}$ in. (·87 mm.)	$\frac{1}{16}$ in. (1·58 mm.)
Origin of stipe on sicula	half way down	base	angle side & base
Character of stipe ...	flexuous	horizontal	rigid at first
Number of thecæ (1) to inch, (2) in 10 mm.	(1) twenty (2) eight	(1) twenty-five (2) ten	(1) eighteen (2) seven
Cell-inclination	20°	15°	15°
Max. width of stipe ...	$\frac{1}{24}$ in. (1·05 mm.)	$\frac{1}{48}$ in. (·5 mm.).	$\frac{1}{30}$ in. (·87 mm.)
Divergence of stipe ...	110°	perpendicular	145°

Note on the *Azygograpti*.

There can be, I think, little doubt that the species of *Azygograptus* appeared in the following order:—(1) *Az. Lapworthi*; (2) *Az. suecicus*; (3) *Az. cœlebs*.

Az. Lapworthi is found in Hodgson How Quarry, near Portinscale, associated with *Dichograptus octobrachiatus* (Hall): immediately outside the village of Portinscale there is in the road-cutting an exposure of Skiddaw Slates, which, from their position, should represent a distinctly higher horizon; this is also borne out by the fauna, which is essentially of the uppermost Arenig type. Though I did not obtain *Az. suecicus* from this locality, the graptolites that I did collect are all those with which it is commonly associated at Barf.

Az. cœlebs is found at Ellergill with a still higher type of fauna, whose characteristic fossils are species of *Diplograptus* and *Climacograptus*, none of which have been recognized at lower horizons.

Genus *Leptograptus*, Lapw.

LEPTOGRAPTUS sp.

There are in Mr. Postlethwaite's collection, and in the British Museum (Nat. Hist.), a few fragments of stipes of a species of *Leptograptus* which seem in every case to be the same.

The genus is easily recognized by the peculiar form of the thecæ. In one specimen a portion of both stipes is seen, but unfortunately no details regarding the thecæ can be made out.

The stipes are flexuous and very slender; they have a width at their origin of $\frac{1}{60}$ inch (·42 mm.), but widen to a maximum of $\frac{1}{40}$ inch (·63 mm.).

The thecæ show the characteristic *Leptograptus*-form; they number twenty-four to the inch (nine to ten in 10 mm.), rather more near the proximal end; are inclined at a low angle of 15° to 20°, and are in contact with each other for about half their length.

Occurrence.—Uppermost Skiddaw Slates.

Localities.—Aik Beck, Pooley; Bassenthwaite Sand-beds.

Genus *Dicellograptus*, Hopk.

DICELLOGRAPTUS MOFFATENSIS (Carr.).

1858. *Didymograpsus moffatensis*, Carruthers, Proc. Roy. Phys. Soc. Edinb. vol. i, p. 469 [fig. 3].

1859. *Graptolithus divaricatus*, Hall, Pal. N. Y. vol. iii, Suppl. p. 513, figs. 1–4.

1865. *Dicranograptus divaricatus*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 57.

1870. *Didymograpsus divaricatus*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. v, p. 350 & pl. vii, fig. 4.

1871. *Dicellograptus moffatensis*, Hopk. Geol. Mag. vol. viii, p. 25 & pl. i, fig. 4.

1875. *Dicellograptus moffatensis*, Hopk. & Lapw. Quart. Journ. Geol. Soc. vol. xxxi, p. 654, pl. xxxiv, figs. 3 *a* & *b* & pl. xxxv, figs. 5 *a* & *b*.

1876. *Dicellograptus moffatensis*, Lapw. Catal. West Scot. Foss. pl. iv, fig. 84.

The actual characters of the cells are difficult to make out, but they number about twenty-four to the inch (nine to ten in 10 mm.), and the form of the species leaves no doubt as to its identity. In one specimen the presence of a membrane is indicated by a band passing across between the dorsal walls of the stipes, rather above the level of the aperture of the second theca.

Occurrence.—Upper Skiddaw Slates.

Localities.—Only two specimens are known to me; one occurs on a slab with *Diplograptus pristiniformis* from the Upper Skiddaw Slates of Thornship Beck, and the other from Mosedale Beck, near Troutbeck. Others have, however, been recorded from Barf; Randal Crag, Skiddaw; and Bassenthwaite Sand-beds.

Genus *Diplograptus*, M'Coy.

(*a*) Diplograptus dentatus (Brongn.).

1828. *Fucoides dentatus*, Brongn. 'Hist. Végét. Foss.' vol. i, p. 70 & pl. vi, figs. 9–12.
1865. *Diplograptus pristiniformis*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 110 & pl. xiii, figs. 15–17.
1868. *Diplograpsus pristiniformis*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 140, pl. v, figs. 14 & 15.
1875. *Diplograptus dentatus*, Hopk. & Lapw. *ibid.* vol. xxxi, p. 656 & pl. xxxiv, figs. 5 *a–k*.

The species *pristiniformis* seems to be the same as the form described earlier by Brongniart as *Fucoides dentatus*, but I do not agree with other authors who consider it identical with Hisinger's species *teretiusculus*; the latter has fewer thecæ in the same unit of length, and these are inclined at a higher angle.

The species varies greatly in its dimensions, and the appearance of the thecæ is so different in various aspects of the rhabdosoma, that it is only after examining a great number of specimens, and comparing them most carefully with each other, that I have come to the conclusion that these different appearances are presented by the same species. In one aspect the rhabdosoma resembles very closely some young forms of *D. foliaceus* (Murch.), in another it appears to be identical with some forms of *Climacograptus*, while in a third the apertural margins of the thecæ are deeply concave and their outer edges broadly rounded.

The variation in dimensions and number of the thecæ is shown in the following table :—

Form and Locality	Length	Maximum width	No. of thecæ in 1 inch	No. of thecæ in 10 mm.
Thornship Beck. (*a*) ...	1 in. (25·4 mm.)	$\frac{1}{12}$ in. (2·1 mm.)	30	12
„ „ (*b*) ...	incomplete	$\frac{1}{16}$ in. (1·58 mm.)	28	11
„ „ (*c*) ...	$\frac{1}{4}$ in. (6·3 mm.)	$\frac{1}{16}$ in. (1·58 mm.)	28	11
Aik Beck, Pooley. (a^1)...	1 in. (25·4 mm.)	$\frac{1}{12}$ in. (2·1 mm.)	36	14
„ „ „ (b^1) ...	$\frac{7}{12}$ in. (14·7 mm.)	$\frac{1}{16}$ in. (1·58 mm.)	36	14
„ „ „ (c^1) ...	1 in. (25·4 mm.)	$\frac{1}{16}$ in. (1·58 mm.)	32	13
Troutbeck	$1\frac{1}{4}$ in. (31·7 mm.)	$\frac{1}{16}$ in. (1·58 mm.)	32	13
Ellergill, Milburn. (a^2)	$\frac{1}{2}$ in. (12·7 mm.)	$\frac{1}{16}$ in. (1·58 mm.)	32	13
„ „ (b^2)	1 in. (25·4 mm.)	$\frac{1}{12}$ in. (2·1 mm.)	24	9–10
„ „ (c^2)	$1\frac{1}{2}$ in. (38 mm.)	$\frac{1}{16}$ in. (1·58 mm.)	28–32	11–13
N.W. Longside, Skiddaw.		$\frac{1}{12}$ in. (2·1 mm.)	28	11
Mungrisedale	$\frac{3}{4}$ in. (19 mm.)	$\frac{1}{16}$ in. (1·58 mm.)	28	11
Bassenthwaite Sand-beds.	1 in. (25·4 mm.)	$\frac{1}{16}$ in. (1·58 mm.)	28	11

As will be seen from the above table, the dimensions given by Nicholson are often exceeded, and there is great variation from the number of thecæ stated by Hall. The highest number of thecæ generally includes those of the proximal end, which are more closely set than those in the adult part of the rhabdosoma.

The maximum width of the rhabdosoma is always reached at an early period of its growth, and is then maintained for the remainder of its length. The proximal end of the rhabdosoma is seen to be furnished with a spine, which probably is the apertural spine of the sicula (=virgella of Törnquist). This varies in length in different individuals; it is usually short and about $\frac{1}{12}$ inch (2·1 mm.) in length, but may be longer; it is stout at its origin, but tapers quickly, and is very slender at its termination. The virgula is often clearly seen and is frequently prolonged for a considerable distance beyond the distal extremity of the rhabdosoma.

The thecæ vary from twenty-eight to thirty-six in the inch (eleven to fourteen in 10 mm.); in their normal aspect they are seen to be inclined at an angle of about 20°, and are free for a third of their length; their apertures are slightly oblique.

Occurrence.—Ellergill Beds=Upper Skiddaw Slates.

Localities.—Thornship Beck; Aik Beck, Pooley; Troutbeck; Ellergill, Milburn; north-west of Longside, Skiddaw; Mosedale Beck; Mungrisedale; Glenderamakin River; Bassenthwaite Sandbeds; Outerside; Master Sike, Crossfell.

(*b*) Diplograptus cf. teretiusculus (His.).

1881. *Diplograptus teretiusculus*, Tullberg, 'On Grapt. descr. by Hisinger, Bihang til k. Svenska Vet. Akad. Handl. vol. vi.

There are some specimens of *Diplograptus* in the Skiddaw Slates which seem to me to bear a very marked resemblance to Hisinger's species; they are certainly different from the species just described. Unfortunately they are not sufficiently well preserved for all the details regarding the cells to be made out.

This form is commonly about an inch (25·4 mm.) long, and has a maximum width of $\frac{1}{8}$ inch (3·2 mm.).

The thecæ number twenty-two to twenty-four in the space of an inch (eight to nine in 10 mm.). There is a short stout spine at the proximal end (virgella).

Occurrence.—Upper Skiddaw Slates.

Localities.—North-eastern side of Souter Fell; Randal Crag, Skiddaw.

(*c*) Diplograptus appendiculatus, Törnq. MS.

Obviously this species is closely allied to the well-known *D. vesiculosus* (Nich.), but is far more slender than that species.

Near the proximal end, which is not seen in this specimen, the width is $\frac{1}{20}$ inch (1·26 mm.); it gradually widens towards the distal end to a maximum of $\frac{1}{12}$ inch (2·1 mm.). From the upper end proceeds the vesicle, inside which the virgula can quite well be detected.

The thecæ number twenty-four to the inch (nine to ten in 10 mm.); their outer walls are slightly convex; they are inclined at about 25°, and overlap for half their length. Their apertures are perpendicular to the general direction of the rhabdosoma.

Fig. 30.—Diplograptus appendiculatus, *coll. J. E. Marr.*

[Nat. size.]

I have observed the same species in the upper part of the Swedish *Phyllograptus*-skiffer, in the zone of *Ph.* cf. *typus*, Hall. The priority of discovery belongs to Dr. Törnquist, of Lund, and for further details concerning the species we must await his full description.

Occurrence.—Upper Skiddaw Slates.

Locality.—Outerside.

Genus *Climacograptus*, Hall.

CLIMACOGRAPTUS SCHARENBERGI, Lapw.

1876. *Climacograptus Scharenbergi*, Lapw. 'Grapt. of Co. Down,' Proc. Belfast Nat. Field Club, p. 138, pl. vi, fig. 36.

Several specimens of this species are preserved together on a block of soft shale which is in the Woodwardian Museum.

The individuals vary greatly in size; some are very small, only $\frac{1}{6}$ inch (4·2 mm.) long, and do not exceed $\frac{1}{24}$ inch (1·05 mm.) in width. The largest specimens have a length of $\frac{2}{3}$ inch (17 mm.) and a maximum width of $\frac{1}{16}$ inch (1·58 mm.).

The rhabdosoma is always narrow at its proximal end, but widens gradually in a distal direction; the width at the proximal end rarely exceeds $\frac{1}{30}$ inch (·87 mm.).

The species is characterized by the peculiar nature of its sutural groove. This is deflected from side to side, and from the outer point of each angulation a short horizontal groove runs out at right angles to the general direction of the rhabdosoma.

The thecæ number between thirty-two and thirty-six to the inch (thirteen to fourteen in 10 mm.), the higher number being characteristic of the proximal end; they consist of short perpendicular tubes whose apertures are slightly introverted.

Occurrence.—Ellergill Beds = Upper Skiddaw Slates.

Locality.—Thornship Beck.

Genus *Cryptograptus*, Lapw.

(*b*) CRYPTOGRAPTUS? ANTENNARIUS (Hall). (Fig. 31, p. 520.)

1865. *Climacograptus antennarius*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 112 & pl. xiii, figs. 11–13.

1868. *Diplograpsus antennarius*, Nich. Quart. Journ. Geol. Soc. vol. xxiv, p. 139.

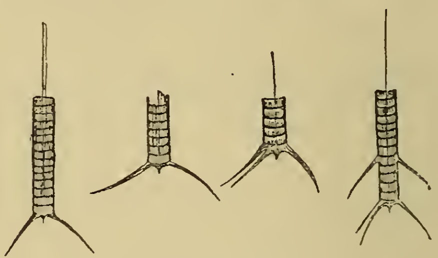
This species, as Nicholson has already noted, seems to be abundant in the Skiddaw Slate of certain localities, such as Outerside. Almost invariably, however, the specimens are badly preserved, and very little can be made out about the thecæ.

Nicholson states the maximum length as $\frac{3}{5}$ inch (15 mm.), but several specimens that I have seen are fully 1 inch (25·4 mm.) long, though there seem to be individuals of all sizes from $\frac{1}{4}$ inch (6·3 mm.) upwards.

The base shows well, even in badly-preserved specimens, and usually three spinous processes are visible; the middle probably represents the apertural spine of the sicula (virgella of Törnquist), and the other two are long spinous outgrowths from the bases of thecæ 1^1 and 1^2. These spines usually include between them an angle of about 120°, or sometimes rather less; they may be straight or slightly curved, are usually rigid, and about $\frac{1}{3}$ inch (8·7 mm.) long. The rigidity and wider angle serve to distinguish them from the similar outgrowths in *Cryptograptus Hopkinsoni.*

The thecæ number between twenty-four and twenty-eight to the inch (nine to eleven in 10 mm.), the virgula is usually prolonged for about $\frac{1}{2}$ inch (12·7 mm.) or more beyond the distal extremity of the rhabdosoma.

Fig. 31.—Cryptograptus antennarius *from Outerside and Mungrisedale, coll. J. E. Marr.*



[Nat. size.]

Two specimens show peculiar features. In one, there appear to be two basal spines on the left side of the rhabdosoma, the occurrence being such as to suggest that a spine proceeded from each of the lower angles of the quadrate basal cell. Whether this is usually the case I am unable to say: I have observed it only in two specimens, and it may be due to a process of exfoliation during preservation.

In the other specimen the basal spines are four in number, two on each side, and in addition to these there are other spines projecting from the side of the rhabdosoma at a point rather more than halfway down its length. The spine on the left is clearly seen, and that on the other side is indicated: both are directed obliquely downwards.

Whether this is merely an accidental occurrence I cannot say; if it should prove to be constant in some forms the variety might be appropriately termed var. *spinosus*, but I incline to the belief that it is merely a pathological variation.

Occurrence.—On slabs with *Didymograptus bifidus*, Upper Skiddaw Slates.

Localities.—Outerside; Mungrisedale; Glenderamakin Valley; Mosedale Beck, near Troutbeck; Bannerdale Fell.

(*a*) Cryptograptus Hopkinsoni (Nich.).

1869. *Diplograpsus Hopkinsoni*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. iv, p. 234 & pl. xi, fig. 7.

The structure of this species, referred originally by Nicholson to the genus *Diplograptus*, seems to be more in accordance with that of *Cryptograptus*, Lapw.[1] Nicholson's type-specimen is in the British Museum (Nat. Hist.); it occurs with *Tetragraptus quadribrachiatus* (Hall). There are also other specimens in the Woodwardian Museum.

[1] See Lapworth, Ann. Mag. Nat. Hist. ser. 5, vol. v (1880) p. 174.

The species is characterized by the spinous processes at its proximal end, which are very similar to those in *Cryptograptus antennarius* (Hall), but are more curved and less rigid than in that species.

The thecæ, with their slightly reflexed denticles, are also peculiar; they number twenty-four to the inch (nine to ten in 10 mm.).

Occurrence.—With *Tetragraptus quadribrachiatus* (Hall) and *Didymograptus indentus* (Hall) in Middle and Upper Skiddaw Slates.

Localities.—Outerside; Bannerdale Fell; Glenderamakin Valley.

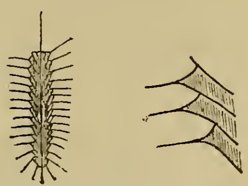
Genus *Glossograptus*, Emm.

(*c*) Glossograptus fimbriatus (Hopk.).

1872. *Diplograptus fimbriatus*, Hopk. Geol. Mag. vol. ix, p. 506 & pl. xii, fig. 8.

There are at least three specimens of this species in the Woodwardian Museum, and one from Ellergill is extremely well preserved. The specimens have a length of ½ inch (12·7 mm.), exclusive of the distal prolongation of the virgula, which is seen in one specimen for ⅙ inch (4·2 mm.) beyond the distal extremity of the rhabdosoma. The sides are parallel, and the width about $\frac{1}{16}$ inch (1·58 mm.), exclusive of the spines. This width is maintained throughout the length of the rhabdosoma.

Fig. 32.—Glossograptus fimbriatus, *from Ellergill; coll. J. E. Marr.*



[Nat. size.] [× 5.]

The thecæ number forty to the inch (sixteen in 10 mm.) in the proximal part of the rhabdosoma, but about thirty-six (fourteen in 10 mm.) nearer the distal end. They are narrow tubes, expanding in the direction of the aperture, and their length is about 3 times as great as their width. They are in contact for about half their length, and are inclined at a low angle of about 20°. The apertures are slightly oblique.

The spines are thick, especially at their bases; they are about $\frac{1}{20}$ inch (1·26 mm.) long, those near the proximal end are directed outwards and downwards, those in the centre of the rhabdosoma are horizontal, while those near the distal end are directed outwards and upwards. The actual base of the specimens is not very clear, but the spines there seem to be directed vertically downwards. The course of the virgula is clearly indicated.

This species differs from *Gl. armatus*—(1) in general form; (2) in the possession of more numerous thecæ in a given unit of length; and from *Gl. Hincksii* (1) in shorter spines; (2) in the possession of more numerous thecæ in a given unit of length; (3) in the greater width attained by the rhabdosoma.

Occurrence.—Ellergill Beds = Upper Skiddaw Slates.

Localities.—Ellergill; Mosedale Beck, near Troutbeck; Barf.

Note.—The specimen from Barf is rather obscure, but, from the number of thecæ in the inch, it seems to belong to the above species; if so, it is a young form.

(*b*) Glossograptus cf. Hincksii (Hopk.).

1872. *Diplograptus Hincksii*, Hopk. Geol. Mag. vol. ix, p. 507 & pl. xii, fig. 9.
1876. *Glossograptus Hincksii*, Lapw. Cat. West Scot. Foss. p. 7 & pl. ii, fig. 57, & 'Grapt. of Co. Down,' Proc. Belfast Nat. Field Club, p. 134 & pl. vi, fig. 24.

The specimen to which this description applies is not well preserved, but it seems to resemble *Gl. Hincksii* (Hopk.) more closely than any other known form of *Glossograptus*. The specimen is $\frac{1}{2}$ inch (12·7 mm.) long, and near the proximal end the width is $\frac{1}{16}$ inch (1·58 mm.), exclusive of the spines; this, however, widens gradually to a maximum of $\frac{1}{12}$ inch (2·1 mm.). The character of the proximal end recalls *Cryptograptus antennarius* (Hall); it is furnished with a very short, stout, median spine, and two slightly curved lateral spines about $\frac{1}{12}$ inch (2·1 mm.) in length. The spines are very long and slender; they have an average length of $\frac{1}{8}$ inch (3·2 mm.); they are probably complete on the right side of the rhabdosoma. The distance between the spines gradually increases towards the distal end, but is never greater than $\frac{1}{12}$ inch (2·1 mm.) in this specimen.

The appearance on the right side suggests that every theca was furnished with a spine, but I am inclined to think that this appearance is misleading, and that the thecæ are better seen on the left side of the rhabdosoma at its distal end. Here their apertures are visible, and they number thirty to the inch (twelve in 10 mm.); if this be the true number, only every two or three can have had spines.

This form agrees with *Glossograptus Hincksii*: (1) in the gradual increase in width; (2) in the gradual increase in distance between the spines; (3) in the length of the spines. It has rather more numerous thecæ in a given unit of length, but this may be partly the result of preservation.

It differs (1) from *Gl. ciliatus*: (*a*) in the number of cells in a given unit of length; (*b*) in the character of the base; (*c*) in the length of the spines.
(2) from *Gl. armatus*: (*a*) in general form; (*b*) in the character of the spines.
(3) from *Gl. fimbriatus*: (*a*) in the length of the spines; (*b*) in the number of cells in a given unit of length.

Occurrence.—Ellergill Beds = Upper Skiddaw Slates.
Locality.—Thornship Beck.

(*a*) Glossograptus armatus (Nich.). (Fig. 33, p. 523.)

1869. *Diplograpsus armatus*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. iv, p. 234 & pl. xi, fig. 8.

The specimens are all much distorted by cleavage, and show no details of structure beyond external form; the great length of the spiniform appendages in proportion to the width of the rhabdosoma is, however, highly characteristic.

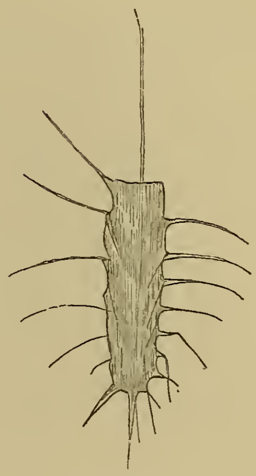
Nicholson's type is in the British Museum (Nat. Hist.), and so are all the other specimens known to me. The specimen that seems to be the reverse of Nicholson's type appears to me to show more than the figured side.

None of the specimens exceed $\frac{1}{4}$ inch (6·3 mm.) in length, exclusive of the long distal prolongation of the virgula. The general form of the rhabdosoma resembles an elongated oval; its maximum width is $\frac{1}{16}$ inch (1·58 mm.).

The spines are stout, they are fully $\frac{1}{10}$ inch (2·5 mm.) long, and are slightly reflexed in every case except two near the distal end, which are directed outwards and upwards. Some appear to be in pairs, but whether this is really the case, or the result of a process of exfoliation during preservation, I am not prepared to say, though I incline to the former view.

The thecæ seem to be more closely set than Nicholson believed; he reckons twelve to the inch (five in 10 mm.), but there are certainly six and probably seven thecæ on each side in some specimens, and no specimen much exceeds $\frac{1}{4}$ inch in length (nine to eleven in 10 mm.). Every theca seems to have been furnished with a spine.

Fig. 33.—Glossograptus armatus, *from Thornship Beck; coll. Brit. Mus. (Nat. Hist.).*



[×5.]

The species seems to be most closely related to *Glossograptus ciliatus*, Emm., from which it differs (1) in its smaller size; (2) in the greater length of the spines.

Occurrence.—Ellergill Beds = Upper Skiddaw Slates.

Locality.—Thornship Beck.

Genus *Trigonograptus*, Nich.

(*a*) Trigonograptus ensiformis (Hall). (Fig. 34, p. 524.)

1865. *Retiolites ensiformis*, Hall, 'Grapt. of the Quebec Group,' Geol. Surv. Canada, dec. 2, p. 114 & pl. xiv, figs. 1–5.

1875. *Trigonograptus ensiformis*, Hopk. & Lapw. Quart. Journ. Geol. Soc. vol. xxxi, p. 659 & pl. xxxiv, figs. 8 *a–c*.

1890. *Trigonograptus ensiformis*, H. O. Nich. Geol. Mag. dec. 3, vol. vii, pp. 340–341, figs. 1 & 2.

There are two specimens in the Woodwardian Museum which seem to be referable to this species, and I have also seen one in Prof. Nicholson's collection.

According to Hall, the species has a maximum length of $2\frac{1}{2}$ inches

(63 mm.), and a maximum width of $\frac{1}{6}$ inch (4·2 mm.), while other specimens $\frac{1}{2}$ inch (12·7 mm.) long and $\frac{1}{10}$ inch (1·26 mm.) wide are also met with. There is a subsequent diminution in width near the distal end; this is shown in Prof. Nicholson's specimen, figured in Geol. Mag. 1890.

The best specimen that I have observed is $1\frac{1}{2}$ inch (38 mm.) long; the width near the proximal end is $\frac{1}{16}$ inch (1·58 mm.), but this increases steadily up to a maximum of $\frac{3}{16}$ inch (4·76 mm.), and is then broken off. The width is trebled within the first $\frac{1}{2}$ inch (12·7 mm.)

Fig. 34.—Trigonograptus ensiformis, *coll. Woodwardian Mus.*

[Nat. size.] [×5.]

The thecæ are twenty-eight to the inch near the proximal end (eleven in 10 mm.), but only twenty-four in the fully-developed part of the rhabdosoma (nine to ten in 10 mm.). They are in contact for their whole length, and have oblique apertures; these are markedly alternate on either side of the rhabdosoma. They are inclined at an angle of about 45°.

There is a very peculiar proximal extension from what appears to be the sicula; the exact nature of this I have not been able to determine.

In one of the specimens the position of the virgula is clearly indicated. It would seem to have been straight.

Locality and Horizon.—Mosedale Beck, near Troutbeck; Ellergill Beds = Upper Skiddaw Slates.

(*b*) TRIGONOGRAPTUS LANCEOLATUS, Nich.

1869. *Trigonograpsus lanceolatus*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. iv, p. 232 & pl. xi, fig. 6.

The only specimens of this species known to me are in Prof. Nicholson's collection. The form is closely related to the foregoing species, but differs in the higher angle of inclination of the thecæ; this is usually about 75°.

The species widens rapidly from its proximal end, and the thecæ are markedly alternate.

Locality and Horizon.—Upper Skiddaw Slates; Ellergill, near Milburn.

Genus *Thamnograptus*, Nich.

THAMNOGRAPTUS DOVERI, Nich.

1875. *Thamnograptus Doveri*, Nich. Ann. Mag. Nat. Hist. ser. 4, vol. xvi, p. 271 & pl. vii, fig. 1.

The type-specimen is in the Woodwardian Museum. I have nothing to add to Prof. Nicholson's description.

Locality.—South-western side of Randal Crag.

IV. Comparison of the Skiddaw Slate Fauna with similar Faunas in Sweden and Canada.

The appended table (II, pp. 526–527) shows the relationship of the Skiddaw Slate fauna to that of other areas. It will be observed that, though it is more closely related to the fauna of the Quebec Group of Canada than to that of any English beds, it is still more nearly related to the Swedish fauna; for, while of the whole 59 species, 25 are common to the Skiddaw Slates and the Quebec Group, and only 14 common to the Skiddaw Slates and the two other English areas, no less than 34 species are common to the beds of Sweden and the Skiddaw Slates.

Of the total number found in the Skiddaw Slates, 15 species are peculiar to the beds, 4 occur elsewhere only in Canada, and 17 in Sweden only, while but one is confined to other English areas.

In the table those species marked (*a*) are also present in the Arenig beds of Australia: those in the Swedish column marked (*b*) occur in beds below the *Phyllograptus*-skiffer; those marked (*c*), in the *Phyllograptus*-skiffer and higher beds; and those marked (*d*), exclusively in higher beds.

It is also worthy of note that those marked (*c*) occur in the *Phyllograptus*-skiffer, only in the zone of *Phyllograptus* cf. *typus*, Hall, which overlies the *Orthoceras*-limestone, and is therefore at the very top of the *Phyllograptus*-beds.

Bryograptus Callavei, Lapw., occurs in the Shineton Shales of England.

V. General Conclusions.

(*a*) Stratigraphical.

The fauna of the Skiddaw Slates points to the beds being in the main of Arenig age, but it also indicates beds belonging to a lower and to a higher horizon.

The occurrence of *Bryograptus* and *Clonograptus tenellus* points to the existence of beds of Tremadoc age, and though evidence has not yet been brought forward to show the existence of still older rocks, their occurrence is not unlikely. It has been shown that the beds have near equivalents in Sweden and Canada. The Tremadoc Beds above mentioned undoubtedly correspond with the shales containing *Bryograptus*, which in some Swedish districts (Scania, etc.) take the place of part of the *Ceratopyge*-kalk.

In most Swedish localities Graptolite-shales succeed the *Ceratopyge*-kalk, and these are overlain by the Orthocerkalk (*Orthoceras*-limestone), which represents everything up to the zone of *Cœnograptus gracilis*. In Scania, however, the succession is rather different; the *Orthoceras*-limestone is not nearly so thick; Tullberg separates off a bed of shales lying immediately above it, as the zone of *Phyllograptus* cf. *typus*, Hall, and this forms the highest bed

Table II.—Comparison of the Skiddaw-Slate, St. David's, Shelve, and Swedish & Canadian Graptolite-faunas.

Names of Species.	Skiddaw Slates. L.	Skiddaw Slates. M.	Skiddaw Slates. U.	Arenig Beds, St. David's. L.	Arenig Beds, St. David's. M.	Arenig Beds, St. David's. U.	Arenig Beds, Shelve. L.	Arenig Beds, Shelve. M.	Arenig Beds, Shelve. U.	Sweden. Phyllograptus-skiffer.	Canada. Quebec Group.
Azygograptus Lapworthi, Nich.	—	+	—	—	—	—	—	—	—	—	—
cœlebs, Lapw.	—	—	+	—	—	—	—	—	—	—	—
suecicus, Moberg	—	+	—	—	—	—	—	—	—	+	—
Bryograptus Kjerulfi, Lapw.	+	—	—	—	—	—	—	—	—	+(b)	—
ramosus, var. *cumbrensis* nov.	+	—	—	—	—	—	—	—	—	+(b)	—
cf. *Callavei*, Lapw.	+	—	—	—	—	—	—	—	—	+(b)	—
Clonograptus tenellus (Linnarsson)	+	—	—	—	—	—	—	—	—	+(b)	—
flexilis (Hall)	—	+	—	—	—	—	—	—	—		—
sp.	—	+	—	—	—	—	—	—	—		—
(a) *Dichograptus octobrachiatus* (Hall)	—	+	—	—	—	—	—	—	—	+	+
separatus sp. nov.	—	+	—	—	—	—	—	—	—	—	—
Didymograptus affinis, Nich.	—	+	—	—	—	+	—	—	+	+	—
bifidus (Hall)	—	+	+	—	—	+	—	+	—	+(c)	+
(a) *extensus* (Hall)	—	+	—	+	—	—	—	—	—	+	+
fasciculatus, Nich.	—	—	+	—	—	—	—	—	—	+	—
(a) *gibberulus*, Nich.	—	+	—	—	—	—	—	—	—	+	?
gracilis, Törnq.	—	+	—	—	—	—	—	—	—	+	—
indentus (Hall)	—	+	+	—	—	+	—	—	—	—	+
——, var. *nanus*, Lapw.	—	+	+	—	—	+	—	—	—	—	?
Nicholsoni, Lapw.	—	+	—	—	—	+	—	—	—	+	—
(a) *nitidus* (Hall)	—	+	—	—	—	+	—	—	—	—	+
patulus (Hall)	—	+	—	—	+	+	—	+	+	+	+
V-fractus, Salt.	—	+	—	—	—	—	—	—	—	+	+
——, var. *volucer*, H. O. Nich.[*]	—	+	—	—	—	—	—	—	—	—	—
(a) *Loganograptus Logani*, Hall	—	+	—	—	—	—	—	—	—	+	+
Phyllograptus Anna, Hall	—	+	—	—	—	—	—	—	—	—	+
(a) *angustifolius*, Hall	—	+	—	—	—	—	—	—	—	+	+
ilicifolius, Hall	—	+	—	—	—	—	—	—	—	—	+

	—, var. *grandis* nov.	—	+	—	—	—	—	—	—	—	—	—
(a)	*typus*, Hall	—	+	—	—	—	—	—	—	—	+	—
	Pleurograptus vagans, Nich.	—	+	—	—	—	—	—	—	—	—	—
	Pterograptus sp.	—	—	+?	—	—	—	—	—	—	+(c)	—
	Schizograptus reticulatus, Nich.	—	+	—	—	—	—	—	—	—	—	—
	tardifurcatus sp. nov.	—	+	—	—	—	—	—	—	—	—	—
	Trichograptus fragilis, Nich.	—	—	+	—	—	—	—	—	—	—	—
	Temnograptus multiplex, Nich.	—	+	—	—	—	—	—	—	—	—	—
	Trochograptus diffusus, Holm	—	+	—	—	—	—	—	—	—	+	—
(a)	*Tetragraptus Bigsbyi* (Hall)	—	+	—	—	—	—	—	—	—	+	+
	crucifer (Hall)	—	+	—	—	—	—	—	—	—	+?	+
	Headi (Hall)	—	+	—	—	—	+	—	—	—	—	+
(a)	*pendens* sp. nov.	—	+	—	—	—	—	—	—	—	+	—
	Postlethwaitii sp. nov.	—	+	—	—	—	—	—	—	—	+	—
(a)	*serra* (Brongn.)	—	+	—	—	+	—	—	—	—	+	+
(a)	*quadribrachiatus* (Hall)	—	+	—	—	+	—	—	—	—	+	+
	Leptograptus sp.	—	—	+	—	—	—	—	—	—	—	—
	Diplograptus dentatus (Brongn.)	—	—	+	—	—	+	—	+	+	+(c)	+
	teretiusculus (His.)	—	—	+	—	—	—	—	—	—	+(d)	+
(a)	*appendiculatus*, Törnq.	—	—	+	—	—	—	—	—	—	+(c)	—
	Climacograptus Scharenbergi, Lapw.	—	—	+	—	—	—	—	—	—	+(d)	—
	Cryptograptus antennarius, Hall	—	—	+	—	—	—	—	—	—	—	+
	Hopkinsoni (Nich.)	—	+	+	—	—	—	—	—	—	—	—
	tricornis (Carr.)	—	—	+	—	—	—	—	+	+	+	—
	Glossograptus armatus (Nich.)	—	—	+	—	—	—	—	—	—	+(d)	—
	fimbriatus (Hopk.)	—	—	+	—	—	—	—	—	—	—	—
	Hincksii (Hopk.)	—	—	+	—	—	—	—	—	—	+(d)	—
(a)	*Trigonograptus ensiformis* (Hall)	—	—	+	+	—	—	—	—	—	—	+
	lanceolatus, Nich.	—	—	+	—	—	—	—	—	—	—	—
	Dicellograptus moffatensis (Carr.)	—	—	+	—	—	+	—	—	—	—	—

Note.—The divisions of the Skiddaw Slates are not synonymous with the divisions of the rocks of St. David's and Shelve.

of his 'Lower Graptolite-Shales' (=*Phyllograptus*-skiffer). This zone is succeeded by a series of Graptolite-mudstones, divided by him into several zones, which form the lower part of his 'Middle Graptolite-Shales' (*Dicellograptus*-skiffer).

The fauna of this zone of *Phyllograptus* cf. *typus*, Hall, is undoubtedly present in the Skiddaw Slates, almost every species which occurs in it in Sweden being also found in the Lake District, such for instance as *Didymograptus gibberulus*, Nich., *D. patulus* (Hall), *D. bifidus* (Hall), *Azygograptus suecicus*, Moberg, *Phyllograptus typus*, Hall, etc., which are all found associated on the same slabs of Skiddaw Slate.

The minuter zones of the *Phyllograptus*-skiffer which lie below the Orthocerkalk are well developed in Vestrogothia, where they have been worked out by Dr. Törnquist (of Lund). He very kindly communicated to me privately the results of his work, but its publication must be awaited before a detailed comparison with the Skiddaw Slates can be made. It may be noted that I have reason to believe that all the zones are represented in the Skiddaw Slates, and are present at Barf and probably also at other localities.

The fossils collected from Outerside, Thornship Beck, Glenderamakin River, and other places seem to indicate the presence of rather higher beds than those at Barf, Randal Crag, etc. The noticeable feature in the fauna from these localities is the abundance of Diplograptids, and the presence of Didymograptids belonging to the 'tuning-fork' group. I consider these to be the equivalents of the Ellergill Beds of the Cross Fell Inlier.

These Ellergill Beds, in addition to numerous Diplograptidæ, have yielded *Placoparia,* a trilobite which has also been found at Outerside; this indicates that the beds are of Llanvirn age, and the overlying Milburn Beds must be newer, and may possibly be referred to the lower part of the Llandeilo. Unfortunately, the fauna which they have yielded at present is scanty, but it does not in any way go against this view.

The Ellergill Beds I believe to be represented by the two lowest zones of the Swedish *Dicellograptus*-skiffer, or possibly even by more zones than these. It is possible that there exists in the Lake District a series of fossiliferous mudstones representing all the beds up to the Glenkiln zone of *Cœnograptus gracilis* (Hall), but whether a detailed zonal classification of these beds by means of their graptolites will ever be feasible it is very hard to say.

A portion of the Skiddaw Slates is certainly represented by the Bennane Shales of Southern Scotland; these beds probably represent the whole of what I have called 'Middle Skiddaw Slates' in the appended table (III, p. 530).

The divisions of the Skiddaw Slates which I have adopted are based entirely on palæontological evidence; the separation of the Lower Skiddaw Slates is sufficiently obvious, but it must be noted that it does not correspond to Nicholson's 'Lower Skiddaw Slates.' The threefold division of the Middle Skiddaw Slates is based upon the following facts:—(1) That I have found *Tetragraptus Bigsbyi*

(Hall) associated with *Bryograptus ramosus* var. *cumbrensis*, showing that *T. Bigsbyi* must occur in the lower parts of the beds.

(2) *Tetragraptus serra* (Brongn.) and other forms are also found associated with the fauna which in Sweden characterizes the zone of *Phyllograptus* cf. *typus* and occur on the same slab as the earliest 'tuning-fork' *Didymograpti*.

(3) *Dichograpti* do not occur with this higher fauna at all, and therefore are probably earlier forms.

The Upper Skiddaw Slates are characterized by the abundance of Diplograptidæ and 'tuning-fork' *Didymograpti*.

The results of my work as regards the stratigraphical relationships of the beds are summed up in Table III (p. 530).

(*b*) Phylogenetic.

It has been established as a general rule that graptolites with numerous branches have been gradually succeeded in time by types in which the branching was simpler. This is no doubt true in a general sense, but I fully agree with Nicholson & Marr that the phylogenetic relationships of the graptolites are not so simple as they appear. These authors, in their paper on the 'Phylogeny of the Graptolites' (Geol. Mag. 1885, pp. 529–539), have called especial attention to the remarkable resemblances which exist between the species belonging to different genera of the Dichograptidæ, and have suggested that these resemblances may be indicative of genetic relationship. They point out how very difficult it is to understand how the extraordinary resemblances between the various species of *Tetragraptus* and *Didymograptus*, etc., have arisen, if, as is usually supposed, all the species of these genera have descended from a common ancestral form for each genus, in the one case four-branched, and in the other case two-branched. On the other hand, they hold it to be comparatively easy to explain the more or less simultaneous existence of forms possessing the same number of stipes, but otherwise only distantly related, if we imagine them to be the result of the variation of different ancestral forms along similar lines. They urge that, when the graptolites (Dichograptidæ) are separated into groups characterized by their hydrothecæ,

(*a*) The different groups exhibit a series of parallel modifications as regards the number of stipes in the rhabdosoma;

(*b*) The older forms of the group are more complex, and the later forms undergo reduction in the number of stipes.

They distinguish nine such groups in the family Dichograptidæ, and select as their first and typical group the series represented by *Bryograptus Callavei*, *Tetragraptus Hicksii*, and *Didymograptus affinis*.

In the course of my own work among the Skiddaw Slate graptolites, I have also been greatly impressed by these remarkable resemblances between species of different genera, and, like these authors, I feel confident that such forms will be found eventually

TABLE III.—CORRELATION OF THE SKIDDAW SLATES WITH EQUIVALENT GROUPS IN OTHER AREAS.

LAKE DISTRICT.	SOUTH WALES.	SOUTH SCOTLAND.	CANADA.	SWEDEN (SCANIA), after Tullberg.
(Borrowdale Volcanic Series.) UPPER SKIDDAW SLATES. (a) Milburn Beds.	? Llandeilo.	? Lower parts of Barr Series and equivalents, Moorfoot Group and Leadhills Black Shales.		Lower part of *Dicellograptus*-skiffer. { Higher Zones of *Dicellograptus*-shales.
(b) Ellergill Beds, with *Diplograptus* and *Placoparia*.	Llanvirn.			Zone (n) Zone of *Glossograptus*. ,, (o) Zone of *Didymograptus geminus* (His.)
MIDDLE SKIDDAW SLATES. (a) Upper *Tetragraptus*-beds.	Upper Arenig.	Bennane Shales.	Quebec Group.	*Phyllograptus*-skiffer. { Zone of *Phyllograptus* cf. *typus*, [Hall.
(b) *Dichograptus*-beds.	Middle Arenig.			*Orthoceras*-limestone. *Tetragraptus*-beds.
(c) Lower *Tetragraptus*-beds.	Lower Arenig.			
LOWER SKIDDAW SLATES. (a) *Bryograptus*-beds. (b) ?	Tremadoc. ? *Lingula*-Flags.			*Ceratopyge*-beds, represented in part by shales with *Bryograptus*.

capable of arrangement into natural phylogenetic groups, of which those of Nicholson & Marr must be looked upon as the first suggestions.

I agree with these authors (1) that these resemblances are of genetic origin, and therefore (2) of systematic value; and further (3) that in any natural group the forms with relatively fewer branches were developed from the more complex forms, so that it follows from this (4) that the so-called 'genera' of the usually accepted classification of the Dichograptidæ are far more of a chronological than of a zoological significance. But my own work among these forms has led me to the conclusion that the forms in question are most probably the result of development along certain special lines, and I would suggest that such is their real origin. The group-relationships which seem to follow from this suggestion are indicated below.

In saying that the apparently simpler types have been derived from the more complex ones, I do not mean to imply that there have been no other modifications: for example, that every *Didymograptus* is necessarily derived from a different species of *Tetragraptus*. Some are, no doubt, merely modifications of previously existing *Didymograptus*-forms. There does, however, appear to be a certain group-relationship. I consider, for instance, that all the 'tuning-fork' *Didymograpti* have been derived from what might be termed the '*fruticosus*-type' of *Tetragraptus*, though not all from *T. fruticosus* (Hall), as Nicholson & Marr seem to consider (Geol. Mag. 1895, p. 535). And on the other hand, the *Didymograpti* in which the stipes form with each other an angle of 180° probably originate from *Tetragrapti* of the *quadribrachiatus*-type, though not all from *T. quadribrachiatus* (Hall) itself. Examples will, perhaps, make this clearer.

Thus, starting with *Bryograptus ramosus* var. *cumbrensis*, we have a *Bryograptus*-form which resembles a *Didymograptus* with compound branches coming off from the celluliferous side of its main stipes. Observation shows that the branching in this case is certainly the result of division of the common canal. Suppose now that, instead of having various compound branches, the division of the common canal takes place only once on each side of the sicula, and near the proximal end of the stipes, the resulting form will be identical with *Tetragraptus pendens*, while the absence of branching altogether gives a form like *Didymograptus indentus* (Hall).

Nicholson & Marr have shown similar cases, though I confess that *Didymograptus furcillatus*, Lapw., seems to me more likely to be the direct descendant of *Tetragraptus fruticosus* (Hall) than *Didymograptus Murchisoni* (Beck); this is, however, a minor point.

On the other hand, starting with *Clonograptus* sp., the reduction of indefinite dichotomy results in *Loganograptus* sp., and a further limitation in branching yields *Dichograptus* sp. Every stage between a typical *Dichograptus octobrachiatus* (Hall) and *Tetragraptus quadribrachiatus* (Hall) can be traced, for there occur in the Skiddaw Slates, in addition to the typical 'octobrachiate' form with eight stipes, forms with seven, six, and five stipes which seem to be identical in all respects except the number of branches.

Then *Tetragraptus* is reached. A further reduction in the powers of dichotomy would result in a *Didymograptus* of the *extensus*-type.

The artificiality of a system of classification that includes in the same genus two forms having such totally different lines of descent as the above forms of *Tetragraptus* is perfectly obvious, but it is not my purpose here to suggest a change in this respect.

In dealing with the phylogeny of the Skiddaw Slate graptolites I divide them into two large groups:—(1) Those derived from a *Bryograptus*-form; (2) those derived from a *Clonograptus*-form.

Nicholson & Marr regard the angle of divergence as being of phylogenetic value. In the foregoing pages I have called attention to the fact that conditions of preservation must affect this angle within certain limits, especially if we hold Lapworth's view of the mode of life of the graptolites[1]; but given a graptolite with a certain amount of rigidity, the angle will probably be approximately constant. Also I think that it has a certain value when used in a general sense, and when absolute constancy in numerical values is not insisted on. For example, I do not believe that a *Tetragraptus* of the *fruticosus*-type would ever resemble a *Tetragraptus* of the *quadribrachiatus*-type, but I consider it very likely that great variation might be observed in a delicate *Clonograptus*-form in the angles at which the stipes of various orders were inclined to each other. For, if we consider the rhabdosoma to have been attached to some floating body, and its branches flexuous, it is obvious that these branches might ultimately come to rest in very various positions.

(1) Graptolites derived from *Bryograptus*.

(*a*) Group containing *Bryograptus ramosus* var. *cumbrensis*, *Tetragraptus pendens*, and *Didymograptus indentus*.

I have already referred to the lines along which *Didymograptus indentus* has been evolved from *Bryograptus ramosus* var. *cumbrensis* through *Tetragraptus pendens*; a detailed examination of these forms shows how complete is the resemblance between them.

Species.	Cell-characters, etc.	No. of cells to inch.	Incli- nation.	Aper- tural angle.	Over- lap.
Bryograptus ramosus var. *cumbrensis*.	Stipes similar in width. Cells very slightly curved, and with slightly concave apertures.	24 (9–10)[2]	20°	115°–120°	less ½
Tetragraptus pendens.		20–24 (8–9)	15–20°	120°	less ½
Didymograptus indentus.		25 (10)	30°	115°	abt. ½

[1] See Walther, Zeitschr. deutsch. geol. Gesellsch. vol. xlix (1897) p. 235.

[2] Figures in parentheses in this and the following tables denote the number of thecæ in 10 mm.

Didymograptus indentus var. *nanus* is a peculiar modification of *D. indentus* (Hall), from which it is, no doubt, derived.

(β) Group containing *Bryograptus ramosus* var. *cumbrensis*, *Tetragraptus fruticosus*, and *Didymograptus furcillatus*.

With regard to *Tetragraptus fruticosus* (Hall) and *Didymograptus furcillatus*, Lapw., the resemblance is not quite so close; nevertheless, the differences are so slight that *Didymograptus furcillatus* may well be developed from *Tetragraptus fruticosus*, with other slight modifications to suit special conditions. It is not reasonable to expect that we should in every case have the simplicity shown in Group α. The simplification in the branching takes place in the same way as in that group.

Species.	Cell-characters, etc.	No. of cells to inch.	Inclination.	Apertural angle.	Overlap.
Bryograptus ramosus var. *cumbrensis*.		24 (9–10)	20°	115°–120°	less ½
Tetragraptus fruticosus.	Gradual increase in width of stipes from origin. Cells curved, apertures concave.	15 (6)	38°	90°	½–⅔
Didymograptus furcillatus.		25 (10)	45°	90°	⅔

(γ) Group containing *Bryograptus ramosus* var. *cumbrensis*, *Tetragraptus Postlethwaitii*, and *Didymograptus bifidus*.

It seems likely that *Didymograptus bifidus* (Hall) may have been similarly developed from *Bryograptus ramosus* var. *cumbrensis* through *Tetragraptus Postlethwaitii* by a process of simplification of the branching accompanied by some other slight modifications, such as gradual increase in the number of cells in a given unit of length, concurrent with a gradual increase in the angle at which the cells are inclined.

Species.	Cell-characters, etc.	No. of cells to inch.	Inclination.	Apertural angle	Overlap.
Bryograptus ramosus var. *cumbrensis*.	Stipes of general uniform width. Cells slightly curved, with slightly concave apertures.	24 (9–10)	20°	115°–120°	less ½
Tetragraptus Postlethwaitii.		30 (12)	30°	130°	¾
Didymograptus bifidus.		32–36 (13–14)	45°	oblique	¾

(δ) Group containing forms derived from *Tetragraptus Bigsbyi*.

I feel certain that *Tetragraptus Bigsbyi* (Hall) has been developed from a species of *Bryograptus* in a manner similar to that described above for other forms of *Tetragraptus*, but the particular species of *Bryograptus* has not yet been recognized. Subsequent development seems to have proceeded along two quite different lines, resulting in one case in *Phyllograptus angustifolius*, Hall ?, and in the other in *Didymograptus gibberulus*, Nich.

Between *Tetragraptus Bigsbyi* and *Phyllograptus* there appears to be an intermediate form, but I have not seen it in England. It has been recognized in Sweden, however, where it has received the name of *T. phyllograptoides* (Linnarsson, MS.). In this form the four stipes are united in the proximal part of the rhabdosoma, but are free at their distal ends; where the four stipes are united for their whole length the form is termed a *Phyllograptus*. The development of *Didymograptus gibberulus* is, I consider, more direct, the main cause being the absence of dichotomous division in the common canal.

In this group the very close resemblance in the characters of the proximal end in the various forms is worthy of notice. In all the forms we note the marked similarity in size and general form of the sicula and the earliest developed thecæ, which differ in direction of growth from all those subsequently formed. A comparison of the structure of this part of the rhabdosoma as worked out by Holm for *T. Bigsbyi*, *D. gibberulus*, and *Ph. angustifolius*[1] will bring this out clearly. Other resemblances between these species are shown in the following table:—

Species.	Cell-characters, etc.	No. of cells to inch.	Incli-nation.	Aper-tural angle.	Over-lap.
Tetragraptus Bigsbyi.	Cells long and curved, in contact for whole length, and with concave apertures.	32–36 (13–14)	40–50°	140°	whole
Tetragraptus phyllograptoides.		36 (14)	......	......	„
Phyllograptus angustifolius ?		32 (13)	variable	variable	„
Didymograptus gibberulus		40 (16)	45°	130°	„

(ε) Group containing forms derived from *Bryograptus Callavei*.

The forms which fall into this group include a *Tetragraptus* of the *Hicksii*-type, but not certainly *T. Hicksii* (Hopk.) itself, *Didymograptus Nicholsoni*, Lapw., *D. affinis*, Nich., *D. gracilis*, Törnq., *Azygograptus Lapworthi*, Nich., and *Az. suecicus*, Moberg.

Nicholson & Marr have already called attention to the relationship between *Bryograptus Callavei*, Lapw., and *Tetragraptus Hicksii*. The latter species has not yet been recognized in the Skiddaw Slates, and probably the form from which the simpler types have been derived may be somewhat different from that species, though closely allied to it. From this type two forms of *Didymograptus* were, I

[1] 'Om *Didymograptus, Phyllograptus*, och *Tetragraptus*,' Geol. Fören. Stockh. Förhandl. vol. xvii (1895).

believe, developed as the result of absence of division in the common canal—namely, *D. Nicholsoni*, Lapw., and *D. affinis*, Nich.; these types have much in common, but present slight differences. It is interesting to observe that in both species further development proceeds along similar lines, resulting in the ultimate production of forms with one stipe only; the one-stiped form developed from *D. Nicholsoni* being *Azygograptus Lapworthi*, Nich., and that developed from *D. affinis* being *Azygograptus suecicus*, Moberg.

There is so great a resemblance between *D. affinis* and *Az. suecicus* that, but for the abundance of the latter species in the beds and the absence of anything resembling a connecting-canal, it might almost be thought that the presence of only one stipe was merely accidental. In the *Azygograpti*, therefore, I consider that we have an extreme type of Dichograptid in which the power of branching is reduced to a minimum, with the result that only one stipe is formed.

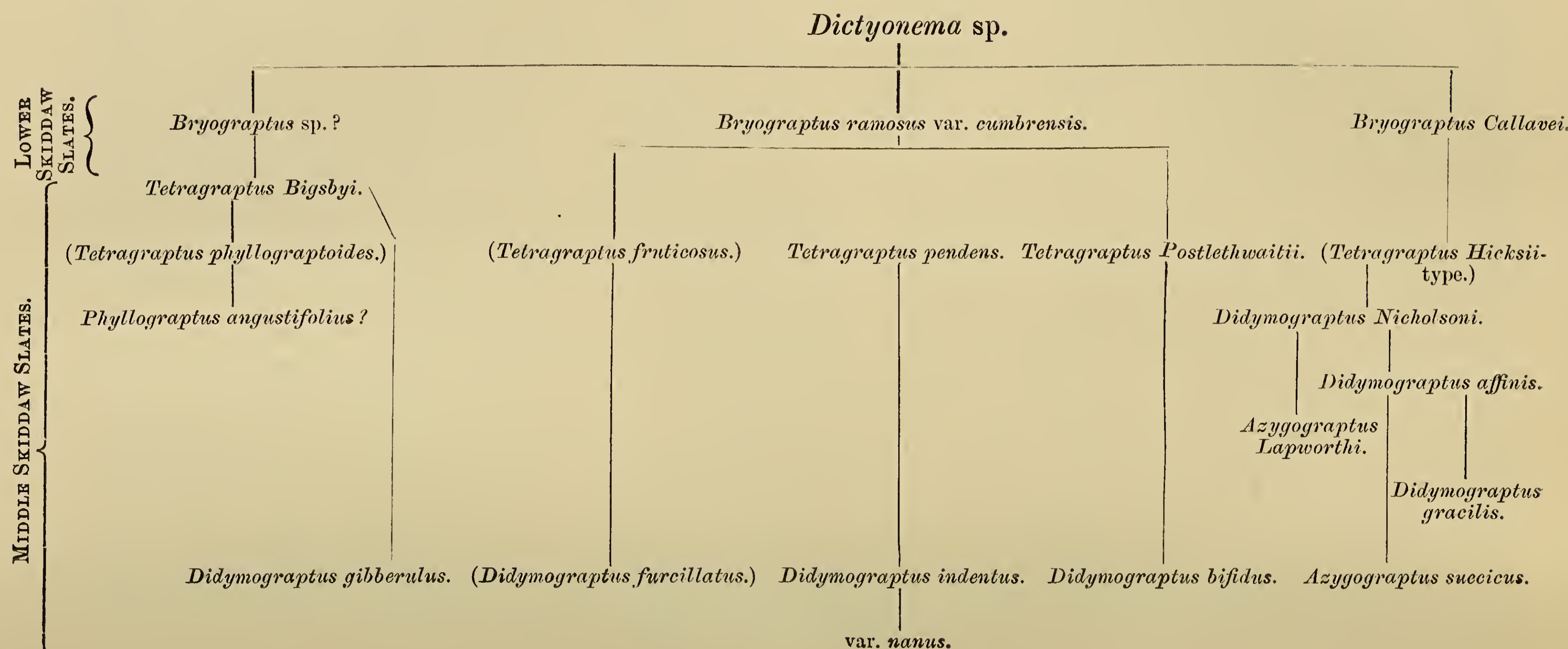
Didymograptus gracilis, Törnq., may be regarded as a slightly modified form of *D. affinis*.

Species.	Cell-characters, etc.	No. of cells to inch.	Inclination.	Apertural angle.	Overlap.
Bryograptus Callavei.	Slender forms. Cells with outer walls straight or very slightly curved. Apertures approximately straight.	28 (11)	20°	105°	$\frac{1}{3}$–$\frac{1}{2}$
Tetragraptus sp. (*Hicksii*-type).		......	......	......	Contact for very short distance at the base.
Didymograptus Nicholsoni		26 (10–11)	20°	105°	
Azygograptus Lapworthi.		20 (8)	20°	90°	
Didymograptus affinis.		18–20 (7–8)	15°–20°	90°	
Azygograptus suecicus.		18 (7)	15°	90°	
Didymograptus gracilis.		18 (7)	15°	90°	

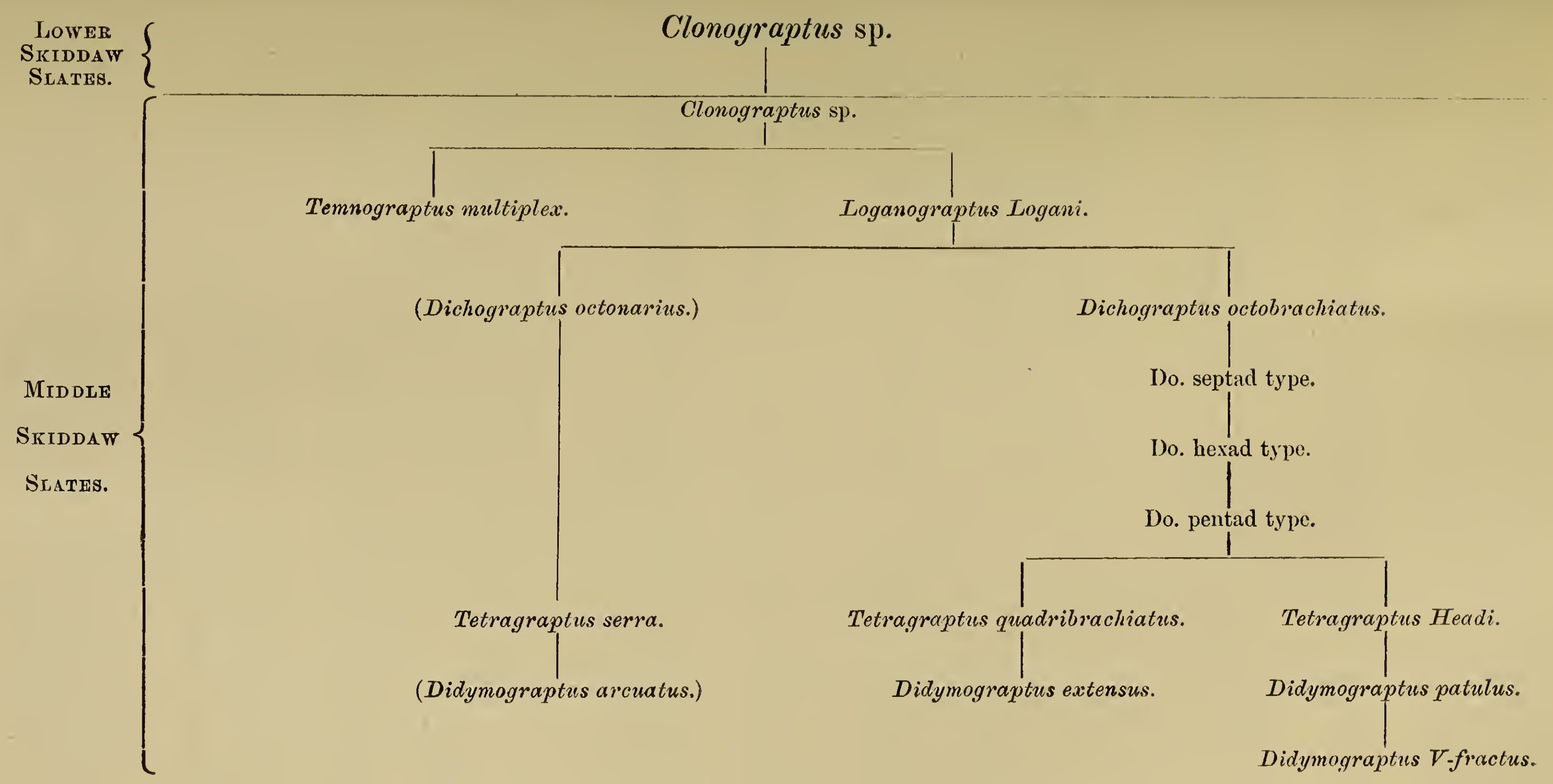
(2) Graptolites derived from *Clonograptus*.

The mode of development of the more simply-stiped forms from the more complex types is similar to that of the other group—namely, failure of dichotomous division in the common canal. If this be true, we should expect that the most primitive *Didymograpti* resulting from such development would have their stipes in one and the same straight line: in other words, have apparently resulted from further growth of the so-called funicle, which, as I have shown, should be regarded as consisting of two stipes of the 1st order, since they are known to be celluliferous. Nicholson & Marr seem to regard the angle of divergence between the two stipes of the 2nd order as of phylogenetic importance. I must confess that I fail to appreciate the reason for their view. I am convinced that the *Didymograpti* in this group have resulted merely from repeated failure in dichotomous division, and I cannot see how the result could have been attained in the unsymmetrical way indicated by those authors.

TABLE IV.—SUGGESTED PHYLOGENY OF THE SKIDDAW-SLATE GRAPTOLITES.



[Those forms, the names of which appear in parentheses, are not at present recorded from the Skiddaw Slates.]


Lower Skiddaw Slates.
Middle Skiddaw Slates.
Clonograptus sp.
Clonograptus sp.
Temnograptus multiplex.
Loganograptus Logani.
(Dichograptus octonarius.)
Dichograptus octobrachiatus.
Do. septad type.
Do. hexad type.
Do. pentad type.
Tetragraptus serra.
Tetragraptus quadribrachiatus.
Tetragraptus Headi.
(Didymograptus arcuatus.)
Didymograptus extensus.
Didymograptus patulus.
Didymograptus V-fractus.

Each primitive *Didymograptus* whose stipes include between them an angle of 180° may also give rise to other forms by slight modifications. My view is certainly borne out in the examples that I adduce, for in each case the resulting *Didymograptus* has its stipes in one and the same straight line.

(α) Group containing *Dichograptus octonarius*, *Tetragraptus serra*, and *Didymograptus arcuatus*.

Nicholson & Marr have already shown the general relationships between these forms (Geol. Mag. 1895); it only remains for me to point out the more detailed resemblances in the characters of the cells.

Species.	Cell-characters, etc.	No. of cells to inch.	Inclination.	Apertural angle.	Overlap.
Dichograptus octonarius (Hall).	Cells curved, and with concave apertures.	24 (9–10)	30°–35°	120°	$\frac{2}{3}$
Tetragraptus serra (Brng.)		24 (9–10)	30°	110°	$\frac{2}{3}$–$\frac{3}{4}$
Didymograptus arcuatus (Hall).		24 (9–10)	30°	110°	$\frac{2}{3}$

(β) Group containing *Loganograptus Logani*, *Didymograptus octobrachiatus*, *D. extensus*, and *Tetragraptus quadribrachiatus*.

I have indicated in the foregoing pages the lines along which such forms as the above have been evolved, but it is interesting to observe the resemblances of the cells to each other.

Species.	Cell-characters, etc.	No. of cells to inch.	Inclination.	Apertural angle.	Overlap.
Loganograptus Logani ...	Cells similar in form, curved, and with concave apertures.	24 (9–10)	35°	90°–95°	$\frac{3}{5}$
Didymograptus octobrachiatus.		20–24 (8–9)	20°–55°	105°–110°	$\frac{2}{3}$
Didymograptus extensus...		24 (9–10)	40°	110°–115°	$\frac{2}{3}$
Tetragraptus quadribrachiatus.		24 (9–10)	40°	100°	$\frac{2}{3}$

(γ) Group containing *Tetragraptus Headi* and *Didymograptus patulus*.

It seems possible that *Tetragraptus Headi* may also have been developed from the pentad type of *Didymograptus octobrachiatus*, and that from it *D. patulus* was subsequently evolved. I would also suggest that *D. V-fractus* may be a modification of *D. patulus*.

Species.	Cell-characters, etc.	No. of cells to inch.	Incli-nation.	Aper-tural angle.	Over-lap.
Tetragraptus Headi	Cells similar in form, and in contact for the greater part of their length.	24 (9–10)	40°	oblique	$\frac{3}{4}$
Didymograptus patulus ...		24 (9–10)	45°	130°	$\frac{3}{4}$

In conclusion, I offer my grateful thanks to all who have helped me in my work.

I cannot sufficiently express my gratitude to Prof. Nicholson and Mr. Postlethwaite for their generosity in placing their entire collections at my disposal. Prof. Nicholson was also kind enough to lend me specimens from the Quebec Group of Canada and from the Arenig Beds of Australia for purposes of comparison.

I wish also especially to thank Mr. Marr for the kind interest which he has shown in my work, and for the great help which he has given me throughout.

My thanks are also due to Prof. Hughes and Dr. Henry Woodward for permission to figure and describe the specimens in the Collections of the Woodwardian Museum and the British Museum (Nat. Hist.); to Mr. W. A. Brend for the loan of specimens; and to Miss V. S. Baker, of Newnham College, for her valuable assistance in collecting in the field.

Discussion.

Mr. Marr said that he was pleased to find that the Authoress was, in the main, in agreement with Prof. Nicholson and himself. In matters of detail, he believed that she did not adopt their views, but he felt that, after the careful manner in which she had studied the fauna, the Authoress was more likely to be correct than previous writers. He had originally intended to describe the fauna of the Skiddaw Slates, but he felt that, after hearing the paper, the Fellows would congratulate the Authoress, the speaker, and themselves that the paper had been written by Miss Elles.

Dr. Hicks recognized that the classification of the Skiddaw Slates adopted by the Authoress, on the strength chiefly of the graptolites, agreed closely with that made out by him from stratigraphical and palæontological evidence in the Lower Ordovician rocks of St. David's. He thought that the paper was a very important one, and would be of great assistance to those who were working on these rocks.

The President and Prof. Watts also spoke.

33. *The* GLOBIGERINA-MARLS [*and* BASAL REEF-ROCKS] *of* BARBADOS.

By G. F. FRANKS, Esq., M.A., F.G.S. and Prof. J. B. HARRISON, M.A., F.G.S. *With an* APPENDIX *on the* FORAMINIFERA. By F. CHAPMAN, Esq., A.L.S., F.R.M.S. (Read June 8th, 1898.)

CONTENTS.

I. INTRODUCTION.

MENTION was made of the *Globigerina*-marls of Bissex Hill in a paper on the Geology of Barbados written by one of us in collaboration with Mr. Jukes-Browne,[1] and the section along the road ascending the hill from the south-western side was there described. The ordinary succession of the Oceanic deposits occurs in the lower part of this section for 70 feet vertical, up to an elevation of about 865 feet. Here the hill rises somewhat abruptly from a small plateau of the siliceous earths to a knoll at an elevation of 966 feet, falling away to a spur on the east, the ridge of which, to the point where it terminates abruptly, has a level of about 900 feet. On the north the knoll slopes steeply down to a level of 820 feet. On the west, below the road, the land falls away rapidly to Dark Hole and the Vale, the lowest exposure of the Oceanic Beds being north of Park's Windmill, at the height of 670 feet.

The whole of the crown of Bissex Hill, instead of showing the usual passage from siliceous earths through white chalks into red clays, was found to consist of a yellowish or buff-coloured marl, which proved to be crowded with *Globigerinæ*, and to include occasional large blocks and several embedded layers of hard *Globigerina*-limestone. In the first instance no change in the character of the deposit was noticed from where it first occurred to the summit of the hill, and it was supposed to be a local deposit taking the place of the usual chalk.

It was afterwards discovered, however, that the marl forming the base of the knoll on the hilltop on the southern face contained a variety of organic remains, and a slide cut from a sample sent to the authors of the above-mentioned paper revealed the fact that it included small fragments or pebbles of true Barbadian chalk. From this it was concluded that the rock of the knoll was a remanié deposit, formed from the erosion of the underlying *Globigerina*-marls and of the neighbouring chalks during the upheaval which culminated in the emergence of the island. It was consequently classed with other beds which seemed to be of intermediate age between the Oceanic Series and the coral-rocks.

[1] Quart. Journ. Geol. Soc. vol. xlviii (1892) pp. 170-225.

It was felt, nevertheless, that the locality required further investigation, and the present paper records the results of subsequent explorations of Bissex Hill. These were communicated from time to time to Mr. Jukes-Browne, and the conclusions to which they seemed to point were mentioned in a letter written by him, and read at a meeting of the Geological Society on Feb. 20th, 1895.[1]

The principal points thus ascertained are as follows:—

(1) That there is no break in the succession of the *Globigerina*-marls and coral-limestone. These marls pass upwards conformably, through a basal reef-rock without corals, into the coral-rock which caps the island. Included fragments of the chalk, of the radiolarian earth, and of clay containing radiolaria occur in the lower beds as well as in the upper. Where these inclusions are largest and most plentiful, they are in the form of rounded, or more often flatly-ovate, pebbles, and are thus easily distinguished from the angular blocks and fragments of *Globigerina*-limestone, which in places occur in the marls and themselves contain inclusions of the Oceanic rocks.

(2) The *Globigerina*-marls lie unconformably on the Oceanic Series, in some places resting on the siliceous radiolarian earths, in others on the upper calcareous earths or chalks.

(3) The central and highest portion of the hill is a faulted tract, the mass of the *Globigerina*-marls being troughed down between two main fault-planes and slightly displaced by another fault.

(4) The same series of *Globigerina*-marls and basal reef-rocks has also been found in a shaft and a natural cave at Bowmanston, an estate about 4½ miles south-east of Bissex Hill.

II. The Orographic and Tectonic Structure of Bissex Hill.

It is on Bissex Hill that we have found the clearest evidence of the unconformity of the *Globigerina*-marls with the Oceanic Series and their conformity with the coral-rocks.

Bissex Hill is a very irregular tract of high ground on the north-eastern side of the island of Barbados. From its highest point, which is 966 feet above sea-level, it sends out spurs towards the east and the north-east, divided by deep valleys which slope steeply down to the coast. On the north a ridge extends to the hill known as Chalky Mount, the northern slopes of which sink almost precipitously to the Valley of St. Andrews. On the south-east and south it slopes somewhat steeply into the valley of a little brook called Joe's River. Another little brook, known as Tar Hole Gully River, divides a spur, running nearly due east and capped by two outliers of radiolarian earth, from two contiguous spurs running a little north of east, along and partly across which a fault-line can be traced. On the west it sinks into another deep valley known as Dark Hole, which drains northward. Between the valley of Dark Hole and the western part of the Joe's River valley is a high ridge running south-westward, which, like the neck of an isthmus, unites Bissex Hill to the central highlands

[1] See Quart. Journ. Geol. Soc. vol. li, p. 311.


Fig. 1.
SKETCH-MAP
OF
BISSEX HILL
BARBADOS.
Scale;- 4 inches=1 mile
Scotland Beds
Oceanic Series
Bissex Beds (Pliocene)
F.F. Faults
Dips
Windmills
Cambridge 394′
To Hopewell
F.5
F.4
F.3
F.2
F.1
F.2&3
Endeavour
Monkey Hill
Bissex 723′
830′
820′
810′
830′
Dark Hole
960′
930′
Bissex Hill
780′
780′
860′
800′
670′
700′
760′
From Chimborazo
Line of Section
Springfield
Tar Hole Gully
To Joe's River
Parks
Cocoa Grove

of the island near Chimborazo, where the elevation reaches 1100 feet. Along this ridge a road is carried from Chimborazo to Bissex Hill, and thence along the western slope of that hill. A branch of this road climbs to the Police Station, which is built a little below the summit of the hill, at the offset of an easterly spur.

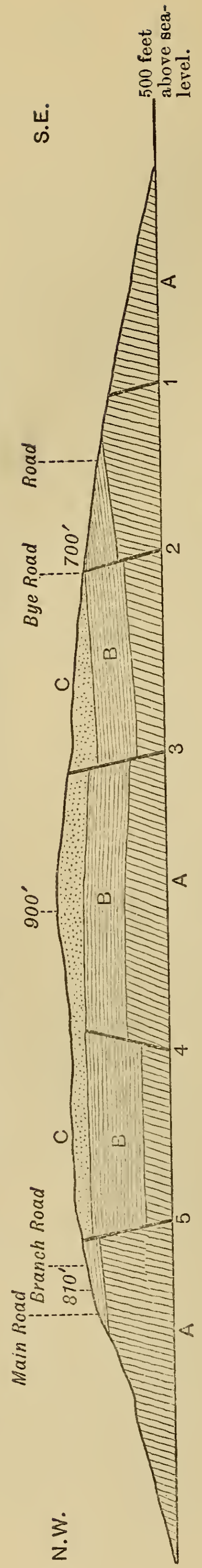
From the main road a branch runs in a north-easterly direction along the face of the southern rise of Bissex Hill, and near the point where the roads diverge a fault occurs, which accounts for the existence of an outlier of Oceanic Beds on Park's Estate at a level of about 700 feet, while the base of the same beds in the roadway is seen at about 800 feet. This fault (*F.* 1 on the accompanying map) has an upthrow on the north side, and the Oceanic Beds seen along the road dip locally at a high angle (45°), later at a low one of about 5° to the north-west, and extend up to a height of about 865 feet. They are then succeeded for a short distance by *Globigerina*-limestone and marl, and again occur as siliceous earths for about 10 feet vertically, overlain by *Globigerina*-marls. The Oceanic Beds form a small plateau or step just before the steep rise to the crown of the hill, and are there terminated by the effects of two branching faults (*F.* 2 & 3) having a total downthrow to the west of north of about 130 feet, which bring the base of the Oceanic Beds down to a level of 670 feet on the slope of the hill north-west of Park's Mill.

The *Globigerina*-marls thus brought in form the mass of the central part of the hill, and continue along the road for some distance till at a point some 120 yards before coming to a branch-road leading to Bissex Hill Estate House we pass over another fault (*F.* 5) which brings up the Scotland Beds, succeeded near the branch-road by the lower part of the Oceanic Series. The latter formation continues for a short distance up the road which runs in an easterly direction to the Estate House, but is cut off by a prolongation of the fault last mentioned, and we again find ourselves (at an elevation of about 820 feet) on the *Globigerina*-marls. The direction of this fault is to the north-north-east. A little farther east, just beyond the entrance to the Estate House, are two exposures, one (at a level of 820 feet) showing the *Globigerina*-marl overlying the Upper Oceanic chalk, the other (at 830 feet) showing marl overlying the radiolarian earths. From these facts we infer that a fault breaks the succession of the underlying Oceanic Series, but does not affect the *Globigerina*-marls: this is numbered 4 on the map.[1]

Coming to the point where a branch-road leads southward and following this, it is found that it runs along the base of the *Globigerina*-marls for about 150 yards, the base being at a level of about

[1] The topography of the accompanying map (fig. 1) is based on the large map constructed by Sir R. Schomburgk in 1848, and we have inserted such other topographical details as we have noticed during many visits to the locality. The topography of Schomburgk's map is more precise than that of the Admiralty chart which formed the basis of the geological map of the island published in 1890. Indeed, the faults could not be correctly laid down on the Admiralty chart. By an oversight, the basal reef-rocks are not shown in our map; they occur chiefly on the eastern part of Bissex Hill, and on the outlier which ends in Monkey Hill.

Fig. 2.—*Section across Bissex Hill (a short distance east of the Police Station).*



[Scales: horizontal, 6 inches=1 mile; vertical, 1 inch=800 feet.]

A=Scotland Beds. B=Oceanic Series. C=Bissex Hill Beds. 1, 2, 3, 4, 5=Faults, indicated in the map (fig. 1, p. 542).

830 feet, and the marl lying on radiolarian earth. The road next turns slightly westward and again southward, exposing sections through the *Globigerina*-marls, in which many sharks' teeth occur. It then descends gradually, until, at a level of about 780 feet, the *Globigerina*-marls are abruptly terminated against locally-contorted radiolarian earth, the latter dipping to the fault in a north-north-westerly direction, its general dip being (as seen lower down on the road, to the south-west. This fault is a prolongation of that (*F.* 2) mentioned as seen on the road south of the turn to the Police Station.

We have, therefore, evidence of the existence of five faults on Bissex Hill, two of them (*F.* 2 & *F.* 5) forming the southern and north-western boundaries of the tract occupied by the *Globigerina*-marls. Fault No. 4 does not seem to shift the boundaries of these beds, and must be therefore of anterior date.

The existence of these faults is confirmed by the outliers of the Oceanic Beds and of the *Globigerina*-marls which occur in the neighbourhood, as shown in the map (p. 542). For the purpose of this paper, it is only necessary to describe the outlier on the ridge at Endeavour, and at Monkey Hill, north-west of Bissex Hill. Here fault No. 2 is seen cutting off beds of radiolarian earth, which dip at a high angle to the north-north-west, and bringing them against the *Globigerina*-marls. On the northern slopes of the ridge the marls are observed lying upon the radiolarian earths in a manner similar to that seen on the north-eastern slope of Bissex Hill. On these outliers the *Globigerina*-marls are in places capped by masses of reef-rock, passing into true coral-rock, which lie conformably upon the *Globigerina*-marls.

The structure of Bissex Hill is shown in the accompanying section (fig. 2) crossing the hill from north-west to south-east along a line a little east of the Police Station.

III. The Succession at Bissex Hill.

The Scotland Beds which form the base of the hill are succeeded unconformably by the Oceanic Series, which shows the usual succession from chalks to calcareo-siliceous beds and in places to the upper chalks. The red clays, which elsewhere occur overlying the upper chalks, are not present or are not exposed on Bissex Hill.

Lying unconformably upon either the calcareo-siliceous beds or the upper chalks is a detrital bed which forms the base of the *Globigerina*-marls of the hill. It consists of a thin band of *Globigerina*-marl containing many rolled pebbles and small lumps of various parts of the beds of the Oceanic Series, but mainly of the chalks. Inclusions of clay, presumably derived from the beds of the Scotland Series, are also found in it in places. The structure of some of the slides prepared from specimens of this bed indicates that the included fragments fell or were carried into the *Globigerina*-marl while it was in course of formation, the *Globigerinæ* being found crowded round the included lumps. This band is especially noticeable from the fact that the foraminifera present in it are chiefly or almost entirely *Globigerinæ*, although at times a few scattered forms belonging to *Ehrenbergina*, *Bigenerina*, *Miliolina*, *Nodosaria*, and *Textularia* are found, while in a very few cases *Amphistegina* appears.

This is succeeded by a series of yellowish to bright buff-coloured marls, which frequently have a coarsely granular appearance, due to the presence in great numbers of large, thick-tested *Globigerinæ*, a texture very different from that of the chalks of the Oceanic Series. The lower beds are particularly rich in *Globigerinæ*, and contain few inclusions of the rocks from the Oceanic or the Scotland Beds. Ascending in the series, it is found that the numbers of foraminifera other than *Globigerina* rapidly increase, and specimens of *Ehrenbergina*, *Nodosaria*, *Textularia*, *Miliolina*, *Bigenerina*, *Cristellaria*, together with some other forms, become common. The higher beds consist of marls with many *Globigerinæ* and of compact *Globigerina*-limestones, both containing many inclusions of Oceanic chalks. In the uppermost of these beds, the *Globigerinæ* gradually die out, while other foraminifera (especially *Amphistegina*) increase in abundance, and fragments of lamellibranch shells are commonly present.

Spines and plates of echinoderms are generally present in all the beds, with the exception of those marls which have few inclusions, where they rarely are found. The distribution of echinid débris is very irregular; in places they are present in great abundance, while in others on the same horizon they may be scarce or apparently totally absent. In some of the blocks of limestone, casts of turbinate corals occur, and at times small joints of *Pentacrinus* are found. Here and there, through the beds, great numbers of sharks' teeth belonging to *Carcharodon*, *Hemipristis*, *Oxyrhina*, and *Lamna* are found. In the upper beds many nullipores, notably *Lithothamnium*, and millepores occur.

As the *Globigerinæ* gradually disappear from the upper members of the group, *Amphisteginæ* become common, and in places the limestone-rocks are almost wholly made up of them. On the eastern spur of Bissex Hill and on the outlier towards Monkey Hill, the gradual change of the Upper *Globigerina*-marls into *Amphistegina*-limestones, and from these, through basal reef-rocks having the characters described by Mr. W. Hill,[1] to true coral-rocks, is well seen.

The total thickness of the *Globigerina*-marls as exposed on Bissex Hill is apparently about 90 feet; that of the passage-rocks, from the marls to the true coral-rocks, is very variable, but probably in no case exceeds 20 feet. The following is a summary of the vertical succession of the *Globigerina*-marls and reef-rocks at this locality:—

REEF-ROCKS: 20 feet.	5. Coral-rock.
	4. Basal reef-rocks without coral.
GLOBIGERINA-BEDS: about 90 feet.	3. *Globigerina*-marls, with many inclusions of Oceanic earths.
	2. *Globigerina*-marls with few inclusions.
	1. Detrital beds of *Globigerina*-marl, with very many inclusions of Oceanic earths and at times of Scotland Clays.

The *Globigerinæ* of the Bissex Hill marls are characterized by their considerable size, their robust, thick-walled tests, and in these characteristics they resemble those dredged by the *Buccaneer* in 1886 in the South Atlantic (lat. 0° 1′ S., long. 15° 56′ 5″ W.) from a depth of 1845 fathoms. They are in marked contrast, in this respect, to the small *Globigerinæ* with thin-walled tests present in the included fragments of Oceanic chalks. Their colour also is different, being generally of a light buff, and at times they contain glauconite; those of the Oceanic earths usually have a glistening white appearance. The Bissex Hill marls bear, however, a remarkable likeness to the *Globigerina*-rock figured by Alex. Agassiz.[2] This is said to be part of a slab dredged off Alligator Reef at 147 fathoms, but no account of it is given, and we are therefore uncertain whether it is derived from a recent deposit or from a submarine outcrop of a rock such as the *Globigerina*-limestone of Barbados.

Apart from the foraminifera enumerated by Mr. Chapman (see Appendix, p. 550), very few fossils have yet been found in the Bissex Hill marls. The following short list includes all that are known, and the sharks' teeth are by far the commonest among them:—

VERTEBRATA	*Carcharodon* (teeth).
	Hemipristis (teeth).
	Lamna (teeth).
	Oxyrhina (teeth).
INVERTEBRATA	*Archæopneustes abruptus*, Gregory.
	Pentacrinus (single joints of stem).
	Small turbinate corals (as casts).

The *Scalaria* described by Sir R. Schomburgk as *Sc. Ehrenbergii* and as having been obtained from Bissex Hill came very probably from these beds, for he found it in a rock 'composed of yellow siliceous limestone or calcareous freestone, in which some shells, spines of *Echini*, and teeth from two species of sharks have been found.'[3]

[1] See Quart. Journ. Geol. Soc. vol. xlvii (1891) pp. 246–247.
[2] 'Three Cruises of the *Blake*,' vol. i (1888) p. 265, fig. 182.
[3] Schomburgk's 'History of Barbados,' 1848.

IV. Bowmanston and other Localities where similar Rocks occur.

Bowmanston is situate on a plateau of coral-rock, the hous being at an altitude of 620 feet above the sea. Many years ago a shaft was sunk here to reach water, and at a depth of about 260 feet the sinking dropped through the roof of an underground water-course, in which the average water-level is 360 feet above the sea, or 280 feet from the surface.

The lower portion of this shaft and the cavern into which it opens have been examined by us on several occasions, and a number of rock-samples obtained. The lower part of the cavern is cut through an ochreous-yellow *Globigerina*-marl much resembling that which occurs on Bissex Hill; above this there is a *Globigerina*-limestone forming a fairly hard rock, containing included fragments of chalk and of indurated radiolarian earth derived from the Oceanic Series. This rock is similar to the limestone that occurs near the summit of Bissex Hill, and on ascending the sides of the cavern it is found to pass into a limestone which is destitute of *Globigerinæ*, but contains a great number of *Amphisteginæ*, together with some *Bigenerinæ*, *Nodosariæ*, *Textulariæ*, and other foraminifera. The calcareous alga *Lithothamnium* and fragments of echinoderms are frequently present. The same *Amphistegina*-limestone occurs at the bottom of the shaft, and continues upward for 10 or 12 feet, but at a level of about 410 feet above the sea it gradually passes into true coral-rock.

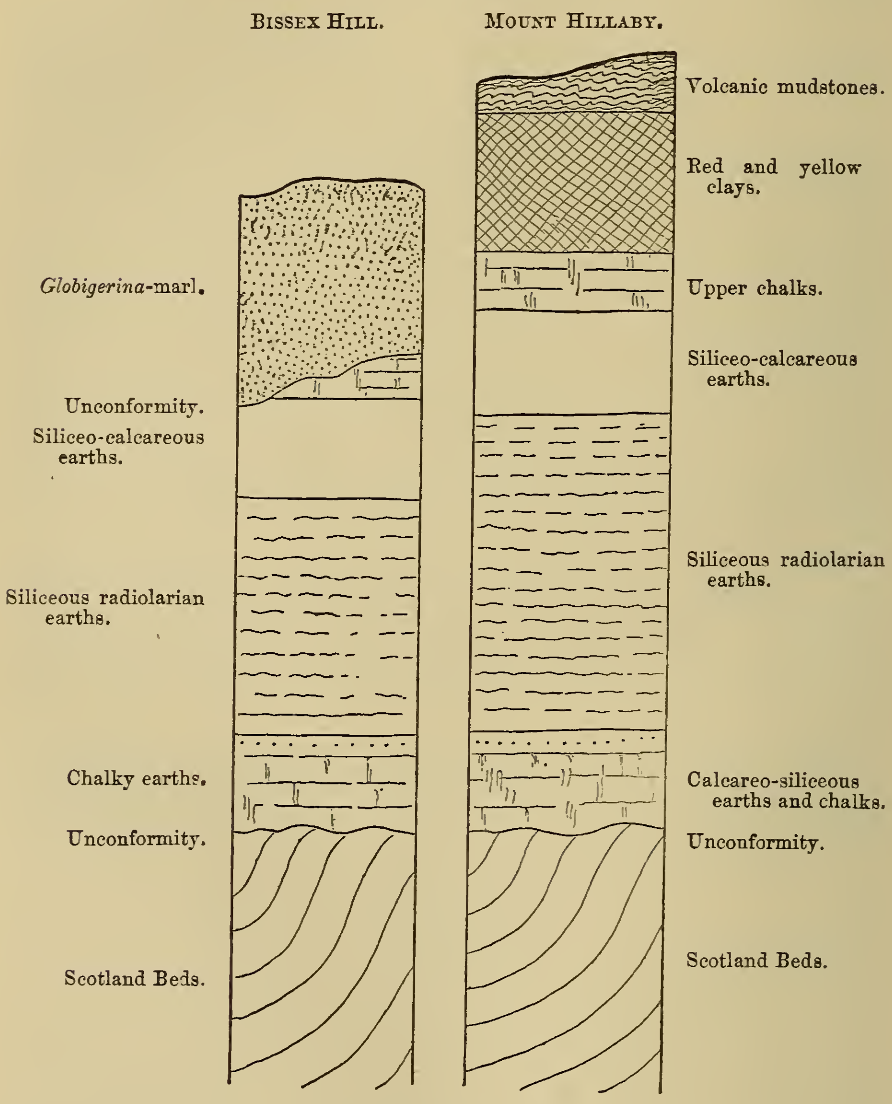
The sequence of rocks below Bowmanston therefore coincides with, and confirms, that observed on and near Bissex Hill. There is no means of ascertaining how much *Globigerina*-marl lies below the floor of the cavern, but its existence there is sufficient to show that the outlier of Bissex Hill is part of a formation which had a considerable extension.

Many borings have been made through the coral-rock capping of the island, and these show that between the Oceanic or the Scotland Beds and the basal reef-rock there is generally a foraminiferal mud. This mud sometimes contains a very few thick-tested *Globigerinæ*, similar to those of Bissex Hill, and inclusions of the Oceanic Beds and of clays possibly derived from the Scotland Beds are not uncommon. Thick-tested *Globigerinæ* occur very sparingly also in limestones obtained from the bottom of shafts sunk through the coral at Plumtree Gully, on Farmer's Estate, at levels of 684, 693, and 706 feet, and also in the earth from an underground cave at Rock Dundo at a level of 262 feet. The first three of these are coral-reef rocks containing abundant *Amphisteginæ* and a great variety of other organisms, including many echinoderm-fragments. They also show the presence of *Lithothamnium* in considerable quantity, while fair-sized inclusions from the rocks of the Oceanic Series are common. The earth from Rock Dundo is soft, and contains inclusions of comminuted radiolaria.

V. Conclusions.

The preservation of the outlier on Bissex Hill is partly due to the faults which have let it down into a trough of the older rocks. It can hardly be doubted that the marls once had a much greater extension over what is known as the Scotland district, and the

Fig. 3.—*Comparative views of the succession on Bissex Hill and Mount Hillaby.*



[Scale: 100 feet = 1 inch.]

frequent occurrence of pebbles and large lumps of the foraminiferal limestone in the alluvial gravels of the districts north and north-west of Bissex Hill is some evidence of such former extension.

We should not be surprised if careful search disclosed the

[1] See Quart. Journ. Geol. Soc. vol. xlviii (1892) p. 210.

existence of *Globigerina*-marl beneath the coral-rock escarpment east of St. Joseph's Church and below Binfield, for that locality is only $1\frac{1}{2}$ mile from Bissex Hill, and would be traversed by a line drawn from that hill to Bowmanston.

Indications of the former existence of *Globigerina*-beds below the coral-rock of the western slopes have also been noticed; but the absence of any trace of such beds on Mount Hillaby, at Chimborazo, and at Castle Grant is worthy of remark, for these places are on the highest part of the island (1000 to 1100 feet), and are localities where the highest known members of the Oceanic Series occur.

If the *Globigerina*-marls were ever deposited over the whole island, it is clear that they must have been removed from its highest parts before the growth of the earliest coral-reefs. It is more probable, however, that they never were accumulated over the highest levels, and that these levels were exposed to current-erosion while deposition was in progress over the Bissex Hill area. At any rate, the facts may be explained on the supposition that there was a time in the elevation of the region, and before any part of it became an island, when the central part of the uplift came within the influence of a current strong enough to prevent deposition and to cause some erosion of the soft Oceanic Beds which then formed the surface of the rising dome or ridge. Small lumps of these beds became sufficiently indurated on the sea-floor to be eventually rolled down the outer slopes and embedded in the dense accumulation of foraminifera which was being formed round its borders.

The sequence of the beds on Bissex Hill shows that after a time the introduction of such detritus became less frequent, and that a nearly pure *Globigerina*-marl was formed. Later again the elevatory movement was renewed, and the depth of the water diminished more and more; molluscs, echinoderms, and other creatures contributed their débris to the deposit, and currents once more rolled along small pebbles and fragments of the older rocks.

Ultimately the central dome came within the limits of coral-growth, and an island was formed, the size of which was continually increased, partly by successive elevations, partly by the outward growth of the foraminiferal and coral-débris deposits, this process of building-up being indicated both at Bissex Hill and at Bowmanston by the sequence of *Amphistegina*-rock, basal reef-rock, and finally rock full of corals.

[The facts recorded in the foregoing pages show that the *Globigerina*-marls must be dissociated from the Oceanic Series and united with the Coral-reef Series.

Dr. Gregory considers that the coral-reefs were not all formed in the late Pleistocene period, but represent a considerable lapse of time. He regards the higher reefs as probably of early Pleistocene, possibly of late Pliocene age.[1] Prof. Heilprin also has shown that in Yucatan there is an associated series of Pliocene and Pleistocene limestones.[2]

[1] Quart. Journ. Geol. Soc. vol. li (1895) p. 297.
[2] Proc. Acad. Nat. Sci. Philad. 1891, p. 141.

We agree, therefore, with the opinions already expressed by Dr. Gregory and Mr. Jukes-Browne as to the relative ages of the Barbadian rocks, namely :—

PLEISTOCENE AND PLIOCENE.	Low-level Reefs. High-level Reefs. *Globigerina*-marls.
	Break.
MIOCENE	Oceanic Series.
	Break.
EOCENE or OLIGOCENE ...	Scotland Beds.—July, 1898.]

An Appendix on the foraminifera which are present in the *Globigerina*-marl and limestone and in the basal reef-rocks has been very kindly supplied by Mr. F. Chapman. Our thanks are due to him and to Dr. J. W. Gregory for the interest taken and assistance afforded during the progress of this work. We are also greatly indebted to Mr. Jukes-Browne for the many suggestions given to us, and for his help in preparing this paper for the press.

VI. APPENDIX ON THE FORAMINIFERA *from* BISSEX HILL *and* BOWMANSTON. By F. CHAPMAN, Esq., A.L.S., F.R.M.S.

Two years ago I received from Mr. G. F. Franks a large number of rock-specimens which he had collected from the *Globigerina*-marls and overlying limestones on Bissex Hill, and at his request I undertook to investigate them for foraminifera.

The samples submitted were of small size, weighing from $1\frac{1}{2}$ to 3 oz., and from these a fairly representative series was chosen, consisting of eight rock-specimens. One of the samples examined and reported on by the late Dr. H. B. Brady[1] (that labelled 'Rotten Earth, Bissex Hill') corresponds with the specimens which are now described.

The specimens that I have selected are friable; they can be broken down and washed without much difficulty; and, generally speaking, they yield about 50 per cent. of pure foraminifera, of which *Globigerinæ* form the greater part. Here and there the tests are encrusted with calcareous matrix, or remain cemented together, but many very perfect and finely-developed specimens of the various forms enumerated were selected from the washings.

It will be seen from the subjoined list (p. 553) that all the species recorded by Dr. Brady from Bissex Hill have again occurred in the samples now described.

Since the present study has resulted in the discovery of additional species of foraminifera, we are now in a better position to form some idea of the geological age of the Bissex Hill *Globigerina*-marls.

[1] Quart. Journ. Geol. Soc. vol. xlviii (1892) pp. 195–199.

The previously-published list of Bissex Hill foraminifera (*Globigerina*-marl) contained 32 species: this number is now increased to 120. From the combined lists of foraminifera here given, as many as 15 are to be found only in fossiliferous strata ranging from the Cretaceous to the Pliocene. These older forms are:—

Nodosaria (*Dentalina*) *spinulosa* (Montagu). Eocene.
" (*D.*) *aculeata*, d'Orb. Cretaceous-Miocene.
" (*D.*) *elegans*, d'Orb. Eocene & Miocene.
" (*D.*) *Verneuili*, d'Orb. Miocene.
" (*D.*) *Boueana*, d'Orb.[1] Miocene.
" (*D.*) *paupercula*, Reuss. Cretaceous.
" *longiscata*, d'Orb. Eocene-Pliocene.
" (*Psecadium*) *simplex*, Neugeb. Miocene.
Lingulina costata, d'Orb. Miocene & Older Pliocene.
Cristellaria excisa, Bornem. Oligocene.
" *inornata*, d'Orb. Eocene & Miocene.
" *discoidalis*, Costa. Pliocene.
" *Clericii*, Fornasini. Pliocene.
" *Josephina*, d'Orb. Miocene.
Truncatulina kalembergensis (d'Orb.). Miocene.

It is plain, from the foregoing list, that the Miocene and Older Pliocene species (and especially the former) are strongly in evidence in the Bissex Hill *Globigerina*-beds, and even in the basal reef-rock, and this is the more marked since some of these forms are very common, such as *Lingulina costata* and *Truncatulina kalembergensis*. Many of the forms known as recent, which are found at Bissex Hill, are also well-known Miocene and Older Pliocene species.

The limestones and marls of Malta in some respects resemble the *Globigerina*-beds of Bissex Hill. On looking through the lists of foraminifera from the Malta deposits given by Sir John Murray,[2] we notice that the foraminifera of the Blue Clays and Marls (classed as Miocene by Fuchs) appear to present the most striking analogy with the facies obtained from the Bissex Hill beds, while the *Globigerina*-limestone of Malta differs somewhat materially.

The rich foraminiferal fauna of the *Globigerina*-beds of Naparima, Trinidad, as recorded by Mr. R. J. L. Guppy,[3] and classed by him as Eocene, also bears a close resemblance to the facies of the Bissex Hill beds, but before a complete comparison can be made the foraminifera of the latter deposits must be worked out in further detail.

The species of *Globigerina* found in the marls are perhaps all comparable with known recent forms, but generally speaking they have tests of abnormal thickness, which call to mind certain specimens that I have seen occurring in cherty pebbles of Eocene age in the Nile Delta-deposits.

[1] Not to be confounded with the *Nodosaria Boueana* of d'Orbigny.
[2] Scot. Geogr. Mag. vol. vi (1890) pp. 449-488.
[3] Quart. Journ. Geol. Soc. vol. xlviii (1892) pp. 533, 534; also Journ. Trinidad Field-Nat. Club, vol. i (1893) no. xi.

The depth at which the *Globigerina*-marls (samples II–VII) were laid down was judged by the late Dr. H. B. Brady to be about 1000 fathoms. From the evidence now before me I have made calculations, based on the occurrence of recent forms, and it is satisfactory to know that these conclusions coincide exactly with those of Dr. Brady. The great proportion of *Globigerinæ* in the rock points undoubtedly to the fact that the deposit was formed at some distance from the land. The marl is not, however, entirely free from terrigenous material, and a beautifully perfect, doubly-terminated quartz-crystal occurred in one sample.

The material kindly supplied to me by Mr. Franks has been subjected only to a preliminary examination in view of the present report, owing to pressure of other work, and I am indebted to Prof. Judd for the facilities afforded at the Royal College of Science for working out a part of these results.

There are several species of the foraminifera which appear to be new, as well as four or five examples of the ostracoda, and with these I hope to deal at some future time, as opportunity permits.

The following are the details of the samples examined, the numbers of which will be found at the head of the columns in the Table:—

I.

'Basal Coral-reef rock, below coral. N.N.E. spur. Spec. 14. July 1893. Bissex Hill.'

II.

'*Globigerina*-marl. N.N.E. spur, end towards sea. Spec. 22. July 1893. Bissex Hill.'

III.

'*Globigerina*-marl, 964 feet above sea, N.E. Spec. 21, 22. Jan. 1893. Bissex Hill.'

IV.

'*Globigerina*-marl, 937 feet above sea, W.S.W. face. Spec. 14. Jan. 1893. Bissex Hill.'

V.

'*Globigerina*-marl, 884 feet above sea, southern face. Spec. 3. Jan. 1893. Bissex Hill.'

VI.

'*Globigerina*-marl, ? 720 feet above sea, eastern spur. Spec. 12. Jan. 1893. Bissex Hill.'

VII.

'*Globigerina*-marl, 375 feet above sea. Spec. 2. August 1892. Bowmanston Shaft.'

VIII.

'Brown Clay in bands and pockets. Spec. D. Bowmanston Shaft.' (Presumably of later date than the examples II–VII.)

No.	Species.	I	II	III	IV	V	VI	VII	VIII
1	*Spiroloculina limbata*, d'Orb.	...	...	...	...	...	...	*	
2	*Miliolina venusta* (Karrer)	...	...	...	...	*			
3	,, *trigonula* (Lam.)	...	...	*					
4	*Sigmoïlina tenuis* (Czjzek)	...	*	*	...	...	...	*	
5	*Ophthalmidium inconstans*, Brady	...	...	...	...	..	...	*	
6	*Reophax nodulosa*, Brady	...	...	*					
7	*Haplophragmium agglutinans* (d'Orb.)	...	...	...	...	...	...	*	
8	*Textularia sagittula*, Defrance	*	*						
9	,, *trochus*, d'Orb.	...	...	...	...	...	*		
10	,, *turris*, d'Orb.	...	...	...	...	...	...	...	*
11	,, *gramen*, d'Orb.	...	*						
12	*Spiroplecta sagittula* (Defr.)	...	...	...	...	...	...	*	
13	*Verneuilina triquetra* (Münst.)	*	...	...	...	*	*		
14	,, *spinulosa*, Reuss	...	...	...	...	...	...	*	
15	*Tritaxia tricarinata*, Reuss	...	*	...	...	...	...	*	*
16	*Bigenerina capreolus* (d'Orb.)	...	*	*					
17	*Gaudryina pupoides*, d'Orb.	*							
18	*Bulimina affinis*, d'Orb.	*	*	...	...	...	...	*	
19	,, *elegans*, d'Orb.	...	*	...	...	*			
20	,, *subornata*, Brady	...	*						
21	,, *Buchiana*, d'Orb.	...	...	...	*	*	*	...	*
22	*Bolivina punctata*, d'Orb.	*	...	...	...	...	...	*	
23	,, *robusta*, Brady	*	...	...	*	*	...	*	
24	,, *Beyrichi*, Reuss, var. *alata*. Seguenza	*							
25	*Pleurostomella rapa*, Gümbel	*	*	...	*	*	*	...	*
26	,, *alternans*, Schwager	*							
27	,, *subnodosa*, Reuss	*							
28	,, ,, var. *attenuata*, Brady MS.	*							
29	*Cassidulina subglobosa*, Brady	*	...	*	...	*	...	*	
30	,, *lævigata*, d'Orb.	*	*	*	...	*			
31	,, *crassa*, d'Orb.	...	*	*	*	...	...	*	
32	*Ehrenbergina serrata*, Reuss	*	*	*	*	*	*	*	*
33	*Lagena lævis* (Montagu)	*							
34	,, *apiculata*, Reuss	*							
35	,, *sulcata* (W. & J.)	...	*						
36	,, *hispida*, Reuss	...	...	...	...	*			
37	,, *striatopunctata*, P. & J.	...	...	...	...	*	...	*	
38	*Nodosaria* (*Glandulina*) *abbreviata*, Neugeb.	*	...	...	...	...	...	*	
39	*Nodosaria* (*Dentalina*) *Adolphina*, d'Orb.	*	*	*	...	*	*	*	
40	,, (*D.*) *Boueana*, d'Orb.	*	*	...	...	...	...	*	
41	,, (*D.*) *consobrina*	*	*	*	...	*	*	*	*
42	,, (*D.*) ,, var. *emaciata*, Reuss	...	...	...	...	*	*		
43	,, (*D.*) *plebeia*, Reuss	...	...	...	...	*			
44	,, (*D.*) *spinulosa* (Montagu)	...	...	*					
45	,, (*D.*) *filiformis*, d'Orb.	*	...	*					
46	,, (*D.*) *aculeata*, d'Orb.	...	...	*					
47	,, (*D.*) *elegans*, d'Orb.	*							
48	,, (*D.*) *Verneuili*, d'Orb.	*							
49	,, (*D.*) *communis*, d'Orb.	*							
50	,, (*D.*) *farcimen*, Reuss	*							
51	,, (*D.*) *obliqua* (Linn.)	*							
52	,, (*D.*) *soluta*, Reuss	...	...	*					
53	,, (*D.*) *pauperata*, d'Orb.	*	*	*	*	*	*	*	

TABLE (*continued*).

No.	Species.	I	II	III	IV	V	VI	VII	VIII
54	*Nodosaria* (*D.*) *paupercula*, Reuss	...	...	...	...	*			
55	„ (*D.*) *intercellularis*, Brady	...	...	...	...	...	*		
56	„ *raphanus* (Linn.)	*	...	*	...	...	...	*	
57	„ *pyrula*, d'Orb.	*	...	...	...	*			
58	„ *raphanistrum* (Linn.)	...	...	...	...	*			
59	„ *radicula* (Linn.)	...	...	...	*				
60	„ „ var. *ambigua*, Neugeb.	*	...	...	...	...	*	*	
61	„ *longiscata*, d'Orb.	*	...	*					
62	„ *vertebralis* (Batsch)	*	...	*	...	...	...	*	
63	„ *hispida*, d'Orb.	*	...	*	...	...	...	*	
64	„ „ var. *sublineata*, Brady	...	...	*	*	...	...	*	
65	„ *verruculosa*, Neugeb.	*	*	...	*	...	*		
66	„ *scalaris* (Batsch)	...	...	...	...	*			
67	„ *comata* (Batsch)	...	...	...	...	...	...	*	
68	„ (*Psecadium*) *simplex*, Neugeb.	*							
69	*Lingulina costata*, d'Orb.	*	...	*	*	*	...	*	*
70	*Frondicularia Millettii*, Brady	...	...	*					
71	*Rhabdogonium tricarinatum* (d'Orb.)	*	*	...	...	*	...	*	
72	*Marginulina glabra*, d'Orb.	*	...	*	...	*			
73	„ *costata* (Batsch)	*	...	...	...	*			
74	*Cristellaria crepidula* (F. & M.)	*							
75	„ *triangularis*, d'Orb.	*							
76	„ *cultrata* (Montfort)	*	...	...	*	*	*	*	
77	„ *excisa*, Bornem.	*	...	...	...	...	*	*	
78	„ *calcar* (Linn.)	*	...	...	...	...	*	*	
79	„ *aculeata*, d'Orb.	*	...	...	...	*	...	*	
80	„ *tenuis*, Bornem.	...	*	...	...	...	...	*	
81	„ *acutauricularis* (F. & M.)	...	*						
82	„ *rotulata* (Lam.)	...	...	*	...	*	...	*	
83	„ *inornata*, d'Orb.	...	...	*					
84	„ *discoidalis*, Costa	...	...	...	...	*			
85	„ *tricarinella*, Reuss	...	...	...	...	*			
86	„ *fragraria*, Gümbel [1]	...	...	...	...	...	*		
87	„ *Clericii*, Fornasini	...	...	...	...	...	*		
88	„ *vortex* (F. & M.)	...	...	...	...	...	*	*	
89	„ *papillosa* (F. & M.)	...	...	...	...	...	*	*	
90	„ *Josephina*, d'Orb.	...	...	...	...	...	...	*	
91	„ *cassis* (F. & M.)	...	...	...	...	...	...	*	
92	„ *mamilligera*, Karrer	...	...	...	...	...	...	*	
93	„ *orbicularis*, d'Orb.	...	...	...	...	...	...	*	
94	„ *gibba*, d'Orb.	...	...	...	...	...	...	*	
95	*Polymorphina lactea* (W. & J.)	...	...	...	*	...	...	*	
96	„ *compressa*, d'Orb.	...	...	...	...	*	...	*	
97	„ *communis*, d'Orb.	...	...	...	...	...	...	*	
98	*Uvigerina angulosa*, Williamson	*	...	*	*	*	*	*	
99	„ *pygmæa*, d'Orb.	*							
100	„ *asperula*, Czjzek	*	...	...	...	...	*		
101	„ *tenuistriata*, Reuss	*	...	*	...	*	...	*	
102	*Sagrina raphanus*, P. & J.	*							
103	„ *virgula*, Brady	*							
104	„ *nodosa* (P. & J.)	*	...	...	...	...	*		

[1] Recorded under the name of *Cristellaria Wetherellii*, Jones, by H. B. Brady.

TABLE (*continued*).

No.	Species.	I	II	III	IV	V	VI	VII	VIII
105	*Sagrina striata*, Schwager	*							
106	*Ramulina aculeata*, Wright	*	...	...	...	...	...	*	
107	*Globigerina conglobata*, Brady	*	...	...	...	*	*		
108	„ *Dutertrei*, d'Orb.	*	*	*	*	...	*	*	
109	„ *pachyderma* (Ehr.)	...	...	*	*	...	...	*	*
110	„ *bulloides*, d'Orb.	...	...	...	...	*	...	*	
111	„ „ var. *triloba*, Reuss	...	...	...	...	...	...	*	
112	„ *rubra*, d'Orb.	...	...	...	...	...	*	...	*
113	„ *æquilateralis*, Brady	...	...	...	*	*			
114	*Pullenia quinqueloba*, Reuss	...	*						
115	*Sphæroidina bulloides*, d'Orb.	...	...	*	...	*	...	...	*
116	*Discorbina rugosa*, d'Orb.	*	...	...	*	*	*		
117	„ *araucana* (d'Orb.)	...	...	...	...	...	*		
118	„ *biconcava*, P. & J.	...	...	...	...	...	...	...	*
119	*Truncatulina lobatula* (W. & J.)	...	...	*	...	*			
120	„ „ var. *variabilis*, d'Orb.	*	*	*	...	...	*	*	
121	„ *reticulata* (Czjzek)	*	*	...	...	...	...	*	
122	„ *culter*, P. & J.	*	*	...	*	*	*	*	
123	„ *Wuellerstorfi* (Schwager) .	*	*	*	...	*	*	*	
124	„ *kalembergensis* (d'Orb.) ...	*	...	*	*	*	*	*	*
125	„ *tenuimargo*, Brady	*	...	*	...	...	...	*	
126	„ *Ungeriana* (d'Orb.)	*	...	...	...	*	...	*	*
127	„ *Haidingerii*, d'Orb.	*	...	...	...	*	...	*	
128	„ *præcincta*, Karrer	*	...	*	...	...	...	*	
129	„ *refulgens* (Montfort)	...	...	*	...	*			
130	„ *Akneriana* (d'Orb.)	...	...	...	...	*			
131	„ *tenera*, Brady	...	...	...	...	...	...	*	
132	*Anomalina grosserugosa* (Gümbel)	*	...	...	...	...	...	*	
133	„ *ammonoides* (Reuss)	...	*	...	*	...	...	*	
134	„ *ariminensis* (d'Orb.)	...	...	...	...	...	...	*	*
135	*Carpenteria monticularis*, Carter	*							
136	*Pulvinulina pauperata* (P. & J.)	*	*	...	...	*	...	*	
137	„ *canariensis* (d'Orb.)	*							
138	„ *Hauerii* (d'Orb.)	...	...	...	...	...	*	*	
139	„ *patagonica* (d'Orb.)	...	...	...	...	...	...	*	
140	„ *tumida*, Brady	...	...	...	...	...	...	*	*
141	„ *Micheliniana* (d'Orb.)	...	...	...	...	...	...	...	*
142	*Rotalia Schreibersii*, d'Orb.	...	...	...	...	*			
143	„ *Soldanii*, d'Orb.	...	...	...	...	...	*		
144	„ „ var. *nitida*, Reuss ...	...	...	...	...	...	...	*	
145	*Nonionina pompilioides* (F. & M.)	*							
146	*Amphistegina Lessonii*, d'Orb.	...	...	...	...	...	...	...	*

DISCUSSION.

Mr. CHAPMAN drew attention to the occurrence in the *Globigerina*-marls of the comparatively large number of foraminifera which are apparently unknown to us from recent deposits, but which occur in strata of Cretaceous, Eocene, Oligocene, Miocene, and Older Pliocene ages. He also pointed out that the evidence for the bathymetrical limit of the deposit is in favour of a depth not much less than 1000 fathoms.

34. *On a* Volcanic Series *in the* Malvern Hills, *near the* Herefordshire Beacon. By H. D. Acland, Esq., F.G.S. (Read May 18th, 1898.)

The rocks of the Malvern Hills have afforded scope for much study and discussion. Dr. Holl, Mr. Rutley, and Dr. Callaway have elaborated papers on them. Mr. Rutley's relates mainly to the general character of the rocks; while Dr. Callaway devotes himself to an enquiry into the genesis of the crystalline schists, and the production of secondary minerals in shear-zones.

I propose to deal with a small area of the hills and describe some of the rocks to be found there. The district lies east and south-east of the Herefordshire Beacon, which has three spurs. The northernmost is Tinker's Hill, south of that comes Broad Down, and south of that again Hangman's Hill. The latter is, in its turn, bounded on the south by the 'Silurian Pass,' so named in the Geological Survey memoir by the late Prof. Phillips.[1] The Beacon Hill itself is of the same character as the main axis of the hills.

Prof. Phillips called attention to these rocks, and remarked that they 'appear partly in lines like dykes.' Dr. Holl also mentioned them, and considered them to be sandstone altered by the intrusion of trap-dykes. He noticed that some of the dykes contain a large proportion of augite.[2] In a note to p. 100 (*op. cit.*) Dr. Holl says that fragments of these rocks are found in the Gullet Wood conglomerate. This statement requires investigation, as it might form a clue to the age of the series.

Dr. Callaway has expressed the opinion that these rocks constitute a second pre-Cambrian group, and that they are of Pebidian age.[3] Mr. Rutley devoted a considerable space to them. He subjected them to careful microscopical analysis, and came to the conclusion that some are anorthite-basalt and others devitrified obsidian.[4]

Prof. A. H. Green described more minutely than previous writers the various rocks in this area.[5] It is scarcely with the hope that I may be able to add anything to his observations that I offer the following remarks; but, living as I do in the neighbourhood of this interesting series of rocks, having paid many visits extending over several years to them, and having commenced these notes some considerable time before the publication of his paper, I venture with all diffidence to place on record some of the results of my work.

The rocks of this area are tuffs, felsites, andesites, and basalts or dolerites.

The felsites are very persistent in their character: they have

[1] Geol. Surv. Mem. vol. ii (1848) pt. i, p. 29.
[2] Quart. Journ. Geol. Soc. vol. xxi (1865) pp. 93 & 100.
[3] *Ibid.* vol. xxxvi (1880) pp. 536 & 537.
[4] *Ibid.* vol. xliii (1887) pp. 497–499.
[5] *Ibid.* vol. li (1895) pp. 1–8.

a cryptocrystalline matrix, which in ordinary light is flecked over with probably an incipient development of epidote. I shall refer again to this occurrence later on. In some cases, as Mr. Rutley has already pointed out, there is perhaps in the arrangement of the flecks evidence of an originally perlitic structure.[1] Some specimens are more glassy in habit, and may be called devitrified obsidian.

The more basic rocks to which I refer under the name of andesites vary rather more, chiefly in respect of the presence or absence of a ferromagnesian constituent and of porphyritic felspars. In some cases the slide shows little but lath-shaped felspars.

The excavations that were necessary for the new Reservoir were looked forward to in the hope that some further light might be thrown on this group. They were made in the 'combe' lying between Tinker's Hill and Broad Down, and I drew attention to them in Geol. Mag. 1894, p. 48. The puddle-trench for the embankment was cut in a very much shattered rock, in which there was so much calcite that at first it was supposed to be Archæan limestone. Under the microscope, however, it is very evident that the calcite is secondary and infiltrated (28).[2]

It was not, however, until the sides of the combe were cut into that any distinct signs of bedding could be made out, and as the work progressed they were gradually revealed. The strike is nearly north-and-south, the dip from 40° east to nearly vertical at the puddle-trench. Unfortunately the excavations were not carried far enough west to uncover the junction between this series of rocks and the crystalline main axis of the Malvern Hills.

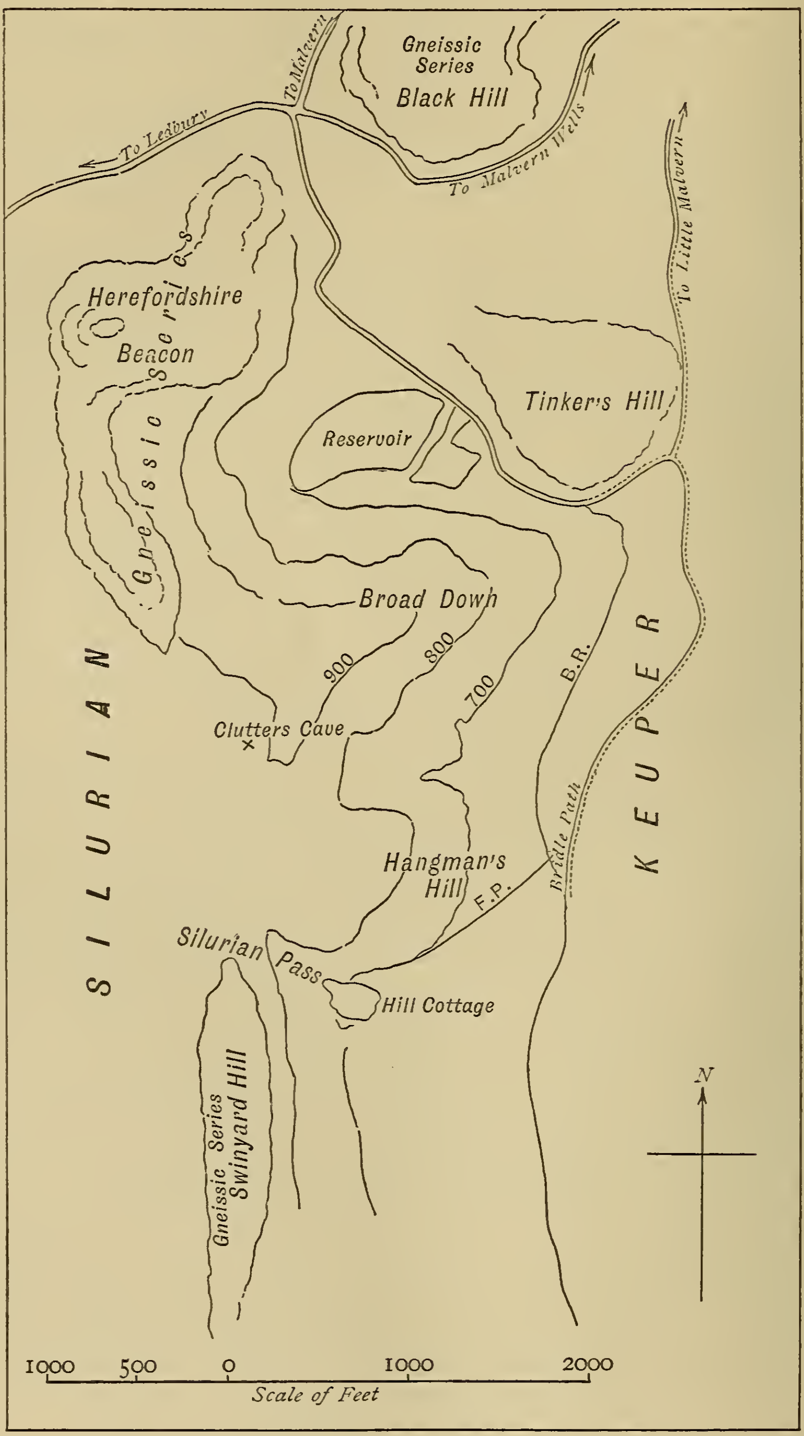
The bed that lay undermost, so far as seen, was of bluish-grey clay. This appears to be derived from the decomposition of a felsite, as the solid fragments show under the microscope all the characteristics of that class of rock (242). Above this is a green rock (203), which is considerably decomposed, and there is infiltration of calcite; but it agrees very well with Mr. Rutley's description of the basalt at the back of Clutter's Cave and with my slices of the rocks there. The felspars are lath-shaped; the ferromagnesian constituent is much altered.

Above this is a red rock (202). The slices show that it is a fine-grained tuff. Eastward and above this is a green rock (168). On each side of the Reservoir appeared a very distinct bed of black clay. The microscopic section of the rock shows that it is a basalt. There is a large development of chlorite replacing augite.

During the excavation it was interesting to note two conspicuous rocks, one green (168), and the other red (117 *a*, 170), side by side. The latter belongs to the bed next above. This bed is at the bottom a fine-grained tuff, and has almost the appearance of having been sorted by or deposited in water. Higher in this bed is a coarse-grained tuff (210, 244, 260). There are in it fine felspar-

[1] Quart. Journ. Geol. Soc. vol. xliii (1887) p. 499.
[2] The numbers in parentheses refer to the slides in my cabinet.

Fig. 1.—*Sketch-map of the Herefordshire Beacon and its immediate surroundings.*



crystals and fragments of basic rock. A remarkable feature of this tuff is that the matrix is isotropic.

Next to the eastward is a fine-grained rock, very much shattered, and having its cracks filled up with calcite. In some places there is a high percentage of carbonate of lime (in one instance 38·57 per cent., and in another 56 per cent.). The rock is, however, undoubtedly a felsite, and at some points (that is, around the filter-beds) is of so glassy a nature as evidently to be a devitrified obsidian (48, 49, 205). The dip at this point becomes nearly vertical. This type of rock is constantly repeated with more or less calcite, generally less, the farther east the specimens are obtained.

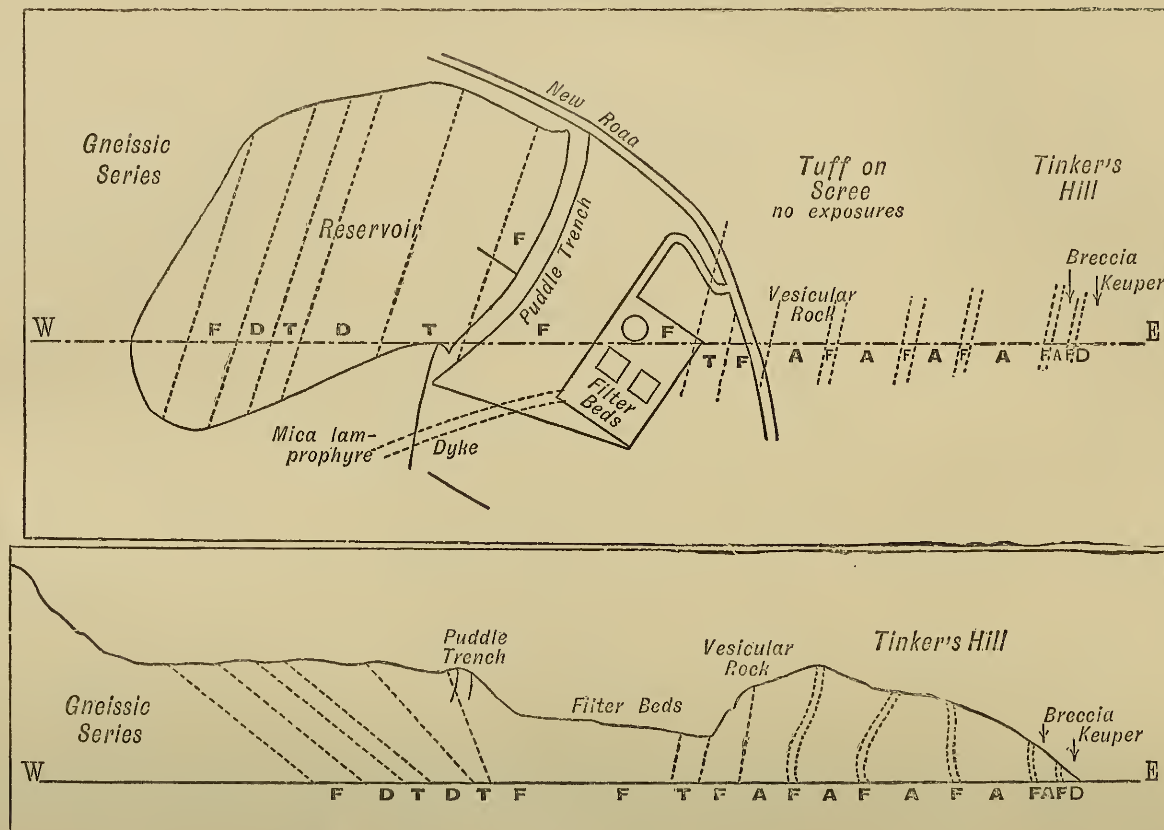
A fine-grained dyke (176) cuts across the southern end of this series of rocks, striking a little south of west. It is very similar in appearance to an elvan, and can be found again some way up the flank of Broad Down.

We now come to Tinker's Hill. There appears to have been much less disturbance here. The rocks are sounder, there is less calcite, and though there are few or no exposures on the northern flank, there are some very good ones on the west, south, and east. The western side was well scarped at the time of making the new road past the filter-beds. It showed that the crushing and shattering of the rocks, so marked in the Reservoir rocks, is still a conspicuous feature. On this flank was the calcareous nodule mentioned by Prof. A. H. Green.[1] Two slides that I have had cut from this (111, 113) entirely agree with his description, 'decomposed tuff permeated by calcite.' The bed of which this is a remainder extends no doubt farther north, as on the scarped bank the bed is well exposed, and many fragments of more or less decomposed tuff (282) may be found on the small mound on the top of Tinker's Hill along the same strike.

Eastward of this is a bed of felsite (336). Eastward of this again, on the side and on the top of the steep bank which forms that flank of Tinker's Hill, is the vesicular rock which I had the pleasure of pointing out to Prof. Green.[2] My (sections 112 *a* & 283) show that the rock is vesicular and amygdaloidal. I cannot agree that this is a similar rock to the 'rock of Clutter's Cave,' though it is with great diffidence that I venture to differ from so high an authority as the late Prof. Green. My sections of the Clutter's Cave rock (7 *a*, 155, 160, 161 & 164) show much more augite, one of them (164) being quite a mosaic of that mineral, whereas the Tinker's Hill rock (291 *a*) has much more the appearance of an andesite than a basalt. My section 283 shows an extremely curious structure. It is very similar to another (180) which comes from a crag much farther south, but almost exactly on the same strike. In both sections are oval and circular rings of some isotropic mineral: inside the rings is chalcedony. The

[1] Quart. Journ. Geol. Soc. vol. li (1895) p. 5.
[2] *Op. cit.* p. 4.

Fig. 2.—*Plan and section of the Reservoir and the neighbouring area. (Scale: $\frac{1}{5000}$ or about 12 inches to the mile.)*



[A=Andesite D=Dolerite; F=Felsite; T=Tuff.]

origin of these rings appears to be very obscure, but it seems to me that they must arise from an originally vesicular structure in the rock. If this be so, as they occur in an isotropic mineral on the edge of an andesitic mass, it would show that this may have been the original surface.

Eastward of this is a narrow bed of felsite about 10 feet wide (292). Next, a bed of andesite (293) 54 feet wide: this, in one place, has a most distinct dip of 45° to the west. My slide shows a good deal of decomposed felspar and of a dichroic mineral, probably an altered augite.

Then again comes a bed of felsite (295), followed by andesite (296), and felsite again (297). In the last-mentioned slide is a curious doubled-up thread which polarizes yellow. The beds alternate until no more exposures are visible. There is a small crag of brecciated dolerite close to the eastern boundary. This corresponds apparently to the rock on the south-east of Hangman's Hill to which I refer later on. It is not possible to measure the definite width of each of these beds, but probably it is not very different from that described above.

There is one interesting rock on the south-eastern flank of Tinker's Hill (289) which has all the appearance of a breccia, and at times almost of a conglomerate. This also occurs on the northern flank of Broad Down: it is probably a crush-breccia. The great scarcity of tuffs is remarkable.

A little farther north is an interesting crag, in which a good junction between the felsites and andesites is exposed (278 & 279). In this case, however, the strike varies from that ordinarily observed, and as seen here it is N. 30° W. There are very few exposures of any sort farther north on Tinker's Hill.

It has been my endeavour to trace these beds over the area lying to the south, but the exposures are so few that the attempt has met with little success up to the present. There are scattered crags showing very much the same class of rocks as those in evidence at Tinker's Hill. One fine crag on the south-eastern flank of Hangman's Hill shows a rock which is a porphyrite, but very near a basalt (181 & 197). This is very similar to one (168) which came from the floor of the Reservoir.

A considerable quarry was opened in the north-eastern flank of Broad Down by the contractor for the Reservoir-works. Whether the rock (194) is a tuff or a 'fluff' (I mean by this term a fluxion-breccia in which the apparent fragments differ very slightly in mineral character, and in which there is not the jumble of fragments usually seen in a tuff) is uncertain. The felspars are fragmental, and the matrix is amorphous or glassy with microlites.

There are two other rocks to which attention may be called. I was searching for the junction of the felsites and the andesites on Hangman's Hill, and found a rock with a very peculiar microscopical structure (180). I have had the advantage of showing it to several high authorities on the subject, and it seems difficult to form a very definite opinion. I have already directed attention to the similarity between this specimen and another from Tinker's Hill (283): they are practically on the same strike, and I have described very shortly their characteristics. There is, however, a great development of epidote in this specimen, which is interesting when I call attention to the other rock that I wish to notice (179). This comes also from the southern flank of Hangman's Hill, within a few feet of 180. The rock is greenish grey with red spots, and very hard (+ 7 in Mohs's scale). Under the microscope it appears to be a highly altered felsite. Mr. Harker, in his 'Petrology' (p. 143), suggests that some of the rocks from the Reservoir may throw light on the origin of epidosites. Now this rock appears to be a true epidosite. The exposure is very small.

I need hardly refer to the rocks in the neighbourhood of Clutter's Cave: Mr. Rutley has described them very fully.[1] What their relation is to those shown by the Reservoir-excavation cannot at present be determined, beyond the fact that a similar rock appears in the series there. They are described by Mr. Rutley as basalts. I have failed to find any of the more acid rocks west of Clutter's Cave.

From the foregoing pages it may be inferred that a very interesting series of rocks is to be found in this limited area. Their age is not easy of determination: they may be, as Dr. Callaway has said in his paper,[2] of a very different period from the rocks of the main axis of the hills. It is evident, from the bosses of igneous rock that occur farther south in the Hollybush Sandstone, that some form of energy was being exerted at a much later date than the consolidation of the Malvern Hills. Whether these Reservoir rocks have any relation to a lost centre of volcanic activity in the neighbourhood must remain, for the present at least, a matter of conjecture.

I desire in conclusion to make my best acknowledgments to the late Prof. Green, Prof. Bonney, Prof. T. McK. Hughes, Mr. Rutley, Miss Raisin, Dr. Callaway, and Mr. H. H. Arnold-Bemrose, who have so kindly placed at my disposal the stores of their greater knowledge and experience.

Discussion.

Dr. Callaway called attention to the resemblance between these volcanic rocks and the Uriconian Series of Shropshire, in which all the principal types were represented.

Prof. Hughes thought that the beds described by the Author belonged to the Bangor Series—that is, to the volcanic beds which in the Bangor area rest upon the massive rhyolites. Those lower rhyolites, which he had distinguished under the name Dinorwig Series, were not, he thought, represented in the Malvern reservoir-section. These two series together constituted Dr. Hicks's original Pebidian. The geological structure of the district he explained by

[1] Quart. Journ. Geol. Soc. vol. xliii (1887) p. 497.
[2] *Ibid.* vol. xxxvi (1880) p. 536

a system of faults running through by Wind's Point, throwing down the volcanic series to the east and south, and causing the advance of the gneissic series towards the Severn Valley in front of Wind's Point.

Prof. Watts pointed out that in the Lickey Hills some of the rhyolites and rhyolitic ashes were so much impregnated with carbonate of lime that they might be easily mistaken for limestone.

Prof. Bonney expressed his sense of the value of the paper, for the subject was one so difficult that only a resident could adequately deal with it. He thought that the carbonate of lime might have filtered down from Silurian limestones that had been subsequently removed by denudation. He was disposed to regard the rocks described by the Author as considerably later than the Malvernian crystallines, though yet Archæan. He might mention that traces of rhyolitic rocks had been found by his friend Mr. Coles in grits on the Abberley Hills.

The President and Mr. H. H. Arnold-Bemrose also spoke.

The Author thanked the Society for their kind reception of his paper. He said that the presence of the lime might be explained on the supposition that the area was at one time overlain by the Silurian rocks. He had in his possession a *Favosites* which had been found just below the filter-beds.

35. *On the* Discovery *of* Natural Gas *in* East Sussex.

By C. Dawson, Esq., F.G.S., F.S.A. (Read June 8th, 1898.)

I. Various Discoveries of the Gas.

The first record of the discovery of an inflammable natural gas in East Sussex is contained in Mr. Henry Willett's 13th Quarterly Report of the Subwealden Exploration (Netherfield), 1875. It is there stated that in making experiments on the temperature, etc. at various depths, and on lowering a light in the bore-tube, an explosion occurred. Strange oscillations in the depth of the water are reported to have been noticed, which at the time were attributed (*inter alia*) to the discharge of inflammable gases derived probably 'from the petroleum-bearing strata beneath' (the Kimeridge Clay).

Another discovery of inflammable natural gas occurred in the year 1895, when a deep artesian bore-tube (6 inches in diameter) was sunk in the stable-yard of the New Heathfield Hotel, close to the Heathfield Station of the London, Brighton, & South Coast Railway Company (Eastbourne & Tunbridge Wells Branch) in the parish of Waldron, East Sussex. At the depth of 228 feet, the foreman of the work noticed that the water which had been put down the borehole to assist the working of the tools was 'boiling.' As he was about to lower a candle to discover the cause, the gas arising from the bubbles caught fire, and burnt 'to about the height of a man.' Subsequently the foreman attached small tubes and ignited the gas at a distance of 15 yards from the borehole. Although he appears to have reported the details of the strata traversed to his employers, he does not seem to have mentioned the discovery of the gas until enquiries were made by the writer, who had heard of it from other eye-witnesses. This boring was not carried any deeper, as no water had been discovered. The borehole has now been covered over, and the upper part cemented and used as a sump.

The third and last discovery was made in August 1896 [1] at a site about 100 yards distant, on lower ground than the last, in the railway-cutting between the north-eastern end of Heathfield Railway-station and the mouth of the tunnel, by the side of the permanent way. The Railway Company desired to obtain a better quality of water for their engine-tank, than that afforded by the present surface-spring supply. Accordingly a 6-inch bore-tube was sunk, commencing at the bottom of a sump 73 feet deep, into which the surface-water had been allowed to flow. The details of the boring are appended (see p. 570). Gas appears to have been discovered a long time before its inflammable properties were tested, a strong odour of gas having been noticed for some days, but the smell was attributed to the presence of 'foul air' in the bore-

[1] A preliminary note of this discovery was given by the Author in 'Nature' of Dec. 16th, 1897 (vol. lvii, pp. 150, 151), with illustrations. See also Proc. S. E. Union Sci. Soc., June 3rd, 1898.

tube. At the depth of 312 feet from the level of the permanent way, the smell and rush of the gas were so pronounced that (by way of experiment) someone applied a lighted match to it, when a body of flame sprang up, the height of which is variously stated, the maximum estimate being 16 feet. It was extinguished with great difficulty, by means of damped cloths thrown over the mouth of the tube. The gas continued to increase during the remainder of the depth bored. The boring was abandoned at the depth of 377 feet, no useful amount of water having been obtained. The wrought-iron tubes were withdrawn from the borehole, with the exception of about one length which still remains in the ground, the tube being continued upward to near the top of the sump. A cast-iron cap has been screwed on to the top of the bore-tube, with a ½-inch bend and stopcock affixed thereto, allowing a continuous escape of gas for the past 18 months.

II. Pressure of the Gas.

Notwithstanding the fact that the bore-tube can be swayed about by the hand at the top of the sump, and that so small a length of tubing remains in the borehole, there appears to be no leakage of the gas between the rock and the iron casting, as evidenced by the absence of bubbles rising through the 13 feet of water now at the bottom of the sump. The joints of the tubing, and the cast-iron cap above the water, are however all very leaky, and the gas may be lit at any of them. An estimate of the pressure under these circumstances can furnish but little guidance as to the pressure of the gas beneath. However, in order to obtain some idea of it, notwithstanding these leakages, a new steam pressure-gauge was affixed to the ½-inch outlet, the stopcock in the cap being first turned off for a few hours (March 1898). The indicator then registered 15 lbs. to the square inch: this pressure was maintained for about 3 weeks (the gauge being then removed), but continually varied slightly, the gauge suddenly rising to ½ lb. in excess, and then slowly subsiding to the 15 lbs.[1] This rise was no doubt to be attributed to the bursting of large bubbles upon the surface of the water beneath. When the ear was applied to the mouth of the bore-tube, the bubbles of gas could be heard loudly and continuously bursting on the surface of the water, which stands in the tube 117 feet below the ground-level. On testing the borehole in March 1898, it was found to be blocked up with blue clay or shale at the depth of 229 feet from the ground-level, the bed having probably swollen and closed up the borehole at that point. It will thus be seen that, at the present time, the supply of gas rising to the surface is only a fraction of that which came up when the boring was not obstructed, before the tubes were withdrawn.

The foregoing details furnish us with a minimum estimate, the real pressure of the gas-field below being probably much greater.

[1] [The pipe has been lately caulked, but still leaks; on June 11th, 1898, it registered 20 lbs. per square inch.]

Coupled with this also we must consider the pressure exerted by a column of water, which, when the tube is clear, stands at 260 feet, and thus exerts the pressure of about 8 atmospheres (= about 120 lbs. per square inch), which the gas at the bottom must overcome before it can make its way through the porous strata into the tube.

Under the present conditions, when the gas is allowed to escape freely from the 6-inch outlet, when all abnormal pressure of collected gas in the empty tube above the water has been dissipated, and the tube is connected to a gas pressure-gauge, it shows a pressure of 20 tenths of an inch of water, rising to 180 tenths (the limit of the gauge employed) in 25 minutes when the water at the top of the gauge is forced out.

Under the same conditions, the amount of gas supplied, tested by a 10-light dry meter (½-inch outlet), with a pressure of 20 tenths maintained in the bore-tube, amounted to 12½ cubic feet per hour.

III. Analysis of the Gas.

The gas has been analysed on the spot by Mr. S. A. Woodhead, B.Sc. (the County Analyst for East Sussex), who kindly conducted the experiment for the purpose of this paper.[1] He reports as follows:—

[July 7th, 1898.

I examined the natural gas at Heathfield Station on Jan. 26th & 27th, 1898, and found the gas as it issued from the bore-tube to be colourless, neutral to test-papers, and possessing a faint paraffin-like odour. When mixed with air it was extremely explosive. It possessed great heating properties, and gave a fine flame in a Bunsen burner.

I analysed the gas, and found its approximate composition to be as follows:—

	Per cent.
Oxygen	18
Higher hydrocarbons	5·5
Carbon monoxide	4·0
Marsh gas[2]	72·5
Total	100·0

The presence of so much oxygen was surprising, but nevertheless it was present, and in such proportion as to make the gas slightly explosive. It was so remarkable that I carried out the analysis twice, with similar results within a few decimal places.

There were no impurities in the gas, such as ammonia, hydrogen sulphide, or carbon dioxide.

The water standing in the borehole, through which thousands of feet of gas must have passed, was analysed by me with a view to discover these impurities, but beyond the discovery of 0·2 parts per million of ammonia nothing remarkable was noticed. The analysis points to the gas being a petroleum-derivative.

Sam. A. Woodhead,
Public Analyst.]

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[1] He fitted up a laboratory on the spot, and checked all his results twice.

[2] On explosion with oxygen on two separate occasions there appeared to be the slightest sign of expansion, which probably indicated the presence of a little ethane.

IV. Origin of the Gas.

Appended to this paper are detailed descriptive sections of the two wells at Waldron (see pp. 569 & 570). The details show that the borings commenced low down in the Ashdown Sands, traversed the whole of those clay-beds below called the Fairlight Clays, and extended into the upper beds of the Purbeck Series.

The division between the Fairlight Clays and the Purbeck Beds appeared to be fairly well marked off by a bed 5 feet in thickness, composed of blue sandy marl-rock, containing bands of bituminous shale and broken fossils. This bed was followed by a series of shelly rocks which were penetrated to a depth of about 38 feet. The following marine and brackish-water mollusca have been identified in the series of rock-samples [1]:—*Melania*, *Hydrobia* (?), *Corbula oblata*, *Cyrena*, *Cardium*, and *Ostrea*. None of these shells, except *Cyrena*, occur in the Fairlight Clays.

Note on the Mollusca.

The writer considers that the appearance of the brackish-water shells in the strata at the bottom of the Hastings Beds marks the true horizon or junction between the so-called Sussex 'Purbecks' and the 'Hastings Beds,' and there is no other indication which can be considered reliable. Thus the appearance of these brackish-water forms denotes the commencement, or, more strictly speaking, the termination of a transitional stage between the more marine beds of the Lower 'Purbeck' strata and the freshwater deposits of the 'Hastings Beds.' There seems to have been a very gradual passage; and the writer is inclined to doubt that the Sussex 'Purbecks' can ever be properly subdivided into the Upper, Middle, and Lower divisions of the Dorset series, since they never appear to become so decidedly marine as the Middle Purbeck of Dorset. It appears to him that the Wealden Beds and these Purbeck Beds will eventually have to be grouped together under one head, since they seem all to have had a common origin.

Considerable misapprehension has been caused by the reported discovery of brackish-water and marine shells in the lower horizons of the Hastings Beds at Heathfield, Burwash, and Brightling (Pounceford and Perch Hill). As a matter of fact, neither Mr. Philip Rufford (of Hastings) nor the writer, who have made a considerable study of these rocks, have ever discovered such shells in the lower horizons of the Hasting Sands; and we do not believe them to exist. The truth seems to be that people have wandered about collecting at Heathfield, Burwash, and Brightling, under the impression that the fossils which they were discovering belonged to

[1] At a depth of between 339 and 377 feet. These beds were very uniform in appearance and structure.

the lowest beds of the Hastings Sands; whereas it is clear to the local observer, both from the localities named by these collectors and from the appearance of the matrices in which these brackish-water forms occur, that the specimens are obtained from the narrow strip of the Sussex Purbeck Beds, which is exposed and has been so mapped by the officers of the Geological Survey in that neighbourhood. The collectors have unconsciously strayed over the division-lines, and specimens collected by them have been wrongly labelled as Wealden forms in the principal museums of England.

Origin of the Gas (*continued*)

Returning to the question of the origin of the gas found at Heathfield, the writer considers that it is derived for the most part from lower beds, either in the Purbeck Series or the Kimeridge Clay. It is true that in most of the Wealden Group beds of lignite occur of considerable thickness[1]; but the phenomenon of spontaneous gas-generation has never been recorded with respect to them. Certain small beds of lignite actually occur in these borings; but, on glancing through the list of the rock-details appended, I do not perceive any adequate source of this enormous accumulation of gas.[2]

Traces of petroleum and bituminous matter not uncommonly occur in the Wealden Beds, but in no considerable quantity. The Purbeck strata (Brightling Series) are a little richer, and it has even been attempted to turn some of the bituminous shales between the greys and the blues to practical account. Mr. R. Hallett, of Swifes Farm, Burwash, had several tons of an unctuous blue clay, exposed in a ghyll or valley near there, operated upon and extracted tar, and subsequently a variety of products, such as pitch, grease, oil, naphtha, and paraffin. But by far the richest supply of paraffin yet discovered in the Sussex rocks, occurred in the Kimeridge strata, penetrated by the Subwealden boring at Netherfield in 1875. I learn from Mr. Henry Willett that slight indications of petroleum were noticed all through the Kimeridge Clay in this boring, but they became more distinct at about 160 feet from the top of the clay (or 450 feet from the surface)[3]; all below that depth was more or less impregnated with petroleum, it being particularly abundant at the following

[1] See W. Topley, Geol. Surv. Mem. of the Weald, 1875, p. 347. The thickest bed of lignite described at Waldron occurs in rocks higher than those in which the Heathfield Station boring was commenced.

[2] The foreman of the works said that the strata seemed full of it, for at least 100 feet.

[3] A great thickness of strata (about 500 feet) intervenes between the bottom of the Heathfield borings and the horizon of the gas discovered in the Subwealden boring. At the same time, it may be stated that in the American natural gas-fields the gas has been proved to rise great distances above its source—the distance depending entirely on the suitability of the structure of rock. See Reports of the Departments of Geology of Indiana (1886–1894) Pennsylvania (1886), California (1897), and Ohio, vol. vi.

depths from the surface:—600, 604, 617, 622, and 651 feet. Fossils were scarce or absent in those parts of the clay which were richest in petroleum. The lower shales in the clay smelt strongly of petroleum, and burnt with a brilliant yellow flame.

The lighter gases given off from the lower beds probably rise through the more porous rocks and fissures, and may be found in more or less abundance, according to the varying structure and texture of the rocks at different horizons. Of course the richest supply will be that which is held back by some comparatively impervious band—especially where such band forms an unbroken arch in an anticlinal. In such cases the gas will collect within the dome or arch by specific gravity, from the lower-lying porous rocks covered by the impervious roof; and the higher up the anticlinal the arch is pierced, the greater will be both the supply and the pressure. At Heathfield the borings pierce the southern slope of a great anticlinal which runs from Fairlight far into Mid-Sussex. It is joined at Heathfield by another considerable anticlinal running through Burwash, and it is here that the lowest strata in Sussex are exposed by upheaval and denudation. The gas rising through the lower petroleum-bearing rocks in the course of ages has probably become 'trapped' in the dome formed by the more clay-bound strata of the Lower Ashdown Beds, the Fairlight Clays, and the probability is that over the whole of the higher lands of this district the natural gas will be found to occur.

1. SECTION *at* HEATHFIELD NEW HOTEL. (*493 feet above O.D.*)

		Thickness Feet	Thickness In.	Depth Feet	Depth In.
Dug Well.	Dark brown rusty ferruginous sand, with very thin bands of lignite	5		5	
Dug Well.	Light yellow and grey sand, with thin bands of lignite	5		10	
Dug Well.	Slate-coloured marl	1		11	
Dug Well.	Yellow and white bands of sand	10		21	
	Sandstone and blue marl in layers	11		32	
	White sandstone	18		50	
	White sandstone, and layers of clay and marl	9		59	
	Bluish sandstone	2		61	
	Bluish sandstone and layers of marl	10		71	
	White and yellow sandstone	5		76	
	Bluish sandstone and marl	10		86	
	Blue marl	3		89	
	Sandstone and marl	5		94	
	Blue marl	57		151	
	Hard sand-rock	4	6	155	6
	Blue marl	12	6	168	
	Hard stone	1	6	169	6
	Hard blue marl	46	6	216	
	Sand-rock	3		219	
	Blue marl (gas first noticed at 228 feet)	30		249	

2. Section *at* Heathfield Railway-station. (*This well is commenced on ground 43 feet lower than the former one, and about 60 yards south of it. Height = 450 feet above O.D.*)

	Thickness Feet	In.	Depth Feet	In.
Dug Well (no record; comparison may be made with the former section—see 186 feet below [1])			73	
Grey sandy marl-rock	6		79	
„ marl-rock, with bands of grey sandstone	17	6	96	6
Blue sandy marl-rock	4		100	6
„ „ with bands of grey sandstone	2	6	103	
„ shale and fossils, grey sandstone with lignite and ironstone	9		112	
Blue marl-rock, with bands of grey sandstone and ironstone	15	6	127	6
„ „ and shale	3	8	131	2
„ sandy marl-rock, with occasional ironstone.	8	10	140	
Hard grey sandstone	1	9	141	9
Blue sandy marl-rock	1	3	143	
„ with bands of grey sandstone	9		152	
„ „ and ironstone	9	6	161	6
Grey sandstone	1	3	162	9
Blue sandy marl-rock, with bands of grey sandstone and ironstone	8	6	171	3
Grey sandstone	1	9	172	
Blue sandy marl-rock, with bands of grey sandstone and ironstone	12		184	
Grey sandstone		8	184	8
Blue sandy marl-rock, with bands of grey sandstone and ironstone	3	4	188	
Blue sandy marl-rock, with ironstone	8	3	196	3
Hard grey calcareous sandstone	1	2	197	5
Blue sandy marl		1	197	6
Grey calcareous sandstone		3	197	9
Blue sandy marl		1	197	10
Grey calcareous sandstone		4	198	2
Blue marl-rock		2	198	4
Grey calcareous sandstone		3	198	7
Bands of the same, and blue marl-rock	1	11	200	6
Blue shale, with thin bands of grey calcareous sandstone	7	6	208	
Blue marl-rock, with thin bands of blue shale ...	6		214	
„ „ „ hard blue shale	1		215	
Blue shale	2	6	217	6
Grey sandstone	1	6	219	
Blue sandy marl-rock	5	6	224	6
„ „ with bands of blue shale...	8		232	6
„ „ and grey sandstone	3	6	236	
„ „ with nodules of clayey ironstone	8		244	
Blue sandy marl-rock and shale	13	6	257	6
Bands of blue sandy marl and shale, with bands of greyish sandstone	7		264	6

[1] [186 feet is the corresponding horizon where the gas was noticed at the hotel, situate 42 feet above top of this well.]

	Thickness Feet	Thickness In.	Depth Feet	Depth In.
Brown and greenish sandy marl, with thin bands of marble	2	6	267	
Blue and greenish sandy marl, with bands of shale	3	6	270	6
Blue and grey do., with bands of shale	6		276	6
Blue, brown, and greyish marl and shale	10	6	287	
Brown and greyish sandy marl and blue shale	13		300	
Grey sandy marl-rock and shale	12		312	
(Gas first lighted, 312 feet.)				
Blue sandy marl-rock and shale	1		313	
Greyish limestone		1½	313	1½
Blue sandy marl-rock	2	10½	316	
„ „ with nodules of grey sandstone	5		321	
„ „ with bands of shale	18		339	
(*Paludina fluviorum*, 333 feet.)				
Blue sandy marl-rock, with bands of bituminous shale and broken fossils (*Corbula* and *Cyrena*, 347 feet)	8		347	
Blue sandy marl-rock, and bands of hard bituminous shale with shells (*Ostrea*, *Melania*, *Hydrobia*?, *Corbula*, *Cyrena*, *Cardium*, etc., 353 feet *et seq.*)	6		353	
Bands of shell-rock and shale	3	6	356	6
Blue sandy marl, and bands of shale with shells.	5	6	362	
Blue shale and bands of shell-rock	3	6	365	6
Shell-rock		8	366	2
Bands of blue shale and marl with shells	1	4	367	6
Blue shale and hard bands of shells	3	6	371	
„ sandy marl, and bands of shale with shells	6		377	

The above details of depth and description of the rocks were supplied by Messrs. Le Grand & Sutcliffe, who made both borings. The Author wishes to place on record his sincere thanks to them for opportunities courteously given to examine the rock-samples, and for general information with respect to the subject.

36. NOTE *on* NATURAL GAS *at* HEATHFIELD STATION (SUSSEX). By J. T. HEWITT, M.A., D.Sc., Ph.D. (Communicated by the PRESIDENT. Read June 8th, 1898.)

IN a boring made for water some months ago at Heathfield Railway-station (L. B. & S. C. R.) an outflow of natural gas was encountered. A cap provided with a cock was placed at the outlet of the boring, and thus the collection of a sample of the gas for analysis was an easy matter. Owing to the courtesy of Mr. R. J. Billinton, the Locomotive Engineer of the London, Brighton, & South Coast Railway, who not only gave me the necessary permission, but also placed every facility at my disposal, I was enabled to take a sample of the gas on Dec. 31st, 1897. Mr. Billinton further informed me that a bed of lignite had been encountered at a depth of about 300 feet; this was of considerable thickness, and was supposed to be the stratum in which the gas had its origin. He very kindly provided me with a specimen of this substance, which one can perhaps better regard as a shale; this also was analysed.

ANALYSIS OF THE GAS.

(*Hempel Method and Apparatus.*)

	Per cent.
Methane (CH_4)	91·9
Hydrogen (H_2)	7·2
Nitrogen (N_2)	0·9
	100·0

The gas was examined for oxygen, carbon dioxide, carbon monoxide, olefines, and hydrocarbon vapours; these were found to be absent.

ANALYSIS OF THE SHALE.

In the first place the shale was analysed according to the customary method of carrying out commercial analyses for coal. The following result was obtained:—

	Per cent.
Moisture	4·90
Volatile matter	15·55
Fixed carbon	1·74
Ash	77·81
	100·00

It should be pointed out that very little reliance can be placed on the numbers for volatile matter and fixed carbon, as, owing to the large amount and porous nature of the ash obtained, it is extremely easy to increase the percentage of volatile matter and diminish that of the fixed carbon, by the combustion of the latter, even with the lid firmly fixed on the platinum crucible in which the analysis is conducted.

Under these circumstances it was very desirable to make a full elementary analysis, which was carried out with a sample dried at 110° to 115° Centigr. In this case we have to deal with 18·18 per cent. of organic material and 81·82 per cent. of ash.

	Per cent.
Carbon	9·43
Hydrogen	1·83
Nitrogen	0·68
Sulphur	1·27
Oxygen (by difference)	4·97
Ash	81·82
	100·00

The sulphur is here reckoned with the organic material; considering, however, that on burning the shale the smell of sulphur dioxide is noticeable, and moreover that the ash contains some $2\frac{1}{2}$ per cent. of sulphur trioxide (as sulphates), it is very probable that the sulphur of the shale actually exists as pyrites. If so, this will make the oxygen percentage, obtained by difference, considerably too low. Taking the above figures, however, and making no correction for the oxidation of sulphides, we should obtain for the organic material of the shale the following result:—

	Per cent.	Per cent.
Carbon	9·43	51·87
Hydrogen	1·83	10·07
Nitrogen	0·68	3·74
Sulphur	1·27	6·99
Oxygen	4·97	27·33
	18·18	100·00

The ash gave the following results on analysis:—

	Per cent.
Silica (SiO_2)	59·72
Alumina (Al_2O_3)	24·40
Ferric oxide (Fe_2O_3)	7·03
Lime (CaO)	2·14
Magnesia (MgO)	0·96
Sulphur trioxide (SO_3)	2·54
Phosphorus pentoxide (P_2O_5)	absent
Alkalies and loss (by difference) on analysis	3·21
	100·00

In conclusion, I desire to express my cordial thanks to Mr. Billinton for the courtesy and kindness with which he placed material at my disposal in the course of this investigation.

Discussion (on the two preceding Papers).

Mr. J. E. Clark remarked that, in view of the strong divergence in the analyses, it would be of interest if the new method by liquefaction could be applied, by the co-operation of the Royal Institution. The idea of collecting the possible gas escaping at the surface beneath ice was interesting. But would it be easy to get areas still enough to freeze, where the absence of all surface-generated marsh-gas could be guaranteed?

Mr. E. T. Newton, having seen specimens from the Heathfield boring, remarked on the difficulty of distinguishing between the Wealden and the Purbeck beds; but, judging from the few fossils identifiable, he thought that Mr. Dawson was correct in ascribing the beds met with at a depth of 353 feet to the Purbeck Series. He also spoke of the high pressure at which the gas escaped from the pipe, when the boring was visited by him about a fortnight before the reading of these papers.

Mr. C. E. Masterman thanked the Fellows for their appreciation of his attempt to demonstrate the suitability of the gas for lighting by incandescent mantles. He explained the nature of the burners used, and said that he hoped shortly to be able to perfect the apparatus still further.

The President and Dr. Isaac Roberts also spoke.

Mr. Dawson said that the absence of the higher hydrocarbons in Dr. Hewitt's analysis could not be reconciled with the normal appearance of the gas, which could not be distinguished from the appearance of ordinary coal-gas, and burnt with a bright yellow flame, as might be seen from the sample now shown on the table. Assuming both analyses to be correct, then the gas must vary very considerably. Although variation had been noticed in the North American natural gas, it had scarcely been to this extent. The analyses of the lignite yielded results similar to those of most lignites. The bands of lignite at the particular horizon from which the analysed sample was taken were thin, and mixed with shale. Thicker beds (about 2 feet) had been met with at Waldron, but no gas had been discovered in them. He considered that the gas was probably derived from the underlying petroleum-bearing strata.

He wished to express his thanks to Mr. E. T. Newton, for the identification of the Purbeck fossils; to Messrs. Le Grand & Sutcliffe, Mr. C. O. Blaber, C.E., and Mr. John Lewis, C.E., for kindly supplying details and plans of borings; and to Mr. S. A. Woodhead, B.Sc., for his analysis.

Dr. Hewitt said, in reply to Mr. Dawson, the fact might be mentioned that vegetable matter, when buried, from the time of its death and through all stages until its final conversion into coal or anthracite, continuously gives off methane; this is shown in the occurrence of marsh-gas and of firedamp. Hence there is nothing absurd in the supposition that the gas actually arose from the clay-bed impregnated with vegetable matter, the analysis of a sample of which had been given. A natural gas having the composition given in the analysis might equally as well have arisen from a known bed containing organic matter as from a hypothetical petroleum-bearing deposit.

37. Post-Glacial Beds *exposed in the* Cutting *of the new* Bruges Canal. By T. Mellard Reade, Esq., C.E., F.G.S. (Read June 22nd, 1898.)

[Abridged.]

When in Belgium in the spring of 1897 as the guest of Prof. A. Renard, of Ghent University, I travelled with him to the coast, to see the excavations of the new Bruges Canal near Heyst, about 6 kilometres from Blankenberghe, a well-known Flemish watering-place. The beds exposed by the excavations bore so striking a resemblance to those which I have studied and mapped in the neighbourhood of Liverpool that I examined them with great interest, and succeeded in identifying the several beds with the deposits carefully mapped in detail by the Belgian Geological Survey on the $\frac{1}{40,000}$ scale. The following beds, enumerated in descending order, were found:—

5. Argile des polders supérieure, equivalent to the Marsh Clay of England.
4. *Cardium* [*edule*]-sand.
3. Argile des polders inférieure.
2. *Scrobicularia* [*plana*]-clay.
1. Peat.

The junction between the clay and the peat is very inconstant; in one place it may be seen markedly distinct and horizontal, and in another very irregular, as if intersected with gullies which had afterwards become filled with the *Scrobicularia*-clay, while above in the base of the clay thin seams of peat are seen intercalated. It is precisely the sort of interchange of *Scrobicularia*-clay and peat that I described as occurring near Southport and at Birkdale in a paper read before the Liverpool Geological Society in 1871.[1] I took out of this clay *Scrobiculariæ* in the vertical attitude of life, just as they occur in our own Formby and Leasowe Marine Beds.

Specimens were taken of the Argile des polders supérieure or Marsh Clay and of the *Scrobicularia plana*-clay, and were afterwards mechanically analysed and microscopically examined, with the following results:—

Argile des polders supérieure.

Weight before washing .... 4 oz.=1·000	
Weight after washing:—	
Retained in the $\frac{1}{20}$-inch mesh	·0005
,, ,, $\frac{1}{40}$,, ,, ...	·0010
,, ,, $\frac{1}{100}$,, ,, ...	·0078
Passed the $\frac{1}{100}$-inch mesh, and deposited by subsidence	·3854
	·3947

Sand = 39 per cent.; clay = 61 per cent.

[1] 'The Geology & Physics of the Post-Glacial Period as shown in the Deposits & Organic Remains in Lancashire & Cheshire,' Proc. L'pool Geol. Soc. 1871–72, pp. 36–88, with four coloured plates of maps and sections.

The foregoing analysis shows how extremely minute the grains of this material were, as only ·0093 of the whole remained in the sieve-meshes, while 61 per cent. of the whole passed off in the floatings and was not even deposited by subsidence.

The material in the $\frac{1}{20}$-inch mesh consisted of shell-fragments, two minute helical shells, some spore-cases, a few grains of sand and globular or pear-shaped aggregates of calcite-crystals. The $\frac{1}{40}$-inch mesh material was largely composed of similar but smaller calcite-grains, with some very rounded and smoothly worn quartz-grains, together with very thin and highly glazed shell-fragments. The material from the $\frac{1}{100}$-inch mesh contained a larger proportion of quartz-grains, some highly rounded and polished, many of the normal calcite-grains, a fair proportion of shell-fragments, flakes of mica, some foraminifera, and a few vegetable fibres. The shell-fragments consisted of both flakes and portions of highly curved helices. The material that passed the $\frac{1}{100}$-inch mesh and was deposited by subsidence consisted of 38 per cent. of the whole. It was a grey powder, mostly made up of clear quartz-sand in very even-sized grains. Some of these were as rounded and highly polished as any that I have ever seen. Two of these grains I remarked specially, as they are less than $\frac{1}{200}$ inch in diameter on the longer axis, and under the microscope are seen to be most beautifully rounded and polished: they are, in fact, microscopical pebbles.

Dr. G. J. Hinde kindly examined specimens of these sedimentary washings for me; of the $\frac{1}{100}$-inch mesh material he says:—'The sample contains a very few broken fragments of spicules of tetractinellid siliceous sponges, now white or changed into crystalline silica, and with the axial canal filled with foreign material, and they evidently originate from Cretaceous beds. The finer sample (that which passed the $\frac{1}{100}$-inch mesh) contains broken fragments of acerate and pin-shaped spicules of monactinellid sponges, very fresh-looking, and they might well belong to forms still living or to those in Tertiary beds; they are certainly more recent than the white crystalline spicular fragments.'

A parcel of this clay was submitted to Mr. Joseph Wright, of Belfast, to whom I am much indebted for the thorough examination which he has made of the foraminifera. The following is his report:—

Argile des polders supérieure.

Weight, 5·6 oz. troy. After washing: fine, ·8 oz.; coarse, ·004 oz. One angular stone. Foraminifera plentiful.

List of Foraminifera.

**Textularia globulosa*, Ehr.[1] Rare.
Bolivina plicata, d'Orb. Rare.
**Lagena globosa* (Mont.). Very rare.
,, *Williamsoni*, Alcock. Very rare.

1 [The species of foraminifera marked with an asterisk in this and subsequent lists in the present paper have been already recorded from similar deposits at Ostend which appear to be classified together as Argile des polders. See Van den Broeck, Ann. Soc. Belg. Microsc. vol. iii (1877) pp. cxvi–cxxi.—T. M. R.]

* *Uvigerina angulosa*, Will. Very rare.
Globigerina bulloides, d'Orb. Rare.
Discorbina Wrightii, Br. Rare.
* *Truncatulina lobatula* (W. & J.). Frequent.
* *Rotalia Beccarii* (Linn.). Rare.
* *Nonionina depressula* (W. & J.). Very common.
* *Polystomella striato-punctata* (F. & M.). Common.

About 300 specimens of *Nonionina depressula* were obtained from this gathering, while the remaining 10 species comprised in all only 40 specimens. A few mollusca were also found, namely, two specimens of *Limnæa peregra* and four of *Zonites nitidulus*, fresh-water and land-shells, no doubt washed into the clay from higher levels.

Cardium-Sand.

This was a fine silty grey sand containing quartz-grains, some rounded calcareous grains, and a few of glauconite. Some of the quartz-grains are fairly well rounded. It is full of valves of *Cardium edule* and many shell-fragments, some very minute and thin. Sponge-spicules and spines of *Echinus* are not uncommon.

Mr. Wright says of this sand:—

Weight of specimen 9·5 oz. troy; after washing, 8·3 oz. fine, nothing remained but a few *Cardium*-shells. Foraminifera extremely abundant. Ostracoda common.

List of Foraminifera.

Biloculina depressa, d'Orb. Two well-grown specimens.
Spiroloculina acutimargo, Brady. One typical specimen.
Miliolina trigonula (Lam.). Rare.
,, *oblonga* (Mont.). Common.
* ,, *seminulum* (Linn.). Common.
,, *Auberiana* (d'Orb.). Frequent.
* ,, *subrotunda* (Mont.). Very common.
,, *seminuda*, Reuss. Rare.
,, *bicornis* (W. & J.). Rare.
,, *Boueana* (d'Orb.). Very rare.
* *Trochammina inflata* (Mont.). Very rare.
Cornuspira involvens, Reuss. Very rare.
Textularia gramen, d'Orb. One very small specimen.
* ,, *globulosa*, Ehr. Frequent; may be derived from the Chalk.
Bulimina pupoides, d'Orb. Very rare.
* ,, *elegantissima*, d'Orb. Very rare.
,, sp. A few small, obscure specimens, probably derived from the Chalk.
* *Bolivina punctata*, d'Orb. Frequent.
,, *plicata*, d'Orb. Very common.
,, *obsoleta*, Eley. Very rare.
Cassidulina crassa, d'Orb. Very rare.
* *Lagena lævis* (Mont.). Very rare.
,, *lineata* (Will.). Frequent.
,, *Williamsoni* (Alcock). Rare.
,, *hexagona* (Will.). Very rare.
* ,, *marginata* (W. & B.). Rare.
* ,, *lucida* (Will.). Very rare.
,, *Orbignyana* (Seguenza). Very rare.
,, *bicarinata* (Terq.). Very rare.
Cristellaria crepidula (F. & M.). One large specimen.
Polymorphina gibba, d'Orb. Very rare.
,, *lanceolata*, Reuss. Very rare.

Polymorphina rotundata (Born.). Very rare.
* *Uvigerina angulosa*, Will. Frequent.
Globigerina cretacea, d'Orb. Common; probably derived from the Chalk.
Orbulina universa, d'Orb. Rare; specimens very small.
Patellina corrugata, Will. Very rare.
* *Discorbina globularis* (d'Orb.). Very rare.
,, *rosacea* (d'Orb.). Common.
,, *orbicularis* (Terq.). Very rare.
,, *Wrightii*, Brady. Very common.
,, *Bertheloti* (d'Orb.). Very rare.
Planorbulina mediterranensis, d'Orb. Rare.
* *Truncatulina lobatula* (W. & J.). Very common.
Pulvinulina Menardii (d'Orb.). Very rare.
,, *Hauerii* (d'Orb.). Very rare.
,, *patagonica* (d'Orb.). ? One small specimen.
,, sp. near *auricula* (F. & M.). One small specimen.
* *Rotalia Beccarii* (Linn.). Very common.
* *Nonionina depressula* (W. & J.). Extremely abundant.
,, *Boueana*, d'Orb. Rare.
,, *scapha* (F. & M.). Two large specimens.
Polystomella crispa (Linn.). Very rare.
,, *macella* (F. & M.). Rare.
* ,, *striato-punctata* (F. & M.). Extremely abundant.

Mr. Wright remarks that the sand from which these foraminifera were obtained is very fine and quite free from coarse materials, all that remained in the coarse sieve after washing being six or eight specimens of *Cardium edule*. Three specimens of *Hydrobia ulvæ* came up in the floatings, also several young of other molluscan shells. The foraminifera and ostracoda were, as a rule, in good condition, notwithstanding the pervious nature of the material in which they were embedded. The specimens of *Globigerina cretacea* were probably derived from older strata, and such may also have been the case with the specimens of *Textularia globulosa* and a few small *Buliminæ*, but the great bulk of the microzoa must have lived on the spot where they are now found. Only two specimens of *Trochammina inflata* were obtained, and these were so fragile that they went to pieces at the slightest touch, probably on account of their being arenaceous. A few specimens of diatoms were found, among which were the following species:—*Triceratium favus*, *Eupodiscus Argus*, and *Actinoptychus splendens*; also a few specimens of echinoderms.

A slide with the mountings of the ostracoda was submitted to Prof. G. S. Brady, who has kindly given me the following list of the species that he was able to name:—

List of Ostracoda.

* *Cythere confusa*,[1] Brady & Norman.
* ,, *pellucida*, Baird.
* ,, *porcellanea*, Brady.
,, *Macallana*, Brady & Robertson.
,, *oblonga*, Brady.

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[1] [Those species marked with an asterisk in the above list have been recorded from estuarine mud, etc. in Holland, in the neighbourhood of the rivers Scheldt and Maas.—T. M. R.]

* *Cythere villosa*, Sars.
,, *lutea*, Müller.
,, *albomaculata*, Baird.
,, *Robertsoni*, Brady.
Cytheridea punctillata, Brady.
Eucythere declivis (Norman).
Loxoconcha impressa (Baird).
,, *fragilis*, Brady.
,, *tamarindus* (Jones).
* *Cytherura angulata*, Brady.
* ,, *striata*, Sars.
* ,, *gibba* (Müller).
* ,, *cellulosa* (Norman).
Cytherideis subulata, Brady.
Cytheropteron, sp.?

Prof. Brady observes: 'The ostracoda are purely marine, and are almost identical in every way with such as we get on the Northumberland coast—in estuarine mud, or in muddy situations between tide-marks. Some of my lists from such localities might be substituted for yours with little or no variation.'

Scrobicularia [*plana*]-Clay
(resting upon peat).

A mechanical analysis of this clay yielded the following results:—

Weight before washing .... 3 oz. = 1·000	
Weight after washing:—	
Retained in the $\frac{1}{20}$-inch mesh	·0069
,, ,, $\frac{1}{40}$,, ,, ...	·0069
,, ,, $\frac{1}{100}$,, ,, ...	·0208
Passed the $\frac{1}{100}$-inch mesh, and deposited by subsidence	·7916
	·8262

Clay = 18 per cent.

Dr. Hinde says:—'The sponge-spicules from this material form a very insignificant proportion of its contents. I found only about a dozen fragments altogether in the coarser sample ($\frac{1}{100}$-inch mesh); these are for the most part trifid spicules of tetractinellid sponges resembling those of the recent genus *Geodia*. These spicules are now opal or milky white in appearance, like detached spicules found in the German Senonian or in our Upper Greensand, where similar forms are very common, and I should say that these Bruges spicules have been washed out of some Cretaceous beds. I find also one dermal spicule and one skeletal spicule of a lithistid sponge, having a similarly ancient appearance to those mentioned above.

'In the finer material (subsidence-matter) were some globate dermal spicules of *Geodia*-sponges, in the same condition as the trifids, and there were some fragments of acerate and pin-shaped spicules, probably of monactinellid sponges, which still retained the fresh glassy appearance of recent and Tertiary spicules, and these would probably be of the same age as the diatoms and fresh-looking foraminifera in the deposit.

'Some of the diatoms are pyritized like those found in the London Clay of Kent. I also noticed detached prisms of *Inoceramus*-shells such as occur in the Chalk, which simulate broken spicules, and minute broken spines of echinoderms looking very fresh.'

Mr. Wright reports upon this clay as follows :—

Scrobicularia plana-clay.

Weight, 8·7 oz. troy. After washing, 3·1 oz. fine, coarse none. Foraminifera abundant.

LIST OF FORAMINIFERA.

* *Trochammina inflata* (Mont.). Very common.
* *Textularia globulosa*, Ehr. Frequent.
Bulimina pupoides, d'Orb. Very rare.
* ,, *elegantissima*, d'Orb. Rare.
* *Bolivina punctata*, d'Orb. Rare.
,, *plicata*, d'Orb. Very rare.
,, *obsoleta*, Eley. Very rare.
Cassidulina crassa, d'Orb. Very rare.
* *Lagena globosa* (Mont.). Rare.
* ,, *lævis* (Mont.). Frequent.
* ,, *clavata* (d'Orb.). Frequent.
* ,, *sulcata* (W. & J.). Very rare.
,, *Williamsoni* (Alcock). Frequent.
* ,, *squamosa* (Mont.). Rare.
* ,, *lævigata* (Reuss). Frequent.
,, *Orbignyana* (Seg.). Very rare.
* *Nodosaria communis*, d'Orb. Very rare.
* *Cristellaria acutauricularis* (F. & M.). Very rare; large specimen.
* *Polymorphina lactea* (W. & J.). Frequent.
,, *lanceolata*, Reuss. Rare.
* *Uvigerina asperula*, Cz. Very rare.
* ,, *angulosa*, Will. Rare.
Globigerina bulloides, d'Orb. One very small specimen.
Orbulina universa, d'Orb. Rare; specimens very small.
Discorbina Wrightii, Br. Common.
* *Truncatulina lobatula* (W. & J.). Rare.
* *Pulvinulina Micheliniana* (d'Orb.). Very rare.
* *Rotalia Beccarii* (Linn.). Very common.
* *Nonionina depressula* (W. & J.). Extremely abundant.
,, *scapha* (F. & M.). Very rare; large specimens.
,, *Boueana*, d'Orb. Very rare.
* *Polystomella striato-punctata* (F. & M.). Extremely abundant.

Nonionina depressula and *Polystomella striato-punctata* occurred in the greatest profusion; it was estimated that about 17,000 specimens of the former and about 3000 of the latter occurred in this gathering, while the other 30 species included in all only 250 specimens. The floatings from which these results were obtained weighed only $2\frac{1}{2}$ grains.

The following diatoms were also plentiful in the clay, namely :—*Triceratium favus*, *Eupodiscus Argus*, and *Actinoptychus splendens*.

All the species of foraminifera, with the exception of *Cristellaria acutauricularis*, *Uvigerina asperula*, and *Bolivina obsoleta*, have been found off the British coast.

Physiography of the Deposits, and Comparison with the Post-Glacial Beds of Lancashire and Cheshire.

From the regular sequence, nature, and levels of these deposits it would appear that they have been laid down upon a land-surface which gradually subsided and was flooded by a shallow sea.

The succession of the beds described in this paper shows that they have been ushered in by a slight overflowing of the peat by the sea, and a deposit of clay, which has allowed the peat to continue growing contemporaneously with the deposit of clay, thus accounting for the inosculation and the irregular, undefined surface of the peat. The ground continuing to sink gradually, the *Scrobicularia*-clay alone was laid down in beds from 1 to 6 metres thick, according to the Belgian Survey. In these deposits, between tide-marks, *Scrobicularia plana* [1] flourished, as it does now in the estuarine mud of the River Mersey.

As the submerged plain became levelled up with this deposit the sea shallowed, and the thin bed, usually less than 1 metre thick, of the Argile des polders inférieure was deposited in places. Upon this was laid down the *Cardium*-sand, so rich in microzoa and full of the remains of *Cardium edule.*

This bed, according to the Belgian Survey from 3 to 4 metres thick, is a strikingly marine or estuarine deposit probably laid down in water of greater depth than either the previous or succeeding deposits. The water was again shallowed by the laying down of this sand, and by the final capping with the Argile des polders supérieure, upon the seaward margin of which the sand-dunes are now superimposed, and the artificial dykes built.

As regards these estuarine clays and silts, the microscopic examination shows that much of the material has been directly or indirectly derived from the underlying and surrounding Tertiary beds, and their distinction lies in the rich abundance in which marine and estuarine foraminifera and other microzoa of existing species occur.

What struck me in these deposits, as compared with those that I have mapped in North-west Lancashire and Cheshire, is their great expansion or horizontal extent at levels varying so little, as is shown in the Belgian Survey map. It would, in the British examples, be impossible, even by a careful systematic chain of borings, to trace successive zones in the way that the Belgian geologists have succeeded in doing.

As regards age, all the estuarine beds described are later than the peat representing the old land-surface, and this peat is newer-looking than the peat of our Lancashire and Cheshire submarine-forest bed, more nearly approaching the inland peat of Altcar and Martin Mere.

Discussion.

Prof. Hull spoke.

The Author, in answer to Prof. Hull, said that the peat in Galway Bay between tides was shown to him by the late Prof. W. King as actually in process of growth. While the peat and forest-beds all round our coasts indicated subsidence, the intercalation of thin seams of peat in either the base or upper part of a purely estuarine deposit such as *Scrobicularia*-clay, a phenomenon often seen, shows that the peat was growing in slacks on the shore while the deposit was in process of formation.

[1] [*Sc. piperata.*]

38. High-Level Marine Drift *at* Colwyn Bay. By T. Mellard Reade, Esq., C.E., F.G.S. (Read June 22nd, 1898.)

[Abstract.]

The drift-deposits of Colwyn Bay were described by the Author in 1885,[1] but at that time he did not find any marine drift above the 200-feet contour. In the winter of 1897–98 he was fortunate enough to discover a mound of marine drift, consisting of sand capped with Boulder Clay, at a level of 560 feet above Ordnance datum. It is situated at a distance of about 1 mile south-by-west of Colwyn Bay railway-station, the longer axis running in a north-easterly direction, and measuring about 90 yards, the shorter axis being about 50 yards in length. It stands upon the watershed separating the valleys of Nant-y-glyn and Colwyn Bay. It is evidently an outlier of the marine drift at a lower level, consisting as it does of the same well-rounded grains of quartzose sand, and containing far-travelled erratics, among which are Eskdale and South of Scotland granites mixed with Welsh rocks, many of which, according to Mr. T. Ruddy, to whom they were submitted, came from the head of the Conway Valley. The interest of this find lies in the apparent isolation of the mound and its situation on the watershed at a high level. The intervening ground between the mound and the marine drift skirting the coast is occupied with blue Till, the product of land-ice, in which only Welsh rocks are found. High-level marine sands are found flanking the Vale of Clwyd on the Flintshire side, but the Author knows of no record of high-level marine drift in the neighbourhood of Colwyn Bay. There is no doubt that the formation of the mound is geologically subsequent to that of the blue Till.

The Author further describes stratified marine sands containing shell-fragments, resting upon brown Boulder Clay, exposed in three sandpits near the Old Colwyn Road at Groes, on the east side of Nant-y-glyn. At Old Colwyn, on the east side of the valley, there is a great development of a similar sand lying between the 100- and 200-feet contours, also containing shell-fragments. A depth of 30 feet of this sand was exposed unbottomed, and it is probably as much as 60 feet deep. On the west side of the valley, below the 100-feet contour, an excavation for a house showed angular and subangular gravels of Welsh rocks containing a lenticular seam of sand with rounded grains, and this appeared to be a passage between the purely land-ice or fluvial drift and the geologically overlying marine sands. It is a notable fact that the marine sands of Groes, of Old Colwyn, and of the Vale of Clwyd lie on the east side of their respective valleys, while the marine Boulder Clays lie to the greater extent on the west side; and that the marine sands have mostly accumulated as bars near the mouths of the valleys.

[1] Quart. Journ. Geol. Soc. vol. xli, pp. 102–107.

Discussion.

Dr. Hicks thought it important that the mound of high-level drift in Colwyn Bay should be recorded, as hitherto it does not appear to have been described. East and west of Colwyn Bay, along the coast of North Wales, numerous sections of drift at the same and higher elevations have been described by various writers, as have also the low-level drifts in Colwyn Bay.

Mr. Goodchild remarked that the Author had referred to the deposits as marine, without giving any reason in support of the view that they were really of that nature. He referred to several possible explanations of the occurrence of sands and gravels in such positions. He thought that they were englacial, and furnished no proof of any submergence.

Prof. Hull concurred with the Author that the beds of gravel which he described were of marine origin, and that (as a previous speaker had stated) they belong to the series of stratified deposits at various points and levels all along the flanks of the North Welsh hills. The Author had not indicated the presence of sea-shells; but that was no objection to the view of the marine origin of the beds. All beds of gravel on our shores do not necessarily contain shells; and if shells had originally existed they may have been dissolved away by the percolation of acidulated rain-water during a period of thousands of years. As regards the view that the shell-bearing gravels of North Wales had been pushed up into their places by an ice-sheet from the Irish Sea, he wished to remind geologists that Sir Andrew Ramsay had shown that, while the northern ice-sheet had crossed the comparatively low ground of Anglesey (in a south-westerly direction, as indicated by the striæ on the rocks), it had never invaded the Caernarvonshire mountains; while, on the other hand, he had recognized the shelly gravels as evidence of submergence to the extent of 1200 and 1500 feet as compared with the present sea-level. No authority was more competent to determine these physical questions as regards North Wales; and in the speaker's opinion these views, and no others, could adequately explain the presence of stratified gravels on the flanks of the Welsh mountains.

Mr. A. E. Salter would like to hear from the Author what definite evidence there was in favour of a marine origin of this deposit. In the Thames Basin, drifts containing a series of erratics similar to those exhibited could be traced in a north-westerly direction as far as the gap in the Oolitic strata at Moreton-in-the-Marsh, at heights up to 300 or 400 feet above O.D. Like many drift-deposits farther south, this one was on a watershed and may have had an origin similar to theirs: that is, the drift-gravels had protected the soft underlying strata, while softer rocks around had been denuded away.

The Rev. J. F. Blake also spoke.

The Author said that, although he had not found marine shells in the drift of the mound, its structure and composition satisfied him that it is an outlier of the marine drift found at lower levels at Colwyn Bay, in which it is well known that marine shells occur, and in which he had proved that foraminifera were to be found in abundance. The sand is quartzose, well rounded, and full of Lake District erratics, and all these materials must have come seawards. This marine drift rests upon a grey Till full of Welsh rocks in which no erratics occur. No one in the least acquainted with the two types could mistake one drift for the other. His object in writing the paper was to record facts; but as the question of land-ice *versus* submergence had been raised, he could only say that all the facts which he had gathered in his study of the high-level drift during the last 25 years were, in his opinion, distinctly in favour of submergence. The underlying Till he considered to be a product of land-ice.

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[No. 216 will be published next November.]

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PART 4.

THE

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OF THE

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THE ASSISTANT-SECRETARY.

[With Two Plates, illustrating Papers by Mr. O. A. Shrubsole and Messrs. E. T. Newton & J. J. H. Teall.]

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Session 1898–99.

1898.		
Wednesday,	November	9–23
,,	December	7–21
1899.		
Wednesday,	January	4–18
,,	February (*Anniversary*, Feb. 17th)	1–22
,,	March	8–22
,,	April	12–26
,,	May	10–24
,,	June	7–21

[*Business will commence at Eight o'Clock precisely each Evening.*]

39. *On some* High-level Gravels *in* Berkshire *and* Oxfordshire.

By O. A. Shrubsole, Esq., F.G.S. (Read June 8th, 1898.)

[Plate XXVIII—Map.]

Contents.

I. Introduction.

After the appearance of Buckland's 'Reliquiæ Diluvianæ,' the higher gravels of this district were for a time somewhat neglected. Much has now been done in the Geological Survey Memoir by Mr. Whitaker, and in papers by the late Sir J. Prestwich,[1] Messrs. H. W. Monckton,[2] H. J. O. White,[3] A. E. Salter,[4] and other observers to throw light upon the interesting and difficult questions connected with the later physical history of this part of England. It has been found convenient in the present paper to refer to these gravels as a whole, but to treat more briefly those points which have been already discussed.

II. The Pebble-gravel.

This term is used for the deposits, composed very largely of flint-pebbles, which are found on the higher slopes of the Chiltern Hills, resting on Lower Tertiary outliers.

A familiar example of this gravel is that at Nettlebed, which has been fully described by Sir J. Prestwich and Mr. White (*op. cit.*). It may be seen at various places on the plateau in the neighbourhood of Cadmore End and Lane End, near High Wycombe, by surface-indications; also at Coleshill, near Amersham, at which locality there is a very good section, showing about 5 feet of the gravel, but at a lower level (500 feet above Ordnance-datum).

The composition of the gravel will be seen from the following

[1] 'On the Westleton Beds, etc.,' Quart. Journ. Geol. Soc. vol. xlvi (1890) pp. 84 & 120.

[2] 'On Boulders & Pebbles from the Glacial Drift,' *ibid.* vol. xlix (1893) p. 308; and Proc. Geol. Assoc. vol. xii (1891) p. 108.

[3] Proc. Geol. Assoc. vol. xii (1892) p. 379, vol. xiv (1894) p. 11, and vol. xv (1897) p. 157.

[4] 'Pebbly Gravel from Goring Gap to the Norfolk Coast,' *ibid.* vol. xiv (1896) pp. 389–404.

table, which states the percentage of the various stones in the samples examined:—

	Chequers Farm (600 feet).	*Cadmore End (600 feet).*	*Lane End (600 feet).*	*Coleshill (500 feet).*
	Per cent.	Per cent.	Per cent.	Per cent.
Flint-pebbles	85	85	75	88
Subangular flints of small size	9	4	20	10
Small quartz-pebbles	6	10	3	2
Sarsen	...	...	1	...
Lydite (?)	...	...	1	...
Friable rocks	...	1	...	...

A pebble of chert, from the gravel at Nettlebed, was submitted to Dr. G. J. Hinde, F.R.S. He found it to be 'packed full of the detached spicules of various forms of siliceous sponges—simple needles, trifid spicules of tetractinellid sponges, also hexactinellid spicules. There are no forms sufficiently distinctive to determine the formation from which the chert may have come, but not improbably it is of Carboniferous Limestone age.' Dr. Hinde informs me that there are pebbles of the same kind of sponge-chert in gravels of the so-called 'Westleton Beds' at Potter's Bar.

This gravel is included in the 'Westleton Shingle' of Sir J. Prestwich. That term has not been adopted here, not from any want of respect to the judgment of so eminent a geologist, but in order that the facts may be more conveniently presented.

Looking at the waste that it has undergone, its elevation, and its composition (which approximates to that of the Eocene pebble-beds), it must certainly be regarded as an old deposit. Whether it is an extension of the Westleton Beds is a point upon which I do not feel competent to offer an opinion. A section, apparently of the latter, which was seen in the cliff near Southwold, was not unlike it in general composition, except that, in the portion examined, more than half the stones were subangular. This is not exactly what one would expect to see if the land lay farther west, and if both deposits were laid down in the same sea.

III. The Goring Gap Gravel.

The last summit of the Chilterns at Woodcote is capped by gravel which may be seen in an old gravel-pit opposite the inn, at a level of a little over 600 feet. This has been fully described by other observers. It may be convenient, however, to state here its composition, as arrived at by counting the stones in a portion of the gravel:—

	Per cent.
Flint-pebbles	42
Subangular flints	52
Quartz-pebbles	3
Sarsens	0·5
Pale quartzites	0·5
Sandstone and other sedimentary rocks	1
Chert	1

About 2 miles north-east of Greenmoor Hill, and at about the same level, is the small patch of gravel which has been described by Messrs. Monckton & Herries [1] and by Mr. H. J. O. White.[2] The proportion of subangular flints appears to be the same here as at Woodcote.

A mile south-west of Greenmoor Hill, where 'Cold Harbour' is marked on the Ordnance-map, the fields are thickly strewn with a somewhat similar gravel, but it has no depth. The level at this place is 541 feet above Ordnance-datum.

The composition of these deposits is consistent with a fluviatile origin; and their position, so near the present breach in the escarpment at Goring, has led me to suggest that they may be the relics of an old river—possibly an early stage of the Thames.

IV. The Quartzose Gravel.

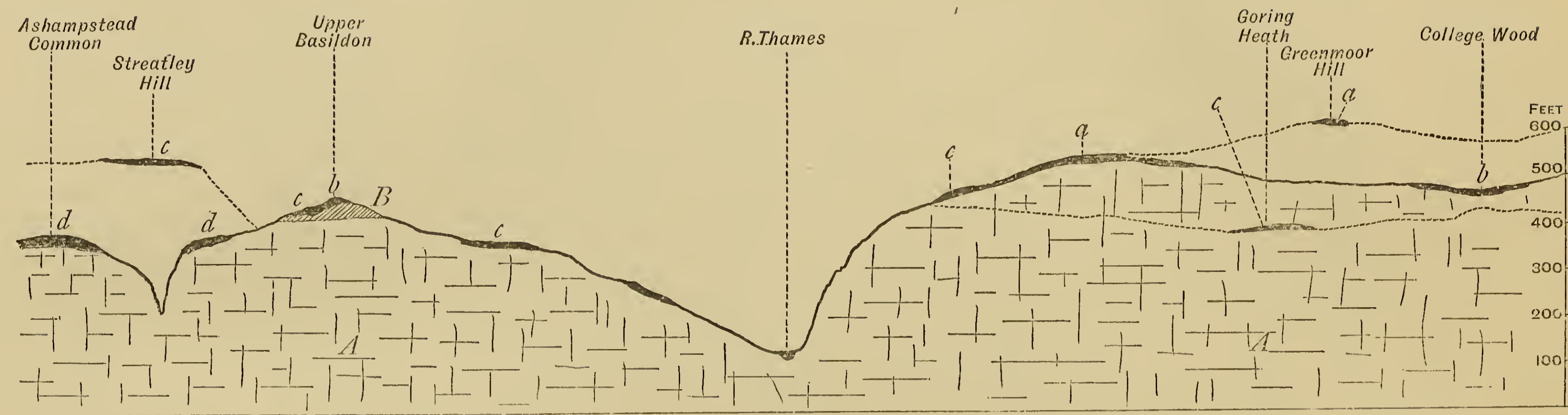
At a lower level than any of the gravels hitherto described occurs a deposit which, as it invariably contains a large percentage of quartz-pebbles, I have called the Quartzose Gravel, and this name enables me to refer to it without making any assumption regarding its precise age. This and the two gravels already described make up the 'Westleton Shingle' of Sir J. Prestwich. A section of the Quartzose Gravel may be seen in a pit at the northern corner of College Wood, about a mile north-east of Greenmoor Hill, near the point marked 'Lodge' on the Ordnance-map. It occupies the higher part of the Goring Heath plateau, at a level of about 475 feet above Ordnance datum. Purple and brown quartzite-pebbles occur here, but in small proportion. Two fragments of old rock were found to contain the impressions of fossils, one of which appeared to be an *Orthoceras*. A somewhat similar gravel caps the Tertiary outlier of Basildon, at 466 feet above Ordnance-datum, on the other side of the Thames; but it contains more of the purple and brown quartzite-pebbles, and on that account some hesitation is felt in classifying it. It has in fact been claimed both as Westleton and as Glacial gravel. At a level only a few feet lower down, it is succeeded by a gravel in which the purplish quartzites are abundant, thus presenting conditions similar to those which were observed at College Wood. (See fig. 1, p. 588.)

The gravel on Ashley and Bowsey Hills, near Wargrave, has been fully described by the late Sir J. Prestwich[3] and others. It is of the quartzose type. The height of these hills is stated as 480 feet and 467 feet respectively. Purple and brown quartzite-pebbles occur here, but they are rare, especially those of a larger size.

The subjoined table (p. 589) will give an idea of the composition of this gravel. The averages are obtained by counting the stones in a representative portion of the gravel, and this method has been followed in all cases. The gravel at Merrill Hill, Hatfield (380

[1] Proc. Geol. Assoc. vol. xii (1891) p. 112.
[2] *Ibid.* vol. xiv (1894) p. 11.
[3] Quart. Journn. Geol. Soc. vol. xlvi (1890) p. 141.

Fig. 1.—*Section from Ashampstead Common to College Wood, Woodcote.*



[Horizontal cale: 1 inch = 1 mile.]

A = Chalk. *B* = Woolwich & Reading Beds.

a = Goring Gap Gravel. *c* = Quartzite-gravel.

b = Quartzose Gravel. *d* = 'Southern' Gravel, invaded by *c*.

feet above Ordnance datum), and that at Bell Bar (378 feet) have been included for purposes of comparison :—

	College Wood.	*Basildon.*	*Bowsey Hill.*	*Ashley Hill.*	*Merrill Hill.*	*Bell Bar.*
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Flint-pebbles	13	7½	35	35	47	37
Subangular flints ...	23	12½	17¾	19	2	5
Quartz-pebbles	28	33½	29	21	28	27
Do. (vitreous)	9	7	8	7	9½	5
Sandstone	1½	10	1½	4	5½	8
Soft do.	1	4	...	1	...	...
Purple quartzite......	...	2	¼	½	...	...
Brown do.	1½	1	...	1	1	1
Pale do.	4	9½	6	6	4½	9
Chert, etc.	4½	4	3	2	...	2
Lydite	1	...	...	...	...	...
Grit	5	5½	...	3	1½	1
Shale, etc.	1	3	...	½	...	4
Chalk and other soft rocks	½	½	...	...	1	1
Sarsens	1	...	...	...	...	...

When we consider the great variety of material composing this gravel, and that sometimes more than half of this is not flint, there seems to be some ground for supposing that it was formed under conditions different from those which prevailed when the pebble-gravel was accumulated. The quartz-pebbles are frequently more numerous than those of flint, and some of the quartz-pebbles, as mentioned by Mr. Salter,[1] are not of the ordinary opaque kind, but transmit a certain amount of light, sometimes having a quasi-granular appearance. This gravel also contains a varying—but always a small, sometimes a very small—proportion of brown or purplish quartzite-pebbles, resembling those from the Bunter conglomerate. It is also in some places closely associated with deposits recognized as Glacial.

It is natural to ask from what source or sources the characteristic materials of this gravel have been derived. In order to ascertain whether the Ardennes were a probable source, I visited that district, and showed a few pebbles from Bowsey Hill to Prof. Dewalque, at Liége. He informed me that some pebbles of grey grit might be Gedinnian, and I afterwards noticed the same resemblance in rocks of that age near Vireux and elsewhere; but, taking the hard rocks of the Ardennes as a whole, it did not appear to me necessary to conclude that they had furnished much, if any, of the materials of the gravel.

The high-level gravels near Liége proved to be of interest. A deposit at Crotteaux contained about 50 per cent. of quartz-pebbles, of which some were of the vitreous kind. This variety of quartz occurs in the Norfolk Forest Bed; but it is found also in the

[1] Proc. Geol. Assoc. vol. xiv (1896) p. 389.

Bunter Beds, in the surface-gravel of the Lickey Hills, in the Faringdon Greensand gravel, and in the Berkshire gravels. This deposit therefore seems to afford evidence that part of the material of these gravels has been derived from the breaking-up of older pebble-beds.

One source of the foreign material in the Quartzose Gravel might perhaps be indicated in the Lower Greensand. The pebble-beds belonging to this formation have been described by the late W. Keeping,[1] and, judging from his description, we have in those beds an assemblage of rocks very similar to that which occurs in the Quartzose Gravel.

Similar pebble-beds nearer to our own area, and now removed by denudation, may have furnished much of the material of that gravel. A relic of such beds still exists at Faringdon in Berkshire. The sponge-beds at that locality contain small pebbles which I found to be in the following proportion:—

	Per cent.
Flint or flinty chert	25
Variegated chert	16
Hard pale sandstone	1
Quartz	35
Quartzite	8
Subangular chert	1
Ironstone-grit	1
Coarse quartz-grit	1
Grey and brown grit	7
Compact sedimentary rock	3
Lydite	2

There is here the same general resemblance to the material of the Quartzose Gravel, and that resemblance roughly holds good for the relative proportion of quartz-pebbles, quartzites, and grits. The red-and-black variegated chert, however, has not yet been noted in the Quartzose Gravel.

Another possible source of some of the constituent materials of this gravel has been suggested by Mr. A. E. Salter.[2] He considers that they may have been derived by re-deposition from an old river formerly draining Dorset and Devon, and connects them with the gravel on Blackdown Hill, regarded by Mr. Clement Reid as of Bagshot age.[3] On this matter I do not venture an opinion.

V. The Quartzite-gravel.

Under this name I refer to the gravel which is generally, and perhaps properly, called 'Glacial.' In composition it is, to some extent, a repetition of that just described, but the brown and purple quartzites are a more conspicuous element, and the material on the whole is of a larger size. It has also a wider range, at least in a north-westerly direction; for I have not observed the Quartzose Gravel on that side of the Goring gorge.

[1] Geol. Mag. 1880, p. 414.

[2] Proc. Geol. Assoc. vol. xv (1898) p. 264.

[3] 'The Eocene Deposits of Dorset,' Quart. Journ. Geol. Soc. vol. lii (1896) pp. 490–495.

Mr. H. W. Monckton has described its occurrence on the Tilehurst and Goring Heath plateaux.[1] In the district to which reference is made in this paper it ranges, roughly speaking, from 200 to 400 feet above the present level of the Thames.

The deposit on the summit of Streatley Hill (Common Wood), at about 550 feet above sea-level, has been described by Mr. H. J. O. White,[2] who notes the occurrence therein of red quartzite-pebbles. At a level of a little over 530 feet, near the road from Goring to Aldworth, there is a gravel-pit on the golf-links which has been worked to a depth of about 6 feet. About one-half of the gravel here consists of rather large rolled flints, with a few flint-pebbles and a quantity of small quartz-pebbles. There are also quartzites of large size and of Bunter character, although these are not relatively numerous, and some fairly large masses of sarsen-stone. The stratification is not very pronounced, but follows the slope of the hill. The association of the small quartzite-pebbles with the larger material may indicate the re-arrangement of an older deposit.

Another interesting section occurs at the brick-kiln near Kiln Farm, Upper Basildon, at a level of about 455 feet. This is only about 10 feet below the hilltop, where the gravel, although containing a few quartzites of Bunter character, is generally of the quartzose type, and has been already mentioned (p. 587). The section seen at the kiln was 5 or 6 feet thick, and consisted of

> Buff clay with few pebbles;
> Pebbly clay, becoming ferruginous and sandy at the base, overlying Woolwich & Reading Clay.

The gravel here contains only 15 per cent. of flint and a large proportion of purple and brown quartzites. The pebbles are in places embedded in a red clay resembling the matrix of the Clay-with-flints. The deposit is of variable thickness, and appears to lie in hollows of the surface.

This section illustrates the close relationship existing between the Quartzite-gravel and the Quartzose Gravel. The sudden appearance of a deposit containing so large a proportion of quartzites of Bunter character is also remarkable as occurring in a Cretaceous district, the proportion of flint-material being really insignificant. The deposit, however, does not suggest ordinary sedimentary action.[3]

A section in this gravel at Rose Hill Kiln, near Caversham, at a

[1] Quart. Journ. Geol. Soc. vol. xlix (1893) p. 308.
[2] Proc. Geol. Assoc. vol. xiv (1894) p. 22.
[3] [It is probable that the gravel at this level was not seen by Sir J. Prestwich. Mr. H. J. O. White (*op. jam cit.*) remarks that the Upper Basildon deposit is 'undoubtedly Glacial.' That is especially true of the section under consideration, and might also be said of the gravel on the hilltop.]

level of about 308 feet above Ordnance-datum, points to a further change in the physical conditions at the later date indicated by the lower level, inasmuch as we meet with unequivocal indications of the results of glacial action. The section shows a thickness of about 7 feet of a reddish and rather loamy sand, in the lower part of which there is a layer of pebbles and other large material rather promiscuously arranged. Besides the pebbles of Bunter character there are subangular fragments of quartz, sedimentary rock, and igneous rock, such as might have been derived from the wasting of Boulder Clay or have been transported by ice.

I submitted to Prof. Bonney a few characteristic pebbles and three fragments of igneous rock from this section. His remarks on them are as follows :—

'1. Slightly felspathic grit or quartzite. Might have come from the Bunter.

'2, 3, 4. Varieties of felspathic grit. Similar varieties occur in the Bunter and at Budleigh Salterton.

'5. Fine-grained quartzite. Appears identical with the liver-coloured quartzite of the Midland Bunter, which I have also found at Budleigh Salterton.

'6. A rather light variety of the liver-coloured quartzite, but with a very typical fracture.

'7. Another fine-grained quartzite. Might have come from either locality.

'8. Vein-quartz [purple]. Plenty like this in the Midland Bunter, also in the Devon pebble-beds.

'9. Appears to be a felstone. Perhaps might be Welsh.

'10. Seems to be a compact felstone, once perhaps an andesite. Probably Welsh.

'11. The hand-specimen is of a rather light greenish-grey colour, weathering to a whitish tint, but occasionally spotted with brown and similarly stained on a joint-face (from limonite). If I had found this specimen in Staffordshire, Shropshire, or Worcestershire, I should have referred it without hesitation to Wales, probably the Arenig district.

'Examined with the microscope, the rock proves to be a devitrified rhyolite, with very well-marked fluxion-structure, one constituent being slightly ferrite-stained, and in this are brownish patches, due no doubt to the formation of limonite. This groundmass is speckled over with a green mineral, the larger flakes of which, at any rate, are a chlorite. Scattered in this are a few grains of an iron-oxide and one or two not very well-formed crystals of a rather decomposed felspar, probably orthoclase. The slice also contains a cavity, the walls of which are now covered with small crystals of quartz with some felspar, and the interior is filled up by a chlorite.'

Prof. Bonney adds :—

'I think that there can be no doubt that certain of the quartzites are from the Bunter, or, at any rate, are the types which occur there, particularly the liver-coloured, which in England, so far as I know, are only found in the Triassic pebble-beds. I am told that this quartzite is *in situ* in the Isle of Jura (Hebrides). The quartz-felspar grits, though not typical Torridonian, are very probably from the Bunter, but rock somewhat of this type, which occasionally comes very near normal Torridonian, occurs *in situ* in the north-western Longmynds.'

The following table will show the composition of the Quartzite-gravel at different localities in the district under review :—

	Streatley. *530–544 feet O.D.*	*Basildon Kiln.* *455 feet O.D.*	*Tilehurst.* *300 feet O.D.*	*Rose Hill.* *305 feet O.D.*	*Norcot.* *294 feet O.D.*
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Flint-pebbles	13	3	7½	14	8
Subangular flints	34	12½	56½	14½	37
Quartz-pebbles, opaque	23	25	11½	18	15
Do. vitreous	10	8	½	3	3
Quartzite-pebbles, grey, etc.	2	19	8	7	5
Do. brown & purple	4	17	10	22	18
Grit	3	9½	2	9	4
Sandstone	5	3	2	3	5
Soft rocks	1	...	2	...	1
Lydite	...	1½	...	...	1
Subangular sedimentary rock	...	...	...	6	1
Igneous rocks	...	...	...	½	1
Chert and jasper	2	1½	...	1½	
Slate, etc.	3				
Conglomerate	...	...	...	1½	1

Gravel of a quartzitic character is abundantly scattered over the fields between Stonesfield and Charlbury at about 500 feet above sea-level; and it was observed at Leafield, above Wychwood Forest, at 550 feet, on the ridge between the Windrush and the Evenlode. In the higher Windrush valley it is absent. At Bourton-on-the-Water, a valley-gravel, at a level of about 430 feet above Ordnance-datum, appeared to consist entirely of materials derived from the Cotteswolds. The quartzites, however, are abundant in the Evenlode valley. No section was seen, but at Adlestrop the surface of a field at a level of 460 feet above Ordnance-datum showed that only about one-third of the gravel consisted of local Oolitic material, the remainder being pebbles of quartz, quartzite, grit, etc.

At Moreton-in-the-Marsh there is a large gravel-pit near the cemetery, ¾ mile east of the town. It is only about 30 feet above the source of the Evenlode; but, as it lies on the watershed common to the Avon and Evenlode, it is of interest. It is also remarkable, inasmuch as one-third of the gravel consists of subangular flints; but there is a still larger proportion of quartzite-pebbles.[1] There are indications at Batsford, near Moreton, that the Quartzite-gravel may have reached the level of 612 feet above Ordnance-datum, but they are superficial only.

Quartzite-gravel, then, is not confined to the Thames Valley system. It was noticed at Shipston-on-Stour, and a gravel of the Avon at Evesham was found to contain 43 per cent. of quartzite-pebbles. These pebbles could be traced along the Salwarp Valley to the Lickey district, where there is an outcrop of Bunter Conglomerate, from which they may have been derived. No section of the Conglomerate-beds was seen, but the slopes of the Lickey Hills are mantled by gravel which consists almost entirely of re-arranged Bunter pebbles. For purposes of comparison the Bunter Beds at Repton (Derbyshire) were examined. The following is the result of the examination of the materials at various localities:—

	Moreton-in-the-Marsh.	*Evesham.*	*Repton (large stones).*	*Lickey (Barnt Green).*	*Upper Basildon Kiln.*
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Flint-pebbles	...	...	...	...	3
Subangular flints	33	6	...	...	12½
Quartz-pebbles	6	9	4	11	25
Do. vitreous	...	6	...	6	8
Quartzites, purple & brown	...	...	39	50	17
Do. pale	39	43	34	18	19
Grit	1	6	11	6	9½
Sandstone	6	9	6	...	3
Lydite, etc.	...	...	...	3	1½
Igneous or Archæan rocks.	5	...	...	2	
Conglomerate	...	3	1	...	
Schist, shale, etc.	4	...	5	4	
Subangular rock	6	18	...	...	
Chert	...	...	...	...	1½

These facts support the view which has been long held, that the Quartzite-gravel of the Thames Valley has derived part of its material from the waste of Bunter Beds in the Midlands. Much of this material probably arrived through a gap in the escarpment near Moreton-in-the-Marsh,[2] but of course under physical conditions different from those now existing there; and, as the later stages of

[1] This section was figured and described by the late W. C. Lucy in 'Gravels of the Severn, Avon, & Evenlode,' Proc. Cotteswold Nat. Club, vol. v (1869) pp. 71–125.

[2] [See also H. J. O. White, Proc. Geol. Assoc. vol. xv (1897) pp. 160 *et seqq.*]

this gravel clearly indicate ice-action, we have in that alone an agent sufficient to account for the changes that have taken place.

It may be useful to note the height above sea-level reached by this gravel at various points in or near the Thames Valley, with the approximate height above the present river-level:—

	Above sea-level. Feet.	*Above river-level.* Feet.
Batsford, near Moreton	612	220
Leafield (Oxon)	550	300
Streatley Hill	544	400
Upper Basildon Kiln	460	330
Tilehurst	341	220
Rose Hill, Caversham	308	187

At Batsford the only evidence of the former existence of this gravel is the surface of a field; this, therefore, must be taken with some reserve. In the admirable map accompanying Mr. W. C. Lucy's paper (*op. jam cit.*) 'Northern' gravel is shown as occurring at Stow-on-the-Wold and Chipping Norton at 750 feet above sea-level. At the last-named locality, however, I failed to discover any sign of such gravel; and at Stow-on-the-Wold I observed only a few pebbles lying on the surface under conditions which suggested that they might have been introduced by human agency.

Taking, however, the level at Batsford as a probable one for this gravel, it will be seen that, assuming that there has been no depression since its deposition, the fall of the present river is much greater than was that of the old waterway, which may, if of freshwater origin, have been a chain of lakes.

VI. The Relation of the Quartzite-gravel to Gravels of Local Origin.

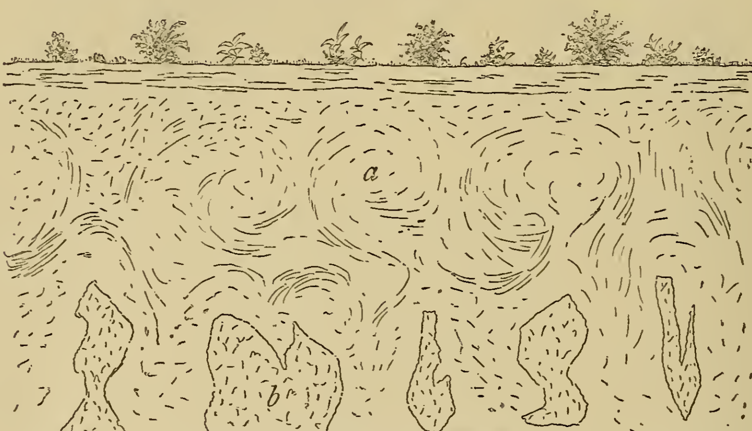
In the neighbourhood of Goring and Pangbourne the Quartzite-gravel is closely associated with deposits of a wholly different character and origin.

On the western slopes of the Chilterns there is a spread of gravel consisting almost wholly of flint, and mostly angular or subangular, which ranges from Little Stoke and Ipsden in a northerly direction to the neighbourhood of Watlington, as shown in the accompanying sketch-map (Pl. XXVIII). It occupies a plateau at a height of about 350 feet above sea-level, and about 200 feet above the river Thames, in places forming a deposit 10 or 14 feet thick. It is worked for road-material north and south of Ewelme, and at Turner's Court, near Wallingford.

At the latter place the excavation is carried down to a reddish, coarse, sandy loam. At one point, however, the bottom was seen to consist of a fine rubble of flint and chalk. The gravel is of flint, with the exception of a few fragments of sarsen- or ironstone.

There are scarcely any pebbles, and the flint-fragments are usually angular. They are whitish externally, and mostly black and grey internally. The gravel shows little, if any, sign of stratification, the general arrangement being a series of whorls or curves. In places near the base patches of gravel in a chalky paste occur, as shown in the appended sketch (fig. 2). These chalky patches resemble, although

Fig. 2.—*Turner's Court gravel-pit, Wallingford.*



[Height of section = 12 feet.]
a = Unstratified angular flint-gravel in ochreous sand.
b = Similar gravel in marly paste.

on a smaller scale, those occurring in stratified gravel at Tilehurst Road, Reading, described in a former paper.[1] I am inclined to think that, in some cases, these chalky patches may be due to the irregular action of solvents subsequent to the formation of the gravel.

At Gould's Grove, between Turner's Court and Ewelme, there is a somewhat similar section, and another at Ewelme itself; but in these cases there was much less irregularity in the deposit.

At Little Stoke, 3½ miles north of Goring, the valley-gravel is composed of very similar materials. In a gravel-pit there, only one quartzite-pebble was found: on the other side of the Thames at Moulsford such pebbles are very abundant in the gravel; while a little farther north the quartzite-pebbles are found on both sides of the Thames, as at Brightwell Barrow, near Wallingford (371 feet above Ordnance-datum), and Primrose Hill, near Drayton (246 feet). At the last-named locality the Quartzite-gravel may be seen in the fields on one side of the road, and the flint-gravel on the other.

What are the age and origin of this flint-gravel? Some barrier has evidently prevented the Quartzite-gravel from having access to the plateau north-west of the escarpment of the Chilterns. I can only suggest that this barrier was the escarpment itself, and that this

[1] Quart. Journ. Geol. Soc. vol. xlvi (1890) p. 582.

has been cut back since the time of the Quartzite-gravel. If this be so, it must mark a very considerable lapse of time.

The flint-gravel would seem to be in part a reconstruction of old hill-gravels, but very largely, particularly at Turner's Court, a residuum left after the dissolution of the Chalk; and the deposit in its present position would necessarily be subsequent in date to the Quartzite-gravel.

On the south side of the Thames also, the Quartzite-gravel comes into relation with the old flint-gravels in a very interesting manner. In the district south of Streatley and west of Pangbourne we come upon gravels of a 'Southern' type. Pits in this gravel may be seen near Bere Court, 2 miles south-west of Pangbourne, and another ¾ mile south-west of Upper Basildon. The gravel at the latter place is at an elevation of about 350 feet above Ordnance-datum.

Similar gravel occurs on Ashampstead Common at about the same level, but the two deposits are separated by a dry Chalk-ravine. The highest parts of this common consist of loamy or sandy gravel, of which a thickness of 4 or 5 feet may be seen in an old pit. It was found to have the following composition:—

	Per cent.
Flint-pebbles	32
Subangular flints, rather small	61
Large flint-pebble	1
Subangular sarsens	3
Veined grey quartzite-pebble	1
Quartz-pebble	1
Purplish chert	1

It will thus be seen that some of the 'Northern' material has reached this gravel. The pit near Upper Basildon, on the other side of the dry chalk-valley, showed a thickness of 6 or 7 feet of small subangular gravel of the flinty type, but the upper 3 feet of it appeared to have been disturbed, and was found to contain here and there quartzite-pebbles. Immediately under this upper part of the gravel I found a large white quartzite, a flint-flake, and also a flint-'core,' from which flakes had apparently been struck. There were also a few large unrolled flints, some of them 15 inches long.

This intrusion of the quartzite-material is not remarkable, when it is considered that at Basildon Kiln there is, at a level 100 feet higher, a remnant of a gravel of an intensely quartzitic type, less than a mile distant from this point. What is noticeable is that the gravels have mingled so little, so that in walking over the fields the surface-drift is found to alter its character suddenly.

One cannot avoid being impressed, both here and elsewhere, with the great physical changes which have taken place since the time of the deposition of the Quartzite-gravel. Valleys must have been scooped out, filled with 'Southern' débris, and, as a result of further denudation, formed into plains since the gravel of Upper Basildon was deposited. Assuming the gravel which flanks that hill to be not so old as the gravel on its summit, yet a large amount of time must be demanded for the changes that are indicated. Another indication of the time which has elapsed since the era of the Quartzite-gravel is found in the fact that its southern boundary is now a plain much lower than its own level.

VII. Traces of Man.

The traces, or supposed traces, of man which have been observed in connexion with these gravels are very slight. Necessarily they would be so. All deposits formed by current-action undergo a sorting process. A Palæolithic implement is a part of the gravel in which it occurs, and an angular instrument would not be looked for in a pebble-gravel. Such implements also are at all times rare, compared with the amount of material which has to be removed in order to find them; but there are few sections in the high-level gravels, and these are not usually available for detailed examination, so that even negative results would have no special significance.

It has been thought desirable, however, to record such slight possible indications as have presented themselves. These have principally been in the form of small flint-flakes having only one 'bulb of percussion.' The value of such an evidence of man is disputed, and disputed, I believe, by so eminent an authority as Sir John Evans. The facts here noted must be taken, therefore, for what they are worth.

Pebble-gravel.

Nothing observed.

Goring Gap Gravel.

At Greenmoor Hill (600 feet O.D.). A very distinct flake about 1 inch long.

Quartzose Gravel.

At Bowsey Hill (467 feet O.D.). A small flake of black flint.

Quartzite-gravel.

Norcot Kiln (278 feet O.D.). A flint-flake, somewhat doubtful, but it has a bulb of percussion.

Rose Hill Kiln (305 feet O.D.). A flake or scraper. Not a very good specimen.

Near Cane End, in rubble in a dry chalk-valley (about 300 feet O.D.). A well-formed Palæolithic flint-implement. The appearance of this implement suggests long exposure at the surface. It is stained of a whitish colour. Its origin is somewhat doubtful.

Local Gravel.

Near Upper Basildon (350 feet O.D.). A flint-'core' and a flake.

Turner's Court (350 feet O.D.) This pit is worked for road-material. It is said that a few flint-implements have been found there, but I have not observed any on the two or three visits which I have made to the pit.

At Moreton-in-the-Marsh, in the pit already referred to (p. 593), was observed a large flake which had apparently been used as a scraper.

VIII. General Conclusions.

The Pebble-gravel has the appearance of being a relic of an old marine pebble-bed, possibly re-arranged. Although it has been claimed as Westleton, one might venture to ask whether it may not possibly be of Diestian age. The exact westerly limit of the sea of the Lenham Beds has never been determined. At Lenham, according to Mr. Clement Reid,[1] there is indicated a depth of about 40 fathoms. Possibly here we have the remains of deposits nearer to the shore-line, but there is no evidence to warrant a positive conclusion.

The Quartzose Gravel.—In stating the facts regarding this deposit, no definite theoretical conclusion has been drawn. Its pebbly nature and its westward limitation by the range of the Chilterns are arguments for a marine origin. No attempt has been made to discuss its suggested connexion with deposits in East Anglia. That this gravel is marine at all has been disputed.

The Quartzite-gravel is generally regarded as a fluviatile deposit, yet its connexion with the foregoing is rather close. A westerly tilt, however, would convert an inlet into a river-valley. If this gravel were a fluviatile accumulation the present Thames Valley would have been probably at that time a chain of lakes.

Although this gravel is characterized by the presence of pebbles from the Bunter, which does not occur *in situ* in the district drained by the present river Thames, it is not distinctly Glacial, in the sense of containing angular fragments of foreign rocks, so far as I have observed, until a later stage of its history, indicated by the presence of such erratics at a level of about 187 feet above the present surface of the Thames at Rose Hill, Caversham.

The remarks of Prof. Bonney suggest the possibility that the fragments of igneous rock occurring in the Quartzite-gravel may be derived from a somewhat definite area. The further investigation of the subject is likely to be of interest.

My sincere thanks are due to Prof. Bonney for having been so good as to examine and describe numerous specimens sent to him, and also to Dr. G. J. Hinde for similar kind services.

Plate XXVIII.

Sketch-map of high-level gravels in the Reading District, on the scale of 4 miles to the inch.

Discussion.

Mr. Monckton complimented the Author on his careful work in the district, and acknowledged his indebtedness to him for many facts. He asked why the gravels on Greenmoor Hill should be called 'Goring Gap Gravels,' the hill being at an elevation much above the valley of the Thames, in which Goring stands.

The speaker remarked that Prestwich characterized his Westleton

[1] Mem. Geol. Surv. 1890, 'The Pliocene Deposits of Britain,' p. 69.

Shingle not so much by the presence of quartz-pebbles as by the absence of stones derived from the Bunter pebble-beds. He agreed with the Author that much of the smaller material of the Westleton Shingle was probably derived from the Greensand pebble-beds.

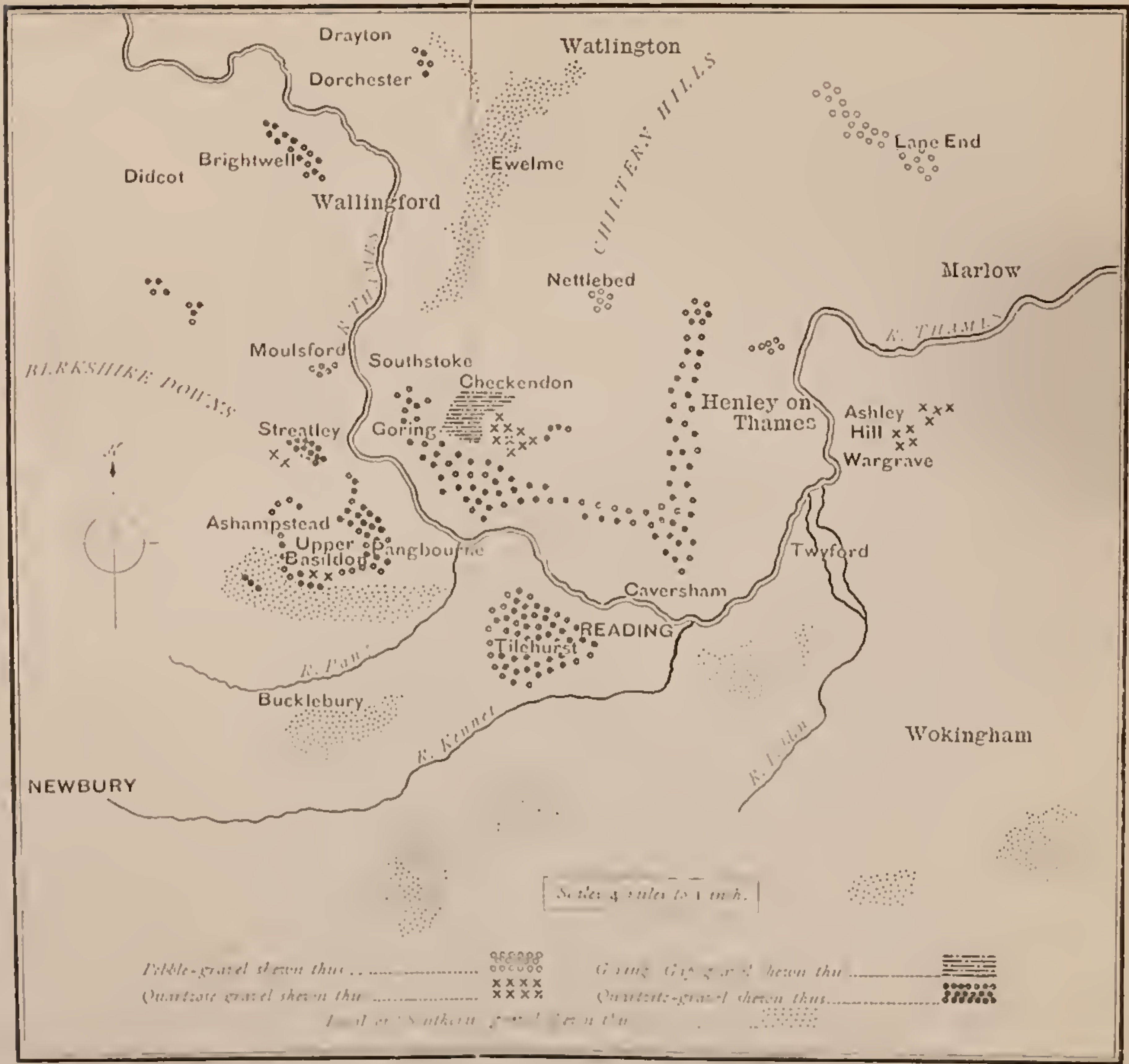
Mr. A. E. Salter was glad to find that the results of the Author's detailed study of the gravels associated with Goring Gap were in general accordance with those to which he had come after a careful study of the Drift-deposits of Southern England. He did not think that the Ardennes were the source of the materials constituting the higher drifts of this area, and was much interested in the Author's remarks on that region. The locality mentioned by the Author in which Southern and Northern Drift are associated was especially interesting, and seemed to point to a confluence of the Northern and Southern Drift-streams at that point. He thought that the Author, besides noting differences in the character of the constituents, might also pay attention to the differences in level of the same kind of gravel over a wider area. Igneous rocks similar to, if not identical with, the devitrified pitchstone or rhyolite, of which the Author had exhibited sections and specimens, had been found by him at Norcot, Aldeburgh, and other Drift-localities.

The President and Mr. F. W. Harmer also spoke.

The Author said that he thought it possible that the Woodcote gravel might represent an early breach of the Chalk-escarpment, and in that sense he had connected it with Goring Gap. The term used was, perhaps, not the best that might have been chosen.

[I.

SKETCH-MAP OF HIGH-LEVEL GRAVELS.—*Reading District.*



40. *On the* Corallian Rocks *of* Upware (Cambs). By C. B. Wedd, Esq., B.A. (Communicated by J. E. Marr, Esq., M.A., F.R.S., F.G.S. Read June 22nd, 1898.)

As any small addition to our knowledge of this interesting district may be acceptable, and as I have lately spent much time at Upware and had access to sources of information too seldom available in the district, it seemed advisable to put on record such new facts as have come to light. The Upware rocks have been so often described by different geologists, to all of whom I am under some obligation, that it is perhaps unnecessary for me to do more than express my especial indebtedness to the important work of Messrs. Blake & Hudleston on the Corallian Rocks of England,[1] to that of Prof. Bonney,[2] to that of the late Mr. T. Roberts,[3] and to the maps and memoirs of the Geological Survey relating to Upware.[4]

The well-known Corallian ridge of Upware is 3 miles long, as mapped by the officers of the Geological Survey, and less than a mile wide in the widest part, and is nearly surrounded by fen. There have long been two principal exposures of the rock: one, the Northern Quarry, in oolitic rock; the other, the Southern Quarry, in 'Rag' and oolite. Part of the intervening area on the western flank of the ridge is covered with Gault and Lower Greensand (see sketch-map, p. 612). Except a few ditch-sections in the lane between the two quarries, there have been till lately no other exposures of importance. The relation of the oolite of the Northern Quarry to the Rag of the other was long a matter of uncertainty. The Northern oolite was at first considered the higher, owing to the slight northerly dip in both quarries. Messrs. Blake & Hudleston placed it below the Rag for palæontological reasons. Mr. Roberts mentioned that the Rag showed signs of oolite beneath it, in which the characteristic sea-urchins of the Northern Quarry occurred, and that this oolite came up towards the south. In the Geological Survey Memoir of the district (1891) it was stated that oolite underlay the Rag in the Southern Quarry.

As now seen, by far the greater part of the rock of the Southern Quarry is oolite or pisolite. This quarry is about 190 yards long. At the southern end, where the surface is about 5 feet lower than at the middle of the digging, the lowest beds are seen, a rather rubbly yellowish-white rock, consisting of a soft calcareous, marly-looking matrix, full of oolite- or rather pisolite-grains. It is exposed in the southern end for about $5\frac{1}{2}$ feet downwards from the surface, and is much less fossiliferous than the higher beds of oolite. In this quarry the dip is northerly, and for the most part at a small angle. In the eastern bank, which is overgrown with grass, the

[1] Quart. Journ. Geol. Soc. vol. xxxiii (1877) pp. 260–404.
[2] 'Cambridgeshire Geology,' 1875.
[3] 'Jurassic Rocks of Cambridge,' Sedgwick Prize Essay for 1886 (1892).
[4] More especially the tables of fossils published in the Memoirs on the Jurassic Rocks of Yorkshire (1892) and the Jurassic Rocks of Britain (1895).

'Coral Rag' can be found coming on at the top at about 50 yards from the southern end. There are some indications of a passage from the oolitic to the Rag-type. A slight dip brings the Rag gradually down the bank-side to the north until, at about 25 yards from the northern end, the dip increases and the base of the Rag, here seen as a hard crystalline band with oolite below, comes down almost to the floor of the quarry at the northern end. The upper part of the bank at the northern end is grass-covered, but the lower part shows a good exposure of Rag almost to the bottom.

The limestone is here hard and somewhat crystalline, there being several very hard crystalline layers in which the coral-structure is sometimes almost obliterated. Still, an examination of the exposure in the northern bank shows coral continuously from top to bottom, only interrupted by thin marly partings, probably due to solution and filtration along divisional planes. Owing to the hardness of the rock, to the mode of preservation and to rapid alteration of the coral on the surface, it is difficult to determine whether *Isastræa* or *Thamnastræa* predominates, but the two certainly form what might be called the framework of the rock. At the base is a well-marked layer of *Isastræa explanata*, continuous for some few yards as far as it could be traced. Many large slabs of *Thamnastræa arachnoides* and *Th. concinna* are seen in a heap of material quarried here.

It has been stated that the Rag here contains some oolitic grains. I have frequently looked for them, but never found any in the true Rag, except at its junction with the lower beds. The Rag-limestone is particularly pure, but no doubt varies slightly in composition with the different degrees of crystallization of individual layers. Typical specimens, not taken from the massive crystalline bands, when dissolved in hydrochloric acid, showed sometimes scarcely any residue, and yielded carbonate equivalent to as much as 98 per cent. of carbonate of lime.

It is often assumed that the fauna of the oolite of the Southern Quarry is much the same as that of the Northern Quarry. This, however, is not the case. The lowest beds of the Southern Quarry, exposed at its southern end, are not very fossiliferous. I have examined carefully the exposure of these beds and a heap of material quarried there, and obtained :—

* *Ammonites* (*Cardioceras*) *vertebralis*, var. *cawtonensis*, Bl. & H.
* *Cerithium muricatum*, Sow.
Littorina muricata, Sow.

* *Arca* sp.
Exogyra nana, Sow.
Gervillia sp.
* *Homomya tremula*, Buv.
Isocardia sp.
* *Lithodomus inclusus*, Phil.
* *Mytilus pectinatus*, Sow.
Mytilus sp.
Opis Phillipsi, Mor.
Opis sp.
* *Ostrea* (*Alectryonia*) *gregaria*, Sow.
Pecten fibrosus, Sow.
* *Quenstedtia lævigata*, Phil.

Vermilia sulcata, Sow.

* *Cidaris florigemma*, Phil. (spines).
Echinobrissus scutatus, Lam.
Holectypus depressus, Leske.
Pygaster umbrella, Ag.

* *Pentacrinus* sp.

* *Montlivaltia dispar*, Phil.
* *Rhabdophyllia Phillipsi*, E. & H.

The species marked with an asterisk have not been found in the Northern Quarry. It is noticeable that spines of *Cidaris florigemma* were not very unusual, but the lowest bed of oolite here is probably not more than 10 feet below the base of the Rag. *Exogyra nana*, *Ostrea gregaria*, *Littorina muricata*, *Cerithium muricatum*, *Holectypus*, and *Serpula* were moderately abundant. The eleven species not recorded from the Northern Quarry seem to belong to rather shallow-water genera for the most part. *Holectypus* and *Echinobrissus*, so common in the Northern Quarry, are found here in diminished numbers. No doubt the other Northern Quarry sea-urchins might be found here, for they have been found higher up in a more fossiliferous bed of the oolite. On the other hand, the reef-corals of the Rag are absent, and its characteristic large Pectens and Arcas are wanting here, or very rare.

It will be noticed that the fauna of this lowest oolite of the Southern Quarry is intermediate in character between those of the Rag and of the Northern Quarry. The change is probably due more to diminution of depth of water than to difference of geological horizon.

The higher beds of the oolite, as exposed in the middle of the Southern Quarry, are much more fossiliferous. A large quantity of material was quarried here during the spring of 1898, and Mr. H. Keeping, of the Woodwardian Museum, obtained a fine series of specimens. Still more 'Rag' forms come in here, but the principal Northern Quarry sea-urchins are still present. More specimens of *Pygaster* than of any other urchin were obtained here: it is noticeable that in the Northern Quarry it is far less common than *Holectypus* and *Echinobrissus*. It is from these beds, or but slightly higher, that the late T. Roberts obtained *Echinobrissus*, *Collyrites*, *Holectypus*, *Hyboclypus*, and *Pygaster*. I have examined the specimens obtained by Mr. Keeping, and have identified the following, adding a few which I have myself noticed since:—

CEPHALOPODA.

Ammonites (*Perisphinctes*) *Achilles*, d'Orb.
Belemnites abbreviatus, Mill.

GASTEROPODA.

Cerithium muricatum, Sow.
Chemnitzia heddingtonensis, Sow.
Littorina Meriani, Goldf.
L. muricata, Sow.
Phasianella striata, Sow.
Pleurotomaria sp.

LAMELLIBRANCHIATA.

Arca quadrisulcata, Sow.
Astarte ovata, Smith.
Cardium sp.?
Gervillia aviculoides, Sow.
Gervillia sp.
Goniomya v-scripta, Sow.
Hinnites tumidus, Ziet.
Homomya tremula, Buv.
Isocardia sp.
Lima læviuscula, Sow.
L. rigida, Sow.
L. rudis, Sow.
Lithodomus inclusus, Phil.
Lucina moreana, Buv.
Modiola subæquiplicata, Goldf.
M. ungulata, Z. & B.
Mytilus jurensis, Mer.
M. pectinatus, Sow.
Opis arduennensis, d'Orb.
O. Phillipsi, Mor.
O. large sp.
O. virdunensis, Buv.
Pecten articulatus, Schloth.
P. inæquicostatus, Phil.
P. vimineus, Sow.

Pecten large sp.
Pecten small sp.?
Perna mytiloides?, Lam. (or *P. subplana?*, Etall.).
Pholadomya decemcostata, Rœm.
Pleuromya Voltzii, Ag.
Quenstedtia sp.
Trichites sp.
Trigonia Meriani, Ag.

BRACHIOPODA.

Terebratula insignis var. *maltonensis*,
Waldheimia sp.

ECHINODERMATA, etc.

Cidaris florigemma, Phil. (a few spines).
Echinobrissus scutatus, Lam.
Holectypus depressus, Leske.
Hyboclypus gibberulus, Ag.
Pygaster umbrella, Ag.

Vermilia sulcata, Sow.

Montlivaltia dispar, Phil.

Holcospongia glomerata? (Quenst.).

At High Fen Farm, less than $\frac{1}{4}$ mile north-east of the Northern Quarry, a small quantity of rock was recently thrown out in deepening a well. By the kindness of the farmer I was enabled to examine this when newly excavated. The bulk of the material consisted of a hard, bedded, oolitic (or rather pisolitic) limestone of a deep bluish-grey colour when wet, the pisolites being darker outside, and giving the rock a spotted appearance. A small quantity of the upper part was softer than the rest, and seemed more marly, perhaps merely because it was near the previous floor of the well. The rock was said to increase in hardness downwards, and at the bottom was so hard as to emit sparks when struck with the pickaxe. It was stated by the farmer that the well had been deepened to a depth of 18 feet, and that formerly another well had been sunk a few yards away to a depth of 20 feet without piercing the limestone. From about two wheelbarrow-loads of material from the first-named well the writer obtained:—

Ammonites (*Perisphinctes*) *plicatilis*, Sow. (several pieces).
Littorina Meriani, Goldf. (two specimens somewhat crushed in the rock).
Pleurotomaria reticulata, Sow.
Dentalium ?
Exogyra nana, Sow.
Lithodomus inclusus, Phil.
Opis Phillipsi, Mor. (several).

Collyrites bicordata, Leske.
Echinobrissus scutatus, Lam.
Holectypus depressus, Leske (several).
Vermilia sulcata, Sow.
Serpula sp.
Pentacrinus, stem-joints and ossicles.
Montlivaltia ? (or *Thecosmilia ?*).

The fauna is substantially the same as that of the Northern Quarry, but the rock in this well seems more fossiliferous, and *Ammonites plicatilis* more abundant.

A feature of interest is the occurrence in the hardest oolite of many small lumps and streaks of soft bluish-black clay. The streaks were seen lying at various inclinations in the same piece of rock, and the lumps of clay were often more than a cubic centimetre in bulk. Many ossicles of *Pentacrinus* and a few stem-joints occurred, all blackened and apparently worn and rolled. Though the earlier well was sunk 2 feet deeper without piercing the limestone, still these clay-inclusions and the rolled and blackened joints of *Pentacrinus* suggest the proximity of a clay-bed, and the influence of current-action. Indeed the farmer stated that the limestone was replaced laterally by a clay of the same appearance, a little farther west on the same farm, beneath the peat; little importance, however, can be attached to the statement, as both Gault and Kimeridge Clay rest upon the flank of the Corallian ridge farther south.

Prof. Bonney remarked long ago that the core of blocks of the Upware oolite was often greyish-blue. Certain fossils in the Woodwardian Museum show a similar matrix. There seems no doubt that such was once the colour of all the Upware oolite, its present buff colour being the result of oxidation. The oolite from this well is, however, less pure than the higher beds. A solution of a small piece of this grey oolite in hydrochloric acid gave a considerable residue of bluish-black mud, which, when dried, formed a clay indistinguishable from the lumps in the limestone. In this grey oolite I estimated carbonate equivalent to 91·5 per cent. of carbonate of lime. The colour of the rock would then seem to be due to finely-divided particles of bluish-black clay, when not oxidized. The result of a similar estimation of the Northern Quarry oolite showed about 95 per cent. of carbonate of lime, but this estimation was not quite satisfactory and the percentage should probably be slightly higher.

The surface of the ground at this well lies perhaps 3 feet above river-level, somewhat higher than the floor of the Northern Quarry. In the lane about 400 yards south of the Northern Quarry very white oolite is seen in a ditch, almost certainly a higher bed than any in the Northern Quarry; for the slope of the ground is decidedly greater than the slight northerly dip in the ditch and in the quarry; and the dip is probably fairly constant about here. On the whole, it seems that the thickness of the oolite of the Northern Quarry and its neighbourhood could scarcely be less than 40 feet, and may be considerably more.

As already mentioned, the stratigraphical relationship of the oolite of the Northern Quarry to the Rag of the Southern Quarry was long a matter of uncertainty, and perhaps even now it is not so surely fixed that additional evidence is superfluous. The grounds on which earlier writers have placed the Northern Quarry oolite below the Rag have been mentioned above. The following points have been brought out so far in the present paper in support of this correlation:—

(1) The fauna of the oolite of the Southern Quarry is intermediate in character between that of the Rag and that of the oolite of the Northern Quarry, and contains many species of each not found in the other.

(2) Beneath some 40 feet of oolite, as seen in the well at High Fen Farm and in its neighbourhood, there is in the well not only no indication of Rag below, either lithologically or palæontologically, but, on the other hand, there are signs of the proximity of clay. The bluish-grey oolite of this well is decidedly less pure than the Rag.

Al hough there is no evidence known to me of diminution of the

Corallian area by denudation, I have found evidence of denudation of the surface-oolite in the material from the Lower Greensand phosphate-beds which overlie part of the western flank of the ridge. In this, rounded pebbles formed of Corallian pisolites often contain phosphatic nodules, small quartz-pebbles, and Greensand brachiopoda, showing denudation and reconstruction of the oolite in Lower Greensand time. Consequently the oolite now at the surface was not originally the highest; but in the Southern Quarry the original top of the oolite is preserved beneath the Rag.

In the autumn of 1897 a small section was opened near the southern end of the ridge and on the western side of it, more than ¼ mile from the Southern Quarry, in a corner of the field immediately north of the Inn-yard, and close to the road (see sketch-map, p. 612). The section is cut obliquely through a little spur which runs out south-westwards from near the end of the ridge. I subsequently excavated a little farther in the bottom of this cutting; the following deposits were exposed:—

		Feet.	In.
5.	Soil, with lumps and grains of limestone	1 to 1	6
4.	Hard, whitish, much-broken, rubbly limestone; many spines of *Cidaris florigemma*, ossicles of *Pentacrinus*, and other fossils	1 to 1	6
3.	A bed almost entirely composed of ossicles of *Pentacrinus* in a yellowish calcareous matrix	2 to 1	0
	Passing down into—		
2.	(*c*) Soft, yellowish-grey, calcareous marl with ossicles of *Pentacrinus*; limonite-stains along the bedding-planes and on the surface of minute joints, of reticulate appearance in the lower part. Passing down into—	1	6
2.	(*b*) Soft laminated grey marl with occasional small ironstone-nodules, thin layers, blotches, and reticulations of limonite; the marl alternating with hard flaggy layers of crystalline limestone full of *Thecosmilia*, one of these layers being at the bottom; ferruginous oolitic grains in the lower part	1	0
2.	(*a*) Soft, dark grey, clayey marl with ferruginous oolitic grains.	0	3
1.	Light, yellowish-grey, impure limestone full of ferruginous oolitic grains (Elsworth Rock)	0	9
		7	6

There are at intervals from top to bottom thin, hard, crystalline bands with traces of coral-structure (*Isastræa* or *Thamnastræa*), as in the Rag. Near the bottom these bands are more or less continuous, but higher up they are shattered and displaced, yet still for the most part recognizable as bands. I could find no trace of unconformity in the section, and I was much struck by the resemblance of the lowest bed to the Elsworth and St. Ives Rock; but, owing to want of sufficient fossil-evidence and the improbability of finding 'Lower Calcareous Grit' so high (and the evidence of fossils from the overlying white limestone was strongly in favour of a high horizon), I was inclined to regard the resemblance as a mere coincidence, and waited for further light on the matter from a well which, as it appeared, was to be sunk close by. Being fortunately present immediately after the opening of the above section, and while the material was being removed, I was able to examine two or three cartloads of the rock. The species enumerated in the appended list were obtained, all occurring in the white limestone at the top, and several also down to the bottom of the section. *Cidaris florigemma*-spines were, abundant down to what proved to be the top of the Elsworth Rock.

LIST OF FOSSILS FROM THE FOREGOING SECTION.

* *Cerithium muricatum*, Sow.
* *Littorina muricata*, Sow.

* *Arca pectinata*, Phil.
Avicula inæquivalvis (?), Sow.
Cucullæa elongata, Sow.
* *Isocardia (?)* sp.
Lima rudis, Sow.
L. rigida, Sow.
* *Lithodomus inclusus*, Phil.
* *Ostrea* (*Alectryonia*) *gregaria*, Sow.
* *O.* (*Exogyra*) *nana*, Sow.
* *Pecten articulatus*, Schloth.
* *P. vimineus*, Sow.

Terebratula insignis var. *maltonensis*, Oppel.

* *Vermilia sulcata*, Sow.
Serpula deplexa (?), Phil.
Serpula sp.

* *Isastræa (?)*.
* *Montlivaltia dispar*, Phil.
Rhabdophyllia sp. (?).
* *Thamnastræa concinna*, Goldf.

* *Cidaris florigemma*, Phil. (spines).
C. Smithii, Wright (spine).
Echinobrissus scutatus, Lam.

* *Pentacrinus* sp.

Holcospongia glomerata (Quenst.).
Holcospongia, another sp. (?).

Haplophragmium (?).
Vaginulina ? legumen ? (or *Dentalina ?*).
Valvulina (?).

[Those marked with an asterisk were abundant.]

It will be seen at once that this is essentially the Upware Rag fauna. All the species here mentioned have been found in the Rag, except the foraminifera; and *Echinobrissus*, found by Roberts, not in the Rag, but in the floor of the Southern Quarry—that is, in the highest oolite. The Rag has probably never been searched for foraminifera. Nearly all these species are particularly characteristic of the Rag, while *Cerithium muricatum*, *Littorina muricata*, *Arca pectinata*, *Lima rudis*, *L. rigida*, *Lithodomus inclusus*, *Alectryonia gregaria*, *Pecten articulatus*, *P. vimineus*, *Isastræa*, *Montlivaltia*, *Thamnastræa*, and *Cidaris florigemma* have never been recorded from the Northern Quarry, though most of them occur in the highest oolite of the Southern Quarry.

The following were obtained lower down in the section, from the beds marked (2), chiefly in and on the hard crystalline bands:—

Cerithium muricatum, Sow.
Littorina sp.

Exogyra nana, Sow.
Gervillia aviculoides (?), Sow.
Lima rigida, Sow.
Lithodomus inclusus, Phil.
Pecten articulatus (?), Schloth.
P. vimineus, Sow.
Perna sp.

Terebratula insignis, var. *maltonensis*, Oppel.

Cidaris florigemma, Phil. (many spines).
C. Smithii, Wright (spine).

Pentacrinus sp.

Rhabdophyllia sp. (?).
Thecosmilia annularis, Flem. (very abundant).
Thamnastræa concinna, Goldf.

The crystalline bands in 2 (*b*) were crowded with *Thecosmilia* evidently in the position of growth. In most instances noticed, the main stem was vertical or nearly so; it seemed that only horizontal sections of the coral had been preserved, in length equal to the thickness of the crystalline layers. No *Thecosmilia* was found in 2 (*c*), 3, or 4, in the broken crystalline bands, the corals here being *Thamnastræa* or *Isastræa*, and probably *Rhabdophyllia*, represented by tubes filled with marl. It was observed that the corals in the lower beds contained in the marl were preserved somewhat differently from those in the Rag, the septa here being preserved in calcite, and the *Thecosmilia* never occurring as hollow casts like the *Montlivaltia* in the Rag.

An estimate of carbonate in the marl 2 (*c*) gave the equivalent of only 53 per cent. of carbonate of lime. The bed (3) of the section has a superficial resemblance to a soft grit. Ossicles of the cirri and pinnules of *Pentacrinus* are the chief constituents, together with stem-joints and occasional calyx-plates. Corals (in the crystalline blocks), *Cidaris florigemma*, *Ostrea gregaria*, *Exogyra nana*, etc. were noticed. The crinoids are wholly disintegrated, two or three joints being seldom found united.

The white rubbly limestone (4) is not like either the Rag or the oolite of Upware. It is possibly conglomeratic, and has the appearance of coral-detritus partly dissolved. This bed and the one below are certainly suggestive of formation in shallow water on the slope of a coral-reef. No certain trace was found in this limestone of the pisolitic or oolitic structure of the Upware oolite. It is difficult, however, to draw a line between rolled and perhaps slightly coated joints of crinoids and the first stages of the true pisolite. I have often found the latter to consist at Upware of ossicles and small stem-joints of *Pentacrinus*, fragments of echinoid spines, and even occasionally small gasteropoda, the last-named preserved as internal casts in the pisolite, all coated with a calcareous growth. Sometimes two or three smaller oolitic grains are cemented together and coated over with this growth, producing an irregular pisolite. I have not succeeded in finding *Girvanella* in this growth, but there is no reason to doubt that it might be found. That the Upware pisolite is a true pisolite, and not merely formed by an agglomeration of rounded shell-fragments, is certain; especially as scarcely any trace, if any at all, of arragonite-shells is preserved in the Upware rock, all such being represented merely by casts.

As mentioned above (p. 606), it had been decided to sink a well close to the section last described. The work was, however, delayed for several months, and when it was carried out I was unable to be present. By the kindness of the well-sinker and the landlord of the Inn, I was informed when the work would be begun, and asked Messrs. H. H. Thomas & G. McFarlane, of Sidney Sussex College, to examine the well. They were good enough to make several journeys to Upware during the progress of the work, and to them I am indebted for the following particulars. The well was sunk by the roadside about 10 yards south-east of the section above described, which will be alluded to hereafter as the field-section:—

Section of a Well at Upware, near the Inn (according to Messrs. Thomas & McFarlane.)

			Ft.	In.
	F.	Surface-soil, disturbed, with lumps of white rubbly limestone .	1	6
Elsworth Series.	E.	Impure limestone full of ferruginous oolitic grains; a layer of corals (*Thecosmilia annularis*) at the top, and a band of hard nodules 6 inches from the base; *Lithodomus inclusus* occurred in the corals........	2	3
Elsworth Series.	D.	Brown clay, containing soft white nodules, and in the lower part *Gryphæa dilatata, Ostrea gregaria, Exogyra nana, Unicardium depressum, Vermilia sulcata, Serpula* sp. .... Passing down into—	2	0
Elsworth Series.	C.	Clay, blue and sometimes distinctly laminated above, blackish below; the lower part full of *Exogyra nana* and *Serpula*; other fossils were *Modiola*, small (young of *M. bipartita ?*), ammonites (apparently either *A. vertebralis* or *A. cordatus*); much iron pyrites, but no pyritized fossils found	7	9
Elsworth Series.	B.	Dark grey impure limestone, full of brown ferruginous oolitic grains, hardest at the bottom, where the fossils were more abundant; the upper part contained *Ammonites* sp., *Avicula inæquivalvis ?*, and a large *Serpula*; the lower part, *Ammonites* (*Cardioceras*) *cordatus, A.* (*C.*) *Mariæ, Exogyra nana, Pecten fibrosus, Modiola bipartita, Rhynchonella varians, Serpula* sp.	4	0
	A.	Soft blue clay with pyritized ammonites and many *Gryphæa dilatata*; at the top a well-marked thick band of *Vermilia sulcata*; other fossils were *Ammonites* (*Peltoceras*) *Eugenii, Cucullæa concinna*, etc.	4	6
			22	0

Mr. Thomas states that on the southern side of the well the depth of soil was 3 feet or more instead of only 1 foot 6 inches, and that the ground, at any rate on this side, had been disturbed, pieces of Roman pottery being found at the bottom of the soil. Below this, there was no sign of either disturbance or unconformity in the section.

The beds (E) of the well-section and (1) of the field-section must be the same. It will be seen that in the short distance between the two sections the Elsworth Rock comes up nearly to the surface, a rapid rise of which there is little or no indication in the field-section. However, there is no reason to suspect a fault, for the rise is hardly, if at all, more rapid, probably, than that shown by the suddenly-increasing angle of dip at the northern end of the Southern Quarry.

Mr. H. Keeping, of the Woodwardian Museum, subsequently examined the material thrown out from the well, and collected a large series of specimens from it. He at once recognized the Elsworth Rock, with Oxford Clay below.

I have examined the fossils obtained by Messrs. Thomas &

McFarlane and by Mr. Keeping, and have identified the following:—

From the Elsworth Rock:—

Ammonites (*Cardioceras*) *cordatus*, Sow.
A. (*C.*) *vertebralis*, Sow.
A. (*C.*) *Mariæ*, d'Orb.
A. (*Peltoceras*) *Eugenii*, Rasp.
Belemnites Oweni, Pratt.
B. hastatus (?), Blainv.
B. abbreviatus (?), Mill.
Pleurotomaria granulata, Lyc. *non* Sow.
Arca æmula, Phil.
Astarte ovata, Smith.
Avicula inæquivalvis, Sow.
Exogyra nana, Sow.
Gryphæa dilatata, Sow.
Modiola bipartita, Sow.
Myacites (?).
Ostrea (*Alectryonia*) *gregaria*, Sow.
Opis Phillipsi, Mor.
Pecten articulatus, Schloth.
P. fibrosus, Sow.
P. lens, Sow.
Pholadomya parcicosta, Ag.
Unicardium depressum, Phil.
Rhynchonella varians, Schloth.
Waldheimia bucculenta (?), Sow.
Serpula sp.
Vermilia sulcata, Sow.

From the Oxford Clay:—

Eryma sp. (?)
Ammonites (*Cardioceras*) *cordatus*, Sow.
A. (*Harpoceras*) *hecticus*, Rein.
A. (*Peltoceras*) *athleta* (?), Phil.
A. (*Peltoceras*) *Eugenii*, Rasp.
A. (*Perisphinctes*) cf. *biplex*, Sow.
Belemnites hastatus, Blainv.
B. Oweni, Pratt.
Cucullæa concinna, Phil.
Gryphæa dilatata, Sow.
Modiola bipartita, Sow.
Nucula sp.
Pecten sp.
Pinna mitis, Phil.

Some of the ammonites in the Oxford Clay here, as usual, are pyritized. This is stated never to be the case in the Ampthill Clay.

Mr. Keeping also caused an excavation to be made in a ditch near the Engine Mill, nearly ¼ mile south of the Inn. Here again Elsworth Rock was found, the bottom of it being reached at a depth of 6½ feet from the surface of the field; below this the excavation was continued a little deeper in Oxford Clay. I have examined the fossils obtained from the Elsworth Rock here also, and have found them to be:—

Ammonites (*Cardioceras*) *Goliathus*, d'Orb.
Gryphæa dilatata, Sow.
Exogyra nana, Sow.
Ostrea (*Alectryonia*) *gregaria*, Sow.
Ostrea (*A.*) *flabelloides*, Lam.
Diastopora (*Berenicea*) *diluviana*, Lamx. (on *Ammonites Goliathus*).
Vermilia sulcata, Sow.

This brings our list of Elsworth Rock species from Upware to twenty-nine. Of these, all but *Ammonites Eugenii*, *A. Mariæ*, *Belemnites abbreviatus* (?), *Rhynchonella varians*, and *Berenicea diluviana* have been found at Elsworth or St. Ives. *Ostrea flabelloides* and *Vermilia sulcata* are in the Woodwardian Museum series of Elsworth fossils, though not recorded by Mr. Roberts. The lithological resemblance between this Upware Rock and those of Elsworth and St. Ives is complete, the lower bed at Upware being grey and unaltered as at Elsworth, the upper brownish-yellow and oxidized as at St. Ives. The brown oolitic grains occur also in the clay between the upper and lower Elsworth limestone at Upware, especially near the top and bottom of it, but not in the Oxford Clay below.

Considering the strong lithological and palæontological resemblance between this Upware rock and the types at Elsworth and St. Ives; considering also the occurrence of a similar rock with similar fossils at several localities in the neighbourhood of Elsworth and St. Ives; also between these places and Upware, at Bluntisham on the authority of Prof. Seeley,[1] and at Chettering Farm, $2\frac{1}{2}$ miles north-west of Upware, on that of Mr. Roberts, there can be no doubt of the correctness of the correlation of this Upware rock with that of Elsworth and St. Ives. At Upware, as at Elsworth, according to Prof. Seeley, the series consists of three members, an upper and a lower limestone separated by clay. The relative thicknesses are, however, naturally somewhat different. The series seems to vary somewhat, for at Chettering Farm there is said to be 8 feet of Elsworth limestone under Ampthill Clay, and overlying 11 feet of light-brown sandstone. Little stress then can be laid on any such identity of divisions at Upware and at Elsworth, and an access of calcareous matter to the middle division at Upware would convert the whole into an uniform limestone of Elsworth type.

The upper limit of the Elsworth Rock at Upware must be more or less arbitrary. It should, perhaps, be placed below the bed of *Thecosmilia*, which forms the top of E in the well-section (p. 609), and below 2 in the field-section (p. 606). The marl above, with its crystalline beds of *Thecosmilia*, and the *Pentacrinus*-beds would then form a passage. It is noticeable that *Thecosmilia*, so abundant in the lower part of these passage-beds, is quite unknown in the Rag and oolite of Upware, but has been found at Elsworth.

The lower limit of the Elsworth Rock is easily fixed by the well-marked band of *Serpula*, which Mr. Keeping states is persistent at the top of the Oxford Clay throughout the whole district. It is, he says, visible at the base of the Elsworth Rock at Elsworth, and at the base of the Ampthill Clay at Gamlingay. At Upware it is crowded with *Serpula*, intermixed with shells of *Exogyra nana*, etc., and may mark a pause in deposition. Its matrix is clayey, and above it there seems to be 2 or 3 inches of clay with ferruginous oolitic grains. A less definite *Serpula*-band occurs here in the clay between the upper and lower Elsworth limestones. Mr. Thomas found it here full of large crystals of pyrites.

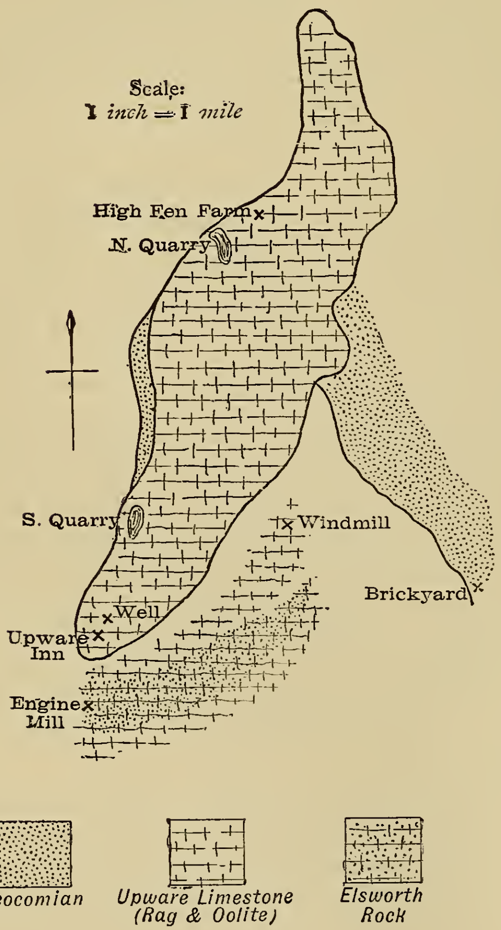
Mr. Keeping has carefully examined the ground for some distance to the south and east. He has shown me that, although the Upware Corallian type is represented by fragments on the surface for a short distance south of the well, it is soon replaced by Elsworth Rock and Elsworth fossils, which occur abundantly both on the surface and in the ditches for $\frac{1}{4}$ mile south of the Inn. As already mentioned (p. 610), he found Oxford Clay below it in a pit which he had dug opposite the Engine Mill, at a point nearly as far south as the last surface-indications of Elsworth Rock. One hundred yards beyond this limit to the south he found the Upware Corallian type again at the surface, till yet farther south it disappears beneath

[1] Ann. Mag. Nat. Hist. ser. 3, vol. x (1862) p. 101.

the fen. He points out that the Elsworth Rock and overlying beds form a denuded anticline south of the well. He has also traced the Elsworth Rock for nearly a mile eastward towards Wicken, where it is followed by higher Corallian for about 20 yards before reaching the fen. Farther north, near the windmill, he found the Upware Corallian type again. It had been recorded, however, by the late Prof. W. Keeping and Mr. Tawney, beneath the Greensand at the brickyard farther east.[1]

A rough sketch-map is here given, showing the position of the Elsworth Rock at the surface, and Mr. Keeping's suggested extension of the Corallian. It is taken from the 1-inch Geological Survey Map, the portions marked off by boundary-lines being those mapped by the Geological Surveyors, while the farther extension to the south is indicated outside these boundary-lines.

Geological Map of the neighbourhood of Upware.



It was stated by Mr. H. B. Woodward (Geol. Surv. Mem. 1891) that the Corallian beds here seem to have no constant dip: it was shown by Mr. Roberts that a fold or a fault (of which latter there is no evidence) was necessary if the Northern Quarry oolite was to be placed below the Rag; I have mentioned (p. 602) that the dip changes visibly in amount within the Southern Quarry; and Mr. Keeping has pointed out that there is an anticline before the final disappearance of the Corallian beneath the fen to the south. There is then abundant evidence that the beds undulate, as Mr. Woodward suggested. Another apparent anticline will be indicated subsequently between the Southern Quarry and the Inn.

The stratigraphical relationship of the Elsworth Rock at Upware

[1] See W. Keeping, 'Fossils ... of Upware & Brickhill,' Sedgwick Prize Essay for 1879 (1883).

to the Rag and oolite is at present dependent on the interpretation placed on the field-section near the well. At first sight it was natural to suppose that the Elsworth Rock formed the base of the Upware Corallian, and that the marl and white rubbly limestone above it represented the lowest part of the oolite. The Elsworth Rock comes to the surface a short distance south of the well, while the higher beds of oolite and the Rag in the Southern Quarry rise towards the south, the last-named being lost at the surface some 50 yards from the southern end of the quarry. With the slight dip there apparent a considerable thickness of oolite might have cropped out, bringing its basement-bed to the surface in the neighbourhood of the field-section and the well. Indeed, but for the white limestone and its fauna in this field-section, probably no one would hesitate to adopt the simpler explanation that the Elsworth Rock comes below the base of the Upware oolite, a considerable thickness of the latter having cropped out and been lost at the surface, an explanation more closely in accordance with preconceived ideas of the position of the Elsworth Rock. Even as it is, the presence above of a fauna not found at Upware lower in the oolite than its highest beds might be explained away on the ground that the rock in which it occurs is not an oolite, and that, under conditions slightly different from that of the oolitic deposit, the Rag-fauna might have come down somewhat lower. This view does not commend itself to the present writer. We may urge against it: (1) that the limitation of a large number of the fossils of this overlying limestone to the Rag and highest oolite is absolute at Upware; (2) that, as already stated, there is no sign of a break; (3) that evidence from dip is of no value here, for it has been shown that the beds undulate, and that the higher Corallian comes on again about $\frac{1}{4}$ mile farther south; (4) that the white limestone here resembles more closely the Rag than the oolite, and has every appearance of a detrital origin, from degradation of the reef, and that, if so, it must necessarily occur above the oolite and not at its base; (5) that, if of detrital origin, its fauna could not be earlier than that of the reef from which it is derived; (6) that if the oolite had cropped out and been denuded, bringing its basement-bed to the surface, then this spot would have been well within the area of oolitic deposit and there would be no apparent reason for the occurrence here of a limestone of a different type; (7) that in the well at High Fen Farm there is no sign of a non-oolitic limestone or of the approach of a 'Rag' fauna, but there are indications of the proximity of clay; (8) that the 'Rag' fauna, well represented in the top of this section by reef-corals, lamellibranchs, and *Cidaris*, seems to belong to somewhat shallow-water conditions, and probably for that reason is not found low down in the oolite.

It may be suggested that possibly the white limestone here is not conformable to the underlying beds. No such unconformity is visible; there seems to be a complete passage upwards: a regular gradation from the continuous crystalline layers with *Thecosmilia* to the higher broken layers with *Thamnastræa* and *Isastræa*. If there were a break at the base of this white limestone, none could be suggested lower; and yet below the laminated marl, in the crystalline bands with *Thecosmilia*, there occur *Cidaris florigemma* (in some abundance), *Terebratula maltonensis*, *Thamnastræa concinna*, and other forms never found below the highest oolite at Upware.

The conclusion, then, seems inevitable that no oolite has been lost here, and that the passage-beds and Elsworth Rock really come just below the Rag horizon. In this case there would be another anticline (or a fault, of which I have found no evidence anywhere in the neighbourhood) between the Southern Quarry and the well- and field-sections.

It appeared, then, desirable to re-examine the evidence on which the Elsworth Rock has been correlated with the Lower Calcareous Grit, by the light of more recent additions to the faunas both of the Elsworth and St. Ives Rock and of the Corallian generally. About a hundred species have been found at Elsworth and St. Ives. On taking the Yorkshire Corallian area and comparing the Elsworth and St. Ives fauna with those of (1) the Lower Corallian Oolite, Lower Calcareous Grit, and still lower British formations, and (2) the higher Corallian beds and higher formations, it appears that some 76 Elsworth and St. Ives species are found in the Lower Corallian Oolite and Lower Calcareous Grit or in Oxford Clay or still lower, while 71 are found above the Lower Corallian Oolite. Of these 76 forms from the Yorkshire Lower Corallian and below, one is a doubtful Elsworth form, and another, not found higher in Yorkshire, is so found elsewhere in England; while, of the 71 higher Corallian species, 2 that are not found lower down in Yorkshire are so found elsewhere.

A comparatively thin and impure calcareous deposit such as the Elsworth Rock, covering no great area and for the most part isolated in the midst of thick clays, might perhaps preserve a greater proportion of Oxford Clay species than more extensive and thicker Corallian rocks did. Moreover, there probably still remain in our Corallian lists certain forms wrongly identified with species of the better-known Lower Jurassic faunas. This, of course, tends towards an exaggeration of the number of Elsworth Lower Corallian forms as compared with those of the Upper. At any rate, if we neglect occurrences in the Oxford Clay and below, we find 58 species common to the Elsworth Rock with the Lower Calcareous Grit and Lower Corallian Oolite of Yorkshire; 3 of these, not found higher in Yorkshire, being so found elsewhere, while as many as 69 forms are common to the Elsworth Rock with higher Corallian beds of Yorkshire, 2 of these, not found lower in Yorkshire, being found lower elsewhere in England.

The late T. Roberts pointed out that though 5 Elsworth species (*Astarte robusta*, *Cucullæa clathrata*, *Cardium Crawfordi*, *Hinnites abjectus*, and *Isocardia globosa*) are elsewhere found only below the Corallian, yet they are all species of long range and not peculiar to the Oxford Clay. One of these, *Hinnites abjectus*, is now recorded from the Malton Oolite, in which *Waldheimia bucculenta* has also been found. This is one of the species mentioned by Mr. Roberts as essentially Lower Corallian, and another of these, *Millericrinus echinatus*, is now recorded higher both in Yorkshire and in the South of England; other Elsworth species not found above the Lower Oolite in Yorkshire are *Goniocheirus cristatus*, *Ammonites convolutus*, *Nautilus perinflatus*, *Natica tenuis*, *Avicula braamburiensis*, and *Waldheimia Hudlestoni*, while *Natica Clymenia*, *Avicula pteropernoides*, *Cypricardia glabra*, *Lima subantiquata*, *Waldheimia margarita (?)*, and *Cidaris florigemma* are peculiar to higher Corallian beds in Yorkshire.

I have not been able to compare the Elsworth Rock fauna with that of the other English Corallian areas in the same way, owing to the inclusion of Elsworth forms in the fauna of the *perarmatus*-zone of the South of England, in the tables published by the Geological Survey, some species being apparently so included only on the strength of their occurrence at Elsworth and St. Ives. Perhaps *Cidaris florigemma* is an instance of this. There are some 71 species common to the Elsworth and St. Ives Rock with the *plicatilis*-zone in the South of England and at Upware. As regards the Oxford Clay forms which occur in the Elsworth Rock, two more may be added to them from that rock at Upware (*Ammonites Eugenii* and *Rhynchonella varians*); yet the base of the Elsworth Rock is here only about 20 feet below a rock full of typical 'Rag' forms.

It is not, of course, suggested that the above comparison affords any ground for placing the Elsworth Rock higher than the Lower Calcareous Grit of Yorkshire; but the foregoing statistics do seem to show that there is no longer any palæontological evidence for correlating it with the Lower Calcareous Grit rather than with higher beds. It is perhaps only another instance of the difficulty of correlating distant Corallian rocks by fossil evidence, where faunistic changes are due more to difference of conditions than of horizon, and most of the species have a wide range. It should be remembered that the Elsworth Rock was first placed in the Oxford Clay, and that anyone thinking it necessary to raise it to a higher horizon would naturally correlate it with the Lower Corallian, in the absence of decisive evidence for a still higher position.

Of stratigraphical evidence for a correlation strictly with the Lower Calcareous Grit there is of course none, if by 'Lower Calcareous Grit' we mean anything more definite than a local base of the Corallian at whatever horizon.

The precise relation of the Elsworth Rock at Upware to the Corallian Oolite, whether the former constitutes the base of the latter or passes into it laterally, cannot be determined at present. The two are certainly very closely associated. It is seen that there is no intervening Ampthill Clay, unless the marly passage-beds above and the clay between the two limestones of the Elsworth Rock are to be regarded as such. Believing that the upper white limestone of the field-section represents the true 'Rag' horizon, I am rather inclined to the opinion that the Elsworth Rock passes laterally into the Oolite eastward and northward. Still there is no real reason against its passing under and forming the base of the Corallian Oolite, except perhaps the thickness of oolite under which it would have to pass. It is worth noting, too, that although there were signs of the proximity of clay in the blue oolite from the bottom of the well at High Fen Farm, no trace of ferruginous oolitic grains was found, and no difference of fauna from that of the Northern Quarry except the greater abundance of fossils and the presence of one coral-specimen which, as embedded in its matrix, might be either a *Montlivaltia* or a *Thecosmilia*, probably the former.

In favour of the view that the Elsworth Rock passes laterally into the Corallian Oolite there are these considerations:—The Elsworth Rock, though found at several places to the west, is not known directly north or east. It is known to be absent at March, where a deep boring [1] showed continuous clay from the Kimeridge into the Oxford. Prof. Sedgwick stated that several wells were sunk between Cambridge and King's Lynn through Kimeridge and Oxford strata without meeting any Corallian. The Elsworth Rock, then, is absent at no great distance north and north-east of its exposure at the southern end of the Corallian ridge of Upware, an area of great change from the prevalent clay-conditions of this part of England, and about the horizon of the Elsworth Rock. It is therefore here, if anywhere, that we might expect the Elsworth Rock to alter in character. Moreover, it seems more natural to account for the introduction of this thick Upware oolite in the midst of Jurassic clays, as an expansion of the Elsworth Rock, than to assume the presence of both at the same spot and leave the former unaccounted for. The continuous *Serpula*-bed at the top of the Oxford Clay and the occurrence of lumps of clay in the lower part of the Oolite at High Fen Farm suggest the possibility of a pause in deposition such as that indicated by the nodule-bed at the base of the Kimeridge, or of an eroded basin, as in the Gault below the Cambridge Greensand. If the deposit which has formed the Elsworth Rock passed into some such local basin, it might well change in character at once rather than continue at first of the same type. Still, I am well aware that no proof has been given here of a lateral passage, and I am content to wait for further evidence which may be forthcoming at Upware.

The Upware Corallian, then, seems to represent the whole of the Ampthill Clay of Bedfordshire and Lincolnshire. In the district between Elsworth, St. Ives, and Upware, and perhaps farther south and east, the lower part of the Ampthill Clay develops into a limestone of Elsworth type which is closely associated with the Upware Corallian and may pass into the Corallian Oolite. In any case, considering the greater thickness of the Yorkshire Corallian, it would seem to belong to a higher horizon than the Lower Calcareous Grit.

In conclusion, I wish to express my thanks to Messrs. H. H. Thomas and G. McFarlane, of Sidney Sussex College, for

[1] Mem. Geol. Surv. S.W. Norfolk & N. Cambs. 1893, p. 154.

their kindness in carefully examining and measuring the well-section at Upware, and in collecting specimens, at some personal inconvenience; to Mr. H. Keeping, of the Woodwardian Museum, for the trouble that he has taken in examining the well and in tracing the further extension of the Elsworth and Upware limestones, also for allowing me to examine the large series of fossils which he has obtained from both rocks; to Dr. G. J. Hinde, for kindly examining certain sponges from Upware; to Mr. F. Chapman, who was good enough to give his opinion on certain foraminifera; and to Mr. J. E. Marr for much valuable advice.

Note on certain Corallian Fossils from Upware.

The small exposure of 'Rag' in the Southern Quarry has been for many years so carefully searched for fossils by many geologists that few new forms are likely to be found, except perhaps among the foraminifera. To the fauna of the 'Rag' proper the present writer is able to add only one form, a tooth of *Hybodus*; this, however, is interesting as being, so far as known, the only vertebrate yet found at Upware. *H. grossiconus* has been recorded from the Elsworth and St. Ives Rock.

Besides this, the sponge recorded by Roberts from the 'Rag' as *Scyphia* sp. proves to be *Holcospongia glomerata* (Quenst.). I have found this species in both the Rag and the oolite, and in the section near the Inn. Thinking that other species of *Holcospongia* might be represented, I submitted specimens to Dr. G. J. Hinde, who was good enough to examine them, and considers them all to be *H. glomerata*, except perhaps one specimen.

In the series of fossils obtained by Mr. Keeping from the highest beds of oolite in the Southern Quarry, beds which have been neither so long exposed nor so frequently worked, there occur a few forms new to Upware, namely:—

Pecten: an internal cast of a rather large species, showing traces of strong concentric marking as well as numerous ribs; it resembles somewhat *P. annulatus*.
Trichites sp.
Opis, large sp. (not *O. virdunensis*): an unnamed specimen of apparently the same species, from the Rag, is in the Woodwardian Museum.
Waldheimia sp.

The following, previously recorded from the 'Rag,' have been obtained by me from the Northern Quarry oolite:—

Eryma sp. (?).
Ammonites (*Cardioceras*) *vertebralis*, var. *cawtonensis*, Bl. & H.
Dentalium sp.
Exogyra nana, Sow.
Gervillia sp.
Ostrea sp.
Vermilia sulcata, Sow.
Holcospongia glomerata (Quenst.).

In the field-section near the Inn, from the limestone with 'Rag'-fossils (bed 4 of the section) *Holcospongia glomerata* (Quenst.), *Holcospongia*, another sp. ?, and *Vaginulina legumen* ? (or *Dentalina* sp.?) may be recorded, the foraminifer on the authority of Mr. F. Chapman. In a slice of this rock Mr. Chapman noticed also other fragments of foraminifera, which, he states, may be *Haplophragmium* and *Valvulina*.

In the 'passage-beds' (2 *b* of the field-section) *Thecosmilia annularis*, Flem., occurs abundantly, and has not been previously found at Upware.

From the two exposures of Elsworth Rock,

Ammonites (*Cardioceras*) *Mariæ*, d'Orb.
A. (*Peltoceras*) *Eugenii*, Rasp.
Rhynchonella varians, Schloth.
Diastopora (*Berenicea*) *diluviana*, Lamk.

are new to the Elsworth Rock fauna.

The Woodwardian Museum has also the following unpublished species from the Rock at Elsworth and St. Ives:—

Ammonites (*Cardioceras*) *cordatus*, var. *excavatus*, Sow. (St. Ives.)
Alaria bispinosa ?, Phil. (Elsworth.)
Cerithium, sp. (St. Ives.)
Trochus, sp. (Elsworth.)
Cypricardia glabra, Bl. & H. (Elsworth.)
Lima subantiquata, Rœm. (Elsworth.)
Opis Phillipsi, Mor. (Elsworth.)
Waldheimia margarita ?, Opp. (Elsworth.)
Hyboclypus gibberulus, Ag. (St. Ives.)

A word may be said about the common '*Serpulæ*' of the Upware rocks. '*Serpula tetragona*, Sow.,' appears in the published list of Upware Rag species, and '*Serpula* sp.' in the Elsworth list; in the Woodwardian Collection '*Serpula tricarinata*, Sow.,' Elsworth Rock, is found; also '*Serpula sulcata*, Sow.,' Oxford Clay. These and the *Serpula* which forms the thick bed at the top of the Oxford Clay are all unquestionably one and the same form, and that form does not agree with Sowerby's figure and description of *S. tetragona*, Sow., or with good examples of it in the Woodwardian Museum from the Oxford Clay elsewhere. They all appear to belong to *Vermilia sulcata*, Sow. There occur, however, among the thick masses of the *Serpula*-bed, and singly on *Gryphæa*, occasional tubes somewhat like Sowerby's *S. tricarinata*, if this be really a distinct species, but otherwise appearing to be possibly only the first stages of the tube of *Vermilia sulcata*.

Discussion.

Mr. Hudleston commented on the fortunate circumstance that so remarkable a development of limestone in the midst of the Fenland clays was sufficiently near Cambridge to attract the attention of geologists, so that any fresh exposures of importance might be recorded from time to time. On the whole, it was satisfactory to find that the original conclusions of Blake and Hudleston as to the relations of Rag and oolite to each other had been more or less confirmed by most of the subsequent writers. In such a series mere stratigraphy counted for very little; one could not trust the beds when once out of sight, while in the present paper abundant evidence of undulation and reversal of dip had been brought forward.

It was obvious that if there was any analogy with other parts of England, and especially Yorkshire, the oolites of the northern pit must be older than the Rag of the southern pit. But one of the most interesting features of this paper was the announcement that the oolite immediately underlying the Rag in the southern pit is to be regarded as an intermediate series, having a fauna approaching that of the Rag in an oolite-matrix. He was perfectly prepared to accept this interpretation, as very much the same occurrence is noted in the upper part of the Coralline Oolite of Malton—an additional resemblance to the series in Yorkshire.

The fossils found in the northern well seem to tally with those in the northern pit, and indicate a Lower Oolite as distinct from the intermediate Oolite of the southern quarry; but surely this horizon cannot be accepted as in any sense the equivalent of the Elsworth Rock, although it may be close upon Oxford Clay.

No one had a better acquaintance with the lithology and palæontology of the Elsworth Rock than Mr. Keeping; and it was interesting to know that equivalents of this well-marked series had been found at Upware. But again he questioned the value of what appeared to be the conformable sequence, and felt sure that the ammonites of the Elsworth Rock were sufficient to show that it could not be classed as higher than the Lower Calcareous Grit.

The Rev. J. F. Blake said that he had lately had an opportunity of revisiting the Upware exposures, and found in the southern quarry that much more of the underlying rock and less of the Rag, which was now a mere patch, was at present exposed. The underlying rocks in the southern quarry were not exactly like those of the northern; but the difference was very slight when compared with the Rag or the so-called Elsworth Rock. He would only add that if the fossils from the rock which had been brought up from the bottom of a well did not, like those of the Elsworth Rock, indicate a distinctly Oxfordian age, then the evidence for the correlation with that rock fell through.

Prof. Watts pointed out that the Author had shown that the Elsworth Rock at Upware appeared to underlie rocks like those under the Rag of the southern quarry without any apparent discordance, although the possibility of unconformity had been kept in view while examining the section. The deposit seemed to resemble that of Elsworth itself in lithological character and fossils. He regretted that, in reading the paper, want of time had prevented him from stating the whole of the evidence brought forward by the Author.

The President also spoke.

41. Observations *on the* Geology *of* Franz Josef Land. By Dr. Reginald Kœttlitz. (Communicated by E. T. Newton, Esq., F.R.S., F.G.S. Read June 22nd, 1898.)

[Abridged.]

Contents.

It is with great diffidence that I venture to communicate some observations on Franz Josef Land to the Geological Society because active labours in other fields of science have, until recently, prevented me from giving much attention to geology. A residence of three years in Franz Josef Land has, however, given me exceptional opportunities for geological investigation in that little-known region, and I venture, therefore, to hope that the following observations may not be without interest.

But, in the first place, I must take this opportunity to express my great indebtedness to Messrs. Newton & Teall for much kindness and most valuable help received by me from them; my thanks are also due to my comrades Messrs. A. B. Armitage, H. Fisher, W. S. Bruce, D. W. Wilton, J. F. Child, and J. W. Heyward, for the valuable information and assistance which they have ungrudgingly afforded me.

I. General Features of the Archipelago.

On approaching Franz Josef Land the observer is struck by the flat-topped, plateau-like aspect which is well known to be a leading feature of all districts largely composed of horizontal sheets of basaltic rock. Even at a distance of 40 miles the nearly horizontal upper edge of the basalt can be seen in the few exposures of rock which protrude through the widespread mantle of snow and ice. A nearer approach reveals the fact that the exposed headlands and rocky masses are formed of successive, sharply defined tiers of basalt. The horizontal line of the upper sheet, though occasionally reaching a height of 1000 feet, is not, however, the highest part of the land. Behind the basalt-cliffs, on a clear day, a rounded surface or dome of snow and ice is seen to rise to a higher level—rarely, perhaps, to 2000 feet—forming a background which shows up distinctly the horizontal arrangement of the rocks below. Snow and ice fill the depressions between the headlands and rocky masses, covering the land down to sea-level and usually ending abruptly in an ice-face from 10 to 80 feet in height.

Below the exposed rocks, which stem back the ice-flow and also absorb the sun's rays, the land is bare. An extensive talus-slope, covered in many places with moss, grass, and other plants, and in some places thickly strewn with large blocks of rock, always occurs at the base of the cliffs where there is any shore; and below this again raised beaches are generally found. Some of the land-areas, as, for example, Bruce Island, are surrounded by a continuous ice-face.

The country is evidently the remains of an old tableland which has been broken up into an archipelago of large and small islands. Some details of various localities visited by me will now be given.[1]

Northbrook Island

is irregularly triangular in shape, measuring about 12 miles from north to south and about the same along its southern shore, which forms one side of the triangle. It is covered with snow and ice over nineteen-twentieths of its area.

Cape Flora forms the western angle of the triangle. It is an isolated hill of no great extent, separated from the main mass of Northbrook Island by a deep, narrow valley known as Windy Gully. Fig. 1 (p. 622) is a section through Cape Flora from south-east to north-west, and from this it will be seen that the top of the south-eastern face is formed of a vertical precipice of ice between 80 and 100 feet in height; that below this is a nearly vertical face of rock, composed of successive tiers of basalt (about 500 feet); and that below this again is the talus. Behind the cliff of ice the surface rises to the summit of the dome, from which it slopes at a more or less gentle, though not regular, angle in a north-westerly direction to the shore of Günther Bay. Here it ends in an ice-face from 10 to 30 feet high. The special features of this north-western ice-slope are again referred to on p. 623.

The southern and south-western sides of the promontory are essentially similar to the south-eastern, except that the top of the cliff is not formed of ice. On these sides there is a ledge of rock about 50 or 60 yards wide at the back of the cliff-face. The highest point reached by the basalt is 1,111 feet.

The basaltic rocks are coarse, and for the most part non-columnar masses, divided horizontally into six or seven tiers. Here and there a rude columnar jointing may be observed. The greatest thickness of basalt is seen on the southern face, where seven distinct beds or sheets may be counted. The different sheets form a succession of steps or terraces which are cut through by a number of small water-courses.

[1] Most, if not all, of these are marked on the map which accompanies Messrs. Newton & Teall's first paper on Franz Josef Land, Quart. Journ. Geol. Soc. vol. liii (1897) fig. 1, p. 478.

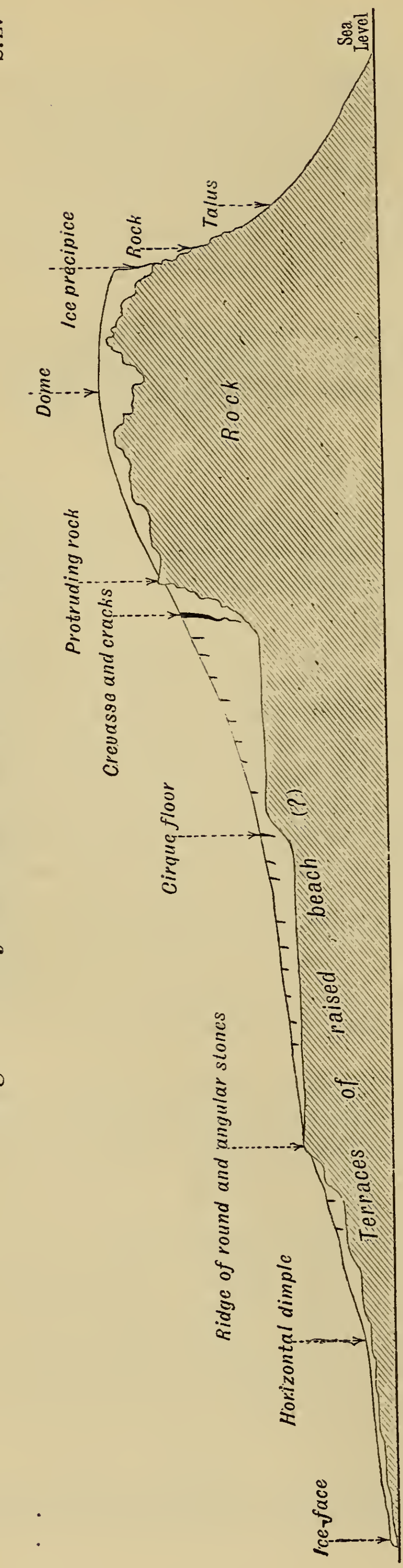


Fig. 1.—*Diagrammatic Section through Cape Flora.*

[The shaded portion indicates the probable contour of the underlying rock; the line above it represents the ice-slope.]

The talus begins at 575 feet above sea-level. It is composed almost entirely of basaltic débris and is traversed by the water-courses streaming down from the rocks above. The angle of this talus varies with its height: for the first quarter of its descent it is about 44° or 45°; for the next about 38°; lower down it becomes 25° and 20°. It finally slopes at a gentle angle on to the raised beach.

Raised beaches of various heights occur at Cape Flora. Thus Elmwood is situated on a well-marked beach which slopes gently from 50 to 36 feet. This beach is prolonged into an apron-like front having an area of about 3 or 4 acres. The surface is strewn with large and small waterworn boulders. Some portions are carpeted with a rich growth of moss, grass, lichens, and other plants; certain parts are formed of bare ground or soft tenacious mud. Many other beaches besides that on which Elmwood stands may be recognized at Cape Flora. At the north-western point of the Cape well-marked terraces occur at 30, 35, and 80 feet above sea-level; and between this point and Elmwood others may be observed at 8, 29, 45, 54, and 65 feet. The highest terrace is that onto which the talus descends. Further particulars regarding raised beaches will be given in a later part of this communication (p. 638).

At first sight, all the rocks below the basalt appear to be hidden by the talus; but after the summer thaw a careful search reveals several spots where the underlying strata can be examined in place. A consignment of rocks and fossils from these and a few other localities, sent home in 1896, formed the basis of the paper by Messrs. Newton & Teall,[1] while a second series of specimens is the subject of further notes by these gentlemen at p. 646 of the present volume.

The north-and-south valley which separates Cape Flora from the high land to the east is about 1 mile long and 500 yards wide, with a general surface about 100 feet above the sea. Some parts, however, rise to greater elevations. The floor is covered over with rounded, waterworn, subangular and angular stones and boulders, together with a dark tenacious mud. Some parts are always covered with snow and ice. Near the southern end of this valley there is a projecting shoulder of rock, some 370 or more feet above the sea, from which *Ammonites Ishmæ* and other fossils were obtained. The bed of rock which yielded these fossils is about 80 feet thick.

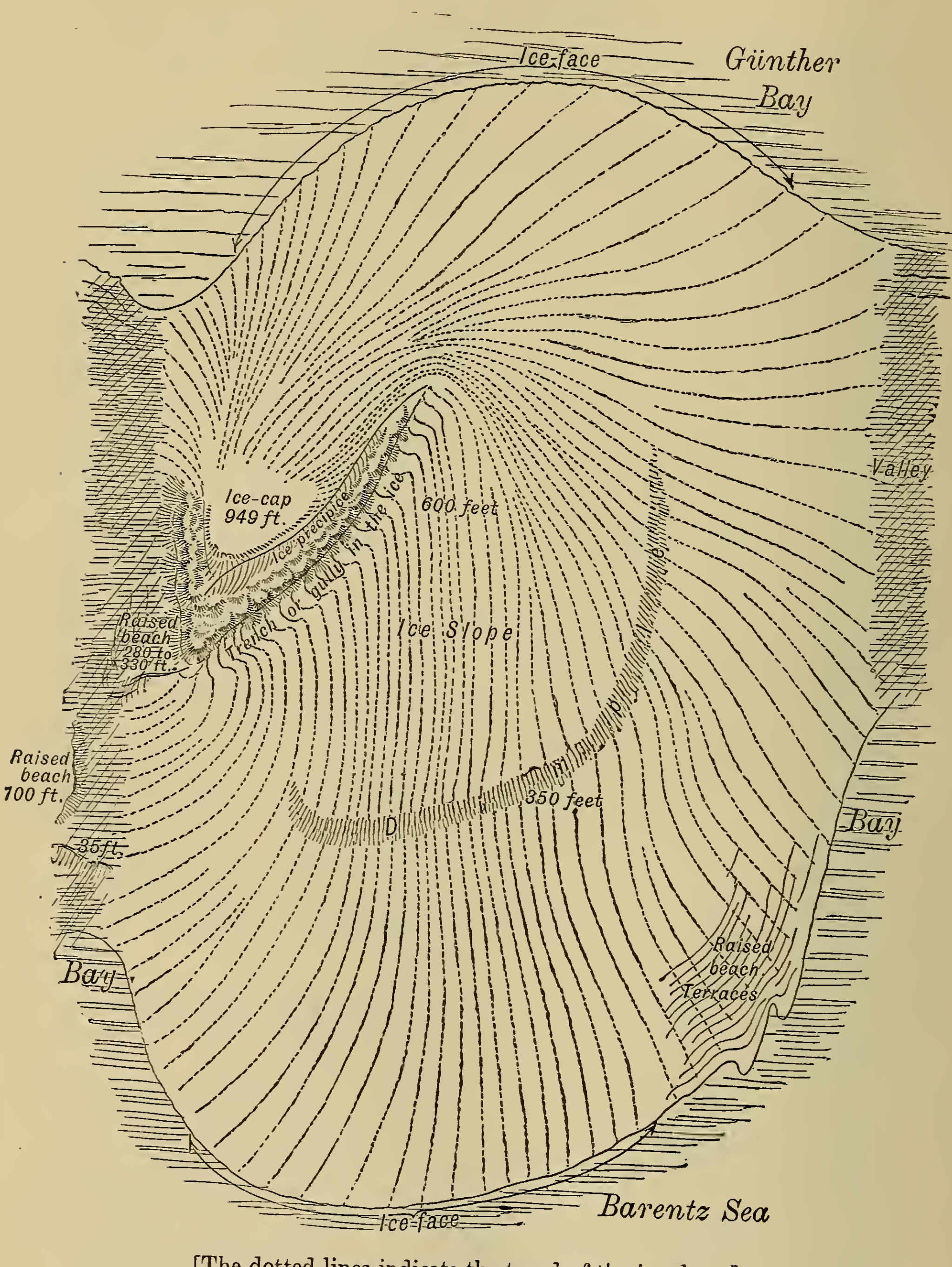
East of Windy Gully is another mass of high ground (Gully Rocks), somewhat similar in general configuration to Cape Flora. It is triangular in form, with the acute angle pointing in a south-south-westerly direction. Five or six ranges of basaltic cliffs one above the other meet to form the angle. The ice-cap reaches a height of 949 feet, and from this the surface slopes towards the north at a gentle angle to Günther Bay, where it ends in an ice-face about 50 or 60 feet high.

Still farther east is another depression or valley separating Gully Rocks from Cape Gertrude. This is mainly occupied by a fan-shaped glacier or ice-slope (see fig. 2, p. 624), along the surface of which, at a height of about 350 feet, there is seen a horizontal dimple. Traces of raised beach are uncovered below this line in summer, thus leaving no doubt as to its meaning. Other portions of this valley are formed of wet, muddy ground, with remains of many recent marine mollusca apparently in the position in which they lived, thus showing how recently elevation has taken place.

The general aspect of the southern coast of Northbrook Island east of the point which we have now reached is represented in figs. 3 & 4 (p. 626). The high land of Cape Gertrude is also roughly triangular in form and is capped by a dome of ice and snow which rises to a height of 1300 feet. It is separated from the rest of Northbrook Island by a wide depression occupied by a fan-shaped ice-slope similar to that represented in fig. 2 (p. 624), but of larger dimensions. Small points of rock protrude through the ice on the summit of the dome during the summer. The main cliff itself is formed of one tier of basalt, which is here markedly columnar and therefore different from the basalt of Cape Flora,

[1] Quart. Journ. Geol. Soc. vol. liii (1897) pp. 477–518.

Fig. 2.—*Diagrammatic sketch of the 'Eastern Glacier,' flowing off Gully Rocks.*



[The dotted lines indicate the trend of the ice-slope.]

Approximate scale: 2 inches = 1 mile.

with two smaller tiers or layers above it, but well back from the cliff-face. Small exposures of stratified rock were observed on the talus, and on the raised beaches below.

In the cliffs 5 miles east of Cape Gertrude (figs. 3 & 4, p. 626) there is another good exposure of basalt made up of several tiers, some of which show curved columnar jointing. Below is a talus-slope through which several bosses of basaltic rock protrude. Under the talus is an extensive shore with imperfect lines of raised beaches, on some of which morainic material has been deposited.

The coast from this point eastward is ice-faced, with small points of rock protruding here and there. Cape Barents, the south-eastern point of Northbrook Island, is a low rocky promontory composed of two main masses of columnar basalt about 150 feet high. There is here no talus, as the rocks rise sheer from the sea. At the time of our visit the floe was still attached to the land, and upon it were lying two or three large blocks of basalt which had recently fallen.

From Cape Barents the coast trends north-westward. It is for the most part masked by an ice-face, but near the north-eastern portion of the island a high mass of basaltic rock was seen. The northern extremity of the island is a low plateau, about 150 feet high, the surface of which is chiefly made up of bare soil sprinkled over with small, weathered fragments of basalt, quartz, and flint. Two small exposures of columnar basalt occur near Camp Point, and one of these undoubtedly extends downward to sea-level.

The north-western side of Northbrook Island is formed by Günther Bay, which is for the most part bounded by ice. Raised beaches and basaltic rocks were observed at four localities near Camp Point and at the northern terminations of the three valleys already mentioned as lying between Cape Flora, Gully Rocks, Cape Gertrude, and the mainland of Northbrook Island.

Reginald Kœttlitz Island

lies almost due north of Cape Albert Markham, on the opposite side of Allen Young Sound, and about 6 miles distant. I have seen only the southern coast, which terminates in a mass of columnar basalt (Guy's Head) about 800 feet high, the foot of which is enveloped by ice flowing from glaciers on each side of it. Mr. Jackson and others who have visited the northern part of the island state that it is low bare land, and that the shore on the western side is irregular in outline and marked by several projecting spits of low beach.

Scott Keltie Island

is about 2 miles from the north-western shore of Hooker Island, from which it is separated by Mellenius Sound. Its south-eastern and south-western shores are formed of basalt rising

Fig. 3.—*Raised beaches near cliffs 5 miles E. of Cape Gertrude (from a sketch by Mr. W. S. Bruce).*

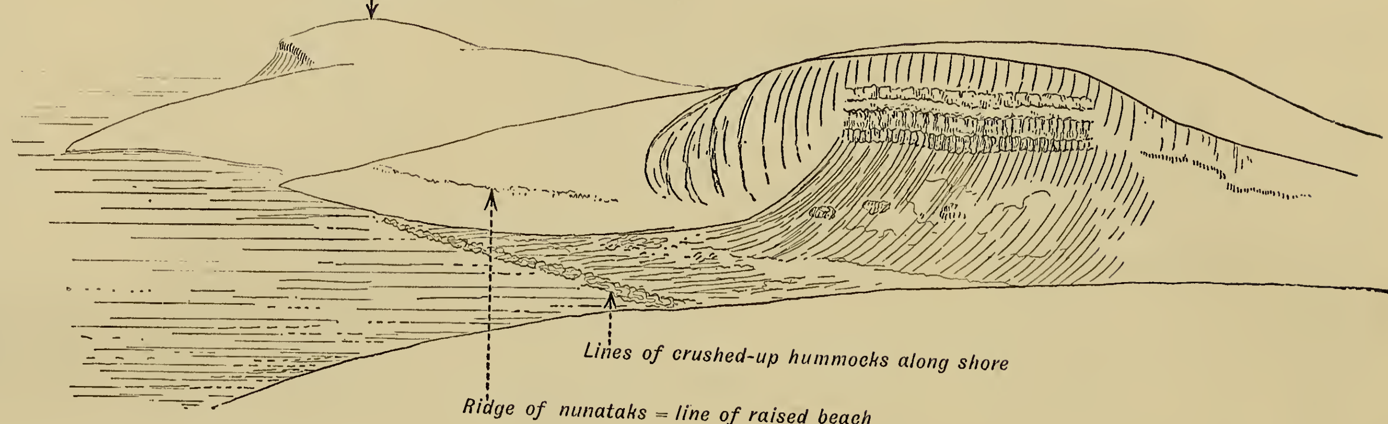
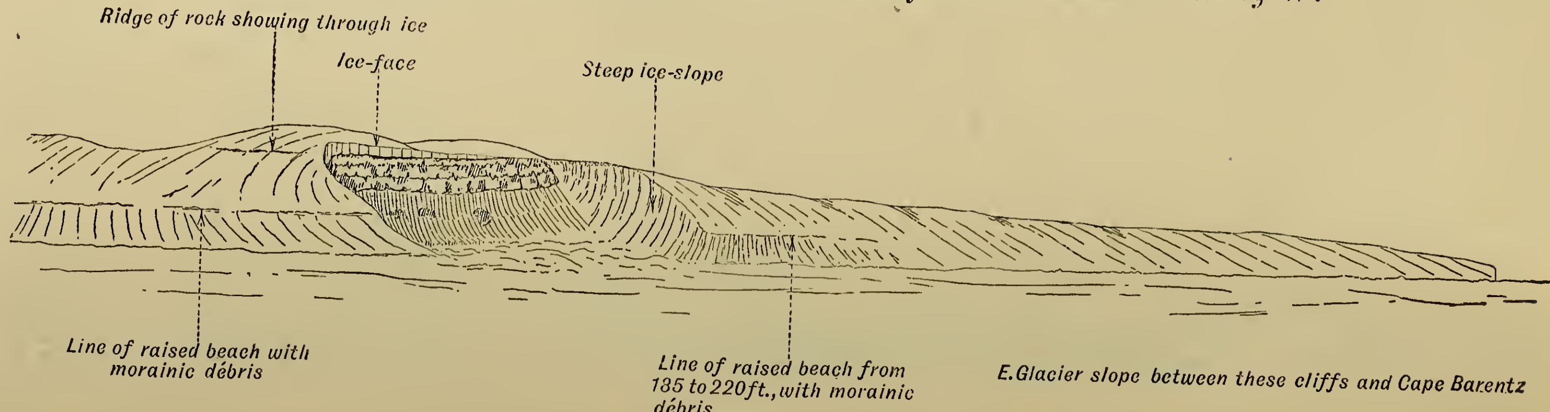


Fig. 4.—*Cliffs 5 miles E. of Cape Gertrude, seen from about 2 miles S.W. by W.*

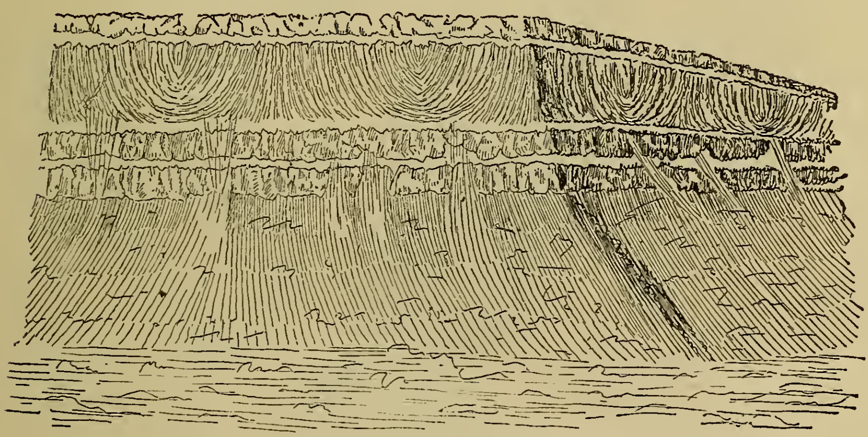


to a height of about 200 feet. At the top of the cliffs is a plateau which slopes northward and finally ends in a low shore. It was visited by us in May 1897, when the surface was covered with snow, so that very little could be seen.

Hooker Island.

To this I refer here merely in order to draw attention to the remarkably perfect, curved, basin-like structure of the columnar basalt, of which I have endeavoured to convey some idea in the appended sketch (fig. 5).

Fig. 5.—*View of headland at the north-western extremity of Hooker Island, showing curved structure of columnar basalt.*



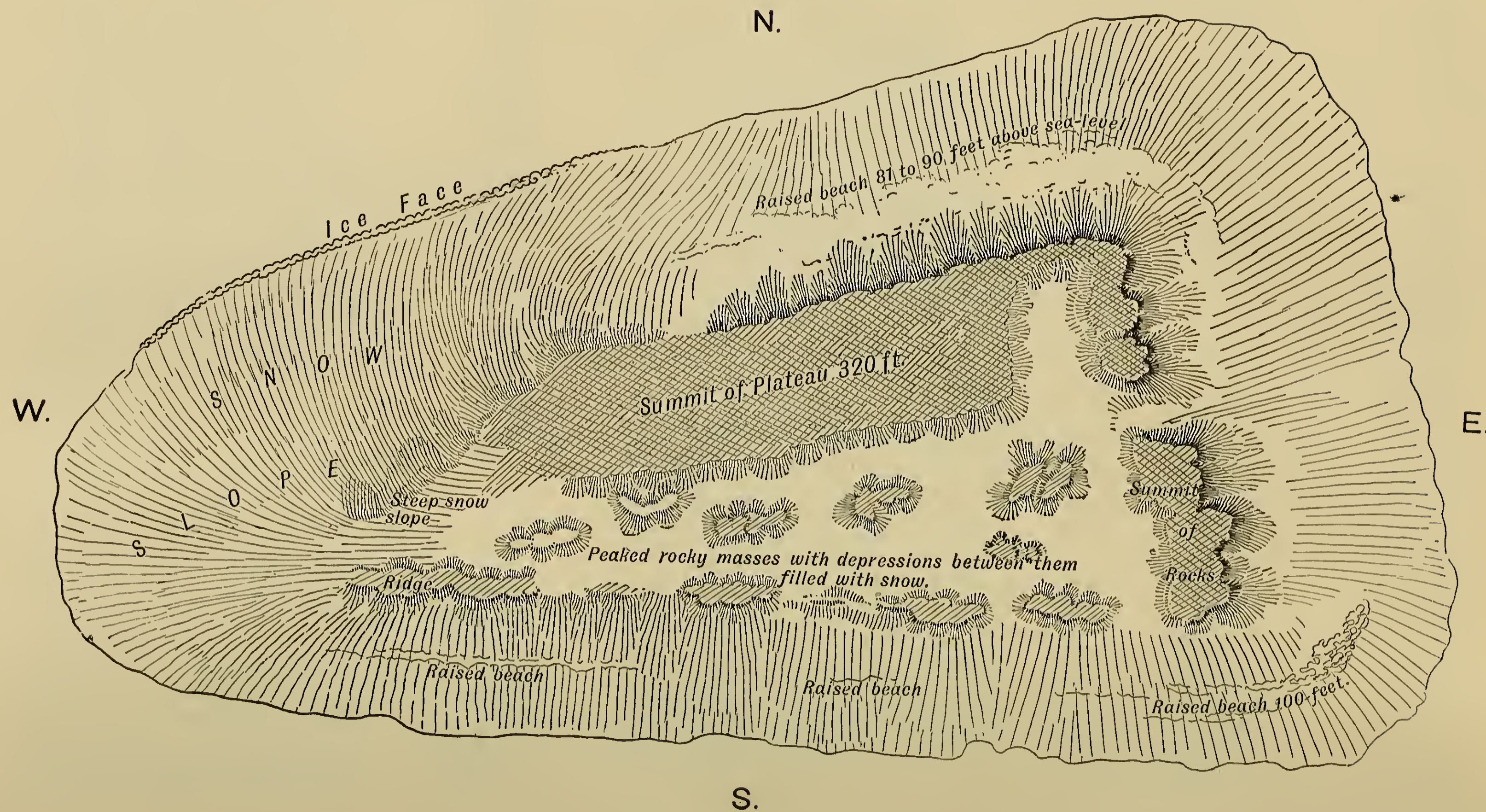
Eaton Island

is a small low islet, apparently composed of rounded basaltic stones and shingle, being little more than a shoal protruding above the level of the sea.

Bruce Island

lies about 8 miles north-west of Northbrook Island. It is irregularly oval in shape, measuring about 12 miles from north to south and 10 from east to west. It is remarkable as being entirely surrounded by an ice-face, from 10 to 60 or 70 feet in height, and as having only small portions of its surface exposed. The slopes ascend from the ice-cliff until at about the elevation of 1000 feet the snow-surface forms a more or less level, slightly undulating plateau. Depressions in the general surface give some indications of the configuration of the land. At a short distance from the ice-face (100 to 300 yards) the actual surface is occasionally exposed, and smaller points of rock protrude at different levels on the

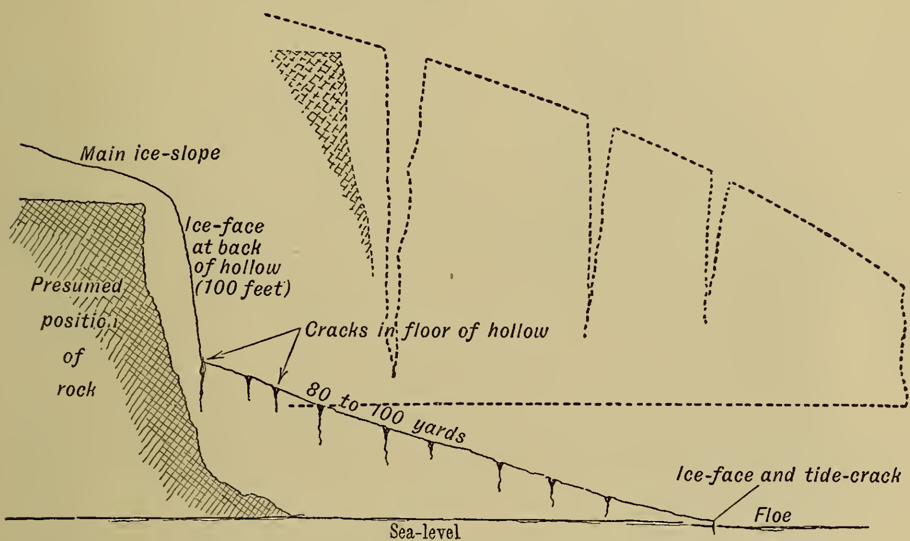
Fig. 6.—*Diagrammatic sketch of the surface of Windward Island.*



ice-slopes. We visited one of the bare plateau-surfaces, and found it to be about ½ mile long and from 100 to 250 yards broad. It was covered with soil, and strewn with fragments of basalt, flint, ferruginous mudstone, and quartz. We also found a few small, well-rounded quartz-pebbles. The rock at the edge of the pltaeau was composed of two, thin, almost horizontal sheets of basalt.

At one spot on this island, where the rock is not exposed, we found a hollow in the ice-slope which appeared to have originated

Fig. 7.—*Diagram to explain ice-hollow on Bruce Island.*



[The dotted portion represents a section on the ice-slope on each side, as we found it.]

in the breaking away of an enormous mass of ice from the lower side of a crevasse, which runs from 80 to 100 yards back from the coast-line or general ice-face. Contrary to our expectation, we found no rock or beach-material below the ice-crust forming the floor of this hollow, but probably the true rock-face is not far behind the vertical ice-wall at the back of the hollow. Fig. 7 may help the reader to understand my necessarily imperfect description.

Windward Island

is a rocky mass rising to a height of 320 feet, and more or less surrounded by raised beaches from 80 to 100 feet above sea-level. The southern face of the rocks is much broken, but the northern and eastern faces show continuous cliffs of roughly columnar basalt (see fig. 6). The northern portion of the high ground is a plateau; but the southern portion, as will be seen from the figure, is broken up into more or less peaked irregular masses, separated from each other by snow-filled depressions.

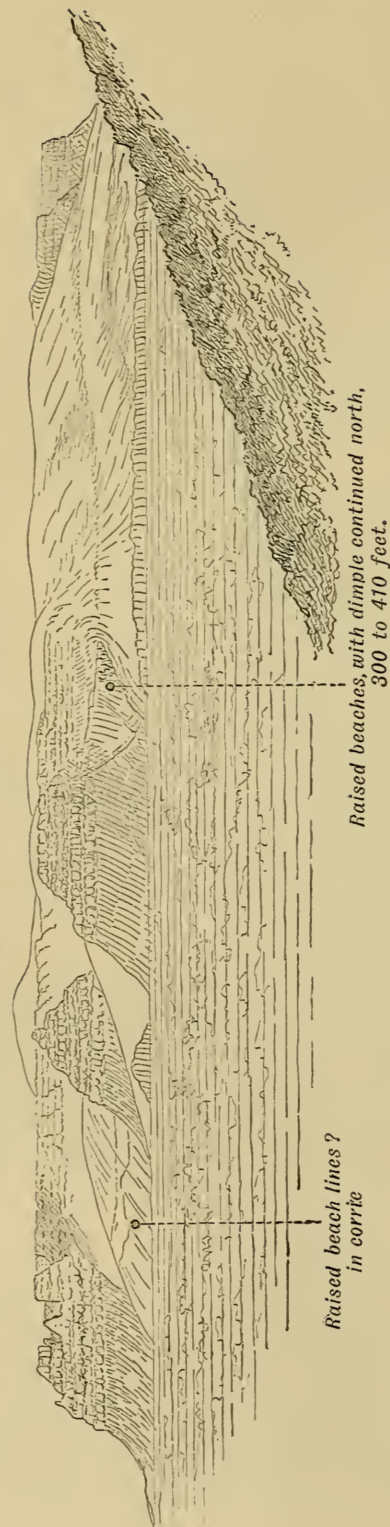


Fig. 8.—*Mabel Island, as seen from Cape Flora, 8 miles south-west.*

Mabel Island

is between 3 and 4 miles south-west of Bruce Island. Its aspect, as seen from Cape Flora, is represented in fig. 8. The ice-covering does not rise much above the level of the basaltic plateau. The surface is uneven, and, wherever the rocks do not obstruct its downward flow, the ice descends to sea-level, ending in cliffs often 60 feet or more in height.

The rocks are of the usual basalt, arranged in five or six tiers and rising to a height of about 750 feet. Sometimes they form cirques or corries, and at others jut out from the ice-slope in the customary way. A talus is found below the rocks, and raised beaches occur at heights of from 22 to 80 feet. In one place on the south-eastern side a well-marked beach was seen at a height of 300 feet, and traces of another at 410 feet above sea-level. I did not see the sedimentary rocks from which the belemnites and other fossils brought home by Messrs. Leigh Smith and Grant were derived; but this is not remarkable, because the surface was much covered with snow when I visited the island in April and May.

Bell Island

is separated from Mabel Island by a narrow channel named Eira Harbour.[1] It is mostly composed of terraces of raised beach, covered with rounded stones and pebbles of basalt and quartzite.

[1] Across Eira Harbour, between the southern extremity of Mabel Island and the opposite point on Bell Island, runs a shoal which almost reaches sea-level. It appears to be made up of the same rounded stones as those which form the raised beaches on Mabel and Bell Islands.

At the southern end is a conspicuous rock made up of seven tiers of basalt and rising to a height of 938 feet. Around this 'bell-shaped' mass may be seen a fine series of raised-beach terraces, up to 300 and 400 feet above sea-level. The talus hides the stratified rocks which undoubtedly exist beneath the basalt.

Bruce, Mabel, and Bell Islands are separated from Alexandra Land by Nightingale Sound. We have now to cross this sound and examine the rocks exposed at several points along the eastern, southern, and south-western shores of Alexandra Land.

Cape Forbes

is a bold mass of rock (630 feet high) separated into two portions by a small ice-slope. It is made up of several tiers of a basalt which has a rounded waterworn appearance, reminding one of ranges of cylindrical chimney-pots of remarkable regularity. The surface of the plateau is covered with soil, as well as with angular fragments of rock and rounded pebbles of basalt. The usual talus and raised beaches occur here at the 25, 50, and 80-foot levels. Basalt and some fragments of chert were the only rocks found here.

Cape Stephen

is a fine headland about 8 miles south-south-west of Cape Forbes, from which it is separated by Baxter Bay. There is about 1 mile of exposed rock on its eastern side, made up of six tiers of basalt showing but little columnar structure. The summit is 792 feet high, and the talus reaches about halfway up. The 50-foot beach is well marked, and I found a portion of a reindeer's antler sticking out of it.[1] I also traced a bed of sandstone containing plant-remains for at least ½ mile. The dip of the bed was 2° or 3° N.N.E. or N.—the same as that of the tiers of basalt above. A loose slab of a hard shaly rock containing plant-remains was found upon the talus.

Proceeding westward we now come to Josephine Peary Bay. The head of this bay is terminated by an ice-face, but several basaltic nunataks protrude through the ice behind.

Cooke's Rocks ("'Tween Rocks")

are directly west of Cape Stephen and about 5 miles distant, on the opposite side of the entrance to Josephine Peary Bay. They show the usual terraces of basalt, some of which exhibit columnar structure in a very perfect manner. A talus is present, and below it only one well-marked beach (50 feet above sea-level), on which was a large trunk of driftwood, about 20 feet long and

[1] [Two more specimens of reindeer-antlers were found by Mr. Bruce and myself, one at Windy Gully, the other on the 50-foot beach, Cape Flora; and Mr. Leigh Smith mentions the finding of a fourth.]

$2\frac{1}{2}$ feet in circumference, in very good condition: the wood burnt fiercely when it was chopped up, and a fire made of it. Stratified rocks were observed on this beach at two localities. At the first a hard calcareous sandstone permeated with veins of calcite, and containing plants similar to those found at Cape Stephen, was seen; at the second a fine, laminated, bituminous paper-shale, which burnt with a good flame, leaving a white ash.

A third and more extensive exposure of stratified rock was observed about 300 feet up the talus. About 100 feet of rock was bare at the time of our visit, consisting of varicoloured sands and soft shales, with a good seam of coal, at least 2 feet thick, at its base. The dip of the strata was about 2° N.N.E.

Cape Grant,

the southernmost point of Alexandra Land, is a fine extensive headland (790 feet), consisting of six or seven basaltic terraces with the ordinary talus below. Crossing the talus at a height of about 120 feet is a well-marked ridge, due to a change in the angle of slope. The surface of this ridge is strewn with the usual angular blocks; but beneath these I found numerous well-rounded waterworn boulders and stones, thus proving that the feature in question is a partially concealed raised beach.

Cape Crowther

is the next headland to the north-west, and is very similar to many that have been previously described, but is more extensive, and bisected by a small glacier $\frac{1}{2}$ mile wide. Basalt was the only rock seen: at one spot it descends to the sea-level.

Cape Neale

marks the south-eastern termination of Cambridge Bay. It is formed of more or less columnar basalt, with talus and raised beaches. The plateau at the top of the cliffs (700 feet) is extensive, and on it were found the entire skeleton of a seal and numerous bones of foxes. The surface consists of soil and mud, with fragments of basalt, quartz, yellow and black flint, fossil wood, and a light-coloured rock resembling siliceous sinter. The ice-cap from the interior descends upon this plateau at a gentle angle of 4° or 5°. An exposure of coarse yellowish sandstone occurs in a gorge cut through the talus at a height somewhere between 200 and 300 feet.

Capes Ludlow, Lofley, and Mary Harmsworth

are all ice-promontories, the only exposed rocks lying back from the ice-face, as on Bruce Island. But west of the last-mentioned Cape there is a considerable area of bare ground made up of a succession of beach-terraces. I counted as many as twelve, and upon most of them driftwood, birch-bark, bones of whales, seals, and bears, and big blocks of red and grey granite and gneiss were to be seen. This is the only spot where granitic rocks of any kind (except a small fragment at Cape Gertrude) were observed.

Driftwood was more abundant at this point than anywhere else in Franz Josef Land. This, and the occurrence of the granite-boulders, may be due to the fact that Cape Mary Harmsworth touches the edge of the great drift across the polar ocean.

The foregoing are briefly the general features of some of the land that I saw. What I have described relates, of necessity, almost entirely to the coasts, and the land seen from the coasts, of the islands forming the south-western part of the archipelago. In this area there seems to be a general tendency for the land to slope downward towards the north-west and north. Thus Northbrook Island is much lower on the north than on the south; Fridtjof Nansen and Reginald Kœttlitz Islands end in low land to the north; so also does Alexandra Land.

II. The Basaltic Rocks.

Mr. J. J. H. Teall[1] has already described examples of these rocks from specimens which were sent home from Franz Josef Land in 1896, and some additional notes by him will be found on p. 646 of the present volume. There are, however, some interesting points to which I desire to call attention, regarding the elevation and other conditions under which these basalts occur.

The heights of several of the capes and cliffs have been already stated, and these altitudes were for the most part calculated by Mr. A. B. Armitage from angular measurements. They refer to the cliffs or exposures of rock which are plainly visible and are almost always uncovered; yet it is certain that in many instances the rocks attain a much greater elevation farther inland, for the ice-domes which cover the inlying regions, and in winter have the appearance of solid ice-caps, in summer are found in many places to be pierced by small bosses of rock. From a number of observations I am satisfied that the ice-cap is comparatively thin, perhaps not more than 20 feet thick; and that for some distance behind what seems to be the summit of the cliff the basalt still ascends by a series of shallow terraces.

Cape Gertrude shows such points at its summit, and there are two terraces of rock between this and the cliffs. Similar conditions may be seen at Cape Forbes, on Bell Island, and on Bruce Island.

The basalt occurs in layers or tiers, varying in thickness from 10 to 70 feet, which often show very conspicuously in the cliffs. These tiers are separated by laminated beds, sometimes only a few inches in thickness, but more often from 2 to 4 feet thick, and occasionally much thicker.

At Cape Flora, where I had more opportunity for examining the rock in detail, I found these intermediate layers to consist

[1] Quart. Journ. Geol. Soc. vol. liii (1897) p. 482.

in part of stratified rocks, sometimes composed of sand, shale, or micaceous sandstone containing lignite ; a brown laminated siliceous rock having the appearance of a tuff proved not to be so when examined microscopically and chemically by Mr. Teall.

The lower part of some at least of these intermediate layers is formed by a tuff-like rock, which decomposes readily and has been described by Mr. Teall as decomposed basalt, basaltic scoria, and basalt-tuff. At one spot between the first and second tiers this intermediate layer was an agglomerate containing some large angular blocks.

The basalt immediately overlying the laminated beds is always vesicular. The vesicles are not uncommonly filled with calcite, or palagonite, and are often elongated to as much as 1 or even 3 inches, their long axes being at right angles to the stratified beds below, which beds show no appreciable alteration by heat.

At a spot near Cape Flora, at the junction between the basalt and the underlying Jurassic beds, I obtained a fragment of an ammonite which Mr. E. T. Newton has identified as *Ammonites Lamberti*; while Mr. Teall describes the rock surrounding this specimen as decomposed basalt or basaltic tuff. One specimen of this tuff is traversed by parallel veins of calcite.

Frequently I have found branches and stems of trees embedded in the basalt, and this most commonly in the second tier. In one instance a branch 3 inches in diameter was in the condition of charcoal, and the surrounding material appeared to be decomposed basalt and contained analcime.

The facts which lead me to think that the basalt (for the most part, at least) was not intruded as sills between older rocks, but was laid down on the surface as sheets of lava, may be thus briefly stated :—

(1) The frequency with which beds of tuff-like material are interposed between the tiers of basalt, and underlie beds of stratified rock.
(2) The presence of petrified and carbonized wood in the basalt.
(3) The beds of tuff-like rock containing plant-remains apparently interstratified with the basalt, which are thin and, to all appearance, undisturbed.
(4) The more vesicular character of the basalt, so generally found, at its upper and lower margins.
(5) The seemingly undisturbed character of some of the thinner among the stratified layers between the tiers. One such layer, about 18 inches thick, I traced for some 600 yards.
(6) The little or no alteration by heat to be detected in the stratified rocks immediately in contact with the basalt.

The evidence for the age of these basalts necessarily depends upon the stratigraphical position of the fossiliferous rocks with which they are associated and their relation to these rocks: the latter question has already been considered. The fact that the basalt is immediately in contact with the underlying Jurassic strata is no evidence of its age; and the presence of a piece of *Ammonites Lamberti* in the lower part of the basalt may be easily accounted for on the supposition that it was picked up by the basalt as it flowed over Oxfordian beds, or it might have been thrown out with the lava.

Much stronger evidence, however, is that of the plant-bed, which has been found at two or three localities between the second and third tiers of basalt, and in one case, although little more than 18 inches thick, could be traced continuously for 600 yards, and had a thick bed of coarse tuff underlying it. The rock of this bed has all the appearance of a fine tuff, but seems not to be of this nature (see p. 634). The plant-remains from one of these beds were examined by Dr. Nathorst, who believes them to be of Upper Jurassic age.[1]

The foregoing facts lead me to believe that the lower, at least, of the basalts of this part of Franz Josef Land are of Upper Jurassic age; and although I am aware that the opinions of those who have studied the basaltic formations elsewhere lean strongly in favour of all these lava-sheets being of Tertiary age, yet, judging from what I saw during my sojourn in Franz Josef Land, I believe some of the basalts of the southern parts of that country to be of the same age as the plant-beds associated with them; and if these be of Upper Jurassic age, then most of the basalts are so likewise.

The basaltic rocks, for the most part, are found at the higher levels and form the plateaux of most of the higher capes. But at certain places these rocks descend to the sea-level; this is the case at three localities on Northbrook Island, namely, Barents Hook, the head of Günther Bay, and at Camp Point. In all three places the rock is of a compact character.

At three localities on Hooker Island the basalt is found at the sea-level; and north of Dundee Point a basaltic mass some 300 or 400 yards in diameter rises from the sea to a height of 300 or 400 feet. There is no talus around this rock, and the summit seems to form a basin; I was unable to approach very closely, but this mass has all the appearance of the core of a denuded volcanic vent.

In the upper part of the Jurassic rocks at the back of Elmwood there is what I at first thought was an intrusive sill. This consists of a layer of vesicular basalt, 6 feet thick, which rests upon claystone and has 3 feet of similar claystone above it; following this is 40 to 50 feet of coarse tuff, succeeded above by the main mass of the basaltic cliff. The vesicular character of this 'sill' leads me to suspect that it may be an old contemporaneous lava-flow.

At Cape Crowther massive columnar rock rises, at one place, from the sea-level to a height of perhaps 100 feet. The top of this is a more or less level surface, apparently a raised beach, extending

[1] See p. 648, and also this Journal, vol. liii (1897) p. 495.

some hundred yards inland, where the talus from the higher rocks descends upon it.

I cannot help thinking that, notwithstanding the general regularity of the strata, which everywhere dip slightly northward, there has been much faulting and local change of level.

Siliceous rocks of various kinds occur abundantly in association with the basalt. Quartz, agate, and chalcedony are frequently found filling up cavities and fissures in the rock. Cherty and flinty masses are of constant occurrence, but have not so far been found *in situ*; they occur in larger or smaller masses, sometimes banded, brown and opaque, or it may be in lustrous black or translucent yellow and brown fragments. These are abundant everywhere, but especially so upon the bare plateaux on the summits of the high capes, and not infrequently they are found crowded together in one spot, where they appear to have been washed out of the underlying rock.

Silicified wood is very plentiful, and has been found embedded in the lower part of the basalt.

Messrs. Newton & Teall have shown that the flinty masses almost invariably contain plant-remains; and they have also mentioned the probability of geyser-action (following upon the volcanic outbursts) being responsible for the large amount of siliceous rock and for the silicification of the vegetable matter (see p. 647).

III. The Jurassic Rocks.

Messrs. Newton & Teall in their earlier paper, written while I was still in Franz Josef Land, used their habitual caution when speaking of the origin of certain specimens, and spoke of them as 'said to be *in situ*,' 'believed to be *in situ*'; the doubt this implied need no longer exist; the specimens were all collected by me, and I had satisfied myself that, in all these cases, they were in place. A discrepancy between the section at Cape Gertrude (fig. 4 of their earlier paper) and the text on p. 503 of that paper is corrected by them in their second paper (p. 646 of this volume); but I may say that the great series of strata seen at that locality is lower down than is there stated, and besides this there is an exposure of sandy strata containing thin beds of lignite at the same place between 20 and 80 feet above sea-level.

The height of the rocks seen between Cape Grant and Cape Stephen, and now named Cooke's Rocks, should be stated as 740 to 800 feet, instead of 700 feet, and the seam of coal there found is 300 feet above sea-level.

The cliffs at Cape Gertrude reach a height of over 1100 feet. It is very probable that the base of the basalt at Cape Gertrude is hidden by the talus; and it is likely that the wood which was found *in situ* in the basalt was not really, as supposed, at the base, but may have been at the second or third tier.

Stratified rocks have been found in place at Capes Neale, Grant, and Stephen, also at Cooke's Rocks, Cape Flora, Cape Gertrude, and at Windy Gully. Evidence of their presence has been obtained at Cape Mary Harmsworth, Bell Island, Mabel Island, and Bruce Island, but not in place.

At Cape Neale a soft, yellow, coarse sandstone occurs in a watercourse on the talus; 30 to 40 feet of this rock was seen, its dip being $1\frac{1}{2}°$ to 2° in a north-east to northerly direction. A similar exposure of sandstone was seen by Mr. Harry Fisher near the sea-level at Cape Grant.

A coarse, hard, calcareous sandstone with abundant plant-remains was met with near the sea-level at Cooke's Rocks. These are the beds which Mr. Newton thought might prove to be of Permian age, as the plants bear a striking resemblance to forms which have been regarded as belonging to that period. North-east of this locality, at a distance of 300 yards, and at about the same level above the sea, a highly bituminous paper-shale was found, containing small fragments of plants and fish-scales. South-west of the sandstone-exposure, at a height of about 300 feet, there is a series of sandy beds and shales of many varying shades of colour, at the base of which is a coal-seam at least 2 feet thick, but neither its exact thickness nor its extent could be traced. All these beds dip $1\frac{1}{2}°$ to 3° N.N.E.

The sandstone plant-bed was again seen at Cape Stephen, where it was some 30 feet above the sea and could be traced for more than $\frac{1}{2}$ mile along the bank of a raised beach. That fossiliferous beds occur high up in the rocks at this locality is proved by the finding of the slab of silicified plant-remains 300 feet up the talus.[1]

The sedimentary strata of Cape Flora are about 600 feet thick, and extend from the sea-level to the base of the basalt; they consist for the most part of soft shales, sands, and sandstones. Layers of hard, grey, ferruginous mudstone-nodules occur in the shales, and sometimes form bands as much as 2 feet thick. The sands frequently contain pebbles of quartz, quartzite, and other rocks, and are occasionally interstratified with thin beds of lignite. The shales and sands vary in colour through shades of yellow, buff, brown, blue, and black, and the sands sometimes show false bedding. The lowest strata seen contained the large *Avicula* and *Belemnites*, and were traced for some distance both eastward and westward from Elmwood. They extended from the sea-level to a height of perhaps 50 feet. In some parts these beds are composed of sand and pebbles, but the fossils occur in shaly clay-beds.

Directly behind the settlement of Elmwood and within about 50 feet of the basalt, clay-beds with mudstone-bands are exposed, and at this spot I found in place the small ammonite which Mr. Newton thinks is in all probability *Ammonites Tchefkini*. Many of the mudstone-blocks had fallen into a watercourse which cuts through the strata, and from these other examples of the same

[1] See Quart. Journ. Geol. Soc. vol. liii (1897) p. 506.

ammonite were obtained, together with *Ammonites macrocephalus* and *A. modiolaris*. It was about $\frac{1}{4}$ mile west of this point, and 50 feet higher in the cliff—that is, at the base of the basalt—that the piece of *Ammonites Lamberti* (see p. 635) was found embedded in the decomposed basalt.

The plant-bed which yielded the specimens submitted to Dr. Nathorst was discovered on the northern side of Cape Flora, overlying a mass of basalt which projected through the ice at a height of some 750 feet. Similar plant-remains have since been found *in situ* in the cliffs above Windy Gully, and the bed was traced for some distance between the second and third tiers of basalt; this seems to show that the plant-bed extends over the whole of Cape Flora at this horizon.

The shoulder of rock which projects from the cliff at Windy Gully slopes from a height of 370 to 450 feet above the sea. It was on this shoulder that the specimens of *Ammonites Ishmæ* were found, and, although some of them lay strewn upon the surface of the ground, there is no doubt as to their having been weathered out from the stratum upon which they rested: this is about 80 feet in thickness.

At Cape Gertrude, which is scarcely 4 miles to the eastward, the strata differ markedly from those at Cape Flora. The only organic remains found were fossil wood and lignite, except that among the pebbles from one of the beds a nodule of radiolarian chert was obtained, and this is of interest as showing the possible origin of the specimen found frozen to an iceberg.[1]

IV. The Raised Beaches.

The frequent occurrence of raised beaches around the shores of Franz Josef Land was alluded to by Messrs Newton & Teall; these evidences of upheaval of the country in comparatively modern times are a marked feature of the whole of the southern part of the Archipelago, and are known to occur in the more northerly parts also. Most of the raised beaches are between the sea-level and 80 or 100 feet above it; but in some places they may be traced as terraces to as much as over 400 feet above the sea. Indeed many rounded pebbles which were found on the summits of Cape Forbes, Cape Flora, and Cape Gertrude seem to me an indication of former beaches even at those elevations; being, however, more ancient than those nearer the sea-level much of their character has necessarily been destroyed by denudation. Drift-wood and bones of whales are not uncommon at the lower levels, and have been met with as much as 90 or 100 feet above the sea. The bones of seals and walrus have been found at much greater elevations (between 300 and 400 feet), and although they may have been carried up by bears, I hardly think so, for I know of no evidence that

[1] See Quart. Journ. Geol. Soc. vol. liii (1897) p. 511.

bears carry their prey to a distance, especially the whole of a seal (a complete skeleton was found on the summit of Cape Neale).

Even where the land is covered with ice it not infrequently happens that ridges and sometimes successive terraces may be seen protruding; on these have been found many rounded waterworn stones, some indeed being rounded boulders of enormous size, mixed with angular morainic débris (always present in such situations). Many of these terraces may be traced horizontally by the ridges and dimples which they cause in the ice-slopes.

Well-marked raised beaches occur around the base of Cape Flora. Ten or more may be counted between 8 and 100 feet above sea-level, and the epiphyses of a large whale's vertebræ were found on the highest of them. Other terraces with rounded waterworn stones and pebbles, as well as walrus and seal-bones, are less distinctly visible between 240 and 340 feet above the sea.

Cape Gertrude has similar well-marked beaches at various heights, and upon one, on the western side at an elevation of 300 feet, large and small rounded waterworn stones, and also seals' bones, were found, with much angular débris. On the eastern side of the valley separating Cape Gertrude from the rest of the high land of Northbrook Island, several terraces are seen between 180 and 220 feet above the sea, one of which is continued as a well-marked ridge in the glacier-slope. Farther east a similar ridge of beach is seen on the ice-slope, at an elevation of 220 feet, extending for a mile towards Barents Hook. This ridge is strewn with enormous basaltic boulders, many of which are unmistakably waterworn, being smooth and rounded as if recently subjected to marine action, but showing no traces of glacial striæ. Some of these rocky masses are angular, and one, of great size, is a column of basalt 18 feet long and 4 feet in diameter.

Mabel Island, besides several terraces at lower levels, has on the eastern side, close to the ice-slope, and at an elevation of 300 feet, an area, several acres in extent, which is paved with smoothly-rounded, waterworn stones. This is, I have no doubt, a raised beach (see fig. 8, p. 630). It ascends by a gentle slope some 20 or 30 feet, to end against the stony bank below the next terrace, which is 410 feet above sea-level. Ridges in the ice-slope to the north suggest that these beaches are continued under the ice.

Upon Bell Island there are very extensive raised beaches, covering several square miles; they are for the most part at elevations between 20 and 30 feet above the sea, but a few others rise to as much as 300 feet. Some of these south-west of the rock were visited, and were found to be perfectly defined beaches rising one above another, and covered with well-rounded stones and pebbles. At many other places that were visited similar evidence was found, and among them may be mentioned Capes Grant, Neale, Crowther, Stephen, Forbes, and Mary Harmsworth, as well as Windward Island. Moreover the plateaux of Camp Point, Hooker Island, and Bruce Island, I think, have once been sea-beaches. Waterworn stones are found on the summits of Capes Neale, Grant, Forbes, Flora, and Gertrude.

There is a point in connexion with the more recent elevation of the land which may be of some interest, and that is the peculiar part played by the floe-ice in the formation of raised beaches.

In the shallow bay on the south-western side of Bell Island I was much struck by observing how the rivulets of water in the summer washed down large quantities of sand and gravel upon the floe, which at this locality did not float away, as it does at most places at this season of the year, being evidently aground. So much sand and gravel had been spread over the ice that at first I was unaware that I was really walking upon the floe and not on land. This heaping up of sand and gravel prevents the sun from melting the ice underneath, a process which may go on from year to year. If at this time the land slowly rises a kind of raised beach tends to be formed, under which is a layer of ice.

This peculiar condition explained what I had observed upon a raised beach, 55 feet above the sea, near the northern shore of Windy Gully, where the surface had fallen in, forming a pit 12 to 15 feet deep and 20 feet in diameter. The sides of this pit presented a very good section, and showed an upper layer of waterworn stones 4 feet thick, resting upon a mass of ice 3 feet thick. Below this was 2 feet of rounded stones, and then another layer of ice nearly 2 feet thick, below which was another bed of stones.

At Cape Mary Harmsworth I noticed a similar covering of the ice with gravel, but brought about in a very different way. The shore on the western side of the cape is evidently subject occasionally to severe ice-pressure, during which the floe-ice, as it grounds close to the shore, pushes up before it large quantities of beach-stones, many of which are angular and not waterworn, and this beach-material is often pushed on to the land-ice, sometimes in considerable heaps, and thus, as in the former case, tends to prevent the melting of the ice and to make it more or less permanent.

Pits similar to that above mentioned are not infrequent here, and it seems highly probable that they are caused by the melting of buried ice, which, I may say, has been met with in many places and under varying circumstances.

Upon one part of the talus on the south-eastern side of Cape Flora one sees (when at a distance) that the ground is cut up into a number of large, more or less regular, pentagonal, hexagonal, or square surfaces, 20 to 30 feet across, and these extend over a considerable area. Upon closer examination it is found to be covered by a thick carpet of moss, and the polygonal figures are caused by fissures about 1 foot wide and 2 feet or more deep. Here, under a few inches of soil and vegetation, there is a mass of solid ice, into which the fissures enter for a couple of feet, but do not entirely penetrate.

On some parts of the raised beaches at Cape Flora, and also on the summit of Cape Neale, I noticed cracks in the soil or mud assuming the polygonal form, but on a much smaller scale, the polygons being only from 2 to 3 feet across. Nordenskiöld observed a similar appearance at Cape Cheliuskin,[1] but he does not mention the size of the figures. Of course, sun-cracks in drying mud assume similar forms, but generally of much smaller size, and I am not aware that figures of a large size are at all common. Having found ice below the surface in one place where the large figures were formed, and knowing how constantly the ground is frozen a little below the surface in Franz Josef Land, I am led to think that ice may play an important part in the formation of large polygonal cracks.

V. Ice-cap and 'Glaciers.'

Although the land is so largely hidden by ice, which often terminates in high faces at the sea-level, I do not think that there is so great a thickness covering the land as might be supposed; for, not only are ridges and dimples to be seen everywhere upon the ice-slopes, but the rock itself frequently protrudes along these ridges. The fan-shaped glaciers on the eastern side of Windy Gully (see fig. 2, p. 624) and east of Cape Gertrude both show, as they descend, variations of angle which produce ridges and dimples, and these are particularly numerous towards the lower parts. When the ice melts in summer small surfaces of the rock are uncovered at these ridges, exposing a series of terraces; and the thinness of the ice covering them, even in winter, can be fully appreciated. This downward flow of the ice over a series of terraces is illustrated by fig. 9 (p. 642). The ice may be thicker on the higher parts than it is at the lower levels, yet I do not think that it attains any great thickness anywhere. I have already mentioned that two points of rock project through the dome of ice on the summit of Cape Gertrude, and that on the northern slope there is a small plateau free from ice.

Although no rock has been seen to protrude at the actual summit of Cape Flora, yet on the northern side, at about 100 feet below the top, and in a line with the highest part of the cliff, points of rock are seen all round a cirque-like hollow (see fig. 1, p. 622). The slope below these rocks becomes steeper, and is interrupted by a crevasse, such as is always found below such protruding rocks. Smaller cracks intersect the slope lower down, which gradually assumes a lower angle. The cracks and crevasses cross the ice-slope in a direction parallel to the line of rocks, thus taking the semicircular form of the cirque in which they lie; but the curve becomes gradually less as they approach the ridge of presumably raised beach at 340 feet above the sea. From this ridge the slope continues, at first more steeply, and interrupted by a crack 1 foot wide, and then is gradually lessened to about 16° at the 150-foot level, where a long dimple marks the change of angle to about 7°, and then gradually sinks to the ice-face on the shore. The raised beaches indicated in fig. 1

[1] 'Voyage of the *Vega*,' Leslie's transl. (1855) p. 258.

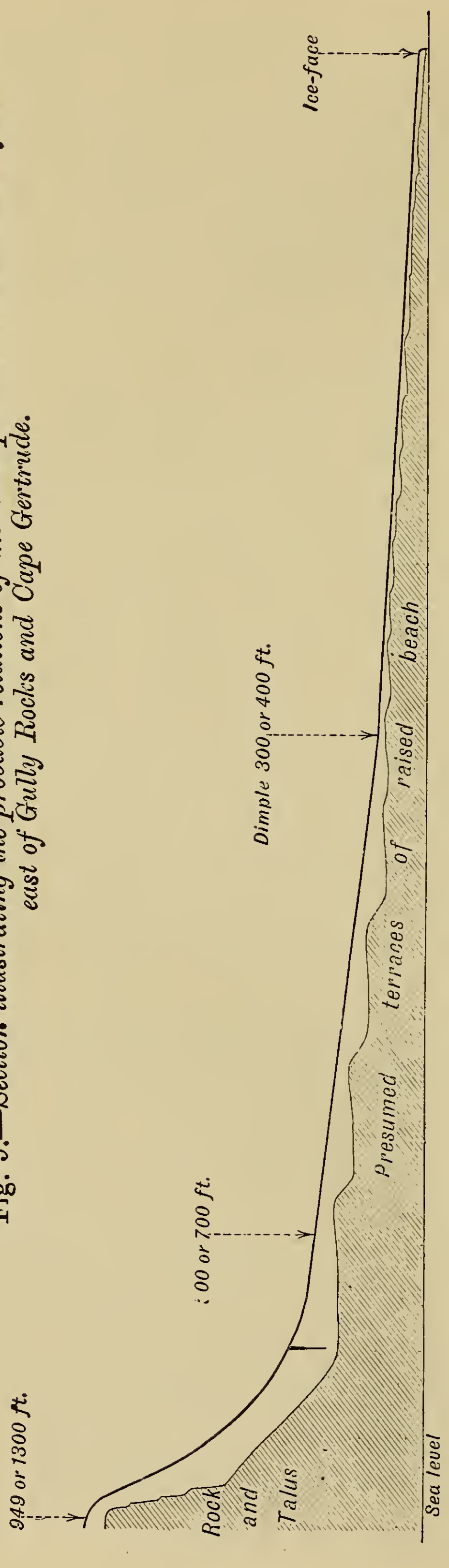


Fig. 9.—*Section illustrating the probable relations of the ice-slope and the true rock-surface east of Gully Rocks and Cape Gertrude.*

(p. 622) were seen in water-courses that had cut their way through the ice down to the rock below.

Other glaciers might be described, all having much the same character, and many similar examples could be given, tending to show the comparative thinness of the ice which covers the southern parts of Franz Josef Land. The ridges and dimpling shown in figs. 4 & 6, pp. 626 & 628, indicate the positions of the rocks near the surface of the ice, but these features were much more evident when viewing the country itself.

There is every reason for thinking that on the larger land-areas of this archipelago, such as Alexandra Land, there is a greater thickness of ice than on the smaller islands. It may be thought that the ice-face which occurs at many places is an indication of a greater thickness of ice behind pressing it downwards; but it is quite certain that, in some cases, this ice-face is merely part of a winter snow-drift and has no glacier behind it. The depth of the sea under these ice-faces is, in some instances at least, not very great, for in two cases—namely, under the ice-face at the base of the northern slope of Cape Flora, and under the eastern fan-shaped glacier—it is not more than 3 fathoms.

On one occasion Mr. Bruce and I had an opportunity of taking the temperature within a crevasse on Bruce Island, and, as our results differ from similar observations by other writers, it may be well to place them on record. Having made a hole through a snow-bridge, we lowered a thermometer into a crevasse to a depth of 3 feet, and then to 15 feet, leaving it for 5 minutes at each depth; a register of +19° and +20° Fahr. was obtained, while the temperature in the air was +30°, with a warm sun shining. The time was 2 P.M.

During the whole of our journeys in Franz Josef Land we never saw any icebergs of the large size reported by both Payer[1] and Leigh Smith[2]; the former writer says that they averaged from 80 to 200 feet in height, and the latter speaks of them as from 150 to 250 feet high. The largest that we saw could not have been more than from 50 to perhaps 80 feet above water, and even these were tilted, and so appeared thicker than they really were. Dr. Nansen saw nothing so large, although he passed very near to where Payer saw his loftiest bergs.

VI. Glacial and other Denudation.

The evidences of glacial action as shown by the smoothing and planing of rocks are very few; roches moutonnées and rounded hills have not been met with. Only in the two valleys separating Cape Flora from Cape Gertrude are there some loose blocks of basalt, which are planed, polished, and somewhat scratched on their upper sides, showing that they have been but little moved since their grinding by the ice. These blocks are sufficiently raised above the sea to be out of reach of floe-ice pressing upon the shore: they are upon low and recently-raised beaches.

No evidence has been obtained of the existence of anything that could be definitely called till.

The granite 'erratics' mentioned by Payer[3] as having been seen attached to an iceberg may have been brought from a distance, or, like the radiolarian chert, quartz, and chert-pebbles which I found frozen to an iceberg, they may have been derived from Jurassic beds in the immediate neighbourhood. Similar fragments of granite were found by me on the beach-terraces of Cape Mary Harmsworth, and one small piece at Cape Gertrude. Dr. Nansen tells me that he thinks he saw granite in place on an island farther north. I have never seen granite-pebbles in the Jurassic strata, but quartzite-fragments are not uncommon, and having found both together on the beaches I infer that they may have had a similar origin.

[1] 'New Lands within the Arctic Circle,' vol. i, p. 16 & vol. ii, p. 141.
[2] Proc. Roy. Geogr. Soc. vol. iii (1881) pp. 131, 135.
[3] 'New Lands within the Arctic Circle,' vol. ii, p. 157.

The general condition of the land-surface beneath the ice has to some extent been noticed when remarking upon the raised beaches, ice-cap, and 'glaciers.' Its terraced appearance is very obvious, especially on the lower parts; and, judging from the depressions and irregularities of the ice-slopes, I am of opinion that the upper basaltic rocks are very much broken up and denuded. This condition is well seen on the upper part of Windward Island (fig. 6, p. 628), where the effects of denudation are strikingly shown on a small scale; isolated rocky masses, more or less terraced by the unequal degradation of the harder and softer layers, stand up in bold relief and are separated by deep gorges or valleys. I am convinced, from the contours of the larger and higher islands, that their upper parts are in a very similar condition of denudation, but they are masked by the ice and snow.

That marine action combined with the ice has had a large share in the work of denudation I cannot but believe, and to it I should attribute much of the terracing: pauses in upheaval and varying hardness of the rock combining to produce the present condition. The greater exposure of the southern and north-eastern shores has caused their more rapid denudation, and thus originated the more precipitous cliffs and fine headlands.

Wherever the sedimentary rocks have been observed they were found to be nearly horizontal, with a slight dip of only 2° or 3° N.E., but the base of the basaltic rocks, although usually at a considerable elevation, is in some cases low down or even at the sea-level. This at once suggests the possibility of faults having let down certain areas; and it may be that this will prove to be the case; but at present we have really no evidence whatever of the existence of such faults, and further the breaking up of what must have been a widely extending plateau into a number of islands may have been due to a similar cause; the lines of weakness and depressed areas, being more readily attacked by subaerial and marine agencies, have become widened into the channels as they now exist.

We have very little evidence as to the depth of the sea around these islands, but the following soundings may be mentioned:— between Windward and Bruce Islands, 57 fathoms; between the latter island and Camp Point there was no bottom at 100 fathoms; $\frac{3}{4}$ mile north of Cape Flora, 18 fathoms; close under the glacier at this place, 3 fathoms; between Bell Island and Cape Flora, 25 fathoms; $\frac{3}{4}$ mile south of Elmwood, as much as 15 fathoms, but more to the westward 50 fathoms; within $\frac{1}{2}$ mile of Cape Ludlow, 158 fathoms; $1\frac{1}{2}$ mile south-east of Cape Mary Harmsworth, 93 fathoms; and 30 miles west of the same point, 230 fathoms.

I trust that the few notes that are here brought together on the geology of Franz Josef Land will not be without value nor altogether devoid of interest, and that the shortcomings, of which I am only too conscious, will be pardoned when it is remembered that it was possible to do geological work during only two or three months of the year, and even that time was chiefly taken up with other duties.

[Since writing the foregoing paper I have visited the island of Skye, and after seeing the conditions of the basaltic formation there, I am convinced that dykes and sills, especially the former, are comparatively rare in Franz Josef Land, where indeed I never saw a dyke at all. Some of the basaltic sheets in Franz Josef Land, however, may possibly be sills, but of this no actual evidence, other than microscopic, is forthcoming. Moreover, nothing that I saw in Skye has led me to change my opinion as to the contemporaneity of the plant-beds with at least the first two or three basalt-flows.—Aug. 26th, 1898.]

42. ADDITIONAL NOTES *on* ROCKS *and* FOSSILS *from* FRANZ JOSEF LAND. By E. T. NEWTON, Esq., F.R.S., F.G.S., and J. J. H. TEALL, Esq., M.A., F.R.S., V.P.G.S. (Read June 22nd, 1898.)

[PLATE XXIX.]

IN our previous notes[1] an account was given of the rocks and fossils which had been collected by Dr. Kœttlitz and sent home in 1896. Another large series was brought back by the same gentleman on the return of the Jackson-Harmsworth Expedition in 1897. These specimens have been examined, and it is satisfactory to have to report that they confirm our previous conclusions, necessitating no modification of our previous notes, except as regards some of the altitudes at which the specimens were obtained; these, however, do not alter the relative positions of the beds. At the same time, there are some additional facts which it is desirable to place on record.

The corrected measurements of altitudes are given by Dr. Kœttlitz on a preceding page (p. 636), and these, it will be seen, alter materially the position of the beds at Cape Gertrude as given in our section. There are two errors on p. 503 of our previous paper which we desire to correct. On line 4 the 100 feet of basalt refers only to what is seen in the cliff-section, and on line 9 'highest' should have been printed 'lowest,' which will be found to agree with the section and the measurement that we then had.

I. ROCKS.

A very large number of rock-specimens have been examined, but as these belong, for the most part, to varieties already described in our former paper, it will be unnecessary to refer to them at any length in these general notes.

The common type of basalt is evidently very widely distributed, for it occurs as far west as Cape Mary Harmsworth. In view of the wide distribution of this type it was thought desirable that it should be analysed, and the specimen represented in fig. 1, pl. xxxvii, Quart. Journ. Geol. Soc. vol. liii (1897), was selected for this purpose. It yielded the following result:—

I. Basalt, Cape Flora (Teall).
II. Do., from the rock-wall, Almannagja, Iceland (Bunsen).
III. Do., from the north-eastern coast of the island of Vidfrey, Iceland (Bunsen).

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[1] Quart. Journ. Geol. Soc. vol. liii (1897) p. 477. In both papers Mr. Teall is responsible for the petrology and Mr. Newton for the palæontology.

	I. Per cent.	II. Per cent.	III. Per cent.
SiO_2	47·28	47·07	47·48
TiO_2	1·48	...	...
Al_2O_3	13·24	12·96	13·75
Fe_2O_3	4·44 }	16·65	17·47
FeO	10·50 }		
MnO	·40	...	...
CaO	11·04	11·27	11·34
MgO	5·94	9·50	6·47
K_2O	·31	·58	·60
Na_2O	2·62	1·97	2·89
Loss on ignition	2·00	...	...
	99·25	100·00	100·00

The two analyses of rocks from Iceland are by Bunsen,[1] but they are quoted from Roth's 'Gesteins-Analysen.' They are selected from eight other analyses of 'normal pyroxenic rocks,' which vary within the limits indicated in the following table :—

	Minimum Per cent.	Maximum Per cent.
SiO_2	47·07	50·25
Al_2O_3	12·55	18·78
FeO	11·69	19·43
CaO	11·10	13·01
MgO	5·20	9·50
K_2O	0·20	0·60
Na_2O	1·24	2·92

It is much to be regretted that we have no recent analyses of the basalts of the Brito-Arctic province, but we may safely conclude, from those quoted above, that the rock from Cape Flora represents a very widely-distributed type.

In our previous paper we called attention to the widespread evidence of silicification. The collection now under consideration includes many specimens which illustrate this point. Quartz, chalcedony, agate, laminated siliceous deposits containing plant-remains and silicified wood, are all represented. In view of the occurrence of geysers in the basaltic region of Iceland, one is naturally led to ask whether some of these siliceous deposits may not indicate the former presence of hot siliceous springs in Franz Josef Land.

Additional specimens of the zeolites, analcime and natrolite, have been received, and among them occur some black crystalline groups of analcime found in a mass of lignite which was associated with the second tier of basalts at Cape Flora. The crystals have evidently grown in the vegetable matter, and their peculiar black colour is due to inclusions of a carbonaceous substance.

Further specimens of radiolarian chert have been found. They occur as pebbles in a calcareous sandstone of Jurassic age, from Cape Gertrude. Their presence under these circumstances strengthens

[1] Pogg. Annalen, vol. lxxxiii (1851) p. 202.

the suggestion made by Dr. Hinde, that they belong to some Palæozoic deposit. The conglomeratic deposits of Jurassic age contain also pebbles of quartzite and vein-quartz.

The only other rock of sufficient general interest to deserve mention in this connexion is a brown shale from Cape Gertrude, highly charged with minute crystalline groups of selenite. The plant-bearing beds from this locality contain marcasite, which is often coated with selenite. It is probable, therefore, that the selenite found in the shale is of secondary origin, and not due to direct precipitation from saline waters.

II. FOSSILS.

The additional information regarding the fossils, which we now possess, will be most conveniently considered, as in the previous notes, under each horizon and locality. Some of the beds, already indicated, have now been traced at other places, and these facts are strong confirmation that the sequence as inferred from the various altitudes of the beds is substantially correct.

1.[1] North of Cape Flora. 'Plant-Bed.'

Although no further collection of specimens has been made at the original locality on the northern side of Cape Flora, yet a number of similar plant-remains have been met with at two other spots at and near Cape Flora.

At the bottom of p. 512 of our previous paper, Dr. Nathorst is said to be of opinion that the plants he saw, from the original locality, were of 'Upper Oolite' age; this is an error, and we should have written 'Upper Jurassic.' What Dr. Nathorst really said, as he points out in a letter, was 'that they more probably belong to the Upper (white) Jurassic than to the Middle (brown).' We are glad of this opportunity of correcting the error and of apologizing to Dr. Nathorst, the more so as there is now found to be a better agreement between the position of this plant-bed and the other strata at Cape Flora than had been supposed; its position will be doubtless in the Oxfordian, at some hundred feet above the *Ammonites Lamberti* which, as will presently be noticed, has been found just at the base of the basalt.

(*a*) A number of small specimens of a brown sandy rock containing impressions of plants were collected on the top of Cape Flora at about 900 feet above the sea, and the rock was thought to be *in situ*, although the specimens were loose on the surface. This rock is somewhat coarser than that from the northern side of Cape Flora, but the plants seem to have the same facies; conifer-needles are most plentiful, but with these is a piece of a fern, like those referred to *Thyrsopteris*, and a fragment which seems to be *Ginkgo*. These plants, it will be seen, occur at some 200 feet higher than those to the north of Cape Flora, but it seems highly probable that

[1] The localities are numbered, for convenience of reference, as they were in our former paper.

they are practically of the same age. If the sheets of basalt be intrusive, the difference of altitude will be no indication of different age.

(*b*) A number of fissile slabs of a brown, laminated, siliceous rock (92 per cent. of silica) have been collected at Windy Gully, north-east of Elmwood, from between the second and third tiers of basalt, at about 700 feet above the sea. These specimens include numerous plant-remains, but for the most part they are very fragmentary. Some few are well preserved, and among these are pinnules of a fern resembling those referred to *Thyrsopteris*; a very perfect leaf of *Ginkgo* (Pl. XXIX, fig. 3), which may be the *G. polaris* of Nathorst; and seeds, with needles of conifers.

The similarity of the plant-remains in the beds which have been observed around Cape Flora, in close relation with the basalts, leaves little room for doubting that these plant-beds are all of the same age.

2. East of Elmwood.

From a spot between Castle Rock and Sharp's Rock, at about a mile east of Elmwood, part of a tree-trunk has been obtained which is 40 inches in circumference. This specimen, which is about 2 feet long, is interesting from its having been found *in situ* at the base of the second tier (from below) of the basalt, and in all probability indicates the horizon from which much of the silicified wood has been derived. This specimen is not wholly silicified, some parts being preserved in carbonate of lime and others possibly in carbonate of iron.

3. Elmwood.

A number of additional specimens have been obtained from the watercourse and talus at the back of Elmwood, but there is nothing to add to the information already derived from the earlier series. A quarter of a mile north-west of Elmwood a fragment of *Ammonites Lamberti* (Pl. XXIX, fig. 2) was obtained *in situ* immediately below the basalt, and consequently about 50 feet higher than the young *A. Tchefkini* found in place at the back of Elmwood. *Ammonites Lamberti* is definite evidence that the beds directly below the basalt are of Oxfordian age, and its position above the *A. Tchefkini* and *A. modiolaris* makes it probable that Oxford Clay occurs at this place.

4. Windy Gully.

The shoulder of rock at the southern end of Windy Gully is, according to Dr. Kœttlitz, about 370 feet above the sea at its lowest part, and rises to over 400 feet. The beds dip at from 1° to 3° to the N.N.E. Several portions of *Ammonites Ishmæ* var. have again been found at this locality; but more interesting perhaps are a large lamellibranch and a belemnite, which seem to be altogether new (Pl. XXIX, figs. 4 & 5). These two fossils were found in one piece of matrix, hard frozen, but Dr. Kœttlitz says that it was certainly *in situ.*

The lamellibranch is a large *Inoceramus*-like shell, about 8 inches long and 5 inches wide in its present imperfect condition. It has a great resemblance to the Cretaceous *Inoceramus Cuvieri.* The margins of the shell have been destroyed, and the outline is therefore unknown, but, judging from the direction of the eight or nine strong, rounded, wave-like folds, it was oval in shape, narrowing towards the umbo. The hinge being destroyed, its generic affinities are uncertain, but provisionally it is placed in the genus *Inoceramus.*

The belemnite is about 3½ inches long, and tapers very regularly from end to end. The upper part shows the thin edge of the alveolar cavity, and the guard cannot therefore have extended much farther. Sections exposed by cross-fractures show that the cavity was central and extended nearly half way down the specimen, also that the guard is compressed and oval very nearly to the apex: the radiation being as nearly as possible concentric. There is no trace of any flattening or grooving towards the apex.

This belemnite resembles the *B. inornatus* of Phillips [1] in its general form; especially is it like the figure in which the grooves of the apex are wanting; but the present specimen is more compressed, and there is nothing to show that grooves were ever present at the apex. There is a specimen in the British Museum from the Inferior Oolite, which is referred to the *B. spinatus* of Quenstedt, that is somewhat like our specimen in form and is much compressed, but the apex is more slenderly pointed and there are other differences.

5. West of Elmwood.

Many new specimens have been collected from this locality, 500 yards west of Elmwood, at a height of 30 or 40 feet above the sea, but most of them are too poor to add anything to what has already been said. Among the many pieces of belemnites there are, however, some which show on the broken surfaces excentric radiation of the *B. Panderi*-type as well as the general form of that species.

Many fragments of *Avicula* and pieces of *Ostrea* have been added to the previous collection, but the former genus is now represented by one or two more perfect specimens. One valve preserved in ironstone is slightly concave, and measures about 3¾ inches in height and about the same in length (Pl. XXIX, fig. 1). The hinge-line is preserved, and is seen to extend as a pointed wing to a greater length than was suggested by the outline in the previously-published plate. This is evidently the same species as the shell there figured, but, being the flattened valve, it has the ornamentation less strongly marked and appears to have been as large as the convex valve.

[1] British Belemnites,' Monogr. Palæont. Soc. 1865, pl. xviii, fig. 46 *l''*.

6. Cape Gertrude.

Many examples of the beds exposed at Cape Gertrude have been received, and these show vegetable remains at several horizons, but nothing sufficiently perfect for identification. One bed may be especially mentioned: it is a grey, calcareous, sandy rock filled with carbonized vegetable remains, and at first sight reminds one of the sandstone with plants found at Cape Stephen; but the present specimens are much more friable, and besides this the plant-remains are indeterminable and seem to be altogether different; there are none of the broad leaves, which are so plentiful in the Cape Stephen rock, but the remains have more the appearance of broken pieces of charcoal and give no outline to indicate the form of the plant.

11. Cape Richthofen.

In the earlier notes on the plant-remains from this locality, the possibility of certain of them being of Tertiary age was suggested. Examples of these plants have since been submitted to Dr. Nathorst, who, in a letter written on board the *Antarctic*, and dated May 30th, 1898, says that the absence of any fragment of a dicotyledon, which probably would not have been the case if the bed had been of Tertiary age, and the presence of two or three species of *Pinites* (one of which may rather be named *Taxites*) lead him to think that these plant-remains correspond with the Jurassic forms from Cape Flora.

In conclusion we desire to express our high appreciation of the services which Dr. Kœttlitz has rendered to geology in connexion with the Jackson-Harmsworth Expedition to Franz Josef Land. He had many duties to perform, and it was only in the intervals that could be spared from these duties that he was able to study the geology of the district. Under these circumstances our warmest thanks are due to him not only for the keen interest that he has taken in our science, for the energy that he has shown in collecting minerals, rocks, and fossils under difficult and adverse conditions, and carefully noting their mode of occurrence, but also for the skill with which he has made his observations on the general structure and physical features of that ice-bound land.

EXPLANATION OF PLATE XXIX.

Fig. 1. *Avicula* sp. Half natural size. Found in place 500 yards west of Elmwood and 30 to 40 feet above sea-level.

2. *Ammonites Lamberti.* Fragment, natural size. Found in place at the base of the basalt, $\frac{1}{4}$ mile north-west of Elmwood.

3. *Ginkgo polaris (?)*, Nathorst. Natural size. From plant-bed, in place, between the second and third tiers of basalt, above Windy Gully.

4. *Inoceramus (?).* Half natural size. Found in place on the shoulder of rock at the southern end of Windy Gully.

5. *Belemnites* sp. Natural size. Found with the *Inoceramus* of fig. 4. The curvature has no doubt been caused by the fractures, which are indicated in the figure. 5 *a*. Cross-section at the point marked, to show the oval and compressed outline, as well as the alveolar cavity.

Discussion (on the two preceding Papers).

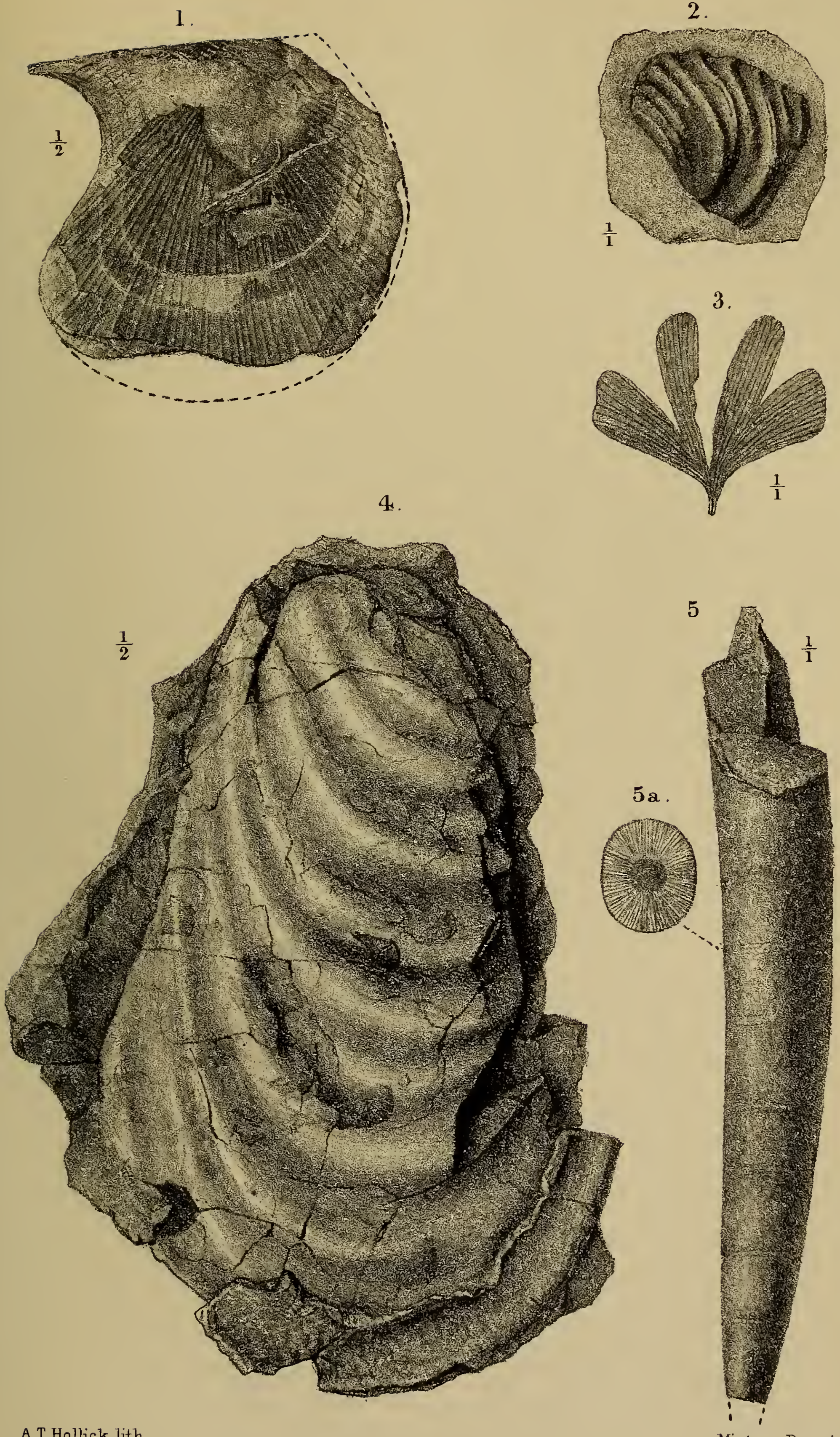
Dr. J. W. Gregory expressed his appreciation of the careful observations made by Dr. Kœttlitz. He asked why Payer's granite-erratic did not come from North-East Land or from one of the granitic areas of Spitsbergen. He thought that there should be considerable hesitation before accepting the basalt as Jurassic. A single seal-skeleton at the height of 700 feet at Cape Neale was hardly conclusive proof of submergence, as bears often carry their prey to some distance. The evidence of the 400-foot terraces, however, was quite convincing. The reindeer-antlers found by Leigh Smith might be explained as due to occasional migrations from Spitsbergen. Reindeer wander for great distances over the ice, there being evidence that Siberian reindeer occasionally reach Greenland.

Mr. Goodchild spoke of the high scientific value of the work done by Dr. Kœttlitz. From what he had heard of the paper it did not appear to be certain that the Author had made out any clear case for the occurrence of fossils of undoubted Jurassic age in any of the rocks interstratified with the lavas. It is possible that the fragment of *Ammonites Lamberti* recorded from the 'basaltic tuff' may be of the same nature as the ejected blocks of older rocks which so commonly occur in connexion with volcanic ejectamenta. He thought that the granite-block to which reference had been made might have reached the surface by the same means.

Mr. Hudleston said that these papers were interesting to Jurassic as well as to Arctic geologists, being supplementary to the very important communication previously made to the Society by Messrs. Newton & Teall. It was evident that the Franz Josef archipelago is the remains of a terrigenous deposit which has been preserved from destruction by a capping of basalt: it must not be regarded as an oceanic group. The faunas hitherto discovered appeared to be Jurassic only, and mainly Oxfordian: but the uppermost plant-bed involved in the basalt might possibly be of another period. At all events he did not feel satisfied as to the Jurassic age of any portion of the basalt, notwithstanding the fact that a fragment of *Ammonites Lamberti* had been found in 'basaltic tuff.' The paper did not appear to throw much light on the sections already exhibited, and the speaker expressed surprise, considering the length of time occupied by the Expedition, that so few specimens had been found *in situ*, but he did not suppose that for this Dr. Kœttlitz was in any way responsible.

Mr. Lobley thought that Dr. Kœttlitz, notwithstanding Arctic climatal conditions and other very serious obstacles, had accomplished geological work which was among the most important of the results achieved by the Expedition.

Mr. E. J. Garwood and Prof. Watts also spoke, and Mr. E. T. Newton replied.



A. T. Hollick lith.

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JURASSIC FOSSILS
FROM FRANZ JOSEF LAND.

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

END OF VOL. LIV.

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PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1897–98.

November 3rd, 1897.

Dr. Henry Hicks, F.R.S., President, in the Chair

Capt. the Hon. William Grimston, R.N., Sopwell, St. Alban's, was elected a Fellow; Dr. Oscar Fraas, of Stuttgart; M. Louis Dollo, of Brussels; and M. Emmanuel de Margerie, of Paris, were elected Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The President read the following letter, received from the Secretary of State for the Home Department, in acknowledgment of the congratulatory address submitted to Her Majesty the Queen, on the occasion of the Sixtieth Anniversary of her Accession, by the President, Council, and Fellows of the Society:—

Whitehall, 15th July, 1897.

Gentlemen,—

I have had the honour to lay before the Queen the loyal and dutiful Address of the President, Council, and Fellows of the Geological Society of London, on the occasion of Her Majesty attaining the Sixtieth Year of Her Reign, and I have to inform you that Her Majesty was pleased to receive the same very graciously.

I have the honour to be,
Your obedient Servant,
M. W. Ridley.

The Secretaries
of the Geological Society
of London.

The Secretary announced that Lady Prestwich had presented to the Society a half-length portrait in oils of the late Sir Joseph Prestwich, painted by Mr. W. E. Miller.

Mr. W. W. Watts proceeded to give details of some interesting geological features recently exposed at the new Sewerage Works at Carshalton, Surrey, now being made by the Urban District Council, to which the attention of the Society had been directed by the Surveyor during the autumn recess.

These excavations are situated at a spot which on the Geological Survey map is coloured as London Clay; and the features of the ground fully justified this colouring. The excavations, however, have shown that there are loamy and sandy beds of a light yellow colour, some 14 or 15 feet in thickness, and apparently occupying a hollow in the London Clay. At the base these sandy beds become dark and clayey in some places, and include flints and pebbles, while below this is the London Clay. In the dark pebbly layer were found a large skull, a piece of a tusk, and a number of smaller bones, which Mr. E. T. Newton has determined to be a piece of elephant-tusk, the skull (31 inches long) of *Rhinoceros antiquitatis* with some of its limb-bones; while the smaller bones represent two or perhaps three horses. Although the teeth of the rhinoceros are wanting, the skull is otherwise very perfect; and, bearing this in mind, as well as the fact that certain of the limb-bones were also found, and that *Elephas* is represented by the tusk, and all three (it is said) at a depth of 14 or 15 feet, little room is left for doubting that we have here at Carshalton a Pleistocene deposit of a somewhat unusual character and at a spot where it was not before suspected.

Mr. Whitaker, who was responsible for the geological mapping of this area, pointed out how the general configuration of the district gave no clue to the presence of this deposit of loamy sand, which occurred on a gentle slope, and that even now it was only possible to mark it on the map as an oval patch round the excavations with uncertain boundaries. The Drift shown, moreover, differs from that of the neighbourhood in that the latter is essentially gravel, while the former is sand, with loamy beds, but, as a rule, not stony, so that there are no surface-indications of gravel.

The mammalian remains are now preserved in the Museum of Practical Geology, through the kindness of the District Council.

Lieut.-Gen. McMahon, V.P.G.S., having taken the Chair, the President made a communication regarding deposits in North-western Middlesex very similar to those above described. Some years ago he described sections in Glacial Drift on the Hendon plateau, exposed during sewerage-operations. More recently the sewers have been carried on at lower levels between Hendon and Edgware; and numerous remains of mammoth and rhinoceros have been found, resting on an eroded surface of London Clay, and covered over by about 7 feet of stratified sands-and-gravels and brickearth. These deposits were found to spread out for considerable distances over the plain, and to be cut through also by the Silke stream, a tributary of the Brent. This area has hitherto been supposed to consist almost entirely of London Clay, but the sections have now shown that the brickearth which, in many respects, simulates the London Clay, is underlain by deposits which must be classed as of Pleistocene age.

The President then resumed the Chair, and Mr. H. B. Woodward called attention to a block of quartzite from Criccieth (Caernarvonshire) which had been sent for exhibition by Mr. G. J. Day. The rock contained a band of disrupted clayey material which presented on the surface of the block a rude resemblance to hieroglyphics. He thought that this curious structure had been produced on a sea-shore bounded by clay-cliffs, where a film of mud had been spread over the sands; and that the mud had dried and curled up before other layers of sand had been accumulated on the top of it. Similar phenomena might be produced at the present day on the Cromer coast, where thin films of mud were in places spread over the sands of the sea-shore. It had been suggested that the appearances in the Criccieth stone might have been produced in the original deposit, during the irregular solidification of the sand and its included layer of mud. The rock itself was regarded by the President as probably derived from the Harlech Grits, in which he had observed somewhat similar features.

Mr. Bauerman, as one of the three Delegates appointed by the Council on behalf of the Society to attend the recent International Geological Congress, held at St. Petersburg, gave a short account of the work of the Congress, dwelling more particularly on the excursion to the Ural Mountains, in which he had taken part.

The following communication was read:—

'A Contribution to the Palæontology of the Decapod Crustacea of England.' By the late James Carter, F.R.C.S., F.G.S. (Communicated by Prof. T. McKenny Hughes, M.A., F.R.S., F.G.S.)

The following maps were exhibited:—

Geological Survey of England and Wales, 4 miles to 1 inch: Index Map, Sheets 3, 4, and 7 (lithographed), and New Series, 1-inch Map No. 263, Cardiff (Solid and Drift), 1897; also Geological Survey of Scotland, 1-inch Map, Sheet 75, Tomintoul (Banff), 1897, presented by the Director-General of H.M. Geological Survey.

Reproductions made by the Science and Art Department from W. Smith's Original Maps, which are in the possession of the Society, presented through Prof. J. W. Judd, C.B., LLD., F.R.S., by that Department.

November 17th, 1897.

Dr. Henry Hicks, F.R.S., President, in the Chair.

Henry Fleck, Esq., 128a Queen's Road, Peckham, S.E.; and Edwin Bennett Brierley Newton, Esq., 131 Monton Road, Eccles (Lancashire), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'The Geology of Rotuma.' By J. Stanley Gardiner, Esq., B.A. (Communicated by J. E. Marr, Esq., M.A., F.R.S.)

2. 'A Geological Survey of the Witwatersrand and other Districts in the Southern Transvaal.' By Frederick H. Hatch, Ph.D., F.G.S.

3. 'Observations on the Genus *Aclisina*, de Koninck, with Descriptions of British Species, and of some other Carboniferous Gasteropoda.' By Miss J. Donald, of Carlisle. (Communicated by J. G. Goodchild, Esq., F.G.S.)

The following specimens and maps were exhibited :—

Rock-specimens and Microscope-sections, exhibited by F. H. Hatch, Ph.D., F.G.S., in illustration of his paper.

Specimens of *Aclisina*, de Kon., and other Carboniferous Gasteropoda, exhibited by J. G. Goodchild, Esq., F.G.S., in illustration of Miss Donald's paper.

A copy of Sheet 3 of the Lithographed Edition of the Geological Survey Index Map, presented by the Director-General of that Survey.

Map of the Transvaal, showing Physical Features and Political Divisions, on the scale of 1 inch=24·78 miles, 1897; and a Geological Map of the Southern Transvaal, on the scale of 1 inch=about 4½ miles, 1897, both maps drawn up by Dr. F. H. Hatch, F.G.S., by whom they are presented to the Society.

December 1st, 1897.

Dr. Henry Hicks, F.R.S., President, in the Chair.

Ernest Lionel Allhusen, Esq., B.Sc., Beadnell Tower, Chathill (Northumberland); William Ralph Baldwin-Wiseman, Esq., B.Sc., Egerton Villa, Brundretts Road, Chorlton-cum-Hardy; James Edmund Clark, Esq., B.A., B.Sc., 112 Wool Exchange, London; Edward Alison Douglas, Esq., Granville House, Overhill Road, East Dulwich, S.E.; William Edwards, Esq., 242 Nantwich Road, Crewe; Percy Griffith, Esq., 55 Parliament Street, Westminster, S.W.; John H. Heal, Esq., Hertford Lodge, Finchley, N.; Albert Ernest Kitson, Esq., 372 Albert Street, East Melbourne (Victoria); Edward St. John Lyburn, Esq., Box 321, Pretoria (South Africa); Clement Hungerford Pollen, Esq., Nelson (British Columbia); Richard P. Rothwell, Esq., 253 Broadway, New York, and 20 Bucklersbury, E.C.; Henry George Scott, Esq., Bangkok (Siam), and Ridgeway House, Oxted (Surrey); Francis J. Stephens, Esq., Ashfield, Falmouth; and Charles Gilbert Cullis, Esq., B.Sc., 15 Fawcett Street, Redcliffe Gardens, S.W., were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'A Revindication of the Llanberis Unconformity.' By the Rev. J. F. Blake, M.A., F.G.S.

2. 'The Geology of Lambay Island (Co. Dublin).' By Messrs. C. I. Gardiner, M.A., F.G.S., & S. H. Reynolds, M.A., F.G.S.

The following specimens, etc. were exhibited:—

Rock-specimens and models, exhibited by the Rev. J. F. Blake, M.A., F.G.S., in illustration of his paper.

Rock-specimens and Microscope-sections, exhibited by Messrs. C. I. Gardiner, M.A., F.G.S., & S. H. Reynolds, M.A., F.G.S., in illustration of their paper.

Sample of Placer Gold-Dust from the Yukon District (North-western Canada), exhibited by Dr. G. J. Hinde, F.R.S., F.G.S.

Copies of the Lithographed Edition of Sheets 10 & 13 of the Geological Survey Index Map, presented by the Director-General of that Survey.

December 15th, 1897.

Dr. Henry Hicks, F.R.S., President, in the Chair.

Charles Dodd, Esq., Clovelly Cottage, Wrexham; Angus Macdonald, Esq., B.Sc., Rockville, Orchard Street, Motherwell; Charles Alfred Matley, Esq., B.Sc., Stechford, near Birmingham; Arthur John Charles Molyneux, Esq., 19 Bury Street, St. James's, S.W.; Josslyn Ramsden, Esq., Willinghurst, Guildford (Surrey); Alexander Reid, Esq., Assoc.M.Inst.C.E., Linden Villa, Folkestone Road, Dover; and Charles Temple, Esq., Heath Brow, Hampstead, N.W., were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On the Pyromerides of Boulay Bay (Jersey).' By John Parkinson, Esq., F.G.S.

2. 'On the Exploration of Ty Newydd Cave, near Tremeirchion (North Wales).' By the Rev. G. C. H. Pollen, S.J., F.G.S.

The following specimens were exhibited:—

Hand-specimens and Microscope-sections of Pyromerides from Boulay Bay, Jersey, exhibited by John Parkinson, Esq., F.G.S., in illustration of his paper.

Specimens from the same locality, exhibited by Prof. T. G. Bonney, D.Sc., F.R.S., V.P.G.S.

Specimens from the Ty Newydd Cave, near Tremeirchion, and Lantern-slides, exhibited by the Rev. G. C. H. Pollen, S.J., F.G.S., in illustration of his paper.

January 5th, 1898.

Dr. Henry Hicks, F.R.S., President, in the Chair.

Albert Henry Turton, Esq., 5 Carlyle Road, Edgbaston, Birmingham, and Tasmania; Henry W. Pearson, Esq., M.I.C.E., Clifton, Bristol; and Hugh Garratt Foster Barham, Esq., Jersey New Waterworks Company Ltd., Jersey, were elected Fellows of the Society.

The following Fellows of the Society, nominated by the Council, were elected Auditors of the Society's Accounts for the preceding year:—Bedford McNeill, Esq., and Hilary Bauerman, Esq.

The List of Donations to the Library was read.

Prof. Judd drew attention to the Outline Geological Maps of England and Wales on the scale of 30 miles to the inch, for the use of schools and colleges, presented by John Lloyd, Esq. These were reproduced, by permission of the Science and Art Department, from the maps in use at the Royal College of Science, South Kensington.

The following communications were read:—

1. 'On the Structure of the Davos Valley.' By A. Vaughan Jennings, Esq., F.L.S., F.G.S.

2. 'Sections along the Lancashire, Derbyshire, and East Coast Railway between Lincoln and Chesterfield.' By C. Fox-Strangwaysl Esq., F.G.S. (Communicated by permission of the Director-Genera, of H.M. Geological Survey.)

In addition to the maps mentioned on p. vi, the following was exhibited :—

Geological Survey of England and Wales, 1-inch Map, n. s., No. 268 Basingstoke, Drift, by F. J. Bennett, J. H. Blake, and C. E. Hawkins. 1897. Presented by the Director-General of H.M. Geological Survey.

January 19th, 1898.

Dr. Henry Hicks, F.R.S., President, in the Chair.

George Percy Ashmore, Esq., 34 Montpelier Road, Brighton; Thomas James Haughton, Esq., Constitutional Club, Northumberland Avenue, W.C.; and the Rev. John Hawell, Ingleby Greenhow, Yorks, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'On some Gravels of the Bagshot District.' By Horace W. Monckton, Esq., F.L.S., F.G.S.

2. 'On the Occurrence of Chloritoid in Kincardineshire.' By George Barrow, Esq., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

The following specimens, etc. were exhibited :—

Specimens and Photographs, exhibited by Horace W. Monckton, Esq., F.L.S., F.G.S., in illustration of his paper; also a specimen belonging to Prof. T. Rupert Jones, F.R.S., F.G.S.

Rock-specimens and Microscope-sections, exhibited by George Barrow, Esq., F.G.S., in illustration of his paper.

Sheet 8 of the Index Map of the Geological Survey, on the scale of 4 miles to the inch, presented by the Director-General of that Survey.

February 2nd, 1898.

Dr. Henry Hicks, F.R.S., President, in the Chair.

William Howard Smith, Esq., Carlisle Villa, Dalmore Road, West Dulwich, S.E.; Samuel Hazzledine Warren, Esq., 9 Cambridge Gate, Regent's Park, N.W.; Charles Lindsay Temple, Esq., Brazil, and Heath Brow, Hampstead, N.W.; Elliott Moore Cairnes, Esq., 'Rivoli,' Barkly Street, St. Kilda, Victoria (Australia); and George Plunkett Chaplin, Esq., B.Sc., 124 Breakspeares Road, Brockley, S.E., were elected Fellows of the Society.

The List of Donations to the Library was read.

The President announced that Dr. Charles Barrois, Secretary of the Organizing Committee of the VIIIth International Geological Congress, which will be held in Paris in 1900, would shortly come to London to invite the Geological Society to the Congress, and to consult the Fellows with regard to the proposed excursions and the subjects of discussion. Dr. Barrois hoped to be present at the Annual General Meeting of the Society on February 18th, and to avail himself of that opportunity of personal intercourse with the Fellows.

The following communications were read:—

1. 'Contributions to the Glacial Geology of Spitsbergen.' By E. J. Garwood, Esq., M.A., F.G.S., and Dr. J. W. Gregory, F.G.S.

2. 'On a Quartz-rock in the Carboniferous Limestone of Derbyshire.' By H. H. Arnold-Bemrose, Esq., M.A., F.G.S.

The following specimens, etc. were exhibited:—

Specimens and Photographs, exhibited by E. J. Garwood, Esq., M.A., F.G.S., and Dr. J. W. Gregory, F.G.S., in illustration of their paper.

Rock-specimens, Microscope-sections, and Photographs, exhibited by H. H. Arnold-Bemrose, Esq., M.A., F.G.S., in illustration of his paper.

Geological Map of the Districts of Klerksdorp, Potchefstroom, and Krugersdorp, illustrating the Position and Extent of the Sedimentary Deposits, and the probable Continuation of the principal Conglomerate-Beds. Scale: about 4 miles to 1 inch. 1896. Drawn up and presented by D. Draper, Esq., F.G.S.

ANNUAL GENERAL MEETING,

February 18th, 1898.

Dr. Henry Hicks, F.R.S., President, in the Chair.

Report of the Council for 1897.

The upward tendency in the number of Fellows and the uninterrupted financial prosperity of the Society, which formed a subject of congratulation in last year's Report, have been steadily maintained during the twelvemonth under review.

In 1897 the number of Fellows elected into the Society was 59, of whom 41 paid their Admission Fees before the end of the year. Fees were also received during the past twelvemonth from 13 Fellows, who had been elected in 1896, the total accession of new Fellows in 1897 being therefore 54.

On the other hand, there was a total loss of 51 Fellows during the past year—31 by death, 10 by resignation, and 10 removed from the List because of non-payment of their Annual Contributions.

From the foregoing figures it will be seen that the actual increase in the number of Fellows is 3.

Of the 31 Fellows deceased 11 had compounded for their Annual Contributions, 13 were Contributing Fellows, and 7 were Non-Contributing Fellows. On the other hand, 3 Fellows during the past year became Compounders.

The total accession of Contributing Fellows is thus seen to be 51, and the total loss being 33 (10+10+13), the increase in the number of Contributing Fellows is 18, as compared with an increase of 13 in 1896.

Turning now to the Lists of Foreign Members and Foreign Correspondents, the Fellows may be reminded that at the end of 1896, there were 3 vacancies in the List of Foreign Members and 1 in the List of Foreign Correspondents. In 1897 two Foreign Members and 4 Foreign Correspondents died. The vacancies thus left were in part filled by the election of 4 Foreign Members and 7 Foreign Correspondents, but at the end of the year there was still 1 vacancy in the List of Foreign Members, and 2 in the List of Foreign Correspondents.

The total number of Fellows, Foreign Members, and Foreign Correspondents, which on December 31st, 1896, was 1329, had increased by the end of 1897 to 1333.

Proceeding now to the consideration of the Society's annual Income and Expenditure, the figures for 1897 may be summarized as follows:—

The total Receipts, including the Balance of £768 3*s.* 0*d.* brought forward from the previous year, amounted to £3610 19*s.* 3*d.*, being £353 4*s.* 3*d.* more than the estimated Income for the year. On the other hand, the total Expenditure during 1897 amounted to £2887 16*s.* 3*d.*, being less by £369 18*s.* 9*d.* than the estimated Expenditure for that year.

The actual excess of Expenditure over current Receipts in 1897 was £45 0*s.* 0*d.*, but a glance at the Balance Sheet will show that this excess is entirely due to Expenditure of a non-recurring character, namely, the cost of compilation and publication of the Index to the first Fifty Volumes of the Quarterly Journal (£350 13*s.* 4*d.*).

There still remained at the end of 1897 a Balance of £723 3*s.* 0*d.* available for Extraordinary Expenditure.

The President, Council, and Fellows shared in the universal expressions of loyalty and attachment to the Throne of which the Sixtieth Anniversary of Her Majesty's Accession was the happy occasion. They presented an Address to the Queen, emphasizing the progress which Geology, in common with other sciences, has made under her long and beneficent rule, and Her Majesty was pleased to receive the Address very graciously.

The Seventh Session of the International Geological Congress was held at St. Petersburg in the first days of September, and the Council appointed as Delegates on behalf of this Society, Sir Archibald Geikie, Prof. T. McK. Hughes, and Mr. H. Bauerman. The Congress was preceded and followed by geological journeys extending from the Baltic to the Siberian steppes, and from Lake Ladoga to the Caspian; and everywhere in that vast country the most generous hospitality was shown by all classes of the Russian people, from the Emperor downwards.

Sir Archibald Geikie in June last drew the attention of the Council to the manuscript, in the Society's possession, of part of the Third Volume of Hutton's 'Theory of the Earth,' and urged the desirability of its publication, offering at the same time to place his services freely at the disposal of the Society for the editing of the manuscript. It has been ascertained that the cost of printing 1000 copies in a style uniform with the First and Second Volumes of the 'Theory of the Earth' would not exceed £80, and the Council feel assured that the Fellows will approve of that Expenditure being incurred during the current year. A reduction on the published price will be made to Fellows.

The Council have pleasure in announcing the completion of Vol. LIII. of the Society's Quarterly Journal, and the commencement of Vol. LIV.

Part II (La–Z) of the General Index to the First Fifty Volumes of the Quarterly Journal was published in May last, and the hope expressed in last year's Report that the great utility and importance of this work would be recognized has been fulfilled. The Council consider that the Fellows owe a deep debt of gratitude to the Assistant Secretary for the exceedingly able manner in which he has carried out the work.

The Record of Geological Literature added to the Society's Library during 1897 will be in the Fellows' hands in the course of a few days, and the mention of this leads to the larger question of the great International Catalogue. In response to an invitation from the Royal Society, the Council have appointed a Geological Sub-Committee in connexion with the International Catalogue Committee. A great number of sittings have been held, and a scheme for Geology has been elaborated which fits in with the general plan of the proposed Catalogue. It is in accordance with this plan also that Index-slips are being issued with the current number of the Quarterly Journal.

The following Awards of Medals and Funds have been made by the Council:—

The Wollaston Medal is awarded to Prof. Ferdinand Zirkel, in recognition of the value of his researches instituted for the purpose of investigating the mineral structure of the earth.

The Murchison Medal, with a sum of Ten Guineas, is awarded to Mr. T. F. Jamieson, in recognition of the value of his work amongst the later deposits of the British Islands.

The Lyell Medal, with a sum of Twenty-Five Pounds, is awarded to Dr. W. Waagen, in appreciation of the value of his researches in Palæontology and Stratigraphical Geology, especially in British India.

The Balance of the Proceeds of the Wollaston Fund is awarded to Mr. E. J. Garwood, in recognition of the value of his work amongst the rocks of the North of England and of his researches in Spitsbergen, and to assist him in further research.

The Balance of the Proceeds of the Murchison Fund is awarded to Miss J. Donald in recognition of the value of her work on the Palæozoic Gasteropoda, and to assist her in further investigations.

A moiety of the Balance of the Proceeds of the Lyell Fund is awarded to Mr. Henry Woods, in recognition of his work in Stratigraphical Geology and Palæontology, and to aid him in further researches.

The other moiety of the Balance of the Proceeds of the Lyell Fund is awarded to Mr. W. H. Shrubsole, in recognition of the value of his work amongst the newer deposits, and to assist him in further researches.

A portion of the Balance of the Barlow-Jameson Fund is awarded to Mr. E. Greenly, in recognition of his work amongst the ancient rocks of Britain and to assist him in further investigations.

Report of the Library and Museum Committee for 1897.

Your Committee are able to state that the additions made to the Library during the past twelve months were in no respect inferior, either in number or interest, to the acquisitions of previous years.

During 1897 the Library received, by Donation, 96 Volumes of separately published works, 500 Pamphlets and detached Parts of works, 120 Volumes and 114 detached Parts of serial publications (Transactions, Memoirs, Proceedings, etc.), and 16 Volumes of Newspapers. The total number of accessions to the Library by Donation is thus seen to amount to 232 Volumes, 500 Pamphlets, and 114 detached Parts. Moreover, 149 Sheets of Maps have been presented by various Donors.

Attention may be directed to such gifts, among others, as the Maps presented by the Imperial Geological Survey of Japan; those of the Geological Surveys of Hesse-Darmstadt and Rumania; the lithographed sheets of the Index Map of the Geological Survey of England and Wales; the Killean and Golspie sheets of the Geological Survey Map of Scotland; and the photographic reproductions of certain of William Smith's maps, presented by the Science and Art Department, through Professor Judd.

Turning from Maps to Books, the following may be especially mentioned:—Sir Archibald Geikie's 'Ancient Volcanoes of Great Britain'; the British Museum Catalogues: Fossil Cephalopoda, Part 3, and Tertiary Mollusca, Part 1: Australasia; 44 Memoirs presented by Prof. Stanislas Meunier; 30 Memoirs presented by Prof. A. Koch; 11 by Prof. G. A. J. Cole; and 12 by M. F. Mourlon. Moreover, Mrs. A. H. Green presented 12 Pamphlets, several Maps, and 13 Geological Photographs of New South Wales from the Library of her deceased husband; and the Director-General of H.M. Geological Survey enriched the Society's Library with a duplicate set of 100 Survey Memoirs.

Lady Prestwich presented a fine portrait in oils of the late Sir Joseph Prestwich, and, with the generous donor's entire approval, the portrait has been hung in the Meeting Room.

The Books, Maps, etc. enumerated above were the gift of 170 Personal Donors, 114 Government Departments and other Public Bodies, and 176 Societies and Editors of Periodicals.

The Purchases made on the recommendation of the Standing Library Committee amounted to 46 Volumes and 18 Parts of separately published works, 28 Volumes and 17 Parts of works published serially, and 14 Sheets of Maps.

The total Expenditure incurred in connexion with the Library during the past twelve months is as follows:—

	£	s.	d.
Books, Periodicals, etc. purchased	81	9	10
Binding of Books and Mounting of Maps....	95	5	5
	£176	15	3

Museum.

No additions have been made to the collections during the past year.

Mr. C. Davies Sherborn has actively continued the work of labelling and registering the type- and other important specimens in the Foreign Collection.

He reports as follows: 'Three hundred and twenty drawers have been examined during the past year. This takes the work on into the South American Collection, and leaves for future examination the whole of the Australasian Collection (144 drawers) and some miscellaneous collections in the small workrooms. I have to acknowledge the valuable assistance afforded by Mr. T. W. Vaughan, of the United States Geological Survey, in the examination of Duncan's types of the Antiguan corals, a task left unfinished by Dr. Duncan.'

The expenditure in the Museum during 1897 was as follows:—

	£	s.	d.
Special work (registration, etc.)	20	0	0
Sundries................................	2	9	6
	£22	9	6

The appended Lists contain the Names of Government Departments, Public Bodies, Societies, Editors, and Personal Donors, from whom Donations to the Library have been received during the past year:—

I. Government Departments and other Public Bodies.

Alabama.—Geological Survey of Alabama. Montgomery.
American Museum of Natural History. New York.
Australian Museum, Sydney.
Austria.—Kaiserlich-Königliche Geologische Reichsanstalt. Vienna.
——. Kaiserlich-Königliches Naturhistorisches Hofmuseum. Vienna.
Baden.—Grossherzogliches Ministerium des Innern. Geologische Landesanstalt. Heidelberg.
Barrande Fund.
Bavaria.—Königlich Bayerisches Oberbergamt. Munich.
Belgium.—Musée Royal d'Histoire Naturelle. Brussels.
Berlin.—Königliche Preussische Akademie der Wissenschaften.
Birmingham.—Mason University College.
Buenos Aires. Museo Nacional.
California.—State Mining Bureau. San Francisco.
California University. Berkeley.
Cambridge (Mass.).—Museum of Comparative Zoology, at Harvard College.
Canada.—Geological and Natural History Survey. Ottawa.
Cape Colony.—Department of Agriculture.
—— ——. Geological Commission.

Chicago.—'Field' Columbian Museum.
Costa Rica.—Museo Nacional. San José.
Denmark.—Geological Survey.
Dublin.—Royal Irish Academy.
Europe.—Commission Géologique Internationale. Berlin.
Finland.—Finlands Geologiska Undersökning. Helsingfors.
France.—Dépôt de la Marine. Paris.
——. Ministère des Travaux Publics. Paris.
——. Muséum d'Histoire Naturelle. Paris.
——. Service de la Carte Géologique. Paris.
Great Britain.—Admiralty. London.
——. Army Medical Department. London.
——. British Museum (Natural History). London.
——. Colonial Office. London.
——. Geological Survey. London.
——. Home Office. London.
——. India Office. London.
——. Ordnance Survey. Southampton.
——. The Lords Commissioners of Her Majesty's Treasury. London.
Greece.—Observatoire National. Athens.
Hesse.—Grossherzogliches Ministerium des Innern. Geologische Landesanstalt. Darmstadt.
Holland.—Departement van Kolonien. The Hague.
Houghton (Mich.).—Michigan Mining School.
Hungary.—Königliche Ungarische Geologische Anstalt (Magyar Földtani Tarsulat). Budapest.
Illinois.—State Museum of Natural History. Springfield.
India.—Geological Survey. Calcutta.
——. India Office.
——. Public Works Department.
Iowa.—Geological Survey. Des Moines.
Italy.—Reale Comitato Geologico d'Italia. Rome.
Japan.—Geological Survey. Tokio.
Kingston (Canada).—Queen's College.
La Plata Museum. La Plata.
Lausanne University.
London.—City of London College.
——. Royal College of Surgeons.
——. University College.
Lund Museum. Denmark.
Mexico.—Comision Geológica de Mexico. Mexico.
Milwaukee Museum.
Minnesota.—Geological and Natural History Survey. Minneapolis.
Missouri.—Geological Survey of Missouri. Jefferson City.
Munich.—Königliche Bayerische Akademie der Wissenschaften.
New South Wales.—Agent-General for, London.
——. Australian Museum. Sydney.
——. Department of Lands. Sydney.
——. Department of Mines. Sydney.
——. Geological Survey. Sydney.
New York State Library. Albany.
—— —— —— Museum. Albany.
New Zealand.—Department of Mines. Wellington.
Norway.—Meteorological Department.
——. Norges Geologiska Undersökning. Christiania.
Nova Scotia.—Department of Mines. Halifax.
Owens College. Manchester.
Padua.—Reale Accademia di Scienze, Lettere, ed Arti.
Palermo.—Reale Accademia di Scienze, Lettere, ed Arti.
Paris.—Académie des Sciences.
Pennsylvania.—Geological Survey. Harrisburg.
Perak Government. Taiping.
Pisa.—Royal University.
Portugal.—Commissão Geologica de Portugal. Lisbon.
Prussia.—Königliche Preussische Geologische Landesanstalt. Berlin.
——. Königliches Ministerium für Handel und Gewerbe. Berlin.
Queensland.—Department of Mines. Brisbane.
——. Geological Survey. Brisbane.

Rome.—Reale Accademia dei Lincei.
Rumania.—Museum of Geology and Palæontology. Bucharest.
Russia.—Comité Géologique. St. Petersburg.
——. Section géologique du Cabinet de S.M. l'Empereur. St. Petersburg.
Saxony.—Geologische Landesuntersuchung des Königreichs Sachsen. Leipzig.
——. Königliches Finanz-Ministerium. Leipzig.
South Australia.—The Agent-General for, London.
Spain.—Comision del Mapa Geológico. Madrid.
St. Petersburg.—Académie Impériale des Sciences.
Stockholm.—Kongliga Svenska Vetenskaps Akademi.
Sweden.—Sveriges Geologiska Undersökning. Stockholm.
Switzerland.—Commission der Geologischen Karte. Berne.
Tokio.—Imperial University.
——. —— ——, College of Science.
Tufts College, Massachusetts.
Turin.—Reale Accademia delle Scienze.
United States Department of the Interior. Washington.
—— —— Geological Survey. Washington.
—— —— National Museum. Washington.
—— —— Treasury (Mint) Department. Washington.
Upsala University.
—— ——. Mineralogical and Geological Institute.
Victoria.—Department of Agriculture. Melbourne.
——. Department of Mines. Melbourne.
Vienna.—Kaiserliche Akademie der Wissenschaften.
Washington (D.C.).—Smithsonian Institution.
Western Australia.—Agent-General for, London.
——. Department of Mines. Perth.
——. Geological Survey. Perth.
Wisconsin University. Madison.

II. Societies and Editors.

Adelaide.—Royal Society of South Australia.
Alnwick.—Berwickshire Naturalists' Club.
Bahia.—Instituto Geographico e Historico.
Barnsley.—Midland Institute of Mining, Civil and Mechanical Engineers.
Bath Natural History and Antiquarian Field Club.
Belfast Natural History and Philosophical Society.
Belgrade.—Annales Géologiques de la Péninsule Balkanique.
Berlin.—Deutsche Geologische Gesellschaft.
——. Gesellschaft Naturforschender Freunde.
——. Zeitschrift für Praktische Geologie.
Bern.—Schweizerische Naturforschende Gesellschaft.
Bombay Branch of the Royal Asiatic Society.
Bordeaux.—Société Linnéenne.
Boston (Mass.).—American Academy of Arts and Sciences.
Boston Society of Natural History.
Brussels.—Société Belge de Géologie, de Paléontologie et d'Hydrologie.
——. Société Malacologique de Belgique.
Budapest.—Földtani Közlöny (Geological Magazine).
Buenos Aires.—Instituto Geografico Argentino.
——. Sociedad Cientifica Argentina.
Caen.—Société Linnéenne de Normandie.
Calcutta.—Indian Engineering.
——. Asiatic Society of Bengal.
Cape Town.—South African Philosophical Society.
Cardiff.—South Wales Institute of Engineers.
Chelmsford.—Felsted School Scientific Society.
Chicago.—Journal of Geology.
Christiania.—Nyt Magazin for Naturvidenskaberne.
——. Videnskabernes Selskab.
Cincinnati Society of Natural History.
Colombo.—Ceylon Branch of the Royal Asiatic Society.
Colorado Springs.—Colorado College Scientific Society.
Copenhagen.—Kongelige Danske Videnskabernes Selskab.

Cordoba.—Academia Nacional de Ciencias.
Cracow.—Académie des Sciences (Akademja Umiejetosci).
Darmstadt.—Verein für Erdkunde.
Davenport (Iowa). Academy of Natural Sciences.
Dijon.—Académie des Sciences.
Dorpat.—Naturforscher Gesellschaft bei der Universität Jurjew.
Douglas.—Isle of Man Natural History and Antiquarian Society.
Dresden.—Naturwissenschaftliche Gesellschaft 'Isis.'
——. Verein für Erdkunde.
Dublin.—Royal Dublin Society.
Edinburgh.—Geological Society.
——. Royal Physical Society.
——. Royal Scottish Geographical Society.
——. Royal Society.
Ekaterinburg.—Société Ouralienne d'Amateurs des Sciences Naturelles.
Frankfurt a. M.—Senckenbergische Naturforschende Gesellschaft.
Giessen.—Oberhessische Gesellschaft für Natur- und Heilkunde.
Glasgow.—Geological Society.
——. Mitchell Library.
——. Natural History Society.
Gloucester.—Cotteswold Naturalists' Field-Club.
Gratz.—Naturwissenschaftlicher Verein für Steiermark.
Haarlem.—Société Hollandaise des Sciences.
Halifax.—Yorkshire Geological and Polytechnic Society.
Halle.—Kaiserliche Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
Hamilton (Canada).—Hamilton Association.
Havre.—Société Géologique de Normandie.
Hermannstadt.—Siebenbürgischer Verein für Naturwissenschaften.
Hertford.—Hertfordshire Natural History Society.
Indianapolis.—Indiana Academy of Science.
Johannesburg.—Geological Society of South Africa.
Lausanne.—Société Géologique Suisse.
——. Société Vaudoise des Sciences Naturelles.
Leeds.—Philosophical Society.
Leicester.—Literary and Philosophical Society.
Leipzig.—Naturwissenschaftlicher Verein für Sachsen und Thüringen.
——. Zeitschrift für Krystallographie und Mineralogie.
——. Zeitschrift für Naturwissenschaften.
Liége.—Société Géologique de Belgique.
——. Société Royale des Sciences.
Lille.—Société Géologique du Nord.
Lisbon.—Sociedade de Geographia.
Liverpool.—Geological Association.
——. Literary and Philosophical Society.
London.—Academy.
——. Athenæum.
——. British Association for the Advancement of Science.
——. Chemical News.
——. Chemical Society.
——. Colliery Guardian.
——. East India Association.
——. Geological Magazine.
——. Geologists' Association.
——. Institution of Civil Engineers.
——. Iron and Steel Trades' Journal.
——. Knowledge.
——. Linnean Society.
——. London, Edinburgh, and Dublin Philosophical Magazine.
——. Mineralogical Society.
——. Nature.
——. Palæontographical Society.
——. Physical Society.
——. Ray Society.
——. Royal Agricultural Society.
——. Royal Astronomical Society.
——. Royal Geographical Society.
——. Royal Institution.

London.—Royal Meteorological Society.
——. Royal Microscopical Society.
——. Royal Photographic Society of Great Britain.
——. Royal Society.
——. Society of Arts.
——. Society of Biblical Archæology.
——. Society of Public Analysts.
——. Victoria Institute.
——. Zoological Society.
Madison (Wis.).—Wisconsin Academy of Sciences.
Manchester.—Geological Society.
——. Literary and Philosophical Society.
Melbourne.—Royal Society of Victoria.
Milan.—Reale Istituto Lombardo di Scienze e Lettere.
——. Società Italiana di Scienze Naturali.
Montreal.—Natural History Society.
Moscow.—Société Impériale des Naturalistes.
Nancy.—Académie de Stanislas.
New Haven (Conn.).—American Journal of Science.
——. Connecticut Academy of Arts and Sciences.
New York.—Academy of Sciences.
——. American Institute of Mining Engineers.
Newcastle-upon-Tyne.—North of England Institute of Mining and Mechanical Engineers.
Northampton.—Northamptonshire Natural History Society.
Oporto.—Sociedade Carlos Ribeiro.
Ottawa.—Royal Society of Canada.
Palermo.—Annales de Géologie et de Paléontologie.
Paris.—Annuaire Géologique Universel.
——. Revue Scientifique.
——. Société Française de Minéralogie.
——. Société Géologique de France.
——. Spelunca.
Penzance.—Royal Geological Society of Cornwall.
Philadelphia.—Academy of Natural Sciences.
——. American Philosophical Society.
——. Wagner Free Institute of Science.
Pisa.—Società Toscana di Scienze Naturali.
Plymouth.—Devonshire Association for the Advancement of Science.
—— Institution, and Devon & Cornwall Natural History Society.
Portland (Me.).—Portland Society of Natural History.
Rochester (N.Y.).—Academy of Sciences.
——. Geological Society of America.
Riga.—Naturforscher Verein.
Rome.—Società Geologica Italiana.
Rugby School Natural History Society.
Salt Lake City.—Utah University Quarterly.
Santiago.—Deutscher Wissenschaftlicher Verein.
——. Sociedad Nacional de Mineria.
——. Société Scientifique du Chili.
Scranton (Pa.).—Colliery Engineer.
St. John (N.B.).—Natural History Society.
St. Petersburg.—Russische Kaiserliche Mineralogische Gesellschaft.
Stockholm.—Geologiska Förening.
Stonyhurst Magazine.
Stuttgart.—Neues Jahrbuch für Mineralogie, Geologie und Paläontologie.
——. Verein für Vaterländische Naturkunde in Württemberg.
Sydney.—Australasian Association for the Advancement of Science.
——. Linnean Society of New South Wales.
——. Royal Society of New South Wales.
Topeka.—Transactions of the Kansas Academy of Science.
Toronto.—Canadian Institute.
Toulouse.—Société d'Histoire Naturelle.
Truro.—Royal Institution of Cornwall.
Vienna.—Berg- und Hüttenmännisches Jahrbuch.
——. Kaiserlich-königliche Zoologisch-botanische Gesellschaft.
——. Mineralogische und Petrographische Mittheilungen.
Warsaw.—Annuaire Géologique et Minéralogique de la Russie.

Warwick.—Warwickshire Naturalists' Field Club.
Washington (D.C.).—Biological Society.
——. Geological Society.
——. Philosophical Society.
Wellington (N.Z.).—Australian Institute of Mining Engineers.
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Wiesbaden.—Nassauischer Verein für Naturkunde.
York.—Natural History Journal.
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COMPARATIVE STATEMENT OF THE NUMBER OF THE SOCIETY AT THE CLOSE OF THE YEARS 1896 AND 1897.

	Dec. 31st, 1896.		Dec. 31st, 1897.
Compounders	306	......	298
Contributing Fellows......	880	......	898
Non-contributing Fellows ..	67	......	60
	1253		1256
Foreign Members	37	......	39
Foreign Correspondents....	39	......	38
	1329		1333

Comparative Statement explanatory of the Alterations in the Number of Fellows, Foreign Members, and Foreign Correspondents at the close of the years 1896 *and* 1897.

Number of Compounders, Contributing and Non-contributing Fellows, December 31st, 1896 ..			1253
Add Fellows elected during the former year and paid in 1897			13
Add Fellows elected and paid in 1897			41
			1307
Deduct Compounders deceased................		11	
Contributing Fellows deceased		13	
Non-contributing Fellows deceased		7	
Contributing Fellows resigned		10	
Contributing Fellows removed		10	
		—	51
			1256
Number of Foreign Members and Foreign Correspondents, December 31st, 1896		76	
Deduct Foreign Members deceased	2		
Foreign Correspondents deceased ..	4		
Foreign Correspondents elected Foreign Members	4		
	—	10	
		66	
Add Foreign Members elected		4	
Foreign Correspondents elected		7	
		—	77
			1333

Deceased Fellows.

Compounders (11).

Cross, Rev. J. E.
Franks, Sir A. W.
Harraden, S.
Heywood, J.
Hunter, Rev. Dr.
Laing, S.
Leaf, C. J.
Maitland, Sir J. R. G.
Ogilvie, A. G.
Renshaw, A. G.
Tabuteau, Lt.-Col. A. O.

Resident and other Contributing Fellows (13).

Ayers, Sir H.
Allport, S.
Bewick, T. J.
Campbell, Lt.-Col. J. R.
Collinson, T.
Drummond, Prof. H.
Farnworth, W.
Ferguson, W. D.
King, Lt.-Col. C. C.
Morris, T.
Myers, E.
Piper, G. H.
Tate, T.

Non-contributing Fellows (7).

Collard, T. W.
Brodie, Rev. P. B.
Cunliffe, B.
Haughton, Dr. S.
Jackson, A. W.
Josephson, J. F.
Smith, T. J.

Foreign Members (2).

Des Cloizeaux, Prof. A.
Steenstrup, Prof. J. J. S.

Foreign Correspondents (4).

Cope, Prof. E. D.
Ettingshausen, Baron C. von.
Fraas, Dr. O. von.
Winkler, Dr. T. C.

Fellows Resigned (10).

Dunhill, Dr. C. H.
Forfeitt, F. J.
John, W.
Leach, Rev. C.
Godwin-Austen, Lt.-Col. H. H.
Moore, R. W.
Pope, W. J.
St. Clair, G.
Spruce, S.
Vinter, H. W.

Fellows Removed (10).

Braga, J. F.
Burkitt, Dr. J. C. S.
Jones, E. M.
Johnstone, A.
Maddison, T. R.
Maddock, Rev. H. E.
Ogle, P. J.
Pagen, J. F.
Wilkinson, Rev. B.
Pope, J.

The following Personages were elected from the List of Foreign Correspondents to fill the vacancies in the List of Foreign Members during the year 1897:—

M. E. Dupont, of Brussels.
Dr. Anton Fritsch, of Prague.
Prof. A. de Lapparent, of Paris.
Dr. Hans Reusch, of Christiania.

The following Personages were elected Foreign Correspondents during the year 1897:—

M. Louis Dollo, of Brussels.
Dr. O. von Fraas, of Stuttgart.
Mr. A. Hyatt, of Cambridge, Mass. (U.S.A.).
Dr. Anton Koch, of Budapest.
Prof. A. Lacroix, of Paris.
M. Emmanuel de Margerie, of Paris.
Prof. Count H. zu Solms-Laubach, of Strasburg.

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 circulated among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to Dr. Henry Hicks, retiring from the office of President.

That the thanks of the Society be given to Lieut.-Gen. C. A. McMahon and Dr. Henry Woodward, retiring from the office of Vice-President.

That the thanks of the Society be given to Mr. J. E. Marr, retiring from the office of Secretary.

That the thanks of the Society be given to Mr. H. Bauerman, Prof. E. Hull, Mr. R. Lydekker, Lieut.-Gen. C. A. McMahon, and Dr. Henry Woodward, 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:—

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THE FOREIGN MEMBERS
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Date of Election.

1848. James Hall, Esq., *Albany, State of New York, U.S.A.*
1856. Professor Robert Bunsen, For. Mem. R.S., *Heidelberg.*
1857. Professor H. B. Geinitz, *Dresden.*
1871. Dr. Franz Ritter von Hauer, *Vienna.*
1874. Professor Albert Gaudry, *Paris.*
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1877. Dr. Eduard Süss, *Vienna.*
1879. M. Jules Marcou, *Cambridge, Mass., U.S.A.*
1879. Dr. J. J. S. Steenstrup, For. Mem. R.S., *Copenhagen.* (*Deceased.*)
1880. Professor Gustave Dewalque, *Liége.*
1880. Baron Adolf Erik Nordenskiöld, *Stockholm.*
1880. Professor Ferdinand Zirkel, *Leipzig.*
1883. Professor Otto Martin Torell, *Stockholm.*
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1896. Professor Albert Heim, *Zürich.*
1897. M. E. Dupont, *Brussels.*
1897. Dr. Anton Fritsch, *Prague.*
1897. Professor A. de Lapparent, *Paris.*
1897. Dr. Hans Reusch, *Christiania.*

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1874.	Professor Igino Cocchi, *Florence.*
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1880. Professor Auguste Daubrée.
1881. Professor P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.
1883. Dr. W. T. Blanford.
1884. Professor Albert Gaudry.
1885. Mr. George Busk.
1886. Professor A. L. O. Des Cloizeaux.
1887. Mr. J. Whitaker Hulke.
1888. Mr. H. B. Medlicott.
1889. Professor T. G. Bonney.
1890. Professor W. C. Williamson.
1891. Professor J. W. Judd.
1892. Baron Ferdinand von Richthofen.
1893. Professor N. S. Maskelyne.
1894. Geheimrath Professor Karl Alfred von Zittel.
1895. Sir Archibald Geikie.
1896. Dr. Eduard Süss.
1897. Mr. W. H. Hudleston.
1898. Professor F. Zirkel.

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. Professor L. C. Miall.
1876. Professor Giuseppe Seguenza.
1877. Mr. R. Etheridge, Jun.
1878. Professor W. J. Sollas.
1879. Mr. Samuel Allport.
1880. Mr. Thomas Davies.
1881. Dr. R. H. Traquair.
1882. Dr. G. J. Hinde.
1883. Professor John Milne.
1884. Mr. E. Tulley Newton.
1885. Dr. Charles Callaway.
1886. Mr. J. S. Gardner.
1887. Mr. B. N. Peach.
1888. Mr. J. Horne.
1889. Mr. A. Smith Woodward.
1890. Mr. W. A. E. Ussher.
1891. Mr. R. Lydekker.
1892. Mr. O. A. Derby.
1893. Mr. J. G. Goodchild.
1894. Mr. Aubrey Strahan.
1895. Mr. W. W. Watts.
1896. Mr. Alfred Harker.
1897. Mr. F. A. Bather.
1898. Mr. E. J. Garwood.

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 enquiries 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. Rev. J. F. Blake.
1878. Dr. H. B. Geinitz. *Medal.*
1878. Professor Charles Lapworth.
1879. Professor F. M'Coy. *Medal.*
1879. Mr. J. W. Kirkby.
1880. Mr. R. Etheridge. *Medal.*
1881. Sir Archibald 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. Martin Simpson.
1885. Dr. Ferdinand von Römer *Medal.*
1885. Mr. Horace B. Woodward.
1886. Mr. W. Whitaker. *Medal.*
1886. Mr. Clement Reid.
1887. Rev. P. B. Brodie. *Medal.*
1887. Mr. Robert Kidston.
1888. Professor J. S. Newberry. *Medal.*
1888. Mr. Edward Wilson.
1889. Professor James Geikie. *Medal.*
1889. Professor G. A. J. Cole.
1890. Professor Edward Hull. *Medal.*
1890. Mr. E. Wethered.
1891. Professor W. C. Brögger *Medal.*
1891. Rev. R. Baron.
1892. Professor A. H. Green. *Medal.*
1892. Mr. Beeby Thompson.
1893. Rev. O. Fisher. *Medal.*
1893. Mr. G. J. Williams.
1894. Mr. W. T. Aveline. *Medal.*
1894. Mr. George Barrow.
1895. Professor Gustav Lindström. *Medal.*
1895. Mr. A. C. Seward.
1896. Mr. T. Mellard Reade. *Medal.*
1896. Mr. Philip Lake.
1897. Mr. Horace B. Woodward. *Medal.*
1897. Mr. S. S. Buckman.
1898. Mr. T. F. Jamieson. *Medal.*
1898. Miss J. Donald.

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 and as an expression on the part of the governing body of the Society that the Medallist (who may be of any country or either sex) 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, either for travelling expenses or for a memoir or paper published, or in progress, and without reference to the sex or nationality of the author, or the language in which any such memoir or paper may be written.'

1876. Professor John Morris. *Medal.*
1877. Dr. James Hector. *Medal.*
1877. Mr. W. Pengelly.
1878. Mr. G. Busk. *Medal.*
1878. Professor W. Waagen.
1879. Professor Edmond Hébert. *Medal.*
1879. Professor H. A. Nicholson.
1879. Dr. Henry Woodward.
1880. Sir John Evans. *Medal.*
1880. Professor F. A. von Quenstedt.
1881. Sir J. W. Dawson. *Medal.*
1881. Dr. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. Dr. J. Lycett. *Medal.*
1882. Rev. Norman Glass.
1882. Professor Charles Lapworth.
1883. Dr. W. B. Carpenter. *Medal.*
1883. Mr. P. H. Carpenter.
1883. M. E. Rigaux.
1884. Dr. Joseph Leidy. *Medal.*
1884. Professor Charles Lapworth.
1885. Professor H. G. Seeley. *Medal.*
1885. Mr. A. J. Jukes-Browne.
1886. Mr. W. Pengelly. *Medal.*
1886. Mr. D. Mackintosh.
1887. Mr. Samuel Allport. *Medal.*
1887. Rev. Osmond Fisher.
1888. Professor H. A. Nicholson. *Medal.*
1888. Mr. A. H. Foord.
1888. Mr. Thomas Roberts.
1889. Professor W. Boyd Dawkins. *Medal.*
1889. M. Louis Dollo.
1890. Professor T. Rupert Jones. *Medal.*
1890. Mr. C. Davies Sherborn.
1891. Professor T. McKenny Hughes. *Medal.*
1891. Dr. C. J. Forsyth-Major.
1891. Mr. G. W. Lamplugh.
1892. Mr. G. H. Morton. *Medal.*
1892. Dr. J. W. Gregory.
1892. Mr. E. A. Walford.
1893. Mr. E. T. Newton. *Medal.*
1893. Miss C. A. Raisin.
1893. Mr. A. N. Leeds.
1894. Professor John Milne. *Medal.*
1894. Mr. William Hill.
1895. Rev. J. F. Blake. *Medal.*
1895. Mr. Percy F. Kendall.
1895. Mr. Benjamin Harrison.
1896. Mr. A. Smith Woodward. *Medal.*
1896. Dr. W. F. Hume.
1896. Mr. C. W. Andrews.
1897. Dr. G. J. Hinde. *Medal.*
1897. Mr. W. J. Lewis Abbott.
1897. Mr. J. Lomas.
1898. Dr. W. Waagen. *Medal.*
1898. Mr. W. H. Shrubsole.
1898. Mr. H. Woods.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY THE LATE

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. Charles Barrois.
1883. Dr. Henry Hicks.
1885. Professor Alphonse Renard.
1887. Professor Charles Lapworth.
1889. Mr. J. J. Harris Teall.
1891. Dr. George M. Dawson.
1893. Professor W. J. Sollas.
1895. Mr. Charles D. Walcott.
1897. Mr. Clement Reid.

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.'

1879. Purchase of microscope.
1881. Purchase of microscope-lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Professor Leo Lesquereux.
1886. Dr. H. J. Johnston-Lavis.
1888. Museum.
1890. Mr. W. Jerome Harrison.
1892. Professor Charles Mayer-Eymar.
1893. Purchase of Scientific Instruments for Capt. F. E. Younghusband.
1894. Mr. Charles Davison.
1896. Mr. J. Wright.
1896. Mr. J. Storrie.
1898. Mr. E. Greenly.

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Compositions				94	10	0
Due for Arrears of Admission Fees	113	8	0			
Admission Fees, 1898	240	0	0			
				353	8	0
Arrears of Annual Contributions	130	0	0			
Annual Contributions, 1898, from Resident Fellows, and Non-Residents, 1859 to 1861	1650	0	0			
				1780	0	0
Annual Contributions in advance				35	0	0
Dividends on £2000 India 3 per cents.				60	0	0
Dividends on £2250 London and North-Western Railway 4 per cent. Preference Stock				90	0	0
Dividends on £2800 London and South-Western Railway 4 per cent. Preference Stock				112	0	0
Dividends on £300 London, Brighton, and South Coast Railway 5 per cent. Preference Stock				15	0	0
Dividends on £1295 Midland Railway 4 per cent. Preference Stock				51	16	0
Sale of Quarterly Journal, including Longman's Account	150	0	0			
Sale of Geological Map, including Stanford's Account	5	0	0			
Sale of Transactions, Library Catalogue, General Index, Hochstetter's 'New Zealand,' and List of Fellows	3	0	0			
				158	0	0
				2749	14	0

Note.—The following Funds are available for Extraordinary Expenditure.

	£	s.	d.
Balance at the Bankers', December 31st, 1897	719	3	4
Balance in the Clerk's hands, December 31st, 1897	3	19	8
	£723	3	0

the Year 1898.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes		15	0			
Fire Insurance	15	0	0			
Electric Lighting	20	0	0			
Gas	30	0	0			
Fuel	25	0	0			
Furniture and Repairs	35	0	0			
House-repairs and Maintenance	50	0	0			
Annual Cleaning	15	0	0			
Washing and Sundries	25	0	0			
Tea at Meetings	20	0	0			
				235	15	0
Salaries and Wages, etc.:						
Assistant Secretary	300	0	0			
„ Half Premium of Life Insurance	10	15	0			
Assistant Librarian	150	0	0			
Assistant Clerk	90	0	0			
House Porter and Upper-Housemaid	91	12	0			
Under-Housemaid	42	12	0			
Errand Boy	39	0	0			
Charwoman and Occasional Assistance	10	0	0			
Accountant's Fee	10	10	0			
Solicitors' Fees	15	0	0			
				759	9	0
Library (Books and Binding)				200	0	0
Museum				30	0	0
Office Expenditure:						
Stationery	25	0	0			
Miscellaneous Printing	35	0	0			
Postages and other Expenses	90	0	0			
				150	0	0
Publications:						
Geological Map	5	0	0			
Quarterly Journal	900	0	0			
„ „ Commission, Postage, and Addressing	100	0	0			
Record of Geological Literature	150	0	0			
List of Fellows	35	0	0			
Abstracts, including Postage	110	0	0			
				1300	0	0
Estimate of Ordinary Expenditure				2675	4	0
Balance in favour of the Society				74	10	0
				2749	14	0
EXTRAORDINARY EXPENDITURE:						
Publication of Hutton MS.				80	0	0
Completion of Redecoration of Society's Apartments				400	0	0
				£480	0	0

W. T. BLANFORD, *Treasurer*.

January 22*nd*, 1898.

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Bankers' hands, January 1st, 1897.	761	13	11			
Balance in Clerk's hands, January 1st, 1897.	6	9	1			
				768	3	0
Compositions				85	8	0
Arrears of Admission-fees	81	18	0			
Admission-fees	239	8	0			
				321	6	0
Arrears of Annual Contributions	186	18	0			
,, ,, Non-Residents	11	1	6			
				197	19	6
Annual Contributions of 1897, viz.:						
Resident Fellows	1666	7	0			
Non-Resident Fellows	14	3	6			
				1680	10	6
Annual Contributions in advance				52	10	0
Publications:						
Sale of Journal, Vols. 1–52	78	14	6			
,, Vol. 53 *	84	9	0			
Sale of Geological Map †	7	7	0			
Sale of Hochstetter's 'New Zealand'		5	0			
Sale of List of Fellows		13	0			
Sale of Geological Literature		7	6			
Sale of Transactions		7	6			
Sale of Index to Quarterly Journal		7	6			
				172	11	0
Income Tax:						
Repayment of Tax under Schedule C for the year 1896–97	10	19	2			
Amount previously unclaimed for the year 1895–96	3	15	3			
				14	14	5
Dividends on						
£2000 India 3 p. c. Stock	58	0	0			
£300 L. B. & S. C. Railway 5 p. c. Consolidated Preference	14	10	0			
£2250 L. & N. W. Railway 4 p. c. Preference	87	0	0			
£2800 L. & S. W. Railway 4 p. c. Preference	108	5	4			
£1295 Midland Railway 4 p. c. Perpetual Preference	50	1	6			
				317	16	10
				£3610	19	3

*Due from Messrs. Longmans, in addition to the above, on Journal, Vol. 53 .... £34 18 7

†Due from Stanford, on account of Geological Map .... £ 2 8 4

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

H. BAUERMAN, }
BEDFORD McNEILL, } *Auditors.*

Year ended 31*st December*, 1897.

PAYMENTS.

	£	s.	d.	£	s.	d.
House Expenditure:						
Taxes		15	0			
Fire Insurance	15	0	0			
Electric Lighting Installation	27	15	0			
Electric Lighting	13	3	6			
Gas	31	7	3			
Fuel	20	7	0			
Furniture and Repairs	17	16	3			
House Repairs	37	16	7			
Annual Cleaning	11	18	6			
Washing and Sundries	30	2	2			
Tea at Meetings and Conversazione	19	15	10			
				225	17	1
Salaries and Wages:						
Assistant Secretary	300	0	0			
„ Half Premium Life Insurance.	10	15	0			
Assistant Librarian	150	0	0			
Assistant Clerk	85	0	0			
House Porter and Upper-Housemaid	89	18	3			
Under-Housemaid	43	18	0			
Errand Boy	36	10	0			
Charwoman and Occasional Assistance	8	18	0			
Accountant's Fee	10	10	0			
				735	9	3
Solicitors' Fees				12	4	0
Office Expenditure:						
Stationery	36	13	8			
Miscellaneous Printing	32	11	3			
Postages, Sundries, and Expenses	82	8	3			
				151	13	2
Library				176	15	3
Museum				22	9	6
Publications:						
Journal, Vols. 1–52	7	1	5			
„ Vol. 53 ... 800 8 0						
„ „ Commission, Postage, and Addressing* ... 119 10 7						
	919	18	7			
Record of Geological Literature	141	18	0			
List of Fellows	35	18	3			
Abstracts, including Postage	106	8	11			
Geological Map	1	9	6			
Index to Quarterly Journal, Vols. 1–50	350	13	4			
				1563	8	0
Balance in Bankers' hands at Dec. 31, 1897.	719	3	4			
Balance in Clerk's hands at Dec. 31, 1897.	3	19	8			
				723	3	0
				£3610	19	3

* [This item includes the postage of the General Index and of the List of Geological Literature.]

W. T. BLANFORD, *Treasurer.*

January 22*nd*, 1898.

Statement of Trust Funds : December 31*st*, 1897.

'Wollaston Donation Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', January 1st, 1897	32	3	0	Cost of striking Gold Medal awarded to Mr. W. H. Hudleston	10	10	0
Dividends on the Fund invested in £1073 Hampshire County 3 per cent. Stock	31	2	4	Award to Mr. F. A. Bather	21	13	0
Repayment of one year's Income Tax	1	2	0	Balance at Bankers', December 31st, 1897	32	4	4
	£64	7	4		£64	7	4

'Murchison Geological Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', January 1st, 1897	20	12	7	Award to Mr. H. B. Woodward, and Medal	10	10	0
Dividends on the Fund invested in £1334 London and North-Western Railway 3 per cent. Debenture Stock	38	13	8	" Mr. S. S. Buckman	28	12	5
Repayment of one year's Income Tax	1	7	7	Cost of Medal		17	0
				Balance at Bankers', December 31st, 1897	20	14	5
	£60	13	10		£60	13	10

'Lyell Geological Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', January 1st, 1897	53	5	7	Award to Dr. G. J. Hinde, and Medal	25	0	0
Dividends on the Fund invested in £2010 1*s*. 0*d*. Metropolitan $3\frac{1}{2}$ per cent. Stock	68	0	4	" Mr. J. Lomas	22	2	4
Repayment of one year's Income Tax	2	8	0	" Mr. W. J. L. Abbott	22	2	4
				Cost of Medal	1	1	0
				Balance at Bankers', December 31st, 1897	53	8	3
	£123	13	11		£123	13	11

'Barlow-Jameson Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', January 1st, 1897	20	0	6	Balance at Bankers', December 31st, 1897	34	1	8
Dividends on the Fund invested in £468 Great Northern Railway 3 per cent. Debenture Stock	13	11	6				
Repayment of one year's Income Tax		9	8				
	£34	1	8		£34	1	8

'Bigsby Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Bankers', January 1st, 1897	10	18	5	Cost of striking Gold Medal awarded to Mr. Clement Reid	13	19	4
Dividends on Fund invested in £210 Cardiff 3 per cent. Stock	6	1	10	Balance at Bankers', December 31st, 1897	3	5	3
Repayment of one year's Income Tax		4	4				
	£17	4	7		£17	4	7

'Geological Relief Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.	£	s.	d.
Subscriptions received	152	17	0	Purchase (on April 9th, 1897) of £133 7*s.* 7*d.* India 3 per cent. Stock @ $110\frac{1}{2}$ per cent.	147	7	8			
Dividends on Fund invested in £133 7*s.* 7*d.* India 3 per cent. Stock, as per Contra	1	18	8	Brokerage		4	4			
								147	12	0
				Balance at Bankers', December 31st, 1897				7	3	8
	£154	15	8					£154	15	8

W. T. BLANFORD, *Treasurer.*

H. BAUERMAN,
BEDFORD McNEILL, } *Auditors.*

January 22*nd*, 1898.

Valuation of the Society's Property; December 31st, 1897.

Property.	£	s.	d.		£	s.	d.
Due from Longmans & Co., on account of Journal, Vol. LIII. etc.	34	18	7	Balance in favour of the Society	11,926	3	8
Due from Stanford, on account of Geological Map	2	8	4				
Balance in Bankers' hands, Dec. 31st, 1897	719	3	4				
Balance in Clerk's hands, Dec. 31st, 1897	3	19	8				
Funded Property:—							
£2000 India 3 per Cents	2082	13	0				
£2250 London & North-Western Railway 4 per cent. Consolidated Preference Stock	2898	10	6				
£2800 London & South-Western Railway 4 per cent. Preference Stock	3607	7	6				
*£300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	502	15	3				
£1295 Midland Railway 4 per cent. Preference Stock	1850	19	6				
Arrears of Admission-fees	113	8	0				
Arrears of Annual Contributions	110	0	0				
[*N.B.—The above does not include the value of the Collections, Library, Furniture, and Stock of unsold Publications.*]	£11,926	3	8		£11,926	3	8

W. T. BLANFORD, *Treasurer*.

January 26th, 1898.

Note.—The investments in Stocks are valued at their cost price. Their selling-price on December 31st, 1897, at the quotations of the day, would increase the above total by more than £1300.

* Wrongly scheduled as £500 in the Statements for 1895 and 1896.

Award of the Wollaston Medal.

In handing the Wollaston Medal (awarded to Prof. Ferdinand Zirkel, F.M.G.S., of Leipzig) to Mr. J. J. H. Teall, for transmission to the recipient, the President addressed him as follows:—

Mr. Teall,—

The Council of the Geological Society have this year awarded the Wollaston Medal to Prof. Zirkel, as a mark of their appreciation of the great services which he has rendered to Geological Science, especially in the department of Petrology. His 'Lehrbuch der Petrographie,' the first edition of which was published more than 30 years ago, is an indispensable adjunct to the library of every petrologist. A comparison of the two editions of this monumental work, the second of which has only recently appeared, illustrates in a most striking manner the enormous advance which has taken place in petrographical science during the interval—an advance in no small measure due to the influence exerted by Prof. Zirkel, both as a teacher and as an original worker.

His classic memoir on the 'Microscopic Structure and Composition of Basaltic Rocks' was one of the first publications in which the results of the examination of an extensive series of microscopic sections were made known. It marks an epoch in the history of petrography, not only because it greatly extended our knowledge of this important group of rocks, but also because it gave a great stimulus to the study of thin sections under the microscope. It must always be a source of gratification to British geologists that this important work was dedicated to our distinguished Fellow and revered master, Henry Clifton Sorby.

It is impossible for me to review all Prof. Zirkel's important contributions to Geological and Mineralogical Science, but there is one other that I cannot pass over in silence. I refer to his 'Geological Sketches of the West Coast of Scotland.' In this memoir Prof. Zirkel applied the methods of microscopic analysis, for the first time, to the wonderful records of Tertiary volcanic activity which abound in that region. As an original observer he has made his mark in the history of our time, and as a Professor he has won the esteem and affection of many enthusiastic students. It only remains for me now to request you to transmit to Prof. Zirkel this Medal, and at the same time to express to him our great regard and our sincerest wishes that he may long enjoy health and strength to continue his important researches in those branches of Geological Science for which he has already done so much.

Mr. Teall, in reply, read the following letter which he had received from Prof. Zirkel:—

'Mr. President,—

The honourable award of the Wollaston Medal is for me one of the most gladdening events of my life. Yet I cannot say whether I am more pleased or surprised at the unexpected announcement that I should be considered worthy of so brilliant a distinction, which has been bestowed by this highest tribunal of Geology only on the most illustrious British and Foreign votaries of the science. But to-day all feelings are merged in one of gratitude to the Members of the Council, who have taken so generous and favourable a view of my modest labours. As, much to my regret and disappointment, I find myself unable to attend the Annual Meeting, I must trespass upon your kindness to express by these written words my heartfelt thanks and best acknowledgment for the great honour conferred upon me, of which the most ambitious may well be proud. I receive the Medal as a token of indulgence and encouragement, and it will be an incentive to me still to strive to be more worthy of it and of your confidence. Probably I never should have been able to do what I have done, but for the wise example and kind instruction of my old master, Henry Clifton Sorby. The tie of personal friendship which connects me with so many fellow-workers in your country since those bygone days, when Murchison, Lyell, and Ramsay favoured the young foreigner with their attachment, this tie will be strengthened to-day, and the Geological Society's prosperity and usefulness will never cease to be the object of my warmest wishes.'

Award of the Wollaston Donation Fund.

The President then handed the Balance of the Proceeds of the Wollaston Donation Fund (awarded to Mr. E. J. Garwood, M.A., F.G.S.) to Mr. A. Strahan, for transmission to the recipient, addressing him as follows:—

Mr. Strahan,—

At the last Meeting of the Geological Society we had the pleasure of listening to a communication by Mr. Garwood and Dr. Gregory which adds much to our knowledge concerning the Glacial Geology of Spitsbergen. Last year Mr. Garwood also gave an address at one of the 'At Homes' of the Society, which was highly appreciated by those present. These communications amply testify to his ability to carry on explorations in difficult regions, where strength of purpose and special training are indispensable to success. Other geological questions have also occupied his attention; and I may here mention the paper by him in the Geological Magazine on 'Magnesian Limestone Concretions' as an interesting contribution to a vexed question, and his paper and reports on Carboniferous Fossils, the result of much labour among the Carboniferous rocks of the North of England. The Council, in making him this Award, hope that it may act as a stimulus to further researches in those fields in which he has already shown such marked ability, and that he will accept it also as a token of appreciation for what he has already accomplished.

Mr. Strahan, on behalf of the recipient, read the following reply:—

'Mr. President,—

In thanking the Council of this Society for the honour which they have done me in awarding to me the Balance of the Proceeds of the Wollaston Fund, I cannot but feel that they have taken far too generous a view of any value which my work in the past may possess.

'Some years ago, it occurred to me that the Carboniferous beds in Britain might be capable of subdivision into life-zones, similar to those already established in Belgium and elsewhere; but, after several years' work, I realized that the task was much too great for the time at my disposal, and I am glad to say that the work is now being carried on by a Committee of the British Association.

'My last two summers have been devoted to work in the far North; and the kind encouragement and assistance which I receive to-day will be a great incentive to the continuance of that work in the future.'

Award of the Murchison Medal.

The President then handed the Murchison Medal (awarded to Mr. Thomas F. Jamieson, F.G.S.) to Mr. Horace B. Woodward, for transmission to the recipient, addressing him as follows:—

Mr. Horace Woodward,—

The Murchison Medal, with the sum of Ten Guineas, has this year been awarded by the Council of the Geological Society to Mr. Thomas F. Jamieson, in recognition of his long and important researches among the Glacial Deposits of Scotland. It is an interesting fact that Mr. Jamieson's first papers were communicated to this Society through Sir Roderick Murchison, the founder of this Medal. From the year 1858, when he read a paper before the Society on the Pleistocene Deposits of Aberdeenshire, up to the present time, Mr. Jamieson has continued his researches with unabated enthusiasm, and the Geological Society has received many valuable communications from him. The list includes papers on 'Drift and Rolled Gravel of Northern Scotland' in 1860, and 'Ice-worn Rocks of Scotland,' 1862, in which he describes great erosion by ice-action and the presence of boulders far above the parent rock, and gives a sketch-map of Scotland showing the direction of the glacial markings. In 1863 was published his well-known paper on the Parallel Roads of Glen Roy, in which he claims that they are beaches of freshwater lakes—the lakes having originated from glaciers damming the mouths of valleys and reversing their drainage. Further papers on Glacial questions were communicated by him to the Society in 1865, 1866, 1871, 1874, 1882, and 1891, and he may, I think, claim to have done more probably than any other man for the Glacial Geology of Scotland. It must not be forgotten also that this Society always received the first fruits of his labours, and that his most important papers are to be found in our Quarterly Journal. These papers are full of carefully observed facts, and abound in valuable suggestions. Many of the views advocated by him in some of his earlier papers have been since further advanced by him and other observers in this and other countries. I will ask you, therefore, to be good enough, in transmitting this Medal to Mr. Jamieson, to express to him the admiration of the Council for the energy and ability with which he has for so long a period, and with such signal success, prosecuted researches amongst the newer deposits in Scotland.

Mr. Horace B. Woodward replied in the following terms:—

Mr. President,—

I esteem it an honour to receive this Medal on behalf of Mr. Jamieson, for no one has laboured more ardently, no one more successfully, than he, in interpreting the Pleistocene records of North Britain. He bids me say:—

'I regret much that my distance from the metropolis will not allow me to be present at the Annual Meeting of the Society. It has also prevented me from taking any part in the pleasant Evening Meetings, which I regret even still more. I think I have been present on only one occasion, and that was before I became a Fellow of the Society, which is a good long while ago.

'It is gratifying, however, to find that, although so far away, and so little known personally to the Council of the Society, they have not only kept me in remembrance, but have done me the honour of awarding to me the Murchison Medal. This I shall value the more as it recalls the recollection of the warm-hearted Sir Roderick, from whom I received much kind attention many years ago. Although then a young man, and quite a stranger to him, I found no one more ready to help me in every way that he thought would be useful. This was a bright feature in his character, which struck me much at the time, and has always kept his memory green in the breast of the present recipient of his Medal.'

I may add that I am sure that Mr. Jamieson will be gratified by the kindly remarks which you have made in reference to his work.

Award of the Murchison Geological Fund.

In handing the Balance of the Proceeds of the Murchison Geological Fund (awarded to Miss J. Donald, of Carlisle) to Mr. E. T. Newton for transmission to the recipient, the President addressed him as follows:—

Mr. Newton,—

On one occasion only has the Geological Society previously granted an Award from its Funds to a lady. This was in the year 1893, when Miss Raisin, so well known to us by her petrographical and stratigraphical work, was the recipient. On the present occasion a lady who has attained distinction as a palæontologist has been selected by the Council to receive an award from the Murchison Fund, and the Fellows generally will, I feel sure, believe that in making this Award to Miss J. Donald the Council has acted wisely and justly. In the Quarterly Journal of this Society are five important papers by Miss Donald. The first, in the year 1887, 'Notes upon some Carboniferous Species of *Murchisonia*,' was followed in 1889 by 'Descriptions of some New Species of Carboniferous Gasteropoda';

in 1892, by 'Notes on some New and Little-known Species of Carboniferous *Murchisonia*'; in 1895, by 'Notes on the Genus *Murchisonia* and its Allies'; and, in the forthcoming Quarterly Journal, by 'Observations on the Genus *Aclisina*, de Kon., with Descriptions of British Species, and of some other Carboniferous Gasteropoda.'

Previous to taking up the study of fossil shells, which I understand she did at the instigation of one of our Fellows, Mr. J. G. Goodchild, Miss Donald had well prepared herself by previous studies of recent shells, and we find in the Transactions of the Cumberland and Westmoreland Association of Literature and Science, so far back as 1881, some notes by her on the 'Land and Freshwater Shells of Cumberland.' Miss Donald has not only visited very many of the collections in this country, but also those in the Continental museums, for the purpose of studying fossil shells, and she is still untiring in her zeal in collecting information for future work. When transmitting this Award to Miss Donald you will be good enough to say that the Council hope it will be accepted, not only as a token of appreciation of the excellent work which she has already accomplished, but in the hope that it may be some incentive to her to continue her palæontological researches among the Palæozoic rocks.

Mr. Newton, in reply, said:—

Mr. President,—

It is with peculiar pleasure that I receive this Award on Miss Donald's behalf, for it is a rare occurrence for a lady to receive one of the Society's Awards, and having for some years watched and appreciated the conscientious and painstaking labour by which Miss Donald has accomplished a very admirable piece of work, it is particularly gratifying to find that this work has met with the appreciation of the Council of the Geological Society.

As Miss Donald cannot be present to receive this Award personally, perhaps I may be allowed to read an extract from her letter:—

'Will you thank the President and Council most heartily on my behalf for the great honour which they have conferred by awarding to me the Balance of the Proceeds of the Murchison Fund? The news came to me as a great surprise, for I had previously deemed it no small honour that my papers should have been considered worthy of publication in the Quarterly Journal of the Society, and this higher recognition will certainly prove an encouragement to further research and, I hope, better work. My studies have been a source of great pleasure to me, and I feel that there is still much to be found out, even with regard to the genus *Murchisonia*, to which I have hitherto devoted the greater share of my attention.'

Award of the Lyell Medal.

The President then handed the Lyell Medal (awarded to Dr. Wilhelm Waagen, F.G.S., of Vienna) to Dr. W. T. Blanford for transmission to the recipient, addressing him as follows:—

Dr. Blanford,—

Owing to ill-health, Dr. Waagen is unable to be present to receive the Lyell Medal, with the sum of Twenty-five Pounds, which the Council of the Geological Society have awarded to him, in appreciation of his excellent Palæontological work. Just 20 years ago (February, 1878) Dr. Waagen was a recipient of the Lyell Fund, soon after his retirement, owing to ill-health, from the Geological Survey of India; and his work was, on that occasion, referred to in terms of great admiration by the then President, Prof. Martin Duncan, and by Dr. Oldham, who was deputed to receive the Award on his behalf. Of the works published by Dr. Waagen, I may mention an important paper, 'On the Classification of Upper Jurassic Beds' (those of Southern England included) in 1865, and in 1869 one on 'The Subdivisions of Ammonites,' of which full abstracts appeared in the Quarterly Journal of this Society in 1865 and 1870. When in India he described the ammonites of the Kach Jurassic beds, and his great knowledge of the Ammonitidæ enabled him to work out the succession in detail. Another most important work was his description of the fossils from the Cambrian, Carboniferous, Permian, and Triassic of the Salt Range in the Panjâb, and his account of the geology in the 'Palæontologia Indica.' His untiring devotion to his work is well known to all those who have been in any way associated with him, and his careful and zealous labours have placed him in the front rank of palæontologists. I now ask you to be good enough to forward to Dr. Waagen this further token of esteem, with every expression of goodwill, from the Council of the Geological Society.

Dr. Blanford replied in the following terms:—

Mr. President,—

I am glad that I am able to comply with the request of my old friend and colleague Dr. Waagen, that I would represent him on this occasion and receive for him the Lyell Medal of the present year.

May I be allowed to express my own gratification at the Award? Few geologists, I think, will question the value of the palæontological work done in connexion with the Geological Survey of India since that Survey was first organized under the late Dr. Thomas Oldham. Dr. Waagen is now the only survivor of the first three Palæontologists who between them occupied the post from 1862 to 1883. As, moreover, Dr. Waagen has been continuously engaged in the study of Indian Palæontology, and in contributing to the Survey publications, from the date when he first joined the Indian Geological Survey to the present day, he is the author of a much larger share of the work than either of his colleagues.

As you, Sir, have already stated, the Proceeds of the Lyell Fund were awarded to Dr. Waagen just 20 years ago, in 1878. There has rarely, I believe, been an occasion on which the intentions of the great geologist who founded this Fund have been more thoroughly carried out. Sir Charles Lyell desired that the interest of this Fund should be given for the encouragement of Geology or of any of the allied sciences by which Geology has been most materially advanced. At the time when the Fund was awarded Dr. Waagen had left India, broken in health, and in serious difficulty through having to resign his appointment on the Indian Survey, on account of his inability to resist the effects of a tropical climate. I know as a fact that the Award was a great encouragement to him, and I think that the volumes which he has since published in the 'Palæontologia Indica,' containing his descriptions of that marvellous series of Salt Range fossils from Lower Cambrian to Trias, and his masterly summary of the Geological results, have thoroughly justified the Award that was made.

In a letter which he wrote to me recently, Dr. Waagen said: 'The decision of the Geological Society's Council to award to me the Lyell Medal is extremely gratifying, and I have to express to the Society my most heartfelt thanks. These I beg you to express to the Society, as my health is yet too untrustworthy for me to go to London and do so myself. I hope yet to do some work, though my chief work has been done. I hope to finish the

Indian Trias; the Nautilidæ and Gasteropoda are in manuscript completed, and the Pelecypoda will soon be commenced. I expect to finish the whole by the end of this year.

'The Medal will give me a new impulse to go on with the work. .... So I beg you to receive it on my behalf and to express my most hearty thanks to the Society for it.'

It only remains for me, Sir, to thank you on behalf of Dr. Waagen for having added to the value of the Medal by the manner in which you have spoken of his services to science.

Award of the Lyell Geological Fund.

In presenting to Mr. H. Woods, M.A., F.G.S., a moiety of the Balance of the Proceeds of the Lyell Geological Fund, the President addressed him as follows:—

Mr. Woods,—

The Geological Society has already received some important communications from you, and I hope that these will be followed by many others. In your paper on the Igneous Rocks of the Neighbourhood of Builth you have successfully applied not only your petrological knowledge, but also your palæontological experience in working out the stratigraphy of an interesting and complicated region; and your papers on the Fossils of the Middle Chalk are very valuable contributions to the study of the Fauna of the British Cretaceous Rocks. Your 'Catalogue of Type Fossils in the Woodwardian Museum' is indispensable to all working palæontologists; and your 'Elementary Palæontology,' written primarily for Cambridge students, has been found so useful that it is now, I understand, adopted as a text-book, not only in many places in Britain, but also in the Colonies and in America. I have much pleasure in handing to you this Award on behalf of the Council of the Geological Society, in testimony of their appreciation of your past work, and in the hope that it may be of some aid to you in your future labours.

Mr. Woods, in reply, said:—

Mr. President,—

It is with much pleasure and gratitude that I receive this Fund which the Council have been good enough to award me; and I can assure you, Sir, that I shall lose no opportunity of continuing the work to which you have referred. Although the greater part of my time is occupied by official duties in the lecture-room and museum, yet it is encouraging to hope that, as a teacher, I may be an indirect means of helping forward palæontological investigation.

In my 'Catalogue of Type Fossils in the Woodwardian Museum,' of which you have so kindly spoken, I endeavoured to give not only a list of types, but also a record of the persons who have enriched the collections in our Museum, and among those benefactors you, Sir, occupy a prominent place.

The President then presented the other moiety of the Balance of the Proceeds of the Lyell Geological Fund to Mr. W. H. Shrubsole, F.G.S., addressing him as follows:—

Mr. Shrubsole,—

For many years your name, as well as that of two of your brothers, has been well known to the Fellows of this Society, and it is a pleasure to me to hand to you, on behalf of the Council, this moiety of the Lyell Fund, in testimony of the valuable services rendered by you to Geological Science.

Although during your long residence at Sheerness you were engaged in business, you lost no opportunity of advancing the science of Geology, to which you had become so ardently attached, and by your exertions you greatly added to our knowledge of the Fauna and Flora of the Lower Eocene of the Isle of Sheppey.

Among your discoveries, which have been described in the Quarterly Journal of this Society, may be mentioned the wing-bones and skull of a bird allied to the albatross, named by Owen *Argillornis longipennis* (Quart. Journ. Geol. Soc. 1878); a new genus and species of Estuarine Gasteropods, described by Lieut.-Col. Godwin-Austen in 1882; and the remains of a giant turtle, named by Owen *Chelone gigas* (Quart. Journ. Geol. Soc. 1889). I understand that your collections of fossil fruits were also of great use to Baron von Ettingshausen and Mr. Starkie Gardner in working out the Flora of the Eocene; and that all your choicest specimens (including another new bird's skull) have been invariably transmitted to the British Museum so soon as discovered. Those who are acquainted with your labours will feel that this Award of the Council has been given to a thoroughly meritorious fellow-worker, and a most patient original scientific investigator.

Mr. Shrubsole replied in the following terms:—

Mr. President,—

This part of the present proceedings has made me realize that once again in my experience, the unexpected has happened. Only this time, unlike many previous experiences, the unlooked-for circumstances are, so far as I am concerned, entirely pleasant and beneficial. In view of what has happened, I am constrained to say that it affords me very great gratification that this distinguished Society has seen fit to include me in its roll of honour, and to present me with a substantial mark of its favour.

It is, indeed, very pleasant to me to find that the geological work carried on quietly and alone for a good many years has now received ample recognition, and has had the stamp of your approval bestowed upon it. Although I had no co-workers in Sheppey from whom to derive encouragement and assistance, yet I always met with kind and helpful attention from all geologists with whom occasionally I came in contact. I have never applied to any Fellow of this Society, or to any official of our Museums, for help in the determination of specimens, without obtaining all that I wanted; and the value of this was enhanced by the extremely courteous way in which it was rendered.

There are gentlemen here—there are others who have passed away—whom I shall always remember with gratitude, for having thus assisted me when I was a geological neophyte. As to the future, I hope that I may be able to render some further scientific service.

It is true, as you can see, that I am no longer troubled with the immaturity of youth, yet I feel that a reserve of energy remains, for which I hope opportunity of exercise may still be found.

Although I no longer reside in Sheppey, I am keeping in touch with the locality and am well represented there. You may rely upon it that no new or rare fossils will escape notice, through any lack of attention on the part of my helpers or myself. In this, and in other ways, I hope to manifest a keen interest in geological pursuits so long as life shall last.

Award of the Barlow-Jameson Fund.

In presenting to Mr. E. Greenly, F.G.S., a portion of the Proceeds of the Barlow-Jameson Fund, the President addressed him as follows:—

Mr. Greenly,—

The Council of the Geological Society have awarded to you the sum of Twenty Pounds from the Barlow-Jameson Fund, in recognition of your scientific labours, and to aid you in the important researches which you are now so assiduously carrying on amongst the older rocks in Anglesey. The experience which you gained when on the staff of the Geological Survey in the North-west of Scotland has enabled you already to attack very successfully some of the problems connected with the older rocks; and many are looking forward with great interest to the further results of your labours. I must not omit to mention that, although no longer a Member of the Geological Survey, you have continued to work as assiduously, and with the same attention to minute details, as when on that staff; and that the expenses, which must have been considerable, have been hitherto defrayed out of your private income. This is a strong testimony to the love which you entertain for that science which you were led to adopt as a profession mainly, I believe, through attending the lectures of Prof. Bonney at University College, London. It gives me great pleasure to hand you this Award on behalf of the Council.

Mr. Greenly, in reply, said:—

Mr. President,—

I wish to express my sincerest thanks to the Council of this Society for the great honour which they have conferred upon me. It is also, Sir, an additional pleasure to receive it at your hands, when I think of your own pioneer researches in the same field. With regard to my own work, its present field was chosen because I wished to continue to utilize the experience and training for which I am so deeply indebted to the Geological Survey. Mapping itself I continue to do, not merely because I have faith in it as a method of research, but because it is a pleasure—because I know no more delightful employment. Nevertheless it is a method which involves much that might be called drudgery, with no apparent reward. At such times this Award will ever be an encouragement to persevere, as I hope to do while I have strength and opportunity.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

Henry Hicks, M.D., F.R.S.

Gentlemen,—

Many well-known names have been removed by death from our list during the past year, and among them we have to regret the loss of such active workers in science as Prof. A. L. O. Des Cloizeaux, the eminent French mineralogist and Wollaston Medallist; Prof. E. D. Cope, the distinguished American palæontologist and biologist and Bigsby Medallist; our much revered friend, the Rev. P. B. Brodie, who had been for 63 years a Fellow of the Society, was a Murchison Medallist, and an indefatigable worker in the cause of Science to the end of his long life; the amiable and patient Samuel Allport, a Lyell Medallist, and one of the pioneers in microscopic petrology; Prof. Steenstrup, of Copenhagen, elected a Foreign Member of this Society in 1879; Dr. T. C. Winkler, of Haarlem, and Dr. O. F. von Fraas, Foreign Correspondents. Of those who had taken an active part in the work of the Society or had contributed papers to the Quarterly Journal, I must specially mention the veteran J. Carrick Moore, who recently died at the age of 93, was elected a Fellow of the Society in 1838, served no less than 26 years on the Council and 7 years as Secretary—a co-worker with Sedgwick, Murchison, and Lyell in the heroic days of British geology. Also the genial, versatile and highly-accomplished Professor at Trinity College, Dublin, Samuel Haughton; the Rev. Dr. Robert Hunter; the Rev. J. E. Cross; Thomas Tate; G. T. Clark; and Lt.-Colonel Cooper King. Among those who do not appear to have contributed papers, but had achieved distinction in other branches of Science, occur the names of Sir A. Wollaston Franks, the learned archæologist and President of the Society of Antiquaries; Sir James Ramsay Gibson-Maitland, one of the leading pisciculturists of the day, and a not unfrequent attendant at our meetings; Prof. Henry Drummond, the popular scientific writer; Sir Henry Ayers, who was seven times Premier of South Australia; Mr. James Heywood, the colleague of Richard Cobden in the establishment of the Manchester Athenæum, and who was mainly instrumental when in Parliament in obtaining the abolition of theological tests at Universities; and Mr. Samuel Laing, who was second wrangler and second Smith's Prizeman in 1832, a scientific writer of much power, for many years an active member of Parliament and Chairman of the London, Brighton, and South Coast Railway Company. Full obituary notices of those here briefly enumerated, as well as of several other deceased Fellows, will be found in the following pages.

Alfred L. O. Des Cloizeaux, Membre de l'Institut de France, Foreign Member of the Royal Society, and Professor of Mineralogy in the Museum of Natural History, Paris, was elected a Foreign Member of this Society in 1884. He received the Wollaston Medal in 1886. Sir Warington Smyth, when receiving the Medal on behalf of M. Des Cloizeaux, said, 'It is more especially in the wide and successful application of Wollaston's invention of the Reflection Goniometer that Des Cloizeaux has attained so deserved an eminence, following closely upon the steps of Prof. Miller, to whom, in his admirable manual, he pays so high a compliment.' Des Cloizeaux's first paper was published 54 years ago, and was the beginning of a long series treating of the forms and optical characters of crystals. After being Professor of Mineralogy for eighteen years at the École Normale Supérieure, he was appointed to the charge of the minerals at the Musée d'Histoire Naturelle, in which office he remained until he reached the limit of age prescribed by the rules of the French Civil Service. His fame rests upon the thoroughness and accuracy of his systematic investigation of the crystals of minerals, more especially as regards their optical properties. The results are incorporated in his 'Manuel de Minéralogie,' a standard book of reference. Prof. Des Cloizeaux died, in the 80th year of his age, in May 1897.

The following is taken from a speech by M. A. Damour, his intimate friend and co-worker for 53 years:—'In everything he applied himself to the spread of all that he deemed useful, just, and wise. All those who knew him honoured him and loved him. His name as a *savant* remains in the history of mineralogy; he there occupies the most honourable place among the founders of this science, and among those who have contributed to its progress and advancement.'

The death of Edward Drinker Cope on April 14th, 1897, at the comparatively early age of 57, removed from our list of Foreign Correspondents a highly-gifted biologist and one of the best known American men of science. He was born in Philadelphia, July 28th, 1840; he attended school in his native city, and also studied for a brief period in the University of Pennsylvania Medical School. At 23 he travelled abroad, and at 24 he was elected Professor in Haverford College, a position he soon resigned. Later he became connected with the Wheeler and the Hayden United States Geological Surveys. In 1878 he assumed the editorship of the 'American Naturalist.' He held a professorship in the University of Pennsylvania and the presidency of the American Association for the Advancement of Science at the time of his death.

The following quotations are taken from an article in the 'Century Magazine' of November 1897, by his friend Prof. Henry Fairfield Osborn :—'His range of study extended with astonishing rapidity—first among the living reptiles and amphibians, then among living and Palæozoic fishes, then among the great extinct reptiles of New Jersey and the Rocky Mountains, finally among the ancient American quadrupeds. He acquired in turn a masterly knowledge of each type. Irreverent toward old systems, eager and ambitious to replace them by new ones of his own, with unbounded powers of hard work, whether in the field or at his desk, he rapidly became a leading spirit among the workers in the great realm of the backboned creation, both in America and Europe. While inferior in logic, he showed Huxley's unerring vision of the most distinctive feature in a group of animals, as well as the broad grasp of Cuvier and of Cuvier's famous English disciple, Owen. . . . . He was fortunate in recording the discovery in North-western New Mexico of by far the oldest quadrupeds known, in finding among these the most venerable monkey, in describing to the world hundreds of links—in fact, whole chains—of descent between the most ancient quadrupeds and what we please to call the higher types, especially the horses, camels, tapirs, dogs, and cats. He laboured successfully to connect the reptiles with the amphibians, and the latter with the fishes, and was as quick as a flash to detect in the paper of another author the oversight of some long-sought link which he had been awaiting. Thus, in losing him, we have lost our ablest and most discerning critic. No one has made such profuse and overwhelming demonstration of the actual historical working of the laws of evolution, his popular reputation perhaps resting most widely upon his practical and speculative studies in evolution.

'Many friends in this country and abroad have spoken of the invigorating nature of his companionship. A life of intense activity, harassed for long periods by many difficulties and obstacles, many of them of his own making, was nevertheless wholly without worry, that destroyer of the mind so common in our country. This half-century's enjoyment of research, extending from his 7th to his 57th year, can only be described in its effects upon him as buoyant; it lifted him far above disturbance by the ordinary matters of life, above considerations of physical comfort and material welfare, and animated him with a serene confidence in the rewards which Science extends to her votaries.'

Johannes Japetus Smith Steenstrup, Professor of Zoology in the University of Copenhagen, who was elected a Foreign Member of this Society in 1879, died in that city on June 20th, 1897. He was born on March 8th, 1813, and became an undergraduate in 1832. His principal teachers at the University were Forchhammer, Reinhardt, and Schouw, whose researches in geology, zoology, and botany exerted a stimulating influence on the direction taken by Steenstrup in his studies. In 1837 he wrote his memoir 'On the Conditions under which Coniferous Stems occur in our Peat-mosses,' which was further elaborated in his epoch-making treatise 'Geognostic and Geological Enquiry into the Evidence of Forest-beds and Small Peat-mosses,' published in 1840. This work, together with the well-known memoir published in the following year 'On the Alternation of Generations,' laid the bases of Steenstrup's reputation in the world of natural science, and this was further strengthened after 1848 by his studies on Kitchen-middens.

Of man's immigration and development he found evidence in the peat-mosses, and with that discovery his interest in archæology waxed strong. And so during the ensuing half-century of his life he spent much of his activity on that science, publishing in 1893 and 1895 the fruits of his long-continued investigations in the form of the voluminous archæological works 'The Great Silver Find at Gundestrup,' and 'The Yak-Lungta Bracteates.' In his latter days, too, he busied himself with questions of Quaternary Geology, whereof the following paper among others bears witness: 'On the Glacial Period in the North, especially its Dwindling and Final Cessation.' This was read on Nov. 4th, 1892, before the Scientific Society of Denmark by its author, who had been for 50 years an associate and member; and a later portion was published in 1896 in the Society's 'Öfversigt.'

If we take a hurried survey of Steenstrup's activity as an author, we see at the first glance that it was spread over many fields without intimate relationship, such as zoology (in part very specially), geology, and archæology, and even purely historical work. But on a nearer view it will be seen that there is a leading thought, on which, as on a thread, are strung together studies seemingly devoid of *ensemble*. From biological researches there is no far cry to geology, and thence the path leads easily on to archæology and to the nearly-related byways of history. Steenstrup's broad mind knew no artificial boundaries between all these sciences.

Steenstrup undertook in 1839–40 a journey to Iceland, and on his return became Reader at the Sorö Academy, whence in 1845 he was transferred to the University of Copenhagen as Professor of Zoology, which post he retained till 1885.

The Royal Academy of Sciences of Stockholm elected him a Foreign Member in 1857, and our own Royal Society a Foreign Member in 1863. At the Lund Jubilee Celebration in 1868 he was called to the honorary degree of Doctor in Philosophy, and he was elected Foreign Member of the Stockholm Geological Society in 1874.

Tiberius Cornelius Winkler, Curator of the Teyler Museum, Haarlem, was elected a Foreign Correspondent of this Society in the year 1874. He died on July 18th, 1897.

Dr. Winkler was the author of many palæontological papers: among others, those on fossil chelonia, published in 1869, and on fishes, crinoids, pterodactyls, and plesiosaurs, which appeared in the 'Archives du Musée Teyler,' 1869–1883, and in the Haarlem Nat. Hist. Soc. Proc. 1861–1862. He also devoted considerable attention to the newer deposits of the Netherlands.

Oscar F. von Fraas, who died on November 22nd, 1897, was elected a Foreign Correspondent of this Society only a few days before his death. He had been in failing health for some time previously. Dr. von Fraas was born at Lorch, in Würtemberg, on January 17th, 1824. He received his education at the University of Tübingen. While there he came under the influence of Quenstedt, who inspired him with zeal in the study of geology and palæontology. He subsequently studied in Paris under d'Orbigny and Élie de Beaumont. In 1854 he was appointed Conservator of the minerals and fossils in the Royal Würtemberg Museum, an office which he continued to hold until a few years ago. His researches were mainly confined to the kingdom of Würtemberg; but he also made two journeys through Syria, and described the results in his work 'Aus dem Orient.' He did much to form the rich collection in the Museum at Stuttgart, and interested himself in many researches beyond his special subjects. He wrote, among other papers, 'Die Fauna von Steinheim,' 1870, and 'Geognostische Beschreibung von Württemberg,' 1882.

The Rev. Robert Hunter, M.A., LL.D., died on February 25th, 1897, at his residence, Forest Retreat, Epping Forest, in the 74th year of his age. He was educated at Aberdeen University and the New College, Edinburgh. On quitting Aberdeen he went out as a tutor to the Bermudas, devoting his spare time to the study of the natural history of those islands. An introduction to Prof. Owen led him to make a collection of the corals. In this he was very successful, and in 1845 he brought back excellently preserved examples of the 'Brain Coral' with the animal, which Owen declared to be the finest specimens that at that time had reached this country. Afterwards he went to Nagpur, India, as a missionary of the Free Church of Scotland, and with his colleague, the Rev. Stephen Hislop, he explored the geology of that region, publishing the results as a joint memoir in the Journal of this Society. After a few years' active work in India he returned home, on account of serious illness. On his recovery he devoted himself to literary work, and published a school history of India and a history of the missions of the Free Church. From 1864 to 1866 he was resident tutor in the Theological College, Queen-square, London. Retiring from this position he devoted himself to the chief work of his life, the 'Encyclopædic Dictionary,' for which he was specially fitted by his linguistic attainments. He was not only well versed in Latin, Greek, and Hebrew, but his residence in India added a knowledge of Hindustani, and he also studied Arabic. He devoted 17 years to the preparation of his dictionary before he began to publish. The work was issued by Messrs. Cassell & Co., and commanded much attention. The mineral 'hunterite' was named after Dr. Hunter by the Rev. Prof. Haughton, and he was elected a Fellow of this Society in 1868. Those who knew Dr. Hunter personally speak of him with much affection as an amiable, unselfish man, endowed with 'vast stores of learning which were at the command of anyone who might ask his help.'

Brooke Cunliffe, J.P., died at St. Asaph, North Wales, on February 27th, 1897, in his 82nd year. He had formerly been in the Madras Civil Service. Mr. Brooke Cunliffe was elected into the Society in 1845, and had therefore been a Fellow for over 50 years.

Thomas White Collard, who was one of the oldest Fellows of the Society, having been elected in the year 1836, died in February 1897. He had resided for many years at Herne Bay, Kent.

The Rev. J. E. Cross, M.A., F.R.A.S., Prebendary of Lincoln, and brother of Viscount Cross, died at Scarborough on February 28th, 1897. He was educated at Christ Church, Oxford, and was appointed to the curacy of Bolton-le-Moors in 1846. Three years later he became curate of Appleby, near Brigg, in Lincolnshire, and he was presented to the vicarage in 1856. In this quiet village he lived and laboured for 35 years, retiring in 1891 to Grange-over-Sands.

To geologists Mr. Cross is known as the author of an excellent paper on 'The Geology of North-west Lincolnshire' (Quart. Journ. Geol. Soc., vol. xxxi, 1875, pp. 115–130. Appendix by R. Etheridge). In this work he described, for the first time in detail, the Jurassic formations from the Lower Lias to the Cornbrash, in the area bordering the southern shore of the Humber between the rivers Trent and Ancholme. It was, as he remarked, 'a corner of the land unknown to fame' until the discovery of the valuable iron-ore in the Lower Lias at Frodingham. Long and diligently had Mr. Cross worked, as shown by his careful record of facts and the numerous fossils which he had collected. Among these, several new species of mollusca were described by Mr. Etheridge. Mr. Cross was elected a Fellow of this Society in 1867. He was born in 1821, and married in 1854 Elizabeth, daughter of the late Admiral Sir Phipps Hornby.

Prof. Henry Drummond, LL.D., F.R.S.E., was a son of Mr. Henry Drummond, J.P., of Stirling. He was born in 1851, and received his education first at Edinburgh University, afterwards at Tübingen. He became a minister of the Free Church of Scotland, and, after a short stay in a mission-station at Malta, was appointed in 1877 Lecturer in Science at the Free Church College in Glasgow, being placed in charge also of a working-men's mission in that city. In 1884 he was raised to the rank of Professor at the College. He had travelled much. With Sir Archibald Geikie he went on a geological expedition to the Rocky Mountains, as well as to Africa; and he had also visited more recently Australia, China, and Japan. In his book 'Tropical Africa,' he gives a lively and eminently readable account of his travels in the interior of that continent. It showed him to be an acute observer, with a faculty for giving vivid accounts of what he saw and learnt, and perhaps it was, on the whole, the most generally popular of his works. Many of his theories—that on the subject of native labour, for instance—excited much opposition; he even went so far as to look forward to the time when the African elephant would be extinct, because he believed that the slave-traffic and trade in ivory were inseparably bound together. But the book was too graphic and too accurate to suffer much from the extreme views of its author on a few questions of this kind, and it remains one of the best and most fascinating books of its class, so far as the general reader is concerned. His well-known work, 'Natural Law in the Spiritual World,' has passed through many editions and has been translated into French, German, Dutch, and Norwegian. He was elected a Fellow of this Society in 1877. He died on March 11th, 1897, at Tunbridge Wells, having been in weak health for some time previously.

Thomas Tate died on April 27th, 1897. He communicated a paper, 'Notes on Recent Borings for Salt and Coal in the Tees District,' to the Society in 1892, and other papers to the Proceedings of the Yorkshire Geological Society and the 'Naturalist.' He resided at Leeds, and was elected a Fellow of this Society in 1879.

Sir Augustus Wollaston Franks, K.C.B., President of the Society of Antiquaries, died in London, on May 21st, 1897, after some weeks' illness, in his 72nd year.

Sir A. W. Franks was the elder son of Captain Frederick Franks, R.N., and Frederica, daughter of Sir John Sebright. He was born in 1826 at Geneva, where, and at Rome, his parents lived during his boyhood, and received his education at Eton and at Trinity College, Cambridge. Even in his college days he developed the taste for mediæval archæology, upon which in later life he became the leading authority, and he published in 1849 a volume of

'Ornamental Glazing Quarries,' containing many drawings by his own hand. At the same time he began his extensive collection of rubbings of monumental brasses which was eventually presented to the Society of Antiquaries. He acted as Secretary of the Exhibition of Mediæval Art held at the Society of Arts in 1850, the first of many similar displays, and it was probably the knowledge of the subject which he then showed that led Mr. Hawkins, the Keeper of the Department of Antiquities at the British Museum, to propose that he should enter the Museum as an assistant, which he did in the year 1851. The department was then a mere collection of odds and ends; when Sir A. W. Franks retired it occupied more than one-half of the upper floor of the building. The post of Principal Librarian of the Museum was offered to him, but he declined it, feeling that his proper vocation lay in his own department. He was a man capable of warm friendships, which was in itself a benefit to the Museum, and it may safely be said that it is to his friendship with Mr. Henry Christy, Mr. Felix Slade, Mr. John Henderson, and Mr. William Burges, and to the advice and help which he gave them in forming their various collections, that the Museum owes their valuable bequests. In March 1864 Mr. Henry Christy invited Sir A. W. Franks, in company with Mr. W. J. Hamilton, Prof. T. Rupert Jones, Sir Douglas Galton, Sir John Lubbock, and Sir John Evans, to examine some of the bone-caves on the Vézère, Dordogne district, in the South of France; and he heartily joined Mr. Christy in the study of stone implements. In the preface to 'Reliquiæ Aquitanicæ,' it is stated:—'In bringing together and arranging the varied materials . . . useful in archæology and anthropology the directing counsels of Mr. A. W. Franks, F.R.S., have been constant and efficient, like his courtesy and knowledge.' Other sections besides his own bear witness to his catholic taste and great liberality, and he was not infrequently requested by Government to give his judgment on proposed purchases. As soon as his retirement from the Museum became inevitable under the Order in Council he was placed on the Standing Committee, and took, up to the time of his death, an active part in the business of the Museum. He was for some time Director of the Society of Antiquaries, a post involving the editorship of the society's publications, and in 1891 he was nominated president for the usual period of seven years. His principal discovery in archæology was to separate the work of the age which produced what he called 'Late Celtic' antiquities—perhaps the most artistic productions of any people who have inhabited this country—from that of the age which preceded and followed it. His persistency as a collector, moreover, managed to secure for the nation the best collection that exists of the remains of this period—a period which lies on the borderland between the prehistoric and historic periods in Britain, and concerning which antiquarian relics are our only means of knowledge. Sir A. Franks was elected a Fellow of the Geological Society in the year 1867.

Sir Henry Ayers, G.C.M.G., died in Adelaide on June 11th, 1897, aged 76. He was for 36 years member for Adelaide in the South Australian Parliament, was seven times Premier, and eleven times a Cabinet Minister. For 12 years he was President of the Legislative Council. Sir Henry Ayers was born in England in 1821, and emigrated to South Australia at the age of 19. He engaged in legal pursuits until 1845, when he became secretary of the Burra Burra Mines. He became a member of the Legislative Council in 1857, was created a K.C.M.G. in 1872, and G.C.M.G. in 1894. He was elected a Fellow of this Society in 1870.

Samuel Harraden was elected a Fellow of the Society in 1861. He was the father of Miss Beatrice Harraden, the well-known novelist, and lived at 5, Cannons Place, Hampstead. He was a man of considerable scientific, literary, and musical tastes. He died on July 17th, 1897.

Lieut.-Col. J. R. Campbell, late Hampshire Artillery Militia, died on June 23rd, 1897. He was elected a Fellow of this Society in 1877.

Samuel Allport was elected a Fellow of this Society in the year 1869. As no one is so competent as Prof. Bonney to give an account of the life-work of this eminent geologist, I here reproduce the biography contributed by him to the 'Geological Magazine' for September 1897:—

'By the death of Mr. Samuel Allport we have lost one of the pioneers in microscopic petrology. He was born at Birmingham on January 23rd, 1816, being descended from an old Staffordshire family, and was educated at King Edward's School in that town. For some years he was in the office of Rabone Brothers, and then went to Bahia in South America as business manager for another firm. There he married a Spanish lady, but had the misfortune to lose his wife within a year. On his return to England, after an absence of 8 years, he took a share in a business on Snow Hill, and devoted all his spare time to scientific work. He had already become an ardent geologist, and his first paper, published in the Quarterly Journal of the Geological Society for the year 1860, was on the discovery of some fossil remains near Bahia (vol. xvi, p. 263).

'But he was quick to perceive the importance of studying the structure of rocks by the method which a few years before had been initiated by Dr. Clifton Sorby. He prepared his own specimens, and acquired such skill that, in the writer's opinion, though he may have been equalled, he has never been surpassed in this craft by any English worker. In course of time he formed a large collection of both rock-specimens and microscopic slides, to the study of which he devoted himself with great energy. The business in which he was a partner, unfortunately, was not prosperous, and had to be abandoned about 1880, when he was appointed librarian to the Mason College. Though circumstances had compelled him to sell his collection some little time before to the British Museum, he set to work energetically to form another, and continued at his favourite study. But now health began to fail; any continuous mental exertion brought on distressing attacks of vertigo, and in 1887 he was obliged to retire from his post at the Mason College. After this, though he was still able to continue his geological reading, and to work quietly with his microscope, he was unfit to bear the strain of writing a paper. His last effort, a valuable report on the effect of contact-metamorphism exhibited by the Silurian rocks near the town of New Galloway (Proc. Roy. Soc. vol. xlvi, p. 193), could not have appeared without collaboration.

'Increasing ill-health and grave anxieties unhappily cast a shadow over Allport's later years, but all was endured with quiet patience and gentle fortitude. Some 3 years ago he quitted Birmingham for Cheltenham, where he died after a very short illness on July 7th, his mind happily remaining unclouded till near the end. Allport was not a voluminous writer. He published rather less than twenty papers in all, most of which appeared in this Magazine, or in the Quarterly Journal of the Geological Society. In the former, those on the South Staffordshire Basalts (1869), the Wolf Rock Phonolite (1871), and the Pitchstones of Arran (1872), may be specially mentioned; in the latter, the highly important papers on the British Carboniferous Dolerites (1874), on the Metamorphic Rocks surrounding the Land's End Granite (1876), on devitrified Pitchstones and Perlites from Shropshire (1877), and on the Diorites from the Warwickshire Coalfield (1879). He became a Fellow of the Geological Society in 1869, was awarded the Proceeds of the Wollaston Fund in 1879, and received the Lyell Medal in 1887.

'We cannot measure the value of Allport's work by its quantity. His extreme care as an observer, alike in the field and with the microscope, his wide range of knowledge, for he was far more than a petrologist, his strictly inductive habit of mind, give to that work exceptional solidity and permanent value. Though he was compelled to feel his way, as a man in an unknown forest, he was one of the safest of guides. To such a patient, accurate observer, and sound, cautious reasoner, flashy hypothesis presented no charms, and Samuel Allport did much to liberate petrology from such errors as making geological age a factor of importance in the classification of igneous rocks. Amiable, courteous, and openhanded, he was beloved by those who had the good fortune to know him. Absolutely free from all petty jealousies, he was the most generous of helpers to all younger men who were attracted to his favourite study. Whatever he knew was at the service of others, and no man owes him a deeper debt of gratitude than the writer of this tribute to his memory.—T. G. B.'

Samuel Laing, late Chairman of the London Brighton, and South Coast Railway Company, was elected a Fellow of this Society in 1858. Mr. Laing's career was distinguished and varied. He was a great authority on railways, and was at one time Financial Secretary to the Treasury and subsequently Financial Minister in India; and he enjoyed considerable popularity as a writer of books of a semi-scientific character. He was the son of Mr. Samuel Laing, of Papdale, Orkney, and was born in Edinburgh in 1810. In 1832 he took his B.A. degree at Cambridge, being second Wrangler and second Smith's Prizeman. Mr. Laing became a Fellow of St. John's College and was called to the Bar in 1840. Shortly afterwards he was appointed private secretary to Mr. Labouchere, who afterwards became Lord Taunton, then President of the Board of Trade. Upon the formation of the Railway Department he was made its secretary, and distinguished himself in railway legislation under successive presidencies of the Board of Trade. It was to his suggestions that the public was mainly indebted for the convenience of Parliamentary trains at a minimum rate of one penny per mile. Mr. Laing entered Parliament for the first time in 1852, being returned for the Wick district in the Liberal interest. He represented Wick until 1857, and was re-elected in 1859, but resigned in 1860 in order to go to India as Finance Minister. From June 1859 till October 1860 he was Financial Secretary to the Treasury. On returning from India he again represented Wick in Parliament from 1865 until November 1868. In 1873 he successfully contested Orkney and Shetland, and sat in the House of Commons until 1885.

Late in life, when his official career had closed and his Parliamentary duties were no longer demanding his energies, Mr. Laing turned his attention to literature. He had in 1863 written a book on India and China, embodying some of his personal observations and experiences, and had also published the results of a study of the prehistoric remains of Caithness. But his later works were of a different character. In 1885, the year of his retirement from the House of Commons, there appeared 'Modern Science and Modern Thought,' a volume which was at the time very widely read. Written in an easy and interesting style, it expressed what was in the minds of many people who had given their attention to the great modern developments of scientific investigation without going into them very deeply or pursuing any line of original research for themselves. The book aimed at being popular rather than technical, and had a decided success. 'Problems of the Future,' published four years later, was a natural sequel, dealing as it did with the developments which might be expected to follow upon the achievements of the recent past; while 'Human Origins,' Mr. Laing's last book, issued some 5 years ago, put into a readable form the fruits of discovery and speculation about the early days of the world's history.

He died on August 6th, 1897.

Lt.-Col. Anthony O. Tabuteau, who was elected a Fellow of this Society in 1875, died at Batheaston, near Bath, on August 18th, 1897, at the age of 62. Col. Tabuteau served with the 93rd Highlanders in the Crimea, receiving the British and Turkish Medals. He retired in 1879.

A. Graeme Ogilvie, B.A., was elected a Fellow of this Society in 1877. He was born on January 31st, 1851, and died on July 29th, 1897.

George Harry Piper, second son of the late Capt. E. J. Piper, R.N., was born in London in 1819. His parents removed to Herefordshire in 1829, taking their son George, then a boy 10 years old, with them. He was admitted as a solicitor in 1849, and from that time commenced to practise in Ledbury, where he continued in his profession until his death on August 26th, 1897.

'Mr. Piper took a keen interest in the progress and work of the Horticultural and Natural History Societies of the County of Hereford, and had filled the position of President both of the Woolhope Naturalists' Field Club and the Malvern Naturalists' Field Club. To these Societies he communicated many papers, and with them he did much excellent work in botany, local archæology, and geology, more especially in the latter field of research.

'Mr. Piper's geological work was carried on for many years in association with the late Rev. W. S. Symonds, M.A., F.G.S., of Pendock Rectory, Tewkesbury; Dr. Bull, of Hereford; the Rev. P. B. Brodie, M.A., F.G.S., and other enthusiastic workers.

'The greatest geological achievement performed by Mr. Piper was the carrying out successfully, after many years of patient exploration, the complete examination and recording, foot by foot, of the famous section near the railway-tunnel at Ledbury, comprising the series of deposits from the Aymestry Limestone, through the Upper Ludlow rocks; the Downton Sandstone, with *Pterygotus*; the Ledbury Shales, consisting of red, grey, purple shales, and grey marl-beds, with *Pteraspis*, *Auchenaspis*, *Cephalaspis*, *Onchus*, *Pterygotus*, *Lingula cornea*, etc.; followed by Lower Old Red Sandstone, with *Pterygotus*, *Pteraspis*, and *Cephalaspis*, etc.

'In Mr. Symonds's paper "On the Old Red of Herefordshire" he writes of the passage-beds at Ledbury: "Having again visited Ludlow, and compared the passage-beds of that district with those of Ledbury, I am convinced that nowhere perhaps in the world is there such an exhibition of passage-beds presented to the eye of the geologist as at the Ledbury Tunnel on the Worcester and Hereford Railway." See H. Woodward's 'Brit. Foss. Crustacea' (Merostomata), Pal. Soc. part iii, 1871, p. 99.

'The rich collection of fossils which Mr. Piper formed from the Ledbury Tunnel section, and from other localities in the neighbourhood, will, it is believed, shortly find a home in the British Museum (Natural History), Cromwell Road, to which institution so many of his fine Cephalaspidian fishes have already been presented in past years, including the superb group of twelve individuals of *Cephalaspis*

Murchisoni, preserved in one block of Old Red Sandstone—forming pl. x in Mr. A. Smith Woodward's Catalogue of Fossil Fishes in the British Museum (Natural History), part ii, 1891, p. 189—from the Passage-beds, Ledbury, presented by Mr. Piper in 1889.

'Mr. Piper was elected a Fellow of the Geological Society of London in 1874, but his numerous scientific papers will mostly be found in the Transactions of the Woolhope Club.'—(Abstracted from Geol. Mag., Feb. 1898.)

To quote the words of Mr. F. Russell in his speech at the Ledbury County Court, 'he was known to all as a genial, upright, and courteous gentleman, whose life was not spent for himself alone, but most largely for the good of others. In him the inhabitants of Ledbury and its neighbourhood have lost an able lawyer and a much-respected friend.'

Thomas John Bewick, M.Inst.C.E., died on August 29th, 1897, aged 75. He was a native of Northumberland, and related to Thomas Bewick, the engraver. He was an articled pupil of the late Mr. Thomas Sopwith, F.R.S., and subsequently his assistant for many years, engaged in lead-mining and railway-works. While Mr. Bewick held the appointment of Engineer to the Beaumont Lead-mines, he directed the tunnelling of the great 'Blackett Level,' 7 miles in length, driven for the purpose of unwatering the Allendale mines, and exploring the lower mineral district—one of the most interesting works ever executed in connexion with mining in this country. Mr. Bewick was connected with a number of mining enterprises, and carried on an extensive business as consulting mining-engineer and manager of mines. He was elected a Fellow of this Society in 1866.

Thomas Morris, who was elected a Fellow of this Society in 1883, died at Warrington on October 10th, 1897. He was born at Bilston in the year 1829. Being left an orphan, he had to begin work at a forge at 11 years of age, and his education was almost entirely obtained by attending evening classes. He gradually attained to positions of great trust, and for many years was a prominent figure in the social and intellectual life of Warrington. He also worked hard to secure the success of technical institutions in the town. He was a member of several local learned societies, and frequently read papers before them, principally on the production and manufacture of iron. He does not appear to have ever read any papers before this Society.

The Rev. Samuel Haughton, M.D., D.C.L., F.R.S., was born at Carlow in 1821. At the early age of 23 he was elected a Fellow of Trinity College, Dublin, having, even then, gained a considerable reputation as a mathematician; and some of his first published works were the well-known Manuals of Mathematical and Physical Science, which he issued in conjunction with his friend, Prof. Galbraith. He was appointed Professor of Geology in Dublin University in 1851. His geological researches were chiefly confined to the study of the Granites of Leinster and Donegal. His class-lectures were always fresh, full of life and interest, and, although he did not attempt to treat the subject exhaustively, he was a stimulating and suggestive teacher. He published a course of his 'Lectures on Geology,' and, later, an interesting though somewhat eccentric course of 'Lectures on Physical Geography.' He had taken holy orders at an early age, but seldom preached. His connexion with medicine began in the year 1859, when, finding that the School of Physic in Ireland was inefficient and in need of reform, he conceived the scheme of entering it as a student, and, having attended the classes and hospital, he graduated in medicine in 1862. He then set himself vigorously to work to reform abuses, and to strengthen the School where it was weak. By his energy and practical wisdom he soon brought about a new state of things, and eventually raised the School to the position which it now occupies as the leading medical school of Dublin. He was most sympathetic and helpful to any who tried to do their duty, but firm and unsparing to those who shirked their obligations. His work was recognized and appreciated not only in Ireland, but by the educational and scientific world generally. Oxford, Cambridge, and Edinburgh gave him honorary degrees. He was Fellow of the College of Physicians of Dublin, Honorary Fellow of the College of Surgeons, and honorary member of many foreign scientific societies. He was for 30 years an active member of the Council of the Royal Irish Academy, and President from 1886 to 1891. In the Royal Society's 'Catalogue of Scientific Papers,' some 206 papers are entered as having been written by Dr. Haughton, besides a few in conjunction with others. These are on very various subjects, and exhibit in a marked manner his great versatility. His papers in the Journal of this Society are mainly on the Granites of Ireland, and are to be found in vols. xii, xiv, xv, and xviii (1856–1864).

All who came in contact with Dr. Haughton were greatly impressed by his charm of manner, and his brightness, humour, and remarkable individuality endeared him to a very wide circle of acquaintances.

James Heywood, F.R.S., M.A., was the fifth son of the late Mr. Nathaniel Heywood, banker, of Manchester, and was born on May 28th, 1810. He was educated at Trinity College, Cambridge, where he was a Senior Optime in 1833. He could not, however, proceed to his degree until 23 years later, on account of the religious tests, which were abolished only in 1856 by the Cambridge University Reform Act. Of this, as Member for North Lancashire, he was the chief promoter; for already in 1854, he had moved and carried, after several previous attempts, a clause, by 233 against 78, in favour of the abolition of religious tests for the Bachelor's degree in Arts, Laws, Medicine, and Music. There can be no doubt that this fundamental reform led the way to the introduction of experimental science into our universities. He was one of the original trustees of Owens College, Manchester, and took a keen interest in the establishment and development of the scientific chairs in that institution. He was elected into the Royal Society in 1839, and was at the time of his death the Fellow of longest standing. Mr. Heywood published in 1853 'The History of University Subscription Tests,' and in 1855 translations of 'The Early Cambridge Statutes,' 'Academical Reform and University Representation'; also 'Cambridge University Transactions during the Puritan Controversies,' Prof. Huber's 'English Universities,' Prof. von Bohlen's 'Illustrations of the First Part of Genesis,' and Prof. Heer's 'Primæval World of Switzerland.' For more than twenty years Mr. Heywood resided in Kensington, and he presented to that parish a free library (to which the Vestry added a reference free library) and a free library for Brompton. Mr. Heywood was elected a Fellow of this Society in the year 1837. He died on October 17th, 1897, at the age of 87.

Charles John Leaf, F.L.S., F.S.A., was elected a Fellow of this Society in 1870. He was a member of the well-known firm of Pawson, Leaf, & Co., St. Paul's Churchyard, and did much to foster a taste for science and literature among the young men employed by the firm by engaging well-known scientific men to deliver to them periodical lectures, etc. He was also the founder of the Old Change Microscopical Club. He died on October 21st, 1897.

The Rev. Peter Bellinger Brodie, M.A., who had been a Fellow of this Society for 63 years, and therefore one of its oldest members, died at Rowington Vicarage on November 1st, 1897, at the ripe age of 82. Up to quite recently he had led a very active life, and he retained a vigorous interest in all scientific matters up to the last. He was born in London in 1815 and was the son of the eminent conveyancer and barrister-at-law, the late P. B. Brodie, and nephew of the celebrated surgeon Sir Benjamin C. Brodie, Bart., who was President of the Royal Society from 1858 to 1861. 'While a youth, and resident with his father at Lincoln's Inn Fields, the younger P. B. Brodie acquired a taste for natural history, and often went as a student to the Royal College of Surgeons. Geology in these early years, attracted his attention, to such good effect that he was proposed as a Fellow of the Geological Society of London by William Clift, the Curator of the College of Surgeons, and he was elected so long ago as January, 1834, just before he went to Cambridge. At that time he was the youngest Fellow ever admitted. H. E. Strickland, with whom in after years Mr. Brodie was much associated, was elected into the Geological Society towards the end of the same year (1834) and during the presidency of G. B. Greenough. At this time, Buckland and Conybeare, Sedgwick, De la Beche and Fitton, Murchison and Lyell, were all members of the Council. Mr. Brodie used to relate that he then attended meetings of the Society held in Somerset House, and listened to many intellectual combats between the geological giants of those days.

'Educated afterwards at Emmanuel College, Cambridge, he naturally came under the inspiriting influence of Sedgwick. He regularly attended the lectures of the famous Professor, and voluntarily assisted him in the Woodwardian Museum. Thus Mr. Brodie's early interest in geology was fostered, and he soon began to undertake original work. His first paper, 'Notice on the Occurrence of Land and Freshwater Shells with Bones of some Extinct Animals in the Gravel near Cambridge,' was read in 1838 before the Cambridge Philosophical Society, but it was not printed until 6 years afterwards. Some notes were contributed to this paper by Sedgwick, and it contained the earliest published record of the mollusca from the now celebrated Pleistocene deposit of Barnwell.

'In 1838 Mr. Brodie was ordained deacon, and the same year he was appointed curate to the rector of Wylye, in Wiltshire. The village is situated on the south-western border of Salisbury Plain, and about 4 miles north of Dinton, in the Vale of Wardour. Here it was that Mr. Brodie became acquainted with that interesting geological region, and his researches added further renown to a district already made famous by the observations of Miss Benett and Dr. Fitton.

'In May, 1839, Mr. Brodie read his first paper before the Geological Society of London, entitled "A Notice on the Discovery of the Remains of Insects, and a new Genus of Isopodous Crustacea belonging to the Family Cymothoidæ, in the Wealden Formation in the Vale of Wardour, Wilts" (Proc. Geol. Soc. vol. iii, p. 134). The new isopod was determined by Owen, and subsequently described by Milne-Edwards under the now familiar name of *Archæoniscus Brodiei.* The strata, in one layer of which this fossil occurs in profusion, have since been grouped with the Purbeck Beds.

'Mr. Brodie was admitted to priest's orders in 1839, and he stayed barely 2 years in his Wiltshire parish. In 1840 he became curate to the vicar of Steeple Claydon, in Buckinghamshire, and entered a region of Oxford Clay and Drift in the vale of Bicester, and a famous hunting country. Steeple Claydon is about 4 miles south of Buckingham, where the Lower Oolites come to the surface; but Mr. Brodie's observations were directed to the country farther south, where he found at Quainton Hill, and at Stone, near Aylesbury, outliers of Portland and Purbeck beds possessing "a certain similarity with those in Wiltshire, but with clearly marked local differences." Staying but a few months at Steeple Claydon, his discovery of remains of insects and other fossils in the "Wealden" (Purbeck) strata of Buckinghamshire was published after he had left the district (Proc. Geol. Soc. vol. iii, p. 780).

'In 1841 Mr. Brodie was appointed rector of Down Hatherley in the Vale of Gloucester, and about 5 miles west of Cheltenham. Here he came into a richly fossiliferous region of Lias and Oolites, and here he had also the advantage of many fellow-workers in geology. Strickland's home at Cracombe House, Evesham, was not far away to the north, and those of Dr. Wright and James Buckman lay a few miles to the east. W. S. Symonds, afterwards rector of Pendock, was from 1843 to 1845 curate of Offenham, near Evesham; and Lycett must about this time have commenced his labours at Minchinhampton. It was not long before Mr. Brodie announced his discovery of insect-remains in the Lower Lias in Gloucestershire, and he published sections of the basement-beds of that formation, and of the underlying strata (now grouped as Rhætic), which he had studied at Wainlode and Westbury-on-Severn. He also in the same year (1842) drew attention to the occurrence of fossil plants in the so-called 'Plastic Clay' of the cliffs at Bournemouth—a locality since famed for the many plant-remains obtained and described by Mr. Starkie Gardner.

'In 1844 Mr. Brodie was associated with Prof. Buckman in a paper on the Stonesfield Slate of the Cotteswold Hills, and, in addition to many stratigraphical details, the authors recorded from the deposit various insects, plant-remains, and other fossils. The researches thus carried on by Mr. Brodie opened up quite a new line of study—that of Fossil Insects. In 1845, assisted by Prof. J. O. Westwood, he embodied his results in a work entitled "A History of the Fossil Insects in the Secondary Rocks of England." This included a particular account of the strata in which the remains were found; and the work was appropriately dedicated to his old master, Sedgwick. The volume was the first ever published on the special subject of Fossil Insects. Later on, Mr. Brodie communicated to the Geological Society of London important papers on the Inferior Oolite of Cheltenham, and on the Purbeck Beds of Swindon.

'Although not one of the original members of the Cotteswold Naturalists' Field Club, which was founded in 1846, Mr. Brodie soon joined its ranks. In 1850 he read before the Club a sketch of the geology of Grantham, and in 1853 he communicated remarks on the Lias of Fretherne and Purton, and on certain Pleistocene deposits in the Vale of Gloucester. It had been his intention to have investigated the Pleistocene formation generally in Gloucestershire, but the duties of his calling led him away this same year (1853) to the vicarage of Rowington, in Warwickshire. It was with great regret that he left so picturesque and instructive a region as that which was embraced by the proceedings of the Cotteswold Club, and his sorrow was increased by the loss of their pleasant meetings, and the parting with many friends, whose companionship had added a charm and a zest to his studies. (Proc. Cotteswold Nat. Field Club, vol. i. p. 246.)

'Rowington village, which now became the scene of Mr. Brodie's labours, is situated on the Keuper marls and sandstones, which are covered here and there by various drift-deposits. Fossils were no longer to be so readily obtained. Nevertheless, the Lower Lias was within reach at Wilmcote, some 6 or 7 miles to the south, and an outlier of the same formation occurs near Knowle, about 6 miles north of Rowington. Mr. Brodie continued to devote his attention very much to the same lines of research, extending them at times to the Upper Silurian and passage-beds of Herefordshire, and recording the occurrence therein of *Eurypterus* and *Pterygotus*, as well as land-plants. He still contributed an occasional paper to the Cotteswold Club, on the Inferior Oolite and Lias of Northamptonshire, and on the Lias of Barrow in Leicestershire.

'Warwickshire, however, naturally claimed his especial attention. Soon after his arrival at Rowington, he became a member of the Warwickshire Natural History & Archæological Society (founded in 1836), and he was at once elected an Honorary Curator of Geology in the Society's Museum at Warwick. Field-meetings were naturally regarded by Mr. Brodie as essential for the proper pursuit of natural history, and in 1854 he was the means of founding the Warwickshire Naturalists' & Archæologists' Field Club, of which he was the first Vice-President and Honorary Secretary. Mr. S. S. Stanley, who for some years acted as junior Honorary Secretary of the Warwickshire Field Club with Mr. Brodie, speaks of the new life and energy which the Vicar of Rowington infused among the naturalists and archæologists of Warwickshire. Foremost as a leader in field-excursions, he kindled in many others an interest in science, as much by his unfailing enthusiasm and good-humour as by his wide knowledge and experience.

'To the Proceedings of the Warwickshire Natural History Society, and of the Field Club, Mr. Brodie contributed very numerous papers and addresses, dealing largely with the Keuper and Rhætic formations, the Lias, and various Drift-deposits. Most important discoveries of fish-remains, and also of mollusca, in the Keuper formation of Warwickshire, have thus been recorded; while the tracts of Lower Lias on the borders of Shropshire and Cheshire, and in Cumberland, have not been unnoticed.

'In 1858 Mr. Brodie contributed a series of articles on the Geology of Gloucestershire to the first volume of the 'Geologist,' and since then he has sent many papers to the Geological Society, the British Association, and the 'Geological Magazine.' Among these articles, those on the Purbeck Beds of Brill, and the Rhætic Beds near Wells, in Somerset, may be mentioned. So recently as August of the present year [1897] he sent a communication to be read at the field-meeting of the Warwickshire Naturalists' & Archæologists' Field Club, held at Wilmcote.

'In the course of his long life, Mr. Brodie formed a most valuable and extensive geological collection, estimated to comprise upwards of 25,000 specimens. The rarer and unique examples have now been placed in the British Museum (Natural History), Cromwell Road; others have unfortunately been dispersed among foreign museums, and a considerable portion in one of our Colonies.

'In 1887 the Murchison Medal was awarded to Mr. Brodie by the Council of this Society, and at that date the President, Prof. Judd, remarked: "Never, probably, has an award of this Society been made to one who can look back upon so long a record of faithful services to Geology as yourself. . . . . . A dweller in the provinces, you have shown how the advancement of our science may best be promoted under these conditions."

Mr. Brodie was elected President of the Warwickshire Natural History & Archæological Society in 1894 and of the Field Club in 1888. His numerous gifts to the Palæontological Collection of the Warwickshire Natural History Society embrace many very rare and fine fossils, amounting to several hundred specimens.

Mr. Brodie was much beloved, not only in the county in which he resided, but by all who had in any way the pleasure of his acquaintance, and his funeral was attended by many of those who had been his fellow-workers in Science. One, writing to me after his death, said, 'Dear old man! He loved God's world, children, animals, nature!' I am indebted for the substance of this biography to Mr. S. S. Stanley, Sec. Warwickshire Nat. Hist. Soc., and to Mr. H. B. Woodward's memoir, Geol. Mag. 1897, pp. 481–485.

Sir James Ramsay Gibson-Maitland, Bart., F.L.S., F.Z.S., one of the most distinguished pisciculturists of the day, was elected a Fellow of this Society in 1890. He was born on March 29th, 1848, and was the son of Sir Alexander Ramsay Gibson-Maitland by a daughter of James Hunt, of Pittencrieff. He was educated at St. Andrew's University and at Sandhurst. In 1867 he received a commission in the 4th Dragoon Guards, but remained for only about a year in the Army. Subsequently he was for some time a Captain in the Highland Borderers Militia. In 1869 he married Frances Lucy Fowke, a daughter of Sir Thomas Woollaston White, Bart., of Wallingwells, Notts. She took much interest in natural science, and her husband acknowledged, in the preface to his 'History of Howietoun,' that his success in fish-culture was largely due to her energy. Fish-culture appears to have attracted Sir J. Maitland's attention in 1873. 'Some words of Frank Buckland,' he says, 'induced me to try to hatch out trout-eggs. I got a copy of Francis Francis's "Fish-culture," and had a box made similar to the one he describes' ('History of Howietoun,' 1887, p. 91). Soon afterwards he started fish-culture on a small burn at Sauchie, his father's property in Stirlingshire. In the next season he built a hatching-home on the same burn. At this time he was living at Craigend, a small house near Sauchie, and in the same season, 1874–75, he repaired an old dam there, and made an experimental hatching-room in the house. In March 1874 work was begun at Howietoun near the site of an old mill on the Sauchie estate. In 1876, on the death of his father, he succeeded to the title and estates. Work at Howietoun progressed steadily, and the number of ponds increased. Meanwhile a most interesting series of experiments in the breeding of trout was in progress, which, having been begun as early as 1874, was afterwards carried on year by year.

In 1881 Sir James published a short essay on the 'Salmon Disease' and a pamphlet on 'Stocking Water with Fish,' which has gone through many editions.

In 1883 he obtained several awards at the Fisheries Exhibition in London, and read a paper on Fish-culture.

In 1881 his attention was turned to the transport of fish ova to the Antipodes, and on December 27th of that year he despatched a consignment of 10,000 Loch Leven trout-eggs to the Otago Acclimatization Society. It proved a failure; but subsequent consignments both of trout and salmon ova were completely successful. In April 1886 Sir Francis Dillon Bell, Agent-General for New Zealand, informed a Committee of the House of Lords that a shipment of nearly ¼ million of ova which had been under Sir James Maitland's charge, and had been taken chiefly by his care and assiduity, had successfully reached the colony, thereby conferring a very great benefit upon New Zealand, and about the same time the Government of that colony presented Sir James with a pair of silver vases in recognition of his services.

In 1887 the first part of the 'History of Howietoun' was published. The volume contains the history of the fishery from its commencement in 1873 up to the middle of the year 1879, and it was intended that a second volume should complete the story up to 1887. Part of the volume was written, and some illustrations were prepared for it, but it has never been completed.

Sir James took part occasionally in the discussions at the Meetings of this Society, but never contributed a paper himself, although it is well known that he gave material assistance in the collection of facts for papers which dealt with the geology of his own estate in Scotland. In papers by his nephew, Mr. H. W. Monckton, one on a 'Picrite and other associated Rocks at Barnton,' Quart. Journ. Geol. Soc. vol. l (1894) p. 39, and another 'On the Stirling Dolerite,' Quart. Journ. Geol. Soc. vol. li (1895) p. 480, reference is specially made to the assistance rendered by Sir James Maitland.

For fish-culture he received as many as five gold medals and two silver medals from the Committees of the London and Edinburgh Fisheries Exhibitions (1882, 1883), and from other public bodies at home and abroad.

He died of heart-disease at Sauchieburn on November 9th, 1897.

Charles Cooper-King, Lieut.-Col., Royal Marine Artillery (Retired), died at his residence, Kingsclear, Camberley, Surrey, on January 16th, 1898, aged 54 years and 11 months.

The only son of Major U. H. King, Royal Marine Light Infantry, he was born at Plymouth, and was at school there until the end of 1859. He passed into the Royal Marines as a Marine Cadet in January 1860, second on the list, and joined H.M.S. *Excellent*. He passed as a Second Lieutenant, R.M., at the Royal Naval College, Portsmouth, first on the list (1862); and, recommended for the R.M. Artillery, he was gazetted at Fort Cumberland. In 1864 he was appointed to command the detachment of Marines on H.M.S. *Scylla* in the China seas and Japan. He was promoted First Lieutenant in 1865, and rejoined Headquarters (Eastney) in 1867. He passed (fourth) into the Staff College, July, 1868; and in August he married Harriet, daughter of the late C. V. Garrett, of Southsea. Passing out of the Staff College, first on the list, and specially recommended, he went through the usual course of study and practice in regimental duties at Aldershot, and the long course of gunnery at Woolwich and Shoeburyness (1871). He was appointed Instructor of Tactics, Administration, and Law at the Royal Military College at Sandhurst in 1872; and was Professor of the same subjects from 1878 to 1885. His promotion as Captain dates from November 1875, and Major by Brevet from 1879.

He retired from the Service in February 1886, and devoted his time and energy to the profession of military instructor or 'coach,' preparing subalterns of the Militia for commissions in the Army. He leaves two daughters and five sons; two of the latter are Lieutenants in the Army.

After the systematic study of geology and chemistry was eliminated from the curriculum at the Staff College, and the professorships thereof had ceased, Col. C. Cooper-King succeeded Major Mitchell as Lecturer on Geology in 1886.

Dealing also with such other branches of Natural Science as the officer-students could find time to study, his synopsis of these lectures on 'Applied Science' embraced not only the land, but water (fresh and salt), air and weather, magnetism and electricity, as well as food and forage.

Col. King drew a large class to Geology, both in the lecture-room and the field; for, being a military expert himself, his explanations of the science in relation to military tactics and battle-fields were well appreciated. Whether on the blackboard or on paper, his apt and facile illustrations of geological conditions and natural history facts were very acceptable to his students and his scientific friends. Always observant, and ready with pen and pencil, he enriched his note-books with reminiscences of places and people, visited or met with, at home and abroad.

In spite of frequent illness, due to rheumatism and heart-failure, his energy spurred him to persist as a hard worker, whether in the study on literary matters, in the field as military correspondent, or in his class-room among military students. Many of his friends in the Army remember with pleasure, and often with gratitude, the advantages which they derived from his teaching, whether private or at college; and indeed he was always ready to help, both cadet and officer, with advice and solid information.

He was an Assistant-Examiner in Geology, Geography, and Physiography for the Science and Art Department (South Kensington), and the Civil Service Commission, for 20 years.

As literary work we may notice his books—'On Map and Plan-Drawing'; 'History of Berkshire'; 'George Washington'; 'The British Army'; and 'The Story of the British Army,' lately published. He was editor of the 'Great Campaigns in Europe,' and, for some time, of 'The United Service Magazine.' Reviews, notices, and miscellaneous pieces by C. C. King are scattered in different periodicals.

In his 'History of Berkshire' (E. Stock, London, 1887), a good knowledge of geology underlies his sketch of the county and his description of the ways and doings, not only of prehistoric man in that region, but of many events in historic times during the conquests and civil wars of Berkshire. The natural features, which have had an effect on the development of the county since the first nomad lived and fished along the banks of the Thames, down to the time in which we live, are carefully considered. We have here a sketch of the evolution of the county, in its races, its homes, fortresses, arts of life, domestic and military; and in its ecclesiastical, military, municipal, and civic relations.

In this, too, his antiquarian knowledge gave his story vigour and accuracy. The ancient camps and earthworks were much elucidated by his familiarity with natural science and military knowledge, also shown in the 'Transactions of the Newbury District Field Club,' of which he was a worthy honorary member. His clear and succinct account of the Stone-Implement Station in Wishmoor Bottom, near Sandhurst, Blackwater, and Camberley, with a good plan and an explanation of the structure of the ground, is published in the Report Brit. Assoc. for 1872 (1873), vol. xlii, Sect. p. 190, and 'Journal of the Anthropological Institute,' vol. ii, no. 6 (Jan. 1873), pp. 365–372, pls. xx & xxi.

Col. King was elected a Fellow of the Geological Society in 1872. In 1875 he communicated to that Society a paper, written in conjunction with his friend T. Rupert Jones, on some newly-exposed sections of the 'Woolwich and Reading Beds' at Coley Hill, Reading, Berks.[1] The features there exposed were correlated with those of neighbouring sections described by Buckland and Rolfe many years ago, and more lately by Prestwich and Whitaker. Two zones of clay-galls were particularly described; and the beds and levels from which these balls of clay (and ochreous nodules) were derived were carefully indicated. Together with the same friend, Col. C. C. King had long studied the conditions and characters of the Bagshot Sands; and his acute observations and thoughtful conclusions must be regarded as having given value to the papers on the Bagshot district published in the 'Proceedings of the Geologists' Association,' vol. vi (1880–1881), pp. 319, 429, etc.

His high grade in college work indicated his mental capacity, strong will, and power of endurance; and his subsequent career showed his versatility and broad intellectual grasp; also his determination to use his gifts for the benefit of his country, and especially of those around him. Thus a man of talent, of great capabilities, of high attainments, and enormous energy, conscientiously and willingly exercising his powers for the good of others, and working hard for the support of his family even to the last, has passed away, like a goodly fruiting-tree, torn away by the ruthless tide of a

[1] Quart. Journ. Geol. Soc. vol. xxxi (1875) pp. 451–457 & pl. xxii.

flooded river, which will distribute the seeds in far-off places, where, like those previously shed, they must produce good results.

T. R. J.

George Thomas Clark, F.S.A., who was elected a Fellow of this Society in 1867, died at the age of 87, at his residence, Tal-y-Garn, Glamorgan, on January 31st, 1898. Mr. Clark was best known as an antiquary, but he also contributed papers on geological subjects to this and other Societies. A paper by him 'On the Neighbourhood of Bombay and certain Beds containing Fossil Frogs' is printed in the Quarterly Journal, vol. iii (1847) p. 219, and another, 'Remarks upon the Basalt Dykes of the Mainland of India opposite to the Islands of Bombay and Salsette,' in the same periodical, vol. xxv (1869) p. 163. Mr. Clark commenced work as a civil engineer, but afterwards was for many years manager and resident trustee of the great Dowlais Ironworks, which, after the death of Sir John Guest, were removed to Cardiff, mainly through Mr. Clark's instrumentality.

John Carrick Moore, M.A., F.R.S., was born in Wigtownshire (where his father, a brother of Sir John Moore, the hero of Corunna, had a residence) in the year 1804. He was educated at Queens' College, Cambridge, and was elected a Fellow of this Society in 1838. In 1841 he accompanied Prof. Sedgwick in his tour in the West of Scotland, and in one of his letters Sedgwick says, 'I found him a very agreeable companion, and we did some good underground work together.' Mr. Moore devoted much time to the study of the coast-sections of his native county of Wigtown, and his first paper communicated to the Society was 'On the Rocks which form the West Shore of the Bay of Loch Ryan in Wigtownshire, N.B.' (Proc. Geol. Soc. vol. iii, 1840, pp. 277 & 278). This was followed by papers

- 'On some Fossiliferous Beds in the Silurian Rocks of Wigtownshire and Ayrshire,' Quart. Journ. Geol. Soc. vol. v (1849) pp. 7–12.
- 'Notice on the Occurrence of Eocene Freshwater Shells at Beaulieu, Langley, etc., in Hampshire,' *Ibid.* pp. 315–316.
- 'On some Tertiary Beds in the Island of San Domingo,' *Ibid.* vol. vi (1850) pp. 39–44.
- 'Notice of the Occurrence of Marine Shells in the Till,' *Ibid.* pp. 388 & 389.
- 'Notes on the Fossil Mollusca and Fish from San Domingo,' *Ibid.* vol. ix (1853) pp. 129–132.
- 'On the Silurian Rocks of Wigtownshire,' *Ibid.* vol. xii (1856) pp. 359–366.
- 'On a Protrusion of Silurian Rock in the North of Ayrshire,' *Ibid.* vol. xv (1859) pp. 1–4.
- 'On some Tertiary Shells of Jamaica,' *Ibid.* vol. xix (1863) pp. 510–513.

He also wrote:—

'On Lake-basins,' Phil. Mag. vol. xxix (1865) pp. 526–527.
'On Glacial Submergence,' *Ibid.* vol. xxxi (1866) pp. 372–373.
'Note on Mr. Croll's paper on the Influence of the Obliquity of the Ecliptic on Climate,' *Ibid.* vol. xxxiii (1867) pp. 536–537.
'Change of Obliquity, a Cause of Change of Climate,' *Ibid.* vol. xxxiii (1867) p. 328.
'Error in Humboldt's Cosmos,' Nature, vol. v (1872) pp. 479–480.

John Carrick Moore was elected one of the Secretaries of this Society in 1846, and served until 1852, and again in 1855. He was Vice-President for six years, and was on the Council altogether for no less than 26 years. He was an intimate friend of Sedgwick, Murchison, and Lyell, and of most of the other leading geologists of their time, and was greatly esteemed and valued by those who were associated with him, either in the active work of the Society or in the field. Sir Charles Lyell, in his 'Principles of Geology' (10th ed., p. 203), refers to Mr. Moore's mathematical and geological work in terms of great admiration, and publishes a Table which had been mainly compiled for him by Mr. Moore, showing 'the variations in the excentricity of the earth's orbit for a million years before A.D. 1800, and some of the climatal effects of such variations.'

Mr. Moore was elected a Fellow of the Royal Society in 1856. He died on February 10th, 1898, at his residence in Eaton Square, having long outlived most of his scientific contemporaries.

On the Evidences of the Antiquity of Man furnished by Ossiferous Caverns in Glaciated Districts in Britain.

Introduction.

As there appears even now to be a doubt in the minds of some as to whether man reached Britain before, during, or after the time known to geologists as the 'Glacial period,' I have thought that it might be well on the present occasion to re-examine some of the evidence which has been brought forward to prove the presence of pre-Glacial man, especially from those areas in Britain which are now admitted to contain Glacial deposits, or to have been overspread by ice and snow in the Glacial period.

The most important evidence yet obtained, it appears to me, is that which has been furnished by the ossiferous caverns in the glaciated areas; but the occurrence in the same areas of the remains of extinct mammalia, which are now admitted to have been contemporary with the Cave Man, buried under great thicknesses of Glacial deposits, must also have an important bearing on the question.

All the evidence tends to show that the so-called Tertiary and Quaternary periods merged gradually into each other, and were not separated by any great break in Britain. The higher mountains, before the close of the Tertiary period, must have been covered in part by ice and snow, and the so-called Glacial period can only have a chronological importance as indicating the increased intensity and climax of that cold condition gradually ushered in at the earlier time. For the same reason there is no marked and definite line separating the fauna of the Pliocene from that of the Pleistocene, for we find remains of the animals of the warmer period closely associated with those of the colder in the same deposits, and under conditions which show clearly that they lived in those areas at the same time.

North Wales and the North-west of England.

It is generally admitted that during the latter part of the Pliocene period the mountains of North Wales stood at a considerably higher elevation than they do at present; therefore it is but natural to suppose that during that time the streams which flowed from them gradually deepened, widened, and also possibly carved out some of the pre-Glacial valleys. The Carboniferous Limestone along the flanks of the mountains, which had at an earlier time been much broken and crushed by earth-movements, now suffered from the additional effects of subaerial action, and wide fissures and caverns were gradually formed in it. In time some of these, as the streams found outlets at lower levels, would be left comparatively dry, and would then be suitable for habitation by man and beast.

In nearly all those caverns where bones of the extinct animals and the implements of contemporary man have been found, there is some amount of sediment underlying the remains. This must have been left there by the streams or floods which also deposited the material that filled up the narrow descending fissures, thereby making a fairly level floor in the caverns before occupation. This material in every case, unless where there is evidence of its having been subsequently disturbed, consists entirely of such local materials as would be brought down by the streams from the immediately adjoining higher ground. When the higher caverns were first occupied by hyænas, it is probable that there was comparatively little ice or snow on the mountains, and many of the animals which lived in the valleys and on the plains extending from them were southern types. Gradually, however, as the cold increased, northern forms appeared on the scene and a commingling of the two groups took place.

The geographical features in the west and north-west in later Pliocene times may be briefly summarized as presenting high mountainous areas in Wales, Cumberland, the South of Scotland, and in parts of Ireland bordering the Irish Sea and St. George's Channel, with extensive plains traversed by great rivers in the areas now submerged, between the west coast of England and Wales, and Ireland. The conditions here were then in every way suitable to form feeding-grounds for herds of the great mammalia, and indeed such as could never have been repeated afterwards in these areas either in late Glacial or in post-Glacial times.

Animals from the south-east could reach these north-western plains across Cheshire and the lowlands in the centre of England, and others from the south by the plains on the west coast of Wales. In this way northern and southern animals would, in a sense, freely commingle and be afterwards driven together to more southern areas as the cold increased, and the conditions became more and more unsuitable to them. At first, in the mountains bordering these plains, when only their higher parts were covered with ice and snow, glaciers would occur only in the higher valleys; but, as the cold increased, they would become confluent with those from adjoining areas, and in time reach the plains and there coalesce to form, perhaps, as suggested by some, one vast sheet reaching across from England to Ireland. Most of the animals, ere the last stage had been reached, would, of course, have disappeared from those parts towards more suitable southern areas.

That the foregoing is, in brief, the history of the incoming of the Glacial period in the north-west is evident from the deposits which have been found in and about the caverns, and in sections at various points on the hills, in the valleys, and around the coast of North Wales. Wherever the earlier materials have been preserved, especially at high levels, they are seen to consist entirely of local materials, that is, such as would be derived from the immediate neighbourhood, or carried down by streams or ice from the adjoining higher ground. Over this, and partly mixed up with it in the areas not reached by the northern ice, there is an admixture of materials from other Welsh districts ; and in the valleys opening out to the north, and along the coast, there is the further admixture of erratics from northern areas. It is an interesting fact that the boundary-line in the Vale of Clwyd reached by the northern erratics is very little farther inland than the area in which the caverns that we have explored occur.

Of the history of the subsequent changes I need say but little ; yet it seems to me that there is fairly good evidence to show that a considerable subsidence did take place towards the close of the Glacial period, and that this was afterwards followed by a certain amount of upheaval in the same areas.

The presence of thick deposits of Drift below the level of the sea, at the entrance to the Vale of Clwyd, with bones of the early Pleistocene mammalia at their very base, is a fairly sure test of a stage of subsidence. Moreover, it is difficult to account for the finding of numerous foraminifera in clays at a height of about 200 feet above present sea-level around the coast,[1] unless alternating movements of subsidence and upheaval took place. The marine sand with broken shells at high levels, formerly regarded as sure evidence of subsidence to that depth, must not, I fear, be relied upon too confidently, as in no case has it been clearly shown that the organisms lived in the positions wherein the shells are now found. In some cases, there are also fairly clear indications that deposits have been transported to comparatively high levels by ice which had passed over and scraped up materials from the sea-bottom.

It seems to me safer, at present, relying upon the evidence which has been brought forward of late years by so many competent observers, to assume that towards the close of the Glacial period the earth-movements produced changes only of a few hundred feet, rather than the great depression and upheaval suggested by the earlier geologists.

[1] See papers by Mr. W. Shone, Quart. Journ. Geol. Soc. vols. xxx (1874) & xxxiv (1878), and by Mr. T. Mellard Reade, *ibid.* vol. liii (1897) p. 341.

The Glacial Deposits of the Vale of Clwyd and adjoining Areas.

Before examining in detail the evidence which has been obtained to show that some of the caverns in the Vale of Clwyd, after occupation, had been buried under the Drift, and that the remains in others had before and during the Glacial period been disturbed by water-action, it may be well to refer more particularly to the deposits which have been classed as of Glacial origin in that area. They have been so fully described in the Memoirs of the Geological Survey by Messrs. Strahan & Tiddeman that it will be unnecessary to do more than refer to the main facts which have been recorded by these authors in regard to them. It is stated[1] that no detailed classification applicable to the whole area had been found possible, and that Glacial sands and gravels are probably intercalated at different horizons in the Boulder Clay. It is also mentioned that one of the best sections of the Drift-deposits in the district was provided in the sinking of Walker's shaft at the Talargoch Mine. The shaft is situated 200 yards away from the limit of the Drift, where the limestone rises in the cliff of Graig-fawr. The following beds were passed through :—

		Feet.	Inches.
Glacial Beds	Soil	1	6
	Marl and Clay	21	0
	Dry Sand	10	6
	Quick Sand	30	0
	Strong clay	6	0
	Gravel	24	0
	Gravelly clay, with water	30	0
	Sand and gravel	36	0
	Gravel, containing bones	12	0
		171	0

Floor of Carboniferous Rocks.

Dr. Buckland[2] also gave a section of the Talargoch Mine, as follows :—

		Feet.
Glacial Beds	Vegetable mould	2
	Clay	78
	Sand and gravel, with pebbles of copper- and lead-ore, and horns, teeth, and bones	204
		284

[1] A. Strahan, 'The Geology of the Coasts adjoining Rhyl, Abergele, & Colwyn,' Mem. Geol. Surv. 1885, p. 28.

[2] 'Reliq. Diluv.' London, 1823, p. 178.

Mr. G. H. Morton ('Geology of the Country around Liverpool,' 1891, p. 182) says :—'The sand and gravel, with pebbles of copper- and lead-ore and horns, teeth, and bones of the stag, found below the surface at the Talargoch Mine, near Prestatyn, and of the elephant at Dyserth, first described by Dr. Buckland, are Glacial beds, the contents having been derived from the pre-Glacial surface.'

Mr. Trimmer ('Geology and Mineralogy,' 1841, p. 401) refers to the lowest deposit in this mine as being a curious mixture of marine and terrestrial remains, 'bones and horns of deer, and trunks of trees, being associated with marine shells.' These sections are important, not only in showing the presence of remains of Pleistocene mammalia under great thicknesses of Drift, classified as of Glacial origin, but also therein that with them are trunks of trees indicating the presence in the neighbourhood of a wooded land-surface in pre-Glacial time.

At p. 31 (Mem. Geol. Surv. 1885) it is stated that 'in the low-lying area of the Vale of Clwyd the newest member of the Drift is a tough, homogeneous, chocolate-coloured clay, with few boulders, consisting of grey granite, porphyries, limestone, quartz, and shell-fragments. The deposit is similar to and continuous with that which overspreads so large a part of South Lancashire and Cheshire, and, like it, is characterized by the large proportion of northern erratics...... The Boulder Clay of the plain runs up the larger valleys so as to be continuous with that of the higher ground...... The passage from the one Boulder Clay into the other is gradual, nor can it be said that one under- or overlies the other. They were, no doubt, formed contemporaneously, differing only in the source of supply of material.'

At p. 127, Mem. Geol. Surv. 1890,[1] Mr. Strahan says :—'The Drift in this part of Wales has travelled, generally speaking, from the west-south-west, though in the neighbouring parts of England it has come down from the north-north-west. Our present district, therefore, includes a portion of the boundary along which the Drift from the west meets and in part mingles with the Drift from the north. To the former belong all the Glacial deposits of the southern half of the Vale of Clwyd and of the Valley of the Alyn, as well as those which lie on the high limestone-plateau west and south of Holywell. The latter includes the Drift of the northern part of the Vale of Clwyd, of the sea-border of Flintshire, and of the Triassic area of Cheshire.'

[1] 'The Geology of the Neighbourhoods of Flint, Mold, & Ruthin,' Expl. of ¼ Sheet 79 S.E.

Sections of Drift are constantly found on each side of the Vale of Clwyd at heights of from 500 to 600 feet, and scattered boulders at much greater elevations. Most of the latter at the higher horizons have been derived from the Snowdon and Arenig groups of mountains, but northern erratics are abundant in the drift at from 500 to 600 feet above sea-level, especially in some areas on the east side of this valley.

Ffynnon Beuno Cave.

The results of researches carried on in the Ffynnon Beuno and Cae Gwyn Caves were communicated by me to this Society in the years 1886 and 1888. The deposits in the Ffynnon Beuno Cave varied somewhat at different points, mainly the result of disturbance since occupation. In a few places, however, a stalagmite-floor was found, and under this an undisturbed cave-earth containing bones of extinct mammalia and some Palæolithic implements. Overlying the stalagmite-floor was a sandy gravel-and-clay, with blocks of limestone, etc.

In other parts of the cavern, especially in some inner tunnels, the whole of the material had been more violently disturbed by water-action, and a general commingling of the materials had taken place. It was quite clear that the cavern had been occupied for some time as a hyæna-den, for the bones had been freely gnawed, remains of hyænas, old and young, were very abundant, and coprolites of the latter were also frequently found. The implements of Palæolithic man in the undisturbed parts of the cavern occurred in such intimate relationship with the bones of the extinct mammalia, that it was perfectly clear that they must have lived contemporaneously. In one place a flint-implement was discovered under the stalagmite-breccia in close proximity to a large portion of a jaw with teeth of *Rhinoceros tichorhinus*, and large fragments of limb-bones of mammoth.

The deposit overlying the stalagmite-floor, excepting near the entrance, where it had been recently removed, consisted of sandy clay with fragments of limestone, shale, etc. The inner tunnels were completely filled up, and there were evidences here of rather violent water-action. The water must have acted from the entrance inward, as fragments of the broken floor and numerous bones were found in the innermost recesses—many bones of large size being in contact with the roof, and others forced into small fissures. They were mixed up with pebbles, gravel, sand, clay, etc., most of which must have been carried into the cavern by the water which broke up the stalagmite-floor, and which disturbed the bones and the other materials previously in the cavern. In regard to the lowest deposit in this cavern, it is clear that it formed the floor of the den, and it consists entirely of such local material as would be left by a stream or flood-water when the cavern was being formed. In this there was not a fragment of any foreign material such as is now abundant in the field above, on the slopes of the valley, and about the entrance of the cavern. The time of occupation was, therefore, certainly before any of these foreign materials could have reached this area. The Rev. G. C. H. Pollen, of St. Beuno's College, recently re-examined some of the lowest deposits which we had left undisturbed in the cavern. In his paper read before the Society in December last, he gives a section of these deposits, and says that he also failed to detect anything but local materials in them. The great importance of the evidence from this cavern is the undoubted fact that not a fragment of anything that could be called foreign material occurred anywhere under the stalagmite-floor, contrasted with its occurrence in the newer and overlying deposits, and everywhere in the neighbourhood of the cave.

The stages indicated in this cavern are the following:—

1. After the formation of the cavern, the deposition in it of some gravel by flood-water when the entrance was nearly on a level with the then floor of the valley.
2. As the valley deepened, and the cavern was above the level of the floods, it was occupied as a den by hyænas and occasionally by man. There was at first but little snow or ice on the neighbouring mountains; but gradually the cold increased, and the hyænas left the higher caverns.
3. This, and other high-level caverns, became now buried under snow, and the conditions were favourable to the formation of stalagmite over the floor because of the moist condition and drip in the cavern.
4. The local glaciers next brought down much material into the valley, and flood-waters re-entered the cavern, breaking up the stalagmite-floor, and carrying in local drift. The floor towards the entrance, being in part protected by limestone-fragments and drift, remained generally intact; but in all the inner recesses there was evidence of rather violent water-action. Here bones, large fragments of the stalagmite-floor, and the drift were mixed up together. The inner tunnels were com-

pletely filled up, and some large bones touched the roofs, while others were forced into small fissures.

5. When subsequently the ice from the western (Arenig and Snowdonian) and from northern areas reached this district, the cavern was again partially disturbed, and some of the mixed drift from those areas was introduced into it. The cavern was afterwards completely covered over by the mixed drift, and its exposure subsequently has been due to subaerial action in post-Glacial times, and in part to mining operations.

Cae Gwyn Cave.

When referring, in my paper before the Geologists' Association in 1885,[1] to this cavern, I stated that when I first crept into it I recognized that it was an entirely unexplored and undisturbed cave, and that we had at that date penetrated to a distance of 150 feet, but that further progress had been impossible, because there was only a very small space between the roof and the material filling the cavern. I then state:—'The original entrance would be probably from 20 to 25 feet nearer the valley, as there are evidences that the limestone here has been, at some previous time, quarried and removed. Between the entrance and the chamber worked there is an average space of from $2\frac{1}{2}$ to 4 feet between the surface of the material on the floor and the roof, but beyond this it gradually diminishes. There was scarcely any drip in the cavern, and the earth is, in places, quite dry. A red earth covered the whole floor, and this was much burrowed by rabbits. In this earth a few recent bones were found, but no remains of extinct mammalia. After removing this earth in the chamber we came upon a tolerably hard floor, which, when broken through, was seen to consist of several layers of ferruginous clay and calcareous matter. Under this floor was found what might be called here the cave-earth, being apparently the usual material found at this horizon in the caves of this district, and that in which the remains are usually enclosed. This earthy clay is identical in appearance with the Upper Boulder Clay in this area, especially that about St. Asaph and in the centre of the Vale of Clwyd, and contains rolled pebbles of felsite, quartz, quartzite, sandstone, Silurian and older rocks, as in that deposit. There were also fragments of an old stalagmite-floor. The bones

[1] 'On some Recent Researches in Bone-Caves in Wales,' Proc. Geol. Assoc. vol. ix (1885) p. 1.

are not found in horizontal layers, but usually inclined or in disturbed positions; and I was surprised to find, on examining some of them, that those which had been broken were filled by a material quite unlike that in which they were now embedded. This fact, not previously, I think, noticed in any of the other caverns, proves that these bones must have been disturbed by water out of a previous deposit before they were enclosed in the present material. To this point I shall refer again. In this same deposit, or at least below the upper earthy layer in the cavern and in association with the bones of the reindeer, we found a flint implement.' This was examined by Sir John Evans, and stated by him to be a scraper rather than a flake, and to show traces of use along the sides, in addition to being rounded at the end. I have given the quotation in full, as at that time we had no idea of finding another entrance, and it has an important bearing on some of the questions subsequently raised in connexion with the position of the flint-flake found outside the new entrance, and under the Drift. We, at this time, clearly recognized the similarity between the material in the cavern and some of the deposits classed with the Upper Boulder Clay in the area; and these, as we afterwards found, extended continuously outwards from the buried entrance to form the lower part of the Drift-section exposed in the field beyond. As in the Ffynnon Beuno Cave, there were in some places local materials at the base which had not been disturbed; but the thick stalagmite-floor which had at one time covered the animal remains had been everywhere broken up, and had been scattered about in the Drift along with the bones. Though it is probable that the earlier deposits in this cavern, like those in the Ffynnon Beuno Cave, were first disturbed when the local glaciers reached the valley, it is clear that they were afterwards rather violently re-arranged, at least in part, when the ice from the western and northern areas reached the district. In a former paper I expressed the opinion that the disturbance took place by marine action during submergence; I now think it may have been done by fresh water near the foot of a glacier which had passed over the sea-bottom. It must be remembered, however, that marine shells are constantly found in the Drift in this area, that a very distinct band containing marine shells in considerable abundance was found in the Drift outside the covered entrance, and that in the lower portion of the section there were very clear signs of stratification. The covered entrance was probably the original or main entrance to the cavern, and it is quite possible that the other entrance was little more than a fissure until the portion beyond the opening had been removed by quarrying operations. On June 28th, 1886, in the presence of Mr. G. H. Morton, F.G.S., of Liverpool, and the writer, a small but well-worked flint-flake was dug up from the bone-earth on the south side of the entrance. Its position was about 18 inches below the lowest bed of sand. Several teeth of hyæna and reindeer, as well as fragments of bone, were also found at the same place, and at other points in the shaft teeth of rhinoceros and a fragment of a mammoth's tooth. One rhinoceros-tooth was found at the extreme point examined, about 6 feet beyond and directly in front of the entrance.

A full account of the later researches in the Cae Gwyn Cave was given in my paper read before the Society in 1888, and I have nothing to add to what is given there. I have, however, visited the cavern since then, and will only repeat that the facts as there given and testified to by so many experienced geologists who visited the cave and the sections during the explorations are, to my mind, quite unassailable. Remains of the following animals, determined by Mr. W. Davies, of the British Museum, were found in the Ffynnon Beuno or Cae Gwyn Caves, namely:—Lion, wild cat, spotted hyæna, wolf, fox, bear, badger, wild boar, great Irish deer, red deer, roebuck, reindeer, horse, woolly rhinoceros, and mammoth.

The following account, taken from 'The Geology of the Country around Liverpool,' ed. 1897, by Mr. G. H. Morton, F.G.S., of his visit to the explorations, is specially important from the wide and long-continued experience of the Author among the Glacial deposits of the district and adjoining areas. He was also present, as already stated, when the flint-flake was found outside the cavern under the undisturbed Drift in June 1886. At p. 184 he says:—'In June 1887, during the progress of an excavation in front of the original [covered] entrance to Cae Gwyn Cave, I stayed in the neighbourhood for 11 days, besides visiting it on other occasions before and since, so that I had ample opportunity of constantly observing the Boulder Clay, as well as the sand and gravel and other beds beneath it. In the Geological Magazine, dec. iii, vol. iii, p. 569, a woodcut showing the section exposed may be referred to by those interested in the subject. It was measured by Dr. Hicks and Mr. C. E. De Rance, F.G.S., when a shaft from the surface down to the entrance of the cave was first sunk in June 1886. In June and October 1887 a much larger excavation was made (about 20 feet long by 10 feet broad, and nearly 20 feet deep), so that the section was more easily seen, but the beds were found of much the same character, the only difference being a slight variation in the persistence and thickness of some of the thin seams of sand interstratified with the Boulder Clay, and the following is the detailed succession :—

'Boulder Clay, 6 feet, overlapping the limestone about the entrance to the cave, and with many species of shells near the base.

'Sand and gravel, 8 feet, ending against the limestone and filling the upper part of the cave.

'Laminated clay, 6 feet, underlying the sand and gravel, and penetrating the whole extent of the cave.

'Bone-earth, 1 foot 6 inches, with fragments of stalagmite, mammalian bones, teeth, and a flint-flake, clearly underlying the laminated clay, over an area of several square yards outside the entrance, and the whole floor inside of the cave.

'The bone-earth had evidently been disturbed, and a stalagmitic floor broken up, and the fragments, often large blocks, mixed up in it. The laminated clay had evidently been tranquilly deposited over it. The sand and gravel were over the laminated clay, but current-bedded, as such so-called "Middle sands" often are. Finally, the Boulder Clay occurred over the sand and gravel, without any evidences of disturbance, or re-arrangement of any kind. The top of the Boulder Clay, as shown in the woodcut referred to, formed the surface of a nearly level field, there being no higher ground near from which débris could have been derived, and there is no reason for supposing that the surface over the cave was ever deeply covered with clay. The entrance to the cave is in a buried limestone-cliff, from which the Boulder Clay dips, but so gradually that nothing of the nature of a talus was suggested, especially considering the rapid fall of the ground in the same direction. The Boulder Clay resembled undisturbed clay as seen anywhere in the Vale of Clwyd, Cheshire, or Lancashire, while the erratics it contained were very similar.'

Ty Newydd Caves.

The results of the researches carried on during the past year in these caves, recently communicated to the Society by the Rev. G. C. H. Pollen, are of great interest, and show conclusively that they were either occupied by some of the so-called early Pleistocene animals, or that remains of extinct mammalia were washed into them before any of the Drift from the western and northern areas, now found so abundantly spread over the ground above and in the neighbourhood of the caverns, could have reached this area. The caverns themselves were entirely filled by local materials which must have been deposited in them by flood-water at the very commencement of the Glacial period. As these caverns are situated in the same ravine, but on the opposite side to those of Ffynnon Beuno and Cae Gwyn, I think it may be well to repeat the conclusions arrived at by Mr. Pollen (Quart. Journ. Geol. Soc. Feb. 1898, p. 132):—

'1. The material in the Ty Newydd Caves, and in the lower part of Ffynnon Beuno and Cae Gwyn, is of purely local origin. Of this we can speak with confidence, as the question was before us from the beginning; we have, therefore, examined all the gravels with minute care, and all stones of whose origin we did not feel certain were forwarded to Dr. Hicks.

'2. This local deposit is of earlier date than the Boulder Clay with western and northern erratics. This was sufficiently proved by the occurrence of the granites and felsites on the hillside at a much higher level than the caves. All doubt on the subject is, however, now removed by our having found the two beds actually superimposed in the second vertical shaft.

'3. The occurrence of the rhinoceros-tooth shows that there was a land-surface, and a climate capable of supporting such large mammalia, either before or during the period when the cave was being filled.'

The height of the caverns above sea-level is 422 feet, or about 20 feet above the floor of the Cae Gwyn Cave.

The Caves on the West Side of the Vale of Clwyd.

When referring to these caves, Prof. Hughes, in his paper,[1] says that the so-called Cefn Caves in the Elwy Valley 'are obviously due to the decomposition of the limestone along the weaker lines in the general drainage-system of that valley; but what the particular local conditions were that caused the subterranean channel to plunge down suddenly to an outlet far below, is not so clear.' Of the Plas Heaton Cave, he says that it 'must have been formed under quite different conditions. It does not lie in the line of any existing drainage-system; it must be a very ancient cave; perhaps it was

[1] Quart. Journ. Geol. Soc. vol. xliii (1887) p. 103.

formed when the streams that flow down near Llysmeirchion ran at a greatly higher level, the intermediate ground being all filled up with drift, or perhaps when the drift choked up the Elwy Valley, as we have seen above was once the case, some of its waters may have found their way into the limestone-rocks above Plas Heaton.' Again he says, 'More probably some, if not all, of the Cefn Caves were formed much later, when the gorge was filled with Boulder Clay, and the water ran into swallow-holes along the margin of the drift and rock, and part of such an one became a sloping cave. In the submergence, this cave cannot have been formed, as nothing would make the current fall to open out vertical passages at the bottom of the sea.'

When the evidence of the earlier explorers of the Cefn Caves (the Rev. E. Stanley and Mr. Joshua Trimmer) is examined, it becomes at once clear that the main Cefn Cavern must have been formed (as was probably the case with most of the others to which I have referred) at a much earlier period than that suggested by Prof. Hughes. Mr. Trimmer says[1]:—'It communicates with the surface by fissures, and has an entrance from the face of the cliff, about 100 feet above the river, and 200 above the sea. The lowest parts yet examined are about 10 feet high, and are filled very nearly to the roof with sedimentary deposits, containing bones and teeth of the hyæna, bear, and rhinoceros. These are found in two strata, separated by a crust of stalagmite. The lowest is below the level of the entrance from the face of the cliff, and contains bones and teeth, enveloped in sediment and mixed with smooth pebbles, like those of the adjacent river, and with fragments of wood. It is covered by a crust of stalagmite, and above that the cave is filled nearly to the roof with calcareous loam, containing bones and angular fragments of limestone, on the surface of which are sand and marl containing fragments of marine-shells, like those dispersed over the neighbouring district. The sediment within the cave is generally finely laminated. This cavern has been compared, as we have already observed, to that of San Ciro; but they differ in these important particulars, that in the Cefn Cave there are no lithodomous perforations in the limestone, that the marine remains are confined to the upper part, and that the lower deposit of pebbles and bones is covered by a crust of stalagmite. This last fact, whether the cave was or was not a den of hyænas, proves that it was subaerial

[1] 'Geology & Mineralogy,' London, 1841, p. 400.

for a considerable time after the formation of the lower deposit and before it was visited by a marine inundation. The marks of teeth on some of the bones leave little doubt that the cave was inhabited by carnivora; and the identity of character which exists between the pebbles and silt below the stalagmite, and those of the river in times of flood, points to the river, when having a different relative level with respect to the cave, as the source from which they were derived.'

From this statement it is clear that the stalagmite was formed over the bones before any of the Northern Drift and sand with marine shells had been carried into the cavern, for the 'rounded pebbles of greywacke,' stated by the Rev. E. Stanley[1] to have been found by him under what had previously been considered the floor of the cave, and in association with the bones, was evidently local material only, and like that found in the Ffynnon Beuno Cave under the stalagmite. Had this cavern been formed after the Northern Drift had been deposited on the surface above the cavern, it is clear that some of that drift would have been carried in through the fissures from the first and mixed with the oldest deposit. The higher caverns on this side of the Vale of Clwyd, like those on the east side, were undoubtedly formed before the Glacial period and were occupied by carnivora before the local glaciers had reached them or deposited sufficient material in the valley to enable flood-waters to disturb and re-arrange the materials which they previously contained. At subsequent periods they were subjected to further water-action, and later were probably occupied in part by more recent animals.

Remains of the following Pleistocene animals have been found in the Cefn Cave:—*Elephas antiquus*, hippopotamus, rhinoceros, cave-bear, and spotted hyæna. In the cave at Plas Heaton explored by Prof. Hughes and Mr. Heaton, remains of the cave-bear, spotted hyæna, bison, reindeer, and glutton were found.

Sir A. Ramsay,[2] in referring generally to caves containing remains of the extinct mammalia, says, 'There is no doubt that many of these caves date from before the Glacial epoch, and also that the bones of animals found their way into some of them before that period.' Of the Cefn Cave, he says that it must have been 'below the sea during part of the Glacial epoch, for the boulder-beds reach a higher level; and, with Dr. Falconer, I found fragments of marine

[1] Proc. Geol. Soc. vol. i (1832) p. 402.
[2] 'Physical Geol. & Geogr. of Great Britain,' 3rd ed. 1872, p. 184.

shells of the Drift in the cave overlying the detritus that held the bones of elephants and other mammalia.'

In his paper on the Cefn and Pont-Newydd Cave-deposits,[1] Mr. D. Mackintosh, in speaking of the clay in the cavern, says, 'This deposit (which contains bones of a number of the usual cave-mammalia) is horizontally continuous with the Upper Boulder Clay of the district.' He further says, 'I have been familiar with this clay in Cheshire and Flintshire for 4 years, and have therefore little hesitation in asserting that traces of it, in an unmodified state, may be found at the entrances of both the Pont-Newydd and Cefn Caves—that in the interior of the Cefn Cave, for a considerable distance from the entrance, there are indications of this clay having once filled the cave nearly, if not quite, to the roof—that in the interior of the Pont-Newydd Cave it maintains its unmodified character for a considerable distance from the entrance—and that in no part of these two caves has this clay been modified further than what may have resulted from the dropping of calcareous matter, from the temporary ponding-back of water in the recesses or hollows, or from accumulation within the caves under conditions which may have differed from those without. The angular limestone-fragments may have fallen from the roof or sides of the caves during the period of accumulation; or previously fallen fragments, along with the bones of animals, may have been washed up into the clay by the waves of the Upper Boulder Clay sea.' At p. 93, Mr. Mackintosh says he cannot believe that in the Pont-Newydd Cave the deposit was washed in through a swallow-hole from the Boulder Clay of the neighbourhood.

Coygan Cave, Caermarthenshire.

This cavern, which was partially explored by Mr. J. Romilly Allen and myself in the year 1866, has proved to be of unusual interest, from the clear confirmatory evidence which it has afforded of the contemporaneity of Palæolithic man with an early Pleistocene fauna.[2] Fortunately this cavern up to that time had not been in any way disturbed, nor was there any evidence to show that it had been occupied at any time by Neolithic man, as had been the case with many of the other ossiferous caverns found in South Wales, on the

[1] Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 92.

[2] Similar evidence had been obtained by Prof. Boyd Dawkins from Wookey Hole in Somerset, and from Kent's Hole, Torquay, by Mr. MacEnery, Mr. W. Pengelly, and others.

northern coast of the Bristol Channel. The cavern is situated in a Carboniferous-Limestone hill, about 2 miles south-west of Laugharne, and the entrance is about 250 feet above sea-level. The orifice was low and narrow, and when we first entered it was almost hidden by talus. From it a low tortuous channel extended inward for about 20 feet, through parts of which it was difficult to pass in a creeping position. A moderately lofty chamber was then entered, and this led to another and larger chamber, about 20 feet wide by 12 in height. Branching from here were two compartments, one extending in a northerly and another in a westerly direction. The former extended inward for about 70 feet, and the latter for about 50 feet, where they terminated in narrow fissures. The entrance-channel, the two chambers, and the westerly compartment were covered with a very thick floor of stalagmite, quite untouched. The northerly compartment was more thinly covered, hence more easily explored. On breaking through this thin coating, we came to a reddish earthy soil, in which the bones were embedded. The bones were submitted to Prof. Boyd Dawkins for examination, and in my paper in the Geological Magazine for 1867, p. 307, 'Discovery of a Hyæna-den near Laugharne, Caermarthenshire,' the following list of the animals then found in it is given:—*Hyæna spelæa*, *Rhinoceros tichorhinus*, *Elephas primigenius*, *Cervus tarandus*, and *Equus*, with the following statement from Prof. Boyd Dawkins. He says:—'All these remains were derived from a hyæna-den, and were introduced by those animals in every case. The lower jaws are in every case without angle or coronoid process, and the rhinoceros-humeri, tibiæ, and radii are gnawed in exactly the same manner as those from Wookey Hole. The teeth, also, of the hyænas indicate every variety, from the whelp to the adult in the decline of life. A lower jaw belonging to Mr. Hicks shows remarkably the results of the diet of the hyænas on their teeth. The first of the two conical bone-crushers is broken, and the fragments of bone gliding down upon the unarmed gum have caused inflammation of the periosteum. One of the hyæna's last lower molars exhibits the accessory cusp, which is but seldom developed. The remains of the rhinoceros are most abundant.'

The cavern was afterwards more fully explored by Mr. Edward Laws, F.S.A., of Tenby, whose careful and important researches among the caves of Western Wales are well known.

In his 'History of Little England beyond Wales,' George Bell & Sons, 1888, he says at p. 7:—'Without doubt the most interesting ossiferous cave in West Wales is the Coygan, near Laugharne, in

Caermarthenshire. . . . . . . So far as I know, there has been no discovery of Neolithic remains in this cave. It was deemed by the late Prof. Rolleston to be the most perfect instance of a hyæna-den he had met with. We found hyæna-bones in position, and their coprolites in great quantities, apparently as fresh as though they had been voided recently; the other remains were similar to those found in the Black Rock and Caldy, but were more plentiful, in good condition, and much scored by teeth-marks. In addition to these ordinary cave-bones, I had the good fortune to find, under rhinoceros-bones which were overlaid by stalagmite, a piece of bone, whittled and rounded into the shape of an awl, lying alongside of two flint-flakes, one of which had indubitably been manipulated; the other was a pebble which had been broken, whether by natural or artificial means it is impossible to say; these are in the Tenby Museum, and constitute the sole proof of the presence of Pleistocene Man in West Wales discovered by me.'

In addition to the animals given in my paper, he mentions the following also as having been subsequently found:—*Ursus arctos*, *U. spelæus*, *Canis vulpes*, *Felis spelæa*, *Cervus megaceros*, *C. elaphus*, *Bos primigenius*, *Bison priscus*.

This cavern is just on the fringe of the glaciated area in South Wales, and was therefore probably occupied to a later time in the Glacial period than those in the Vale of Clwyd, North Wales. However, the abundance of drift-material in the valleys of the neighbourhood and on the plains immediately to the north shows that the area could not have been suitable for occupation by the larger Pleistocene animals at the time of maximum glaciation. Nor could they have returned into the area after the submergence, at the close of the Glacial period, of the plains now under the waters of the Bristol Channel. The implements found below the *Rhinoceros*-bones, and under the thick stalagmite floor, must therefore have belonged to Man occupying the area in an early part of the Glacial period, for the cavern could not have been used as a den by the hyænas when the ground was almost perpetually covered with snow, as it must have been here during much of the Glacial period.

The Victoria Cave, Settle (Yorkshire).

In his reports to the British Association, in 1874 and 1875, on the explorations carried on in this cavern, Mr. Tiddeman has given, in my opinion, satisfactory evidence to show that the cavern was occupied by the so-called early Pleistocene animals in pre-Glacial time, and that the bones of the extinct mammalia found in the cavern were covered over by material conveyed by glaciers during the Glacial period. He says:—'The extent of the Glacial deposits now exposed is so great that it is impossible that they can be a mere chance accumulation of boulders, which have been re-deposited in their present position since Glacial times. This being the case, it is clear from the position of the boulders beneath all the screes that they form a portion of the general glacial covering of the valleys and hillsides which was left by the ice-sheet at the time of its disappearance. These are the main arguments to be derived from the cave itself; but further strong presumptive evidence that the Pleistocene fauna lived in the North of England before the ice-sheet exists as follows:—The older fauna once lived in that district, a point which admits of no dispute from its existence in the Victoria Cave, in Kirkdale Cave, Raygill Cave in Lothersdale, and perhaps in other caves; but their bones are now found nowhere in the open country. None of the river-gravels contain them; and just that district which is conspicuous by their absence is also remarkable for the strongest evidences of great glaciation. If these facts be taken together, the probability is very strong that it was glaciation which destroyed their remains in the open country.'[1]

Prof. Boyd Dawkins[2] says that the remains found in this cave 'belong to a fauna that overran Europe and must have occupied this very region before the Glacial period'; therefore it may 'reasonably be concluded that they occupied the cave in pre-Glacial times.'

The Victoria Cave is 1450 feet above sea-level, and remains of the following early Pleistocene mammalia have been found in it:—*Elephas antiquus*, *Rhinoceros leptorhinus*, hippopotamus, hyæna, bear, and red deer.

Scotland.

A few caverns have been discovered in Scotland, but in none of these apparently has there been evidence of occupation by Palæolithic man. Remains of the Pleistocene mammalia, so constantly found with the implements of Palæolithic man in caverns in England and Wales, have been discovered in several places, and it is of

[1] Rep. Brit. Assoc. 1875, p. 168.
[2] 'Cave Hunting,' 1874, p. 124.

importance to note that they are invariably found either in or under the Glacial deposits. In his important paper,[1] Sir H. Howorth has given a careful summary of the evidence then obtainable from Scotland, and he arrives at the conclusion that here, as in all other places in the British Isles, when the remains have not been afterwards disturbed 'the mammoth-beds are in every instance overlain by the Drift, and are never underlain by it.' Sir A. Geikie, in describing the Glacial deposits in Scotland,[2] mentions the 'Upper Boulder Clay' as consisting of 'rudely stratified clays with sands and gravels,' and the 'Till or Lower Boulder Clay' as 'a stiff, stony, unstratified clay, varying up to 100 feet or more in thickness. Bands of fine sand, finely laminated clays, layers of peat and terrestrial vegetation, with bones of mammoth and reindeer, also in some places fragmentary or entire arctic and boreal marine shells, occur either in the Till or between it and the upper Boulder Clay.' The intercalations of sand, gravel, and clay which frequently occur in the Drift in some areas, are supposed by Prof. J. Geikie to indicate five glacial intervals, separated from each other by four interglacial periods of mild temperature, and he is inclined to the belief that man did not occupy Britain before 'the advent of the second Glacial epoch,' . . . and 'that it is not until we reach the deposits of the second interglacial epoch (*Elephas antiquus*-stage) that we encounter abundant and unequivocal traces of man.' He further states that 'not a trace of Palæolithic man is forthcoming from any deposit that overlies the morainic and fluvio-glacial accumulations of the third Glacial epoch in North-western Europe.'[3] The latter statement is important, but I cannot agree with him as to the period when man first appeared in Britain, and the changes to which Prof. J. Geikie refers as occurring in the Drift-deposits may be easily accounted for without invoking the aid of warm interglacial periods.

Early Pleistocene Conditions on the East Side of England.

On the east side of England, as on the west, there were at this time great plains, extending out from the valleys, and much of the area now covered by the North Sea must have been dry land where northern and southern animals commingled. That this was the

[1] 'Did the Mammoth live before, during, or after the Deposition of the Drift?' Geol. Mag. 1892, p. 250.

[2] 'Text-book of Geology,' 3rd. ed. 1893, p. 1044.

[3] 'Great Ice Age,' 3rd. ed. 1894, pp. 689, 690.

case is shown by the finding of their remains in close association in the hyæna-den at Kirkdale and in other caverns in Yorkshire. Prof. Phillips many years ago came to the conclusion that the Kirkdale Cave was occupied in the 'pre-Glacial condition of the land which is now Yorkshire,' and he also maintained that the lowest Hessle Gravels which rest upon the Chalk, and which contain mammoth and other remains, and are covered by Boulder Clay, are pre-Glacial in age.

Mr. G. W. Lamplugh's careful researches seem to show clearly that the Sewerby 'infra-Glacial Beds,' which have yielded so many Pleistocene remains, are at the base of the Glacial series in that area. He says of the fauna at the base of the drift at Sewerby:—'It is essentially the fauna of the Kirkdale Cave.'[1] In his conclusions, given in the same paper (p. 428), when referring to the physical conditions prevailing in the area during the formation of the drift-deposits, he says:—'At a period not long anterior to that of the glaciation of the coast, Flamborough Head was in existence as a bold promontory jutting out into a sea whose level was slightly above that of to-day. Most of the mammals characteristic of the Glacial period were already living, and tenanted the interior in large numbers. The climate was moist and not very severe, the prevalent winds, as shown by the sand-dunes of Sewerby, being from the west or south-west. After the land had remained for a long time stationary, a slow elevatory movement set in, and the climate became much colder; so that the Chalk-surface was disintegrated by frost and eroded by sudden floods, which spread thick beds of muddy detritus over much of the low or slightly sloping ground in the vicinity. Meanwhile the bed of the North Sea was being rapidly filled with ice through the great extension of the Scandinavian glaciers; till at length the Scotch and Scandinavian ice coalesced, and what remained of the North Sea was well nigh ice-locked.'

Although some southern forms whose remains have been discovered in the forest-bed on the Norfolk coast do not appear to have reached much farther north than that area, this does not, in my opinion, make it in any way certain that even these were not, in part at least, contemporaneous with the so-called mixed early Pleistocene fauna of the more northern districts. It is also an important fact that many of the most characteristic animals whose remains have been discovered in the caverns in North Wales and Yorkshire are now always included in the fauna of the Forest Bed.

[1] Quart. Journ. Geol. Soc. vol. xlvii (1891) p. 412.

The position of the Forest Bed of Norfolk under high cliffs of Boulder Clay[1] is also very similar to that of the lower deposits near the entrance to the Vale of Clwyd, containing Pleistocene remains and trunks of trees in like manner covered over by a great thickness of Glacial drift. It may also be compared with the forest-bed in Holyhead Harbour, buried under 'stiff blue clay,' in which two perfect heads of the mammoth were found when the excavations for the railway were made in 1849. The tusks and molars were buried 2 feet deep, in a bed of peat 3 feet thick, with stumps and roots of trees.[2]

It may be well to mention that the following mammals, whose remains have been found in caverns in North Wales, Derbyshire, and Yorkshire are now generally regarded as forming a part of the fauna of the Norfolk Forest Bed, and that several of them, such as the glutton, musk sheep, and mammoth, must be considered typically northern animals. The list is taken mainly from those published by Prof. Boyd Dawkins or Mr. E. T. Newton,[3] and there are animals which may be classed as characteristic of arctic, temperate, and hot climates. The principal animals whose remains have been found in caverns in association with human implements, and which are stated also to occur in the Norfolk Forest Bed, are the following:—*Elephas antiquus*, *El. primigenius*, *Hippopotamus amphibius*, *Equus caballus*, *Sus scrofa*, *Bison*, *Ovibos moschatus*, *Cervus elaphus*, *C. capreolus*, *C. megaceros*, *Machairodus*, *Canis lupus*, *C. vulpes*, *Hyæna crocuta*, *Ursus spelæus*, *Gulo luscus*, *Lutra vulgaris*, *Arvicola amphibius*.

When the cold increased, the animals on the East coast, as on the West side, were driven farther south, and those least able to bear the increased severity of the climate were the first to migrate from the various areas. The southern forms may consequently be looked upon, for the areas in which they have been found, as the oldest fauna; but it is reasonable to suppose that they were contemporary with the more northern forms, which at that time lived in other districts where the conditions were more

[1] Mr. Clement Reid, in his memoir (Geol. Surv.) 'On the Country around Cromer,' 1882, says that the Glacial drifts in that area were contorted by ice-pressure. 'The extreme shallowness of the North Sea would cause it to be entirely filled with ice, which, flowing over or abutting against the older Drifts, contorted them in the way we now see' (p. 114).

[2] Lyell, 'Principles of Geology,' 10th ed. vol. i (1867) p. 545.

[3] I am also greatly indebted to Mr. A. Smith Woodward for a list of the mammalia in the Savin Collection in the Natural History Museum, South Kensington.

suitable to them. When the northern forms reached the South of England, the conditions in and around the mountainous districts were such that few animals could remain there, as most of the valleys and plains had become buried under ice and snow, and they would have to seek feeding-grounds outside these areas. It is to this period that we must assign the remains of the mammoth and rhinoceros which are so abundantly found on the old land-surfaces on the north of the Thames, usually hidden under great thicknesses of drift, as in Endsleigh Street, and in other places in Middlesex. Here, and in some areas farther south, they could have lived during most of the Glacial period until at last driven away, when the valleys and plains became covered with vast sheets of water, due in part probably to subsidence, but largely owing to the gradual melting of the ice and snow farther north. Whether the mammoth and rhinoceros continued to live much longer in some parts of the South and South-west of England there is very little evidence at present to show. The supposition, however, held by some that they returned to the glaciated areas after the Glacial period had passed away does not seem to me in any way probable, for hitherto their remains have only been found either under or in the Drift, and not above it, excepting when they have been washed out from the earlier deposits.

Sir Joseph Prestwich, who, as all will allow, had a unique acquaintance with the Pliocene and Pleistocene deposits in England and on the Continent, in his important paper read before the Society in 1887,[1] says:—'My first impressions with respect to the Valley of the Somme were:—that the high-level gravels originated in early Glacial times; that the intermediate stages and terraces were formed during the excavation of the valley as a consequence of the great Glacial and post-Glacial floods; and that the low-level gravels formed the concluding stage of those conditions. But in the absence of data, since acquired, the strong prepossessions then existing, and the novelty of the subject, I was then led to conclude that the whole might be post-Glacial.'

'So much evidence has, however, since been brought forward with respect to the so-called pre-Glacial man, that I feel I am now justified in reverting in great part to my original position. The cave-work of Mr. Tiddeman and Dr. Hicks gives strong presumptive evidence of the earlier geological appearance of Man in the British

[1] Quart. Journ. Geol. Soc. vol. xliii (1887) p. 406.

area.' Again, on p. 407, he says:—'I may briefly state my conclusions that the high-level beds of the Somme Valley at Amiens, of the Seine in the neighbourhood of Paris, of the Thames at the Reculvers, and of the Avon at Salisbury, together with the caves above-named, date back to Glacial or pre-Glacial times, not in the sense of being anterior to the Glacial epoch, but in the sense of belonging to that part of the Glacial epoch when the great ice-sheet was advancing, but had not yet invaded the whole of this area.'

In later years, as is well known, owing to the researches of Mr. B. Harrison, of Ightham, and others, he constantly advocated the view that the implements found in the plateau-gravels in Kent and Sussex may have been used by man during 'an early Glacial or even a pre-Glacial period.'[1]

Summary.

The evidence which has been obtained from ossiferous caverns at high elevations in the glaciated areas shows conclusively that the remains of the extinct mammalia found in them must have been introduced before any of the Glacial deposits now in or upon them could have been laid down, therefore either before, or so early in, the Glacial period that there could not have been at the time any considerable amount of snow on the neighbouring mountains, or glaciers even in the higher valleys.

From caverns in glaciated areas in North and South Wales, where Palæolithic implements have been found in association with remains of the extinct mammalia, facts have been obtained which make it certain that the implements were those of man living at the same period as the extinct animals in those areas, and therefore of pre-Glacial age. It has also been shown that as the cold increased the higher valleys became filled with glaciers and the caverns became uninhabitable; that afterwards, as the snow-line and glaciers descended lower and lower, some of the caverns were subject to inundations, which not only disturbed and re-arranged the deposits previously in them, but wholly or partially filled them up with local materials; and that in the Vale of Clwyd, North Wales, the local glaciers gradually coalesced with those from the western and northern areas, and a mixed material was distributed over the district to a height of over 600 feet, burying the ossiferous caverns beneath it. During this time also water

[1] 'Controverted Questions of Geology,' 1895, p. 72.

re-entered some of the caverns, redisturbing in part the earlier contents and depositing some of the mixed drift over that previously in the caverns.

While these caverns were occupied as dens by the hyænas, northern and southern animals commingled in the valleys and on the great plains reaching out from them to the area now covered by the Irish Sea.

From numerous examinations made of undisturbed Glacial deposits in Wales, the North of England, and Scotland, it has also been proved very clearly that the extinct mammalia, whose remains are found in association with the implements of Palæolithic man in caverns, must have lived there before those deposits had been laid down, as their remains always occur at the base or in the lower parts of the Drift, and never above it. Further, there is not a particle of evidence to show that these extinct mammalia ever revisited those areas after the close of the Glacial period.

Before vacating the Chair I wish to express my warmest thanks to you all for the honour which you conferred upon me 2 years ago when you elected me your President. I further desire to thank the Council, Officers, and permanent staff for the unvarying kindness and ready assistance which they have extended to me on all occasions during my term of office.

My friend and successor, Mr. W. Whitaker, F.R.S., from his long connexion with the Society and with the Geological Survey, is so well known to you all that it only remains for me now to tender to him my heartiest wishes that he may find his term of office as pleasant and enjoyable as that which has fallen to my lot.

February 23rd, 1898.

W. WHITAKER, B.A., F.R.S., President, in the Chair.

F. C. Harrison, Esq., Silcoates Hall, Wakefield, Yorks, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'On some Submerged Rock-Valleys in South Wales, Devon, and Cornwall.' By T. Codrington, Esq., M.Inst.C.E., F.G.S.

2. 'Some New Carboniferous Plants, and how they contributed to the Formation of Coal-Seams.' By W. S. Gresley, Esq., F.G.S.

The following drawings, maps, and specimens were exhibited :—

Drawings of Carboniferous Plants, exhibited by W. S. Gresley, Esq., F.G.S., in illustration of his paper.

Reptilian Bone derived from the Laramie Beds, found in the Glacial Deposits, Edmonton (N.W. Terr., Canada); Silicified Wood from the Glacial Deposits (derived), same locality; and Auriferous Sand from the North Saskatchewan River (N.W. Terr., Canada), exhibited by W. P. D. Stebbing, Esq., F.G.S.

Six sheets of the $\frac{1}{100,000}$ Geological Survey Map of Italy, Calabria, by E. Cortese and C. Aichino.

Plan of the Witwatersrand Goldfields, Transvaal, $\frac{1}{29,750}$, drawn up and presented by W. F. Regan. 1897.

Geological Survey of England and Wales. Index Map, 1 inch = 4 miles, Sheets 5 and 14 (Lithographed Edition), 1897. Presented by the Director-General of H.M. Geological Survey.

March 9th, 1898.

W. WHITAKER, B.A., F.R.S., President, in the Chair.

The List of Donations to the Library was read.

Prof. J. W. JUDD exhibited, on behalf of the Coral Reef Committee of the Royal Society, the lowest core (698 feet) from the boring at Funafuti (Ellice Is.,), and drew attention to the remarkable changes exhibited by the rocks obtained at this depth. The core from this boring (a mass of material more than a ton in weight) had been sent to this country by Prof. Edgeworth David, and was now being submitted to careful study. The last 20 or 30 feet of the boring was carried on in a rock which was of a very soft character, and highly but minutely crystalline. Microscopic examination shows that the rock is almost completely converted into a mass of very small rhombohedra, the organic structures being nearly obliterated; while a preliminary chemical examination seems to indicate that magnesia has been introduced into the rock to a considerable extent. The complete study, microscopical and chemical, of all the stages of the change which has taken place in this rock—a study which will be undertaken by Mr. C. G. Cullis—promises to throw much light on processes of rock-formation of very great interest to the geologist.

The following communications were read :—

1. 'Note on Clipperton Atoll.' By Rear-Admiral Sir W. J. Wharton, K.C.B., F.R.S., Hydrographer to the Admiralty. (Communicated by Sir Archibald Geikie, D.Sc., F.R.S., F.G.S.)

2. 'A Phosphatized Trachyte from Clipperton Atoll.' By J. J. H. Teall, Esq., M.A., F.R.S., V.P.G.S.

3. 'The Pliocene Deposits of the East of England.—Part I. The Lenham Beds and the Coralline Crag.' By F. W. Harmer, Esq., F.G.S.

In addition to the exhibit mentioned above, the following specimens and photographs were exhibited :—

Photographs, Rock-specimens, and Microscope-slides, exhibited in illustration of the papers by Rear-Admiral Sir W. J. Wharton, M.A., K.C.B., F.R.S., and J. J. H. Teall, Esq., M.A., F.R.S., V.P.G.S.

Conglomerate-pebble from Glacial gravels, Woolmer Green, near Welwyn, Herts, exhibited by A. E. Salter, Esq., B.Sc., F.G.S.

March 23rd, 1898.

W. Whitaker, B.A., F.R.S., President, in the Chair.

John Casper Branner, LL.D., Ph.D., B.S., Leland Stanford University, California (U.S.A.); James Johnston, Esq., Assoc. M.Inst.C.E., Bond Street, Brighton; Harry Innes Perkins, Esq., Georgetown (British Guiana); and George Winship, Esq., Borough Buildings, Abingdon, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Eocene Deposits of Devon.' By Clement Reid, Esq., F.L.S., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

2. 'On an Outlier of Cenomanian and Turonian near Honiton, with a Note on *Holaster altus*, Ag.' By A. J. Jukes-Browne, Esq., B.A., F.G.S. (Communicated by permission of the Director-General of H.M. Geological Survey.)

3. 'Cone-in-Cone: Additional Facts from Various Countries.' By W. S. Gresley, Esq., F.G.S.

The following specimens, etc. were exhibited:—

Specimens and a Microscope-section, exhibited by Clement Reid, Esq., F.L.S., F.G.S., in illustration of his paper.

Fossils and Rock-specimens, exhibited by A. J. Jukes-Browne, Esq., B.A., F.G.S., in illustration of his paper.

Diagram of Cone-in-Cone Structures, exhibited by W. S. Gresley, Esq., F.G.S., in illustration of his paper.

April 6th, 1898.

W. Whitaker, B.A., F.R.S., President, in the Chair.

Albert Churchward, M.D., 206 Selhurst Road, South Norwood, S.E.; William Gould Churchward, Esq., 206 Selhurst Road, South Norwood, S.E.; William Albert Downham, Esq., 66 Grenville Street, Stockport; and Hugh Colley McNeill, Esq., A.R.S.M., 29 North Villas, Camden Square, N.W., were elected Fellows of the Society.

The List of Donations to the Library was read.

Prof. T. Rupert Jones exhibited and commented upon a series of large stone-implements, sent to England by Mr. Sidney Ryan, from the tin-bearing gravels of the Embabaan in Swaziland, South Africa. They consist of fine-grained quartzite, chert, lydite, siliceous schist, and quartzites composed of breccia and grit-stones, one of the latter mylonized. Also some corresponding rock-specimens from the neighbouring Ingewenyaberg, with a map and section by Mr. S. Ryan. Some similar implements from the same district, lent by Mr. Nicol Brown, F.G.S., and some analogous implements of rough quartzite, from Somaliland, lent by the Rev. R. A. Bullen, F.G.S., were also exhibited.

Prof. Seeley exhibited the humerus of a Plesiosaurian in which the substance of the bone was almost entirely replaced by opal. He explained that the fossil was from the opal-mines of New South Wales. Externally there is no indication of its internal condition as a pseudomorph, and it had been broken to ascertain its commercial value as opal. It is translucent, of a bluish tint, with a slight red fire. So far as he was aware, it was the only example of a fossil bone in this condition; and he was indebted to Messrs. Hasluck, the opal-merchants, for the opportunity of placing the specimen before the Fellows.

The following communications were read:—

1. 'On some Palæolithic Implements from the Plateau-Gravels, and their Evidence concerning "Eolithic" Man.' By W. Cunnington, Esq., F.G.S.

2. 'On the Grouping of some Divisions of Jurassic Time.' By S. S. Buckman, Esq., F.G.S.

In addition to the specimens mentioned above, the following were exhibited:—

Flint-implements, exhibited by W. Cunnington, Esq., F.G.S., in illustration of his paper, from his own and Mr. B. Harrison's collections.

Flints from the Plateau-gravel, Alderbury Hill, near Salisbury, exhibited by Dr. H. P. Blackmore, F.G.S.

Flint-implements, exhibited by the Rev. R. Ashington Bullen, B.A., F.G.S.

Flint from Thornton Heath, exhibited by E. A. Martin, Esq., F.G.S.

New Geological Map of England and Wales, scale: 1 inch = 10 miles, by Sir Archibald Geikie, D.Sc., F.R.S.

Geological Map and Sections of the Heidelberg District (Transvaal), scale: 1 inch = 3·8 miles, drawn up and presented by A. R. Sawyer, Esq., F.G.S.

April 20th, 1898.

W. Whitaker, B.A., F.R.S., President, in the Chair.

Theodore Charles Cotherill, Esq., 8 St. Martin's Place, Trafalgar Square, W.C.; Charles Hawksley, Esq., 30 Great George Street, Westminster, S.W.; Herbert Stanley Jevons, Esq., 2 The Chestnuts, Branch Hill, Hampstead, N.W.; and William John Waterman, Esq., Vancouver (British Columbia), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'Note on an Ebbing and Flowing Well at Newton Nottage (Glamorganshire).' By H. G. Madan, Esq., M.A., F.C.S. (Communicated by A. Strahan, Esq., M.A., F.G.S.)

2. '*Petalocrinus.*' By F. A. Bather, Esq., M.A., F.G.S.

3. 'On the Origin of the Auriferous Conglomerates of the Gold Coast Colony (West Africa).' By T. F. B. Sam, Esq. (Communicated by J. L. Lobley, Esq., F.G.S.)

The following specimens were exhibited:—

Rock-specimens from Newton Nottage, exhibited by H. G. Madan, Esq., M.A., F.C.S., in illustration of his paper.

Specimens of *Petalocrinus* and Microscope-sections of the Matrix, exhibited by F. A. Bather, Esq., M.A., F.G.S., in illustration of his paper.

Type-specimen of *Hapalocrinus Victoriæ*, Bather, from the Silurian of Victoria (Australia), exhibited by F. A. Bather, Esq., M.A., F.G.S.

Specimens of Auriferous Conglomerate and Vein-quartz from Adjah Bippo, Gold Coast Colony (West Africa), exhibited by J. L. Lobley, Esq., F.G.S., in illustration of Mr. T. B. F. Sam's paper.

May 4th, 1898.

W. Whitaker, B.A., F.R.S., President, in the Chair.

M. Marcelin Boule, of Paris; Dr. W. H. Dall, of Washington, D.C. (U.S.A.); and M. A. Karpinsky, of St. Petersburg, were elected Foreign Correspondents of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Carboniferous Limestone of the Country around Llandudno.' By G. H. Morton, Esq., F.G.S.

2. 'On the Graptolite-Fauna of the Skiddaw Slates.' By Miss G. L. Elles. (Communicated by J. E. Marr, Esq., M.A., F.R.S., F.G.S.)

The following specimens were exhibited:—

Rock-specimens and Photographs, exhibited by G. H. Morton, Esq., F.G.S., in illustration of his paper.

Fossils from the Woodwardian Museum and other collections, exhibited in illustration of the paper by Miss G. L. Elles.

May 18th, 1898.

W. Whitaker, B.A., F.R.S., President, in the Chair.

John Ballot, Esq., 113 Cannon Street, E.C., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Garnet-Actinolite Schists on the Southern Side of the St. Gothard Pass.' By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., V.P.G.S.

2. 'On the Metamorphism of a Series of Grits and Shales in Northern Anglesey.' By Dr. C. Callaway, M.A., F.G.S.

3. 'On a Volcanic Series in the Malvern Hills near the Herefordshire Beacon.' By H. D. Acland, Esq., F.G.S.

The following specimens were exhibited:—

Rock-specimens and Microscope-sections, exhibited by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., V.P.G.S., in illustration of his paper.

Rock-specimens and Microscope-sections, exhibited by Dr. C. Callaway, M.A., F.G.S., in illustration of his paper.

Rock-specimens and Microscope-sections, exhibited by H. D. Acland, Esq., F.G.S., in illustration of his paper.

June 8th, 1898.

W. Whitaker, B.A., F.R.S., President, in the Chair.

James Willoughby Small, Esq., Principal of Victoria College, Jaffna (Ceylon), was elected a Fellow; and Prof. O. C. Marsh, Ph.D., LL.D., M.A., Yale University, New Haven, Conn. (U.S.A.), was elected a Foreign Member of the Society.

The Names of certain Fellows were read out for the first time, in conformity with the Bye-Laws, Sect. VI. Art. 5, in consequence of the non-payment of Arrears of Contributions.

The List of Donations to the Library was read.

The following communications were read:—

1. 'On the Discovery of Natural Gas in East Sussex.' By C. Dawson, Esq., F.G.S., F.S.A.

2. 'Note on Natural Gas at Heathfield Station (Sussex).' By J. T. Hewitt, M.A., D.Sc., Ph.D. (Communicated by the President.)

3. 'On some High-level Gravels in Berkshire and Oxfordshire.' By O. A. Shrubsole, Esq., F.G.S.

4. 'The *Globigerina*-Marls of Barbados.' By G. F. Franks, Esq., M.A., F.G.S., and Prof. J. B. Harrison, M.A., F.G.S. With an Appendix on the Foraminifera by F. Chapman, Esq., A.L.S., F.R.M.S.

The following exhibits were shown:—

Mr. C. E. Masterman, Manager of the Denayrouze Light Syndicate, in illustration of Mr. Dawson's paper, exhibited the natural gas as burnt in incandescent burners; also as ignited in its raw state.

Specimens and Microscope-sections, exhibited by O. A. Shrubsole, Esq., F.G.S., in illustration of his paper.

Specimens and Microscope-sections, exhibited by G. F. Franks, Esq., M.A., F.G.S., and Prof. J. B. Harrison, M.A., F.G.S., in illustration of their paper.

A series of 17 mounted Slides of Foraminifera from the *Globigerina*-Marls of Barbados, exhibited by F. Chapman, Esq., A.L.S., F.R.M.S.

June 22nd, 1898.

W. Whitaker, B.A., F.R.S., President, in the Chair.

Hugh Davies, Esq., 58 Ronalds Road, Holloway, N., was elected a Fellow; and Prof. H. Credner, Ph.D., of Leipzig, was elected a Foreign Member of the Sociey.

The following Names of Fellows of the Society were read out for the second time, in conformity with the Bye-Laws, Sect. VI. Art. 5, in consequence of the non-payment of Arrears of Contributions:—W. H. Clarke, Esq.; G. Dent, Esq.; Rev. Z. T. Dowen; J. Evans, Esq. (Bulli); G. A. Lefroy, Esq.; C. G. Richardson, Esq.; R. Taylor, Esq.; E. Kemper-Voss, Esq.; D. J. Williams, Esq.; and A. Woodhouse, Esq.

The List of Donations to the Library was read.

The following communications were read:—

1. 'Post-Glacial Beds exposed in the Cutting of the new Bruges Canal.' By T. Mellard Reade, Esq., C.E., F.G.S.

2. 'High-level Marine Drift at Colwyn Bay.' By T. Mellard Reade, Esq., C.E., F.G.S.

3. 'Observations on the Geology of Franz Josef Land.' By Dr. R. Kœttlitz. (Communicated by E. T. Newton, Esq., F.R.S., F.G.S.)

4. 'Notes on Rocks and Fossils from Franz Josef Land brought home by Dr. Kœttlitz, of the Jackson-Harmsworth Expedition.' By E. T. Newton, Esq., F.R.S., F.G.S., and J. J. H. Teall, Esq., M.A., F.R.S., V.P.G.S.

5. 'On the Corallian Rocks of Upware.' By C. B. Wedd, Esq., B.A. (Communicated by J. E. Marr, Esq., M.A., F.R.S., F.G.S.)

The following specimens were exhibited:—

Hand-specimens and Microscope-slides, exhibited by T. Mellard Reade, Esq., C.E., F.G.S., in illustration of his papers.

Fossils and Rock-specimens collected by the Jackson-Harmsworth Expedition, exhibited by Messrs. E. T. Newton, F.R.S., F.G.S., and J. J. H. Teall, M.A., F.R.S., V.P.G.S., in illustration of the papers on Franz Josef Land.

Fossils from the Corallian Rocks of Upware, exhibited by H. Keeping, Esq., of the Woodwardian Museum, in illustration of the paper by C. B. Wedd, Esq., B.A.

Holocene (Roman and pre-Roman) and Pleistocene Shells from Buckland, Dover, overlying Rubble Drift; with Photographs of the Sections, exhibited by the Rev. R. Ashington Bullen, B.A., F.G.S.

ADMISSION AND PRIVI[illegible]

OF

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CONTENTS.

PAPERS READ.

[No. 217 will be published on the 1st of next February. The List of Geological Literature for the year ending on Dec. 31st, 1898, will be issued with the May number of the Journal.]

[The Editor of the Quarterly Journal is directed to make it known to the Public, that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

*** The Council request that all communications intended for publication by the Society shall be clearly and legibly written on one side of the paper only, with proper references, and in all respects in fit condition for being at once placed in the Printer's hands. Unless this is done, it will be in the discretion of the Officers to return the communication to the Author for revision.

The Library and Museum at the Apartments of the Society are open every Weekday from Ten o'clock until Five, except during the fortnight commencing on the first Monday in September, when the Library is closed for the purpose of cleaning; the Library is also closed on Saturdays at One P.M. during the months of August and September. It is open until Eight P.M. on the Days of Meeting for the loan of books, and from Eight P.M. until the close of each Meeting for conversational purposes only.